Influences of browsing and fire on sagebrush taxa of the Northern Yellowstone Winter Range
by Chris Allen Mehus

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Range Science
Montana State University

Abstract:
Sagebrush (Artemisia L.)/grass habitat types on the Northern Yellowstone Winter Range near Gardiner, Montana provide critical winter habitat for many big game species, particularly mule deer (Odocoileus hemonius ssp. hemonius) and elk (Cervus elaphus ssp. nelsoni). Because 4 sagebrush taxa are common throughout the area, often occurring in the same communities, this area also provides a unique opportunity to study relationships among these taxa.

Sagebrush communities, containing Wyoming big sagebrush (Artemisia tridentata ssp. wyomingensis Beetle and Young) 4 sites, mountain big sagebrush (A. t. ssp. vaseyana [Rydb.]. Beetle) 4 sites, basin big sagebrush (A. t. Nutt. ssp. tridentata) 3 sites, and black sagebrush (Artemisia nova) 1 site, distributed throughout the area are described. These 12 sagebrush communities of varying levels of past browsing use were measured for canopy cover, density, and production. Canopy cover correlated most closely with browsing history, ie. heavily used sites tended to have less canopy cover than lightly used sites. Density and production appeared to be influenced more by individual site characteristics such as elevation, topography, precipitation, and soils. Mule deer and elk browsing of sagebrush and diet composition (where feces were available) were also measured on many of these sites. For all sites but 1, use was greater during the winter of 1992-93 than 1993-94. Big sagebrush was the most significant forage item in mule deer diets across the area during both winters, averaging 33% of the total diet across 9 sites. Common grass species comprised a large proportion of elk diets at the 2 sites sampled, averaging 76%, while big sagebrush averaged 3%.

An area burned by wildfire in 1974 was studied 19 years later to compare relative reestablishment of big sagebrush and rabbitbrush (Chrysothamnus Nutt.) taxa. Recovery was minimal for subspecies of big sagebrush, while rabbitbrush abundance was much greater than that of unbumed areas. Wyoming big sagebrush recovered to a lesser extent than mountain big sagebrush or basin big sagebrush ($P<0.05$). Mountain and basin big sagebrush recovered to the same extent. These relationships were consistent for canopy cover, density, and production.

Rabbitbrush canopy cover and density were not consistent. Threadleaf rubber rabbitbrush (Chrvsothamnus nauseosus ssp. consimilis [Greene] Hall & Clem.), mountain low rabbitbrush (C. viscidiflorus ssp. lanceolatus [Nutt.] Hall & Clem.), and narrowleaf low rabbitbrush (C. y. ssp. viscidiflorus var. stenophyllus [Hook.] Nutt.) recovery as expressed by canopy cover were not different ($P>0.05$). ,However, mountain low rabbitbrush established to a greater density than threadleaf rubber and narrowleaf low rabbitbrush ($P<0.05$). The differences are a result of the large number of seedling and small rabbitbrush plants not expressed by canopy cover. Because a large proportion of seedlings may not reach maturity, canopy cover is probably a better indicator of long-term establishment than density.

This, study should help natural resource managers to make habitat management decisions. Because big sagebrush is a critical cover and browse species for wintering ungulates in the study area, habitat management should focus on protection of these habitat types. Fire negatively influences non-sprouting

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APPROVAL

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Chris Allen Mehus

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

27 November 1995 — Carl L Wambolt

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ABSTRACT

Sagebrush (Artemisia L.)/grass habitat types on the Northern Yellowstone Winter Range near Gardiner, Montana provide critical winter habitat for many big game species, particularly mule deer (Odocoileus hemonius ssp. hemonius) and elk (Cervus elaphus ssp. nelsoni). Because 4 sagebrush taxa are common throughout the area, often occurring in the same communities, this area also provides a unique opportunity to study relationships among these taxa.

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This study should help natural resource managers to make habitat management decisions. Because big sagebrush is a critical cover and browse species for wintering ungulates in the study area, habitat management should focus on protection of these habitat types. Fire negatively influences non-sprouting browse species like big sagebrush that are already declining under intense browsing pressure.

CHAPTER 1

INTRODUCTION

Big sagebrush (Artemisia tridentata Nutt.) inhabits over 58 million ha throughout the western United States (Beetle 1960), and provides habitat for many species of wildlife. Management of big sagebrush and its associated plant communities has been highly controversial, ranging from no manipulation to the complete eradication of big sagebrush in an attempt to encourage herbaceous species.

Big sagebrush communities in the upper Yellowstone River valley, near Gardiner, Montana constitute a key portion of the Northern Yellowstone Winter Range. This area provides important winter habitat for mule deer (Odocoileus hemonius ssp. hemonius) and elk (Cervus elaphus ssp. nelsoni) as well as many other ungulate species. Thus, the area provides a unique opportunity to study relationships among big sagebrush taxa and wildlife species that utilize big sagebrush habitat types during the winter months.

As other important browse species have decreased on the Northern Yellowstone Winter Range (Wright and Thompson 1935, Kay 1990, Chadde and Kay 1991, Patten 1993, Fortney and Wambolt 1995, Hoffman and Wambolt in press, Keigley, R.B. pers. comm., Wambolt in press), big sagebrush has become increasingly important as a climax dominant and browse for wild ungulates. At the same time, natural resource management agencies have developed differing strategies regarding treatment of big sagebrush to provide habitat for wintering mule deer and elk.

Big sagebrush is a diverse species occurring over a wide variety of soil, temperature, and moisture conditions. Three subspecies of big sagebrush are common throughout the Northern Yellowstone Winter Range: Wyoming big sagebrush (Artemisia tridentata ssp. wyomingensis Beetle and Young), mountain big sagebrush (A. t. ssp. vaseyena [Rydb.] Beetle), and basin big sagebrush (A. t. Nutt. ssp. tridentata). Vegetative response of these subspecies to disturbance may be different from one area to another.

My study was established to (1) provide managers with general information regarding big sagebrush communities on the Northern Yellowstone Winter Range near Gardiner, Montana, and (2) compare the relative reestablishment of 3 subspecies of big sagebrush and associated shrub taxa following disturbance.

Chapter 3 of this thesis fulfills purpose (1) by describing the attributes of big sagebrush communities in the Gardiner valley. One objective of this chapter was to determine the distribution and current status of the 3 big sagebrush subspecies in plant communities surrounding the Yellowstone River valley north of Gardiner, Montana. The distribution of big sagebrush across this diverse area could provide insight as to the relative health of the big sagebrush component in the various plant communities. A second objective was to determine the extent to which mule deer and elk use this portion of the Northern Yellowstone Winter Range.

Chapter 4 of the thesis meets purpose (2) by comparing the recovery of Wyoming big sagebrush, mountain big sagebrush, and basin big sagebrush following fire. Hypotheses were that burned and unburned communities contain equal amounts of big sagebrush, and the 3 subspecies have reestablished equally following disturbance.

Rabbitbrush (Chrysothamnus Nutt.) is a commonly occuring shrub in big sagebrush plant communities on the Northern Yellowstone Winter Range. Chapter 4 also compares the relative establishment of 3 rabbitbrush taxa following fire. These include threadleaf rubber rabbitbrush (Chrysothamnus nauseosus ssp. consimilis [Greene] Hall & Clem.), mountain low rabbitbrush (C. viscidiflorus ssp. lanceolatus [Nutt.] Hall & Clem.), and narrowleaf low rabbitbrush (C. v. ssp. viscidiflorus var. stenophyllus [Hook.] Nutt.). I hypothesized that burned and unburned areas will contain equal amounts of rabbitbrush, and that the 3 taxa have reestablished equally following fire.

CHAPTER 2

LITERATURE REVIEW

Big Sagebrush -- Historical Perspectives

The extent and significance of big sagebrush dominated plant community types in western North America has been debated for more than 50 years. Scientists and resource professionals generally accept that the climax sagebrush/grassland plant community type characteristic of much of the Intermountain West historically consisted of some balance of woody and herbaceous vegetation (Jorgensen 1990). However, there are 2 schools of thought regarding the relative abundance of big sagebrush throughout the region and how these vegetative communities should be managed.

One school maintains that big sagebrush has historically been the dominant component of the sagebrush/grasslands (Mueggler and Stewart 1960), and that the relative abundance of sagebrush has not increased since the arrival of European man ; i.e., domestic livestock grazing and fire suppression have not resulted in an increased distribution and abundance of sagebrush (Tisdale 1969, Vale 1975). Advocates of this view generally oppose management efforts to reduce the density of sagebrush. These individuals maintain that the existing plant community is stable. Further they generally believe that vegetation manipulation efforts disturb the ecological balance of the community and, thus, may be detrimental to the overall health and productivity of the system.

Analyses of the historical accounts of some of the earliest European travelers to the Intermountain West lend credence to this argument. Tisdale et al. (1969) and Vale (1975), interpreting these historical observations, maintain that sagebrush and other shrubs were the major component of plant communities in the region before the arrival and establishment of European culture, and have not increased since that time.

Field studies by Tisdale et al. (1969) and Vale (1975), as well as others, also indicate that removing the human influence of livestock grazing does not necessarily result in reduced abundance of sagebrush (Passey and Hugey 1962, Robertson 1971, West et al. 1984). Further, studies of burned sagebrush/grassland communities indicate that big sagebrush ultimately reestablishes its previous dominance (Pechanec et al. 1954, Harniss and Murray 1973, Watts and Wambolt in press).

The second school of thought believes that excessive livestock grazing and the suppression of natural wildfires have resulted in the overabundance of big sagebrush in some shrub/grass communities (Stewart et al. 1940). Advocates argue that a combination of human-induced influences has led to a disproportionate amount of big sagebrush in certain areas of the Intermountain West. Because of this, manipulative management practices such as decreased grazing pressure and periodic range burning may be needed to return the plant community to an earlier successional stage where different plant species are more productive, at least for a period of time (Wright 1974).

Stewart et al. (1940), Woodbury (1947), Cotter (1969), and Young et al. (1979) agree that historical accounts indicate an abundance of big sagebrush throughout the region. They maintain however that formerly abundant grass has been replaced by big sagebrush in many areas. They further argue that overgrazing by domestic livestock reduced the abundance of native grasses. In the absence of competitive pressure from grasses and the occurrence of wildfires, big sagebrush has increased its frequency and canopy within plant communities.

Results of field studies by Tisdale (1947), Wright and Wright (1948), Cooper (1953), Harniss and Murray (1973), and Wright (1974) appear to support this thesis. Wright and Wright (1948) and Cooper (1953) found that, as livestock grazing intensity decreased, grass production generally increased while abundance of big sagebrush diminished. In addition, several authors, notably Harniss and Murray (1973), have indicated that fire may enhance the productivity and overall abundance of grasses in some plant communities until big sagebrush becomes reestablished.

Many other studies have attempted to answer this rhetorical question regarding sagebrush management (Pechanec et al. 1954, Mueggler and Blaisdell 1958, Johnson 1969, Harniss and Murray 1973, Thelenius and Brown 1974, Young and Evans 1978, Ralphs and Busby 1979, Johnson and Strang 1983, Wambolt and Payne 1986). Because of differing environmental conditions and biological factors, results from these studies are quite variable.

In light of the different points of view and conflicting evidence, the question whether big sagebrush dominated plant communities in the Intermountain West are healthy and productive in their current condition remains. Similarly, the need for management to alter the composition of these plant communities, periodically returning them to an earlier stage of successional development is unclear.

The use of fire as a management tool is of particular concern. Fire is generally considered a naturally occurring element of disturbance in vegetative systems. In addition, fire may be more environmentally acceptable and in some cases less expensive than other methods, such as chemicals or mechanical treatment (Pechanec et al. 1948, Wright 1974). Variation among big sagebrush taxa and its influence on reestablishment following fire is important to the use of fire in management.

Big Sagebrush Taxa

Four subspecies of big sagebrush occur across a wide variety of moisture regimes and soil types (Winward and Tisdale 1977). Because of the variation among these plant community types, the different response among sagebrush taxa is another critical factor that must be considered when predicting vegetation response to manipulation (Harniss and Murray 1973).

Three subspecies of big sagebrush dominate most big sagebrush/grassland community types and nearly all of the literature: Wyoming big sagebrush, mountain big sagebrush, and basin big sagebrush. These subspecies may be found in the same plant community, where site specific conditions allow, but generally exist exclusive of one another.

Wyoming big sagebrush is found on fairly shallow soils at lower elevations, typically between 700m and 1,980m (Winward and Tisdale 1977). Moisture is usually limited on these sites, and drought-resistant species are commonly found with Wyoming big sagebrush. Because Wyoming big sagebrush typically occurs on more xeric sites with relatively low site productivity, Wyoming big sagebrush would likely be the slowest among the big sagebrush taxa to reestablish following fire.

Mountain big sagebrush occurs in deeper soils at elevations between 1,370m and 2,740m (Winward and Tisdale 1977). Precipitation is generally higher on sites dominated by mountain big sagebrush. As a result, site productivity is greater than on Wyoming big sagebrush-dominated sites. Despite greater interspecific competition, mountain big sagebrush would most likely reestablish more quickly than Wyoming big sagebrush following a fire as a result of the greater site productivity.

Basin big sagebrush is found in draws and topographic depressions between 700m and 2,140m where precipitation collects and soil moisture is highest (Winward and Tisdale 1977). This subspecies produces the greatest amount of above-ground tissue per plant of the 3 common subspecies, and is most often associated with the taller growing grass species. Because of this great site productivity potential, basin big sagebrush should also reestablish more quickly than Wyoming big sagebrush. The relationship between mountain big sagebrush and basin big sagebrush is more difficult to predict. Interspecific competition on particular sites may produce differing results.

The reestablishment of each of these taxa following fire has been studied on an individual basis in some of the research summarized above. However, a direct comparison of these 3 taxa under the same environmental conditions has not been documented. Thus, the primary goal of this study was to compare the reestablishment of Wyoming, mountain, and basin big sagebrush following fire.

Rabbitbrush (Chrysothamnus) is an important associate of sagebrush in rangeland plant communities across the Intermountain West. Rabbitbrush readily establishes itself following fire (McKell and Chilcote 1957, Young and Evans 1974, Young and Evans 1978). As a result of some possible influence of rabbitbrush on reestablishment of big sagebrush following fire, another objective of this study was to compare the establishment of threadleaf rubber rabbitbrush, mountain low rabbitbrush, and narrowleaf low rabbitbrush.

Importance of Big Sagebrush to Wildlife

Big sagebrush/grassland plant community types are particularly important to mule deer (Julander and Low 1976, Hobbs and Spowart 1984, Welch and Wagstaff 1992). These vegetative types provide particularly important cover and forage during the winter months (McNeal 1984, McArthur and Welch 1986). During these periods, big sagebrush provides an important source of forage (Welch and McArthur 1986, Welch and Wagstaff 1992). While winter is the dormant season for most other plants, big sagebrush maintains a crude protein level of approximately 11% (Welch and McArthur 1979).

Elk also use big sagebrush dominated vegetative types during the late fall and winter (McNeal 1984). However, elk are more dependant on grasses throughout the year (Morris and Schwartz 1957, Greer 1970). Depending on winter severity and availability of grass, elk will utilize big sagebrush as a forage source (Greer et al. 1970, McNeal 1984). According to Greer et al. (1970), in a study conducted over a 7 year period, big sagebrush comprised as much as 9% of elk diets and was among the most frequently found forages in elk diets over the study period. Peaks in big sagebrush use corresponded to years in which elk concentrations were highest.

CHAPTER 3

SAGEBRUSH COMMUNITY DESCRIPTIONS

Study Area

Location

The upper Yellowstone area on which this portion of the study was conducted is on the Northern Yellowstone Winter Range near Gardiner, Montana. It extends north approximately 28km from MacMinn Bench, just inside the northern boundary of Yellowstone National Park, to the southern edge of Yankee Jim Canyon (Fig. 1). The area includes sagebrush habitats between the Yellowstone River and coniferous forest habitats at higher elevations.

Elevation and Topography

This portion of the area selected for study consists of 2 topographically distinct sections. The southern portion of the study area, bounded by MacMinn Bench to the south, Little Trail Creek to the north, Reese Creek to the west, and the Jardine gold mine to the east (Fig. 1), is characterized by relatively moderate, south and west facing slopes between 1600m and 2050m. Open, wind-swept benches on these slopes provide the majority of important wintering areas for wild ungulates (McNeal 1984). Steeper, south and west facing slopes rising above these benches allow additional winter foraging opportunities. Many of the north and east facing slopes in this portion of the study area provide timbered thermal cover for wintering ungulates (McNeal 1984).

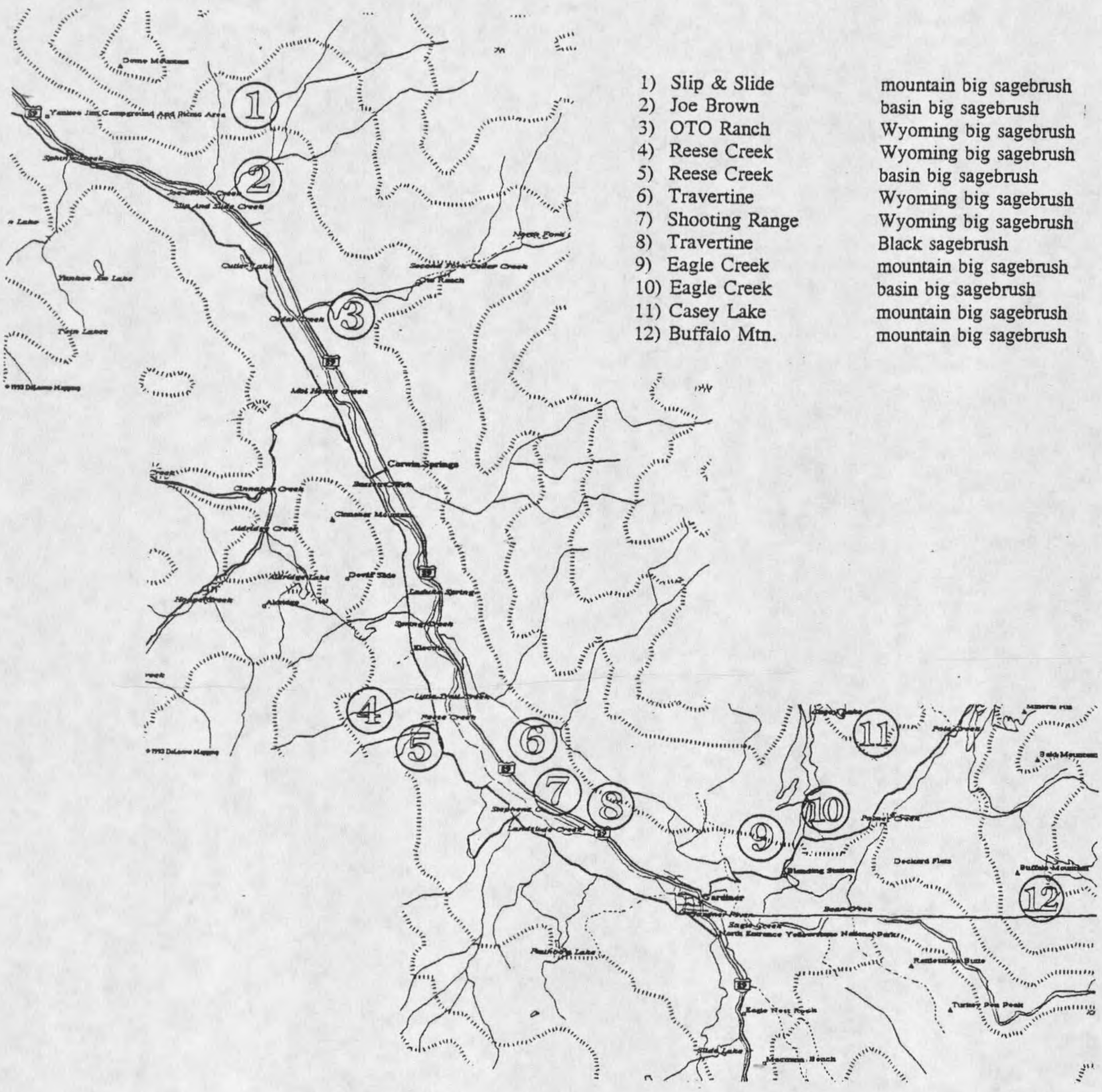


Figure 1. Study area map showing 12 study sites used in Chapter 3 to describe various attributes of sagebrush communities in the Yellowstone valley north of Gardiner, Montana.

The northern portion of the area, adjacent the Yellowstone River from Little Trail Creek north to Yankee Jim Canyon (Fig. 1), and bounded to the east and west by timbered habitats above approximately 2134m, consists mainly of steep, northeast and southwest facing slopes between 1550m and 1700m. These largely talus slopes are sparsely vegetated and relatively inaccessible to most ungulate species. Limited riparian habitat occurs along the Yellowstone River, but extensive development largely precludes most ungulate use. In this northern portion of the study area, most winter ungulate use occurs on moderate slopes above 1700m and in and around major creek drainages such as Slip and Slide Creek, Cedar Creek, and Cinnabar Creek (Lemke, pers. comm.). As snow accumulates, portions of these areas occasionally become inaccessible.

Climate

Average annual precipitation varies greatly across the study area, from as little as 305mm on the low benches to as much as 762mm in the adjacent mountains (NOAA 1994). Although snow accounts for about half of the overall moisture, the largest percentage of the precipitation falls during the months of May and June. Convectional showers provide moisture for plant growth in late summer and early fall (NOAA 1994).

The frost-free season varies with elevation, but averages 90-100 days between mid-May and early September. The actual dates of the growing season are quite variable depending on temperature and precipitation patterns. Mean annual temperatures average 3.1°C (NOAA 1994).

The rugged mountains on the west flank of the valley create a rain shadow. As a result, most of the precipitation falls before it reaches the gently rolling benches on the east side of the valley. Prevailing winds and exposure to solar radiation free many of the south and west facing slopes of snow, providing wintering areas for several big game species.

Soils

Past glacial scouring and deposition have created a variety of soil conditions throughout the valley. Soils are generally characterized as Mollisols under a cryic temperature regime--the mean annual temperature falls between 0°C and 8°C (NOAA 1994). Less developed Alfisols and Inceptisols are common under forest canopies and rock outcrops respectively (McNeal 1984). Parent materials are mostly granites and limestones. Soil profile depth may be only a few cm in scoured areas; whereas, several m may have accumulated in depositional areas. Soil texture is typically sandy loam, and coarse fragments ranging from gravel to boulders are common (McNeal 1984).

Vegetation / Habitat Types

Because of the range in topography, soil, and weather conditions, vegetation across the area studied varies from wooded river bottoms, to sagebrush-grassland dominated footslopes and benches, to the lower edge of the heavily forested uplands. The predominant vegetation is the sagebrush-grassland. According to the work of Mueggler and Stewart (1980) and the later refinements of McNeal (1984), 5 sagebrush habitat types are found on the study area.

The Wyoming big sagebrush and bluebunch wheatgrass (Agropyron spicatum [Pursh] Scribn. & Smith) habitat type is typically found below 1980m. Other common graminoids are prairie junegrass (Koeleria macrantha Ledeb.), Indian ricegrass (Oryzopsis hymenoides [R. &

S.] Ricker), needleandthread (Stipa comata Trin. & Rupr.), and green needlegrass (Stipa viridula Trin.). Common forbs include hairy goldenaster (Chrysopsis villosa [Pursh.] Nutt.), milkvetch (Astragalus spp. L.), and locoweed (Oxytropis spp. D.C.). Fringed sagewort (Artemisia frigida Wild.), green rabbitbrush, rubber rabbitbrush, and grey horsebrush (Tetradymia canescens D.C.) are common shrubs in this community.

The mountain big sagebrush and bluebunch wheatgrass habitat type occurs above 1770m, generally on south and west facing slopes. Associated species of this vegetative type are prairie junegrass, green needlegrass, arrowleaf balsamroot (Balsamorhiza sagittata [Pursh.] Nutt.), lupine (Lupinus spp. L.), fringed sagewort, green and rubber rabbitbrush, and grey horsebrush.

The mountain big sagebrush and Idaho fescue (Festuca idahoensis Elmer) habitat type is also found above 1770m, but commonly occurs on north and east facing slopes. Other common species found in this type are mountain brome (Bromus carinatus H. & A.), timothy (Phleum pratense L.), sticky geranium (Geranium viscosissimum F. & M.), snowberry (Symphoricarpos albus [L.] Blake), and Wood's rose (Rosa woodsii Lindl.).

The basin big sagebrush and bluebunch wheatgrass habitat type occurs on sites with higher available moisture and often deeper soil in the mesic-hypermesic sagebrush component, such as talus slopes and topographic depressions. Common understory species include basin wildrye (Elymus cinereus Scribn. & Merr.), Columbia needlegrass (Stipa columbiana Macoun), and the exotics smooth brome (Bromus inermis Leys) and crested wheatgrass (Agropyron cristatum [L.] Gaertn.).

The black sagebrush (Artemisia nova) habitat type is scattered throughout the study area, but is most common on the shallow, calcareous soils of the Travertine flats just north of

Gardiner. Bluebunch wheatgrass, prairie junegrass, Sandberg bluegrass (Poa secunda Vasey), and fringed sagewort are other common species found in this plant community.

Between 1800m and 2050m where microsite characteristics such as soil and topography are adequate, the 3 subspecies of big sagebrush and black sagebrush occur in mixed communities. These mixed shrub communities provide a unique opportunity to study inter-taxon relationships.

Wooded riparian areas occur along the Yellowstone river as well as around creeks and springs at higher elevations. Black cottonwood (Populus deltoides Marsh.), and willow (Salix spp. L.) are the dominant plant species along the Yellowstone river. Irrigated cropland is also common on the Yellowstone river floodplain. At higher elevations, quaking aspen (Populus tremuloides Michx.) and snowberry are common in areas of higher soil moisture.

Timbered areas are common along the upper boundaries of the study area. Douglas fir (Pseudotsuga menziesii [Mirbel] Franco), whitebark pine (Pinus albicaulus Englem.), lodgepole pine (Pinus contorta Dougl.), and subalpine fir (Abies lasiocarpa [Hook.] Nutt.) are the dominant conifer species at these higher elevations.

Ungulate Species and Populations

Mule deer were the most consistent year-long resident ungulate species found on the study area. An annual aerial survey conducted by the Montana Department of Fish, Wildlife, and Parks (MTDFWP) yielded a 1994 spring count of 1,985 mule deer in the vicinity. Similar counts dating back to 1986 fluctuate from year to year around approximately 2,000 animals (Lemke, pers. comm.). These include resident and migratory individuals.

During the summer, mule deer are found scattered throughout the study area. In winter, they become increasingly restricted to lower areas with less snow accumulation and greater forage availability.

In early winter 1993-94, MTDFWP counted 19,045 elk, the highest number ever recorded for the area (Lemke, pers. comm.). From this count, it was estimated that the Northern Yellowstone elk population totalled 20,349 animals (Lemke, pers. comm.). The population was apparently near this level before the winter of 1988-89, when the early winter count yielded 18,813 elk. Following that count, 25-30% of the herd was lost as a result of severe winter conditions (Lemke, pers. comm.).

Depending on winter severity, elk often greatly outnumber mule deer in the study area during the winter months. According to January aerial surveys by MTDFWP, as many as 7,000 elk winter between the Gardiner valley and Immigrant. Over half of these animals winter on or near the study area. Most of these elk return to Yellowstone Park as the snow recedes in the spring, typically around mid-March. However, approximately 1,450 are considered "resident" on the study area, inhabiting higher elevations during the summer period (Lemke, pers. comm.). These animals remain in these more remote areas from spring calving through the fall breeding period. Typically sometime in November snow levels again begin to limit mobility and foraging, forcing the animals to concentrate at lower elevations.

Bison (Bison) wander from Yellowstone Park into the study area during most winters. Nearly 600 bison were harvested on the area during the winter of 1988-89 when especially high numbers migrated out of the Park. A record 3,529 bison, almost twice the estimated population in 1988-89, were counted during the winter of 1993-94 when mild winter conditions allowed most of the northern herd to remain in Yellowstone Park (Lemke, pers. comm.).

Pronghorn antelope (Antilocapra americana) numbers have decreased over the last 3 years on the southwest portion of the study area (Lemke, pers. comm.). In 1993, the population was estimated at 439 animals distributed west of the Yellowstone river between Mammoth, Wyoming and Corwin Springs, Montana (Lemke, pers. comm.). Sagebrush is an important component of pronghorn diets, particularly during the winter months (Barmore 1980). Microhistological analyses of pronghorn feces for the Gardiner area yielded 48.7% big sagebrush and 67.2% total sagebrush species for 3 winter periods, 1985-1988 (Singer and Norland 1995). These high values are especially significant because very little sagebrush remains in their traditional wintering areas.

Small bands of bighorn sheep (Ovis canadensis) inhabit 3 specific areas: the bluffs west of Corwin Springs, the ridge above La Duke hot springs, and the steep slopes south of MacMinn bench (Fig. 1). Recent aerial surveys, conducted in 1992, indicated 154 sheep inhabited the study area (Lemke, pers. comm.). Although some of these animals move from 1 area to another, exchange among the 3 populations is limited because of geographic obstacles.

Methods

Site Selection

To describe the sagebrush communities and measure mule deer and elk use and feces composition across the study area, I selected 12 sites (Fig. 1) dominated by Wyoming big sagebrush (4 sites), mountain big sagebrush (4 sites), basin big sagebrush (3 sites), and black sagebrush (1 site). To account for some of the variability contained within the study area, these sites were distributed throughout the valley.

Many shrubs develop a hedged appearance or "form class" based on the intensity of past use (Dasmann 1954, Cole 1958). This tendency is evident in Wyoming, mountain, and basin big sagebrush (Wambolt et al. 1994). Generally, axillary growth is stimulated when terminal buds are removed (Bilbrough and Richards 1992). After several seasons of browsing, big sagebrush plants develop a more compact or hedged appearance, because of branching and shorter twig growth that occurs as a result of frequent tissue removal. Plants that are exposed to little or no browsing have a more open canopy because of the prevalence of relatively long, unbranched stems.

Sagebrush stands containing both light and heavily hedged plants were located at sites distributed throughout the study area. Two sites each were identified for Wyoming, mountain, and basin big sagebrush showing light hedging. Two sites each were also located for Wyoming and mountain big sagebrush with heavy-use form classes. Only 1 site was located for heavily used basin big sagebrush. Basin big sagebrush typically occurs in communities too small to sample, and plants often grow out of reach of browsing animals. One site was also located for black sagebrush. Black sagebrush is a compact, low growing species, and form class is very difficult to discern. The abundance of threadleaf rubber rabbitbrush, mountain low rabbitbtrush, and narrowleaf low rabbitbrush were also measured at each of the 12 sites.

Shrub Community Variables

Canopy cover and density of all shrub taxa, and production of the big sagebrush taxa were measured along ten 30m transects located 10m apart and set parallel to the overall slope. All sagebrush and rabbitbrush plants rooted within 2m x 30m belt transects were counted. Big sagebrush plants were recorded as mature or young. This distinction was not made for rabbitbrush plants as relative age class is difficult to discern.

Mature big sagebrush plants were defined as all plants with a maximum canopy diameter greater than the minimum crown diameter (MCD) used in big sagebrush production equations developed by Wambolt et al. (1994) for each subspecies/form class combination (Table 8). Young plants were all plants smaller than these values. MCD's ranged from 22cm for heavily browsed mountain big sagebrush to 36cm for lightly browsed Wyoming big sagebrush. Wambolt et al. (1994) studied plant size dynamics in sagebrush stands in the Gardiner area for many of the same sites described in this study. Thus, I felt justified using their minimum requirement for mature, established plants.

Canopy cover by taxon was quantified by measuring the amount of shrub canopy intercepted along a 30m transect tape (Canfield 1941). A plumb bob was suspended below the transect tape to accurately measure the amount of shrub canopy as a proportion of the total transect length. Openings in the shrub canopy smaller than 5 cm were not recorded.

Models developed by Wambolt et al. (1994), for light and heavily hedged form classes of each big sagebrush subspecies were used to calculate sagebrush production based on several plant measurements (Table 8). Thirty plants were randomly selected and measured at each site. The proportions of small, medium, and large plants selected for measurement were determined to approximate the proportion observed during the density counts (Creamer 1991). Production was calculated for each plant and averaged to determine mean per plant production. This mean was then multiplied by the plant density to calculate total production for the site. Partially dead plants were entered into this calculation according to the proportion of the plant estimated to be alive.

Browsing and Fecal Composition

Mule deer and elk use of the sagebrush taxa was monitored during the winters of 1992-93 and 1993-94. In the fall, before winter use had begun, 50 tags were attached to sagebrush branches at each of the 12 study sites (Fig. 1). Numbers of leaders greater than 13mm long and numbers of seedheads extending beyond the tag were recorded. The following spring, each of the tagged branches was relocated and numbers of remaining leaders and seedheads was recorded. Mule deer and elk use was then calculated as the percentage of leaders and seedheads removed over the winter period.

Following winters 1991-92 and 1992-93, deer and elk pellets were collected where available from each of the sites. Composite samples for analysis of plant material in feces were taken from 10 deer and 10 elk pellet groups selected at random (Hansen and Clark 1977). Because the primary objective of this research was to study mule deer/sagebrush relationships, analysis of deer feces was given priority. Mule deer pellets were collected at 9 of the 12 sites; elk pellets were collected at 2. The pellets were sent to the Composition Analysis Laboratory at Colorado State University for microhistological analysis. Twenty fields per slide were read from 5 slides per sample.

Results and Discussion

General Description

The 12 sites represented a wide variety of environmental conditions (Table 1). Elevations ranged from 1676m at the Wyoming big sagebrush dominated Shooting Range site to 2286m at the mountain big sagebrush dominated Buffalo Mountain site (Fig. 1). Slope varied from level at several sites to 24° at the Eagle Creek mountain big sagebrush site. North and east aspects were less well represented than south and west aspects, as typical of the entire study area. The combination of elevation, slope, and aspect with surrounding topographic features heavily influence accumulation and persistence of snow and, in turn, site productivity and the particular sagebrush taxon present.

In the elevational zone where Wyoming, mountain, and basin big sagebrush occur in mixed communities, approximately 1800m to 2050m, Wyoming big sagebrush tends to dominate steeper south and west facing slopes at lower elevations. Conversely, mountain big sagebrush tends to dominate more level, north and east facing slopes at the upper end of the elevational gradient. Basin big sagebrush occurs on sites where moisture is more abundant such as depressions and talus slopes.

Table 1. Location, physical characteristics, and dominant plant species on 12 study sites in the Yellowstone valley north of Gardiner, Montana.

SITE ID	LEGAL	TAXON *	ELEV (m)	SLOPE (%)	ASPECT	ASSOCIATED SPECIES**
Shooting Range	T9S R8E S16,NE/SW	WYO	1676	5	SW	Agsp,Orhy, Koma,Arfr
Reese Cr	T9S R8E S7,SE/SW	WYO	1768	8	ESE	Agsp,Koma, Arfr,Feid
Travertine	T9S R8E S10,SW/SW	WYO	1875	0	--	Agsp,Orhy, Koma,Stco
OTO Ranch	T8S R8E S13,NE/SE	WYO	1685	17	W	Agsp,Koma, Orhy,Stco
Casey Lake	T9S R9E S7,NW/E	MTN	2210	6	WSW	Feid,Brca, Gevi,Rowo
Buffalo Mtn	T9S R9E S21,SE/SW	MTN	2286	13	SSW	Feid,Brca, Syla,Gevi
Eagle Cr	T9S R8E S13,NE/SW	MTN	1951	24	S	Agsp,Feid, Koma,Basa
Slip&Slide	T7S R8E S35,SE/SW	MTN	1966	12	SSE	Feid,Agsp, Koma,Basa
Joe Brown	T8S R7E S3, NW/SE	BAS	1554	0	--	Elci,Agcr, Syla
Reese Cr	T9S R8E S18,NE/NW	BAS	1692	3	NE	Stcol,Brin, Elci
Eagle Cr	T9S R9E S18,SE/SW	BAS	1935	14	SSW	Agsp,Stcol, Basa
Travertine	T9S R8E S15,NW/E	BLK	1875	0	--	Koma,Agsp, Arfr

* WYO=Wyoming big sagebrush, MTN=mountain big sagebrush, BAS=basin big sagebrush, BLK=black sagebrush

** Agsp=bluebunch wheatgrass, Orhy=indian ricegrass, Koma=prairie junegrass, Arfr=fringed sagewort, Stco=needleandthread, Feid=Idaho fescue, Brca=mountain brome, Gevi=sticky geranium, Rowo=woods rose, Syal=snowberry, Basa=arrowleaf balsamroot, Elci=basin wildrye, Stcol=Columbia needlegrass, Brin=smooth brome

Associated plant species were also influenced by these factors. Bluebunch wheatgrass, prairie junegrass, Indian ricegrass, and hairy goldenaster were frequently found with Wyoming big sagebrush on more xeric sites at lower elevations. Idaho fescue, mountain brome, arrowleaf balsamroot, and sticky geranium were common in mountain big sagebrush communities under mesic conditions at higher elevations. Basin wildrye and columbia needlegrass inhabited basin big sagebrush stands where the water table is elevated during the growing season.

Sagebrush Canopy Cover, Density, and Production

Sites with a history of relatively light use had greater canopy cover than those with heavy use (Table 2). For Wyoming big sagebrush, sagebrush cover on 2 lightly used sites had 17% and 14% canopy cover, while 2 heavily used sites had 9% and 6%. Lightly used mountain big sagebrush sites had 18% and 13% canopy cover, while the more heavily browsed sites had 10% and 8%. Similarly, basin big sagebrush sites characterized by a history of light use had canopy cover measurements of 17% and 13%, as opposed to 8% for the heavily used site.

For Wyoming, mountain, and basin big sagebrush, plant density appeared less dependent on browsing history than canopy cover. Density of Wyoming big sagebrush varied from .32 plants/m^2 on 1 heavily used site to .67 plants/m^2 on the other heavily used site. The lowest density for a mountain big sagebrush site, .36 plants/m^2, occurred on a heavily used site, while the highest density of mountain big sagebrush, .78 plants/m^2, was also found on a heavily used site. Density of basin big sagebrush was also variable. Both the lowest density, .15 plants/m^2, and the greatest, .30 plants/m^2, occurred on a lightly used site.

Table 2. Form class, canopy cover, density (mature plants), and production measurements for 4 sagebrush taxa on 12 study sites in the Yellowstone valley north of Gardiner, Montana, summer 1992.

SITE ID	TAXON*	FORM CLASS**	CANOPY (%)	DENSITY (p/m^2)	PRODUCTION (g/m^2)
Shooting Range	WYO	L	17	.47	17
Reese Cr	WYO	L	14	.57	60
Travertine	WYO	H	6	.32	8
OTO Ranch	WYO	H	9	.67	117
Casey Lk	MTN	L	18	.62	44
Buffalo Mtn	MTN	L	13	.71	32
Eagle Cr	MTN	H	10	.36	16
Slip&Slide	MTN	H	8	.78	52
Joe Brown	BAS	L	17	.15	17
Reese Cr	BAS	L	13	.30	60
Eagle Cr	BAS	H	8	.18	13
Travertine	BLK	NA	7	1.7	NA

* WYO=Wyoming big sagebrush, MTN=mountain big sagebrush, BAS=basin big sagebrush, BLK=black sagebrush

** L=light browsing history, H=heavy browsing history

Production was also quite variable for the 3 subspecies, and did not correlate with the browsing history (Table 2). Wyoming big sagebrush was least productive on 1 heavily used site, $8g/m^2$, and most productive on the other, $117g/m^2$. The extreme production estimates for mountain big sagebrush, $16g/m^2$ and $52gm^2$, also occurred on heavily used sites. Production estimates for basin big sagebrush varied from a low of $13g/m^2$ to a high of $60g/m^2$, both on lightly used sites.

Interpretation of these results is limited to apparent general influences of browsing history on canopy cover, density, and production. Measurements were limited to 2 sites for each subspecies and browsing level. To adequately account for variability among sites and achieve statistical differences, a larger number and variety of sites than provided in this study would be required.

Of the 3 parameters measured, canopy cover seemed to relate most closely to browsing history based on plant form class. This relationship was consistent among all 3 subspecies of big sagebrush (Table 2). Sites with a history of light use tended to have greater canopy cover than those characterized by heavy use. This conclusion could be explained by the fact that heavily browsed plants tend to develop a more compact shape because of increased branching and decreased leader length (Bilbrough and Richards 1992). Observations also indicated that heavy browsing may induce shrub mortality, which would also decrease total canopy cover.

There is no apparent ecological explanation why heavily browsed sites exhibited the highest and lowest density and production values for Wyoming and mountain big sagebrush, while lightly browsed sites exhibited the highest and lowest density and production values for basin big sagebrush. Density and forage production appeared to be more dependent on abiotic site conditions such as elevation, precipitation, and soils than on browsing history. Sites at higher elevations and with deeper, less rocky soils (as evidenced by soil surface characteristics and associated vegetation) had greater densities and forage production. Density is also a direct result of germination and seedling establishment, which are strongly influenced by site specific growing conditions (Sabo et al. 1979, Booth et al. 1990, Young et al. 1990).

Total site production for big sagebrush taxa was estimated by multiplying the density/m^2 by the production/plant. There was opportunity for error using this method, both in estimating the proportion of small, medium, and large plants per stand and in using this estimate to guide the selection of plants to be measured for production. Thus, there is potential for variability both within and among observers. A more accurate method for estimating production, involving measurement of every plant on a site for production, rather than arbitrary observer selection of plants is described in Chapter 4.

Density and canopy cover were also measured for a site dominated by black sagebrush. This shrub grows low to the ground and has a compact shape regardless of browsing history. Thus, form class was difficult to identify and not reported. The density of black sagebrush was 1.7 plants/m^2; canopy cover was 7%.

Mule Deer and Elk Use of Sagebrush

Utilization measurements (Table 3) showed that, with the exception of the Slip and Slide mountain big sagebrush site (the farthest site from Yellowstone Park), browsing of big sagebrush was greater during the winter of 1992-93. Greater snow accumulations occurred during the early winter months of 1992-93 compared to 1993-94 (NOAA 1994). This apparently resulted in larger numbers of mule deer and elk browsing big sagebrush on the southern portions of the study area the first winter of study, as observed in other studies (Greer et al. 1970, Houston 1982, and Wambolt in press). During the 1992-93 winter, sites closest to the Park boundary received the heaviest use. The Eagle Creek basin big sagebrush and the Eagle Creek mountain big sagebrush sites were browsed at 71% and 54%, respectively.

The Slip and Slide site, which received 36% use in the winter of 1992-93 and 58% use in the winter of 1993-94, was the only site with greater utilization of big sagebrush during the winter of 1993-94. This site was in the northern-most portion of the study area. During severe winters mule deer and elk eventually work their way down the valley toward this area, where they gather on wind-swept south and west-facing slopes for the remainder of the winter months. During winter 1993-94, snow did not accumulate until late January and February (NOAA 1994). This could account for greater mule deer and elk use of big sagebrush on the Slip and Slide mountain big sagebrush site during late winter.

All 3 of the sites where use was heaviest--Eagle Creek mountain, Slip and Slide mountain, and Eagle Creek basin--are steep, south facing slopes where prevailing winds and solar radiation keep them relatively free of snow throughout the winter months. These conditions allow for better mobility and easier foraging.

Table 3. Percent of leaders and seedheads of 4 sagebrush taxa removed by mule deer and elk on 12 study sites in the upper Yellowstone valley north of Gardiner, Montana during the winters of 1992-93 and 1993-94.

SITE ID	TAXON *	FORM CLASS**	%USE 93 leaders	%USE 94 leaders	%USE 93 seedheads	%USE 94 seedheads
Shooting Range	WYO	L	42	23	67	0
Reese Cr	WYO	L	46	9	50	6
Travertine	WYO	H	34	15	60	10
OTO Ranch	WYO	H	48	9	63	8
Casey Lk	MTN	L	7	3	4	4
Buffalo Mtn	MTN	L	43	27	61	35
Eagle Cr	MTN	H	54	19	61	2
Slip&Slide	MTN	H	36	58	71	27
Joe Brown	BAS	L	37	3	29	0
Reese Cr	BAS	L	34	21	38	21
Eagle Cr	BAS	H	71	20	79	39
Travertine	BLK	NA	4	0	0	0

* WYO=Wyoming big sagebrush, MTN=mountain big sagebrush, BAS=basin big sagebrush, BLK=black sagebrush

** L=light browsing history, H=heavy browsing history

The only site that was relatively lightly browsed during both winters was the Casey Lake mountain. On this site, 7% of the big sagebrush was utilized during winter 1992-93 and 3% during winter 1993-94. This site was located at 2210m, the second highest elevation of all sites. Also, the relatively slight 6% slope allowed for deep, persistent snow cover.

Mule deer and elk use on the 1 black sagebrush site was only 4% the first winter and none the next despite its close proximity to the Park and high accessibility. Because of its compact, low-growing form, snow cover may have influenced the use of black sagebrush. However, Wambolt (in press) found that black sagebrush was the least preferred of 4 sagebrush taxa in the same area.

Distribution of deer and elk use was quite variable across the study area during both winters. The timing, duration, and severity of weather patterns, and subsequent availability of forage, cause movement of elk from Yellowstone National Park toward, and often beyond the northern boundaries of the study area. Mule deer are also displaced by severe weather conditions to areas of greater shelter and less snow accumulation. Because of this and other factors influencing deer and elk distribution and use across the area, use between sites cannot be compared in terms of preference for the taxa.

Mule Deer Feces Composition

Major forage items found in mule deer feces include wheatgrass species (primarily bluebunch wheatgrass), Idaho fescue, bluegrass species, bottlebrush squirreltail, needlegrasses species, fringed sagewort, big sagebrush, Rocky Mountain juniper, and Douglas fir (Table 4). The analysis did not indicate any difference in feces composition between the winters of 1991-92

Table 4. Mule deer fecal composition by species groups as indicated by microhistological analysis of feces collected at 9 sites in the Yellowstone valley north of Gardiner, Montana following the winters 1992 and 1993.

SITE	Wheat-grass	Idaho fescue	Blue-grass	Fox-tail	Needle-grass	Misc. herbs	Big sage-brush	Rocky Mtn. Juniper	Doug. fir	Misc. browse
Shooting Range	3 1	1 51	10 0	1 0	17 10	0 1	46 20	5 13	4 0	13 4
Reese Cr	0 0	4 2	3 2	1 0	22 6	2 0	20 64	26 8	14 8	8 10
Traver-tine	1 1	1 22	0 0	0 1	4 34	1 0	30 12	36 16	18 4	11 12
OTO Ranch	4 0	1 11	3 1	1 0	53 2	1 0	17 73	4 7	14 1	2 6
Buffalo Mtn*	4	21	7	2	17	2	20	1	12	13
Eagle Cr	1 3	5 5	2 1	0 1	9 27	1 1	71 47	1 1	3 12	7 3
Slip & Slide	4 1	41 33	3 1	29 0	0 7	3 0	9 38	0 3	6 8	5 9
Reese Cr	4 16	11 12	5 7	2 1	35 60	2 1	10 1	14 1	8 1	9 0
Eagle Cr	6 0	17 8	1 7	0 0	20 7	6 1	30 56	3 1	6 3	11 18

-- the first number in each cell is the % of total fecal material sampled during the winter of 1991-92, the second is % diet during the winter of 1992-93

-- categories are species groups as determined by microhistological analysis

* Pellet groups not available on Buffalo Mtn. site for the winter of 1991-92

and 1992-93. Both winters were fairly mild when compared with the long-term averages (NOAA 1994).

With the exception of the Slip and Slide mountain big sagebrush site during the first winter of study, 5 items accounted for over 70% of the mule deer fecal material collected on the study area. These include Idaho fescue, needlegrass, big sagebrush, Rocky Mountain juniper, and Douglas fir.

Wheatgrasses, the most common grass taxa across the study area, comprised more than 6% of the deer fecal material at only 1 site during the winter of 1992-93. By comparison, Idaho fescue accounted for over 30% of the deer feces at 3 sites over the 2 winters of study; the high at any site was 51%. Needlegrasses, which are not nearly as common as the other taxa, comprised more than 25% of mule deer feces at 5 sites over the 2 winter periods. Samples for 2 sites recorded highs of 53% and 60% of fecal material (Table 4). Because of the scarcity of the needlegrass compared to wheatgrass and Idaho fescue, needlegrasses may be more preferred by deer. However, the needlegrasses also tend to be more common on the driest, steepest sites that remain free of snow a greater proportion of the winter months, and thus attract greater mule deer use.

Big sagebrush was the most significant forage item in mule deer feces at sites throughout the study area, comprising an average of 33% of the fecal material collected across all sites, with highs of 71% and 73%. Needlegrass species ranked second comprising 19% of the fecal material across all collection sites (Table 4).

Utilization of big sagebrush by mule deer in this study was lower than reported by Wambolt (in press). The latter study, conducted in the same area but on a smaller portion of the winter range over a 10 year period showed big sagebrush to comprise an average of 52% of the mule deer fecal material. The wide spatial and edaphic distribution encompassed by the 9 sites in this portion of this study may account for greater variability in mule deer diets. Also, my study was conducted during 2 fairly mild winters. Greater amounts of big sagebrush may have been consumed during more severe winters previous to this study (Greer et al. 1970, Wambolt in press).

Elk Feces Composition

Although elk use of specific forage items differed greatly from mule deer, nearly the same plant species and forage classes were present in elk feces. The major forage items found in elk fecal material included wheatgrasses, Idaho fescue, needlegrasses, big sagebrush, and Douglas fir (Table 5).

Table 5. Percentages of 5 species groups in elk feces during winters 1991-92 and 1992-93 as determined by microhistological analysis for 2 sites in the Yellowstone valley north of Gardiner, Montana.

SITE	Wheat-grass	Idaho fescue	Needle-grass	Sage-brush	Douglas fir
OTO Ranch	7 4	11 10	64 78	6 3	7 1
Slip & Slide	6 2	47 65	23 22	1	12 3

-- the first number in each cell is the percent of the diet during the winter of 1991-92; the second is the percent of the diet the winter of 1991-92, the second represents the diet for the winter of 1992-93

The grasses were much more common than browse species in elk feces for the 2 sites during both winters. Also for both winters, wheatgrasses, Idaho fescue, and needlegrasses accounted for over 76% of elk fecal sample collected at the 2 sites, with a high of 92%. As with deer, the needlegrasses comprised the largest portion of the grass consumption, with an average of 47% between the 2 sites and winter periods. Again, this may reflect preference, greater availability, or both. Idaho fescue also comprised a large portion of the elk fecal sample, averaging 33%.

Big sagebrush accounted for only a small portion of elk feces, comprising an average of 3% and a high of 6% of the samples. Douglas fir topped the browse category with an average of 6%, and a high of 12%. As in the case of mule deer, there were no apparent differences in elk feces composition between the 2 winters.

The minor use of big sagebrush was quite similar to findings of Greer et al. (1970), who reported that big sagebrush comprised up to 9% of the total diet during a multi-seasonal, 7 year study of elk food habits in Yellowstone National Park. Of 793 individual elk rumens sampled in that study, grasses comprised the greatest proportion of forage eaten throughout the year. Peaks in big sagebrush consumption corresponded with years of greatest elk concentrations on the winter range, as well as with peaks in consumption of other browse species such as Douglas fir and Rocky Mountain juniper. This indicates that during years of the most severe winter conditions, elk may select big sagebrush and other browse species as supplemental nutrient sources following significant migration events (McNeal 1984).

According to Wambolt (in press), the amount of big sagebrush contained in fecal pellets collected on the study area may not accurately reflect the amount of big sagebrush consumed by elk on the winter range outside of Yellowstone National Park. Large ruminants typically require several days to process forage, and late season elk hunts result in large, sudden movements of elk in and out of Yellowstone. Big sagebrush has been greatly reduced within the boundaries of the Park because of heavy browsing (Wright and Thompson 1935, Patten 1993). The decreased availability of big sagebrush inside the Park boundary may lead to lower amounts observed in elk feces from the study area than would be expected if elk were allowed to forage on the area without the disruption of these late season hunts (Wambolt, in press).

CHAPTER 4

REESTABLISHMENT OF SAGEBRUSH AND RABBITBRUSH FOLLOWING WILDFIRE

Study Area

Location

Studies on the response of various sagebrush and rabbitbrush taxa following fire were conducted on the bench just north of Gardiner, Montana. This area is characterized by the environmental conditions described previously for mixed communities of Wyoming, mountain, and basin big sagebrush and black sagebrush (Chapter 3, p. 13-15). In July 1974, a wildfire burned approximately 80ha just west of Blanding Station (an old U.S. Forest Service Ranger Station). Because of the persistence of burned sagebrush stumps, the fire boundary is still very evident, even after 19 years. Adjacent plant communities indicate that this area contained a mixture of the 3 subspecies of big sagebrush and black sagebrush.

Elevation and Topography

Elevations on this bench, between the travertine quarries on the west and the Jardine road on the east, range from 1,735m to 2,135m. Topography varies due to past glacial activity, with slopes between 0% and 18%. Aspect also varies with all exposures represented, but is generally south-southwest. Solar radiation, prevailing winds, and the rainshadow created by the mountains to the west provide excellent winter habitat for mule deer and elk, which use this area extensively.

Soils

The geography of the study area is a result of glacial activity, and the soils have been strongly influenced by this process. Most soils on this bench are Mollisols with depth varying from a few cm in scoured areas to several m in depositional areas. Shallow soils, particularly near the travertine quarry are strongly calcareous because of the underlying limestone parent material. Soil texture is generally sandy loam with a high percentage of coarse fragments, from gravel to boulders.

Vegetation

The plant communities are dominated by Wyoming, mountain, and basin big sagebrush, and black sagebrush. The sagebrush taxa present at any given location vary with microsite characteristics. Generally, the Wyoming big sagebrush/bluebunch wheatgrass habitat type dominates the south and west facing slopes below 1,980m. The mountain big sagebrush/bluebunch wheatgrass habitat type dominates the south and west slopes below 1770m, while the mountain big sagebrush/Idaho fescue habitat type dominates north and east facing slopes above 1,770m. A mix of basin big sagebrush and basin wildrye is common at the bottom of gullies and depressions where soils are deeper and along talus slopes where soil moisture is more available. The black sagebrush/bluebunch wheatgrass habitat type is common in shallow, calcareous soils. Threadleaf rubber rabbitbrush , mountain low rabbitbrush, and narrowleaf low rabbitbrush occur within these habitat types. Rocky Mountain juniper (Juniperus scopulorum Sarg.) and limber pine (Pinus flexilis James) are scattered throughout.

Wild Ungulates

Because of the aspect and exposure to prevailing winds, the bench provides excellent winter habitat for mule deer and elk. Mule deer are found on the area throughout the year, but become much more common as winter conditions limit mobility and forage availability at higher elevation. Elk, on the other hand, are rarely observed on the study area until severe winter conditions force them to lower elevations, at which time they are often quite common (McNeal, 1984). Bison are occasionally observed on the study area, but only when winter conditions drive them from Yellowstone National Park.

Methods

Study Design

During the summer of 1992, 190 sample plots of 182m^2 (a circle with 7.6m radius) each were established every 60m along east-west lines set 60m apart. These sample plots were distributed across the entire burned area and in the surrounding unburned community. Descriptive information recorded for each plot, included slope, aspect, general soil conditions, approximate shrub densities, and associated plant species. This information served as a basis for selecting an adjacent unburned, mixed sagebrush community for comparative study to the burned area.

During summer 1993, shrub density, canopy cover, and production were measured both within the 1974 wildfire and in an adjacent, unburned sagebrush community. These data were analyzed to describe the extent to which each shrub taxa had recovered relative to the adjacent, unburned community. Three north-south baselines running the length of the burn were established 200m apart. Sampling sites were located every 10m for a total of 60 sites per baseline. These sites were located at random distances between 0 and 100m either east or west of the baseline (odd distances east, even distances west). Distances from the baseline were generated from a random numbers table. At each of the sites, shrub canopy cover, density, production, and age were measured.

Three unburned portions of the mixed big sagebrush community, each approximately 600m^2 in size, were identified in close proximity to the burned area. Shrub density, canopy cover, and production were measured on 30 plots within each portion of the unburned community. Because aging sagebrush requires destructive sampling of important browse plants, and more time and labor than available, this parameter was not measured in unburned plots.

Shrub Variables

The parameters used to describe sagebrush and rabbitbrush are canopy cover, density, and production. Production was only calculated for big sagebrush taxa. Measurements were taken along a 30m transect line at each site.

All shrubs rooted within each 2x30m belt transect were counted. Young and mature big sagebrush plants were tallied separately. Rabbitbrush plants were counted, but not classified by age. Age was impossible to discern in most cases because root cross-sections were often partially decayed, or had been bored through or inhabited by insect larvae.

Mature or established big sagebrush plants were all plants with a diameter greater than the minimum crown diameter (MCD) used in big sagebrush production models developed by Wambolt et al. (1994) for each subspecies/form class combination (Table 8). Young plants were all plants with a diameter less than these values. MCD's ranged from 22cm for heavily browsed mountain big sagebrush to 36cm for lightly browsed Wyoming big sagebrush.

Canopy cover was measured by the line intercept method (Canfield 1941). A plumb bob was suspended below the 30m tape, and all living shrub tissue intercepted by the device was recorded. Openings in the shrub canopy smaller than 5cm were not recorded.

Rather than attempting to estimate the number of small, medium, and large plants over a large area, as described in the previous chapter for general shrub community descriptions, every plant counted in the $60m^2$ belt transects was measured for production. This method provided a more accurate and precise estimate of production, as subjective judgements regarding relative shrub size were not necessary. Major axis, minor axis, average cover, circular area, and height were recorded for each mature big sagebrush plant. The models described in the previous chapter were then used for production calculations (Appendix).

In the burned area, each of the big sagebrush plants counted in the belt transects was cut at ground level and aged by growth ring analysis, after Ferguson (1964). This procedure provided actual shrub ages that were used to eliminate any sites that may have been only partially burned, although very few were encountered. Plants were not destroyed on the unburned areas because of excessive sampling time and their value as forage.

Statistical Analysis

Canopy cover, density, and production data were compared between burned and unburned areas using Student t-tests. For useful comparisons among the shrub taxa, data from the burned and unburned areas were combined into ratios (burned/unburned) for each parameter. This ratio represents the extent to which (percentage) each shrub taxon has recovered since the 1974 wildfire. Because both the numerator and denominator of the ratio have distinct variability values, a combined variance term was calculated for each ratio (Cochran, 1977). The ratios were then compared using multiple t-tests.

Because only 1 burned area was available for study in this experiment, I could not determine experimental error. Measurement error is assumed to approximate experimental error given the environmental and physical characteristics of the study area. Thus, any inferences from the results of this study to other areas or regions are limited by the topographic, climatic, and edaphic diversity listed in the study area description.

Results and Discussion

Wildfire Treatment Conditions

Total precipitation during the 3 years preceeding July 1974 resulted in conditions susceptible to wildfire. The 100 year average annual precipitation is 41.25cm (McNeal 1984). Total annual precipitation for 1972 was 51.51cm (NOAA 1994). This increased amount of precipitation likely resulted in extraordinarily high plant productivity, and thus large accumulations of plant litter. Total precipitation during the following years, 33.40cm and 31.80cm, respectively (NOAA 1994), was well below the long term average. The combination of an extremely wet year, followed by 2 years of very dry conditions set the stage for the wildfire that burned approximately 80ha in a short period of time in the late summer of 1974.

The intensity of the 1974 wildfire was sufficient to eliminate big sagebrush completely within the perimeter of the burn. Of the plants counted and aged by growth ring analysis during the summer of 1993, not 1 was older than 18 years. Wyoming, mountain, and basin big sagebrush had previously been well established on the site as indicated by adjacent shrub communities. The major assumption of this portion of the study is that the 3 subspecies of big sagebrush had an equal opportunity to reestablish using perimeter plants as seed sources. Preliminary sampling during the summer of 1992 provided evidence that adjacent communities contained a favorable mix of the 3 big sagebrush subspecies as a seed source.

Sagebrush Recovery

Burned vs. Unburned

Wyoming, mountain, and basin big sagebrush have reestablished only slightly in the 19 years following the 1974 wildfire (Fig. 2, 3, and 4). Even the casual observer can easily distinguish the abrupt boundary between grass dominated vegetation in the burned area and the shrub dominated community outside the burn. Nearly the entire perimeter of the burn can be retraced by the absence of sagebrush and persistence of burned stumps.

Canopy cover, density of mature plants, and production of the 3 big sagebrush taxa were all significantly greater ($P < 0.0001$) in the unburned area compared to the burned area (Table 6). Comparison of burned and unburned canopy cover, density, and production in plots indicated very low reestablishment of each of the 3 big sagebrush subspecies.

Wyoming big sagebrush covered 5.5% of the unburned area and only 0.03% of the burned area. The density of Wyoming big sagebrush plants in the unburned area was 4.4 plants/m^2 compared to .09 plants/m^2 in the burned area. Production of Wyoming big sagebrush production was 773.8 g/m^2 on the unburned area compared to 1.1 g/m^2 on the burned area.

Mountain big sagebrush covered 4.4% of the unburned area and only 0.07% of the burned area. Density was 5.4 plants/m^2 in the unburned area compared to 0.67 plants/m^2 in the burned area. Production estimates for mountain big sagebrush were 327.0 g/m^2 and 45.0 g/m^2 on the unburned and burned areas respectively.

Figure 2. Photographs taken in the fall of 1974 (above), and again in the fall of 1994 (below), 20 years following the wildfire.

Figure 3. Photographs taken in the fall of 1974 (above), and again in the fall of 1994 (below), 20 years following the wildfire.

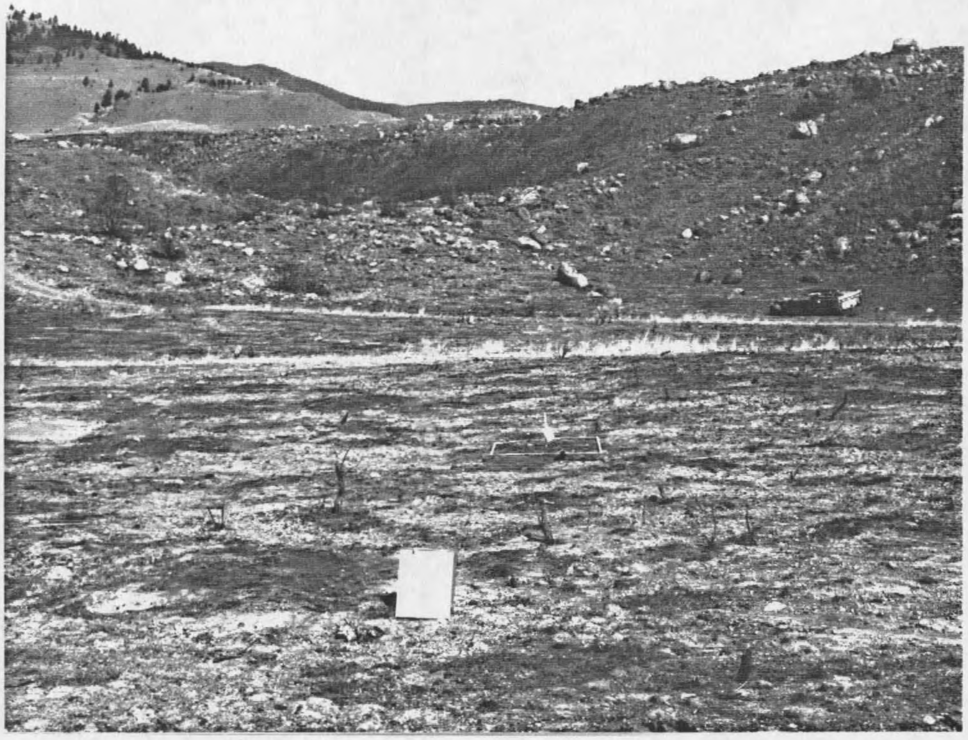


Figure 4. Photographs taken in the fall of 1974 (above), and again in the fall of 1994 (below), 20 years following the wildfire.

Table 6. Density, canopy cover, and production of 3 big sagebrush subspecies in a burned and an unburned area near Gardiner, Montana, 19 years following wildfire.

TAXON	DENSITY mature plants* (plants/m^2)		CANOPY COVER (%)		PRODUCTION (grams/m^2)	
	BURNED	UNBURN.	BURNED	UNBURN.	BURNED	UNBURN.
WYO	.09	4.4	.03	5.5	1.1	773.8
MTN	.67	5.4	.07	4.4	45.0	327.0
BASIN	.85	5.4	1.5	7.5	83.0	727.8

-- For each parameter (density--mature plants, canopy cover, production) all mean comparisons between burned and unburned values are different ($P<0.0001$).

* Mature plants determined by Minimum Crown Diameter (Table 8)

Canopy cover values for basin big sagebrush were 7.5% and 1.5% for the unburned and burned areas, respectively. The density of basin big sagebrush was 5.4 plants/m^2 in the unburned area and 0.85 plants/m^2 in the burned area. Production estimates for basin big sagebrush yielded 727.8 g/m^2 on the unburned area and 83.0 g/m^2 on the burned area.

Black sagebrush was not included in the analyses. Following preliminary sampling in the summer of 1992, it was determined that very little of the black sagebrush habitat type burned in the 1974 wildfire. This sparsely vegetated plant community occurs over strongly calcareous soils with much limestone covering the surface and typically does not carry a fire.

Based on sampling results, the null hypothesis that the burned and unburned areas contain equal amounts of big sagebrush is rejected. To the contrary, the 3 big sagebrush taxa have recovered only slightly 19 years following the fire.

The results of this study were similar to those of Wambolt and Payne (1986), who found that of 4 big sagebrush control techniques, Wyoming big sagebrush reestablished most slowly following burning. After 18 years, Wyoming big sagebrush had recovered to only 12% of its original abundance. In a subsequent study of the same area, Wambolt and Payne (in press) found that Wyoming big sagebrush reestablished to the level of unburned areas after 30 years.

A similar study, testing the effectiveness of burning to control mountain and basin big sagebrush was reported by Blaisdell in 1953. In 12 years following treatment, Blaisdell reported little reestablishment of mountain and basin big sagebrush. However, when the same areas were examined by Harniss and Murray (1973) 30 years after burning, mountain and basin big sagebrush had almost fully recovered.

Johnson and Payne (1968) indicated that sagebrush reestablishment may be highly dependent on the "completeness" of the treatment; i.e., persistence of mature plants following disturbance. Such residual plants provide an important seed source for reestablishment of big sagebrush after a disturbance. Presence or absence of these plants may account for much of the variation in past studies regarding big sagebrush reestablishment. This combination of factors may provide basis for a conceptual model for the rate of reestablishment of big sagebrush on areas where disturbance completely eliminates all seed producing plants.

Seed dispersal and growing conditions are probably the most important factors influencing big sagebrush recovery. Seedling germination and establishment are very dependent on these 2 factors (Sabo et al. 1979). Once the seeds have dispersed, growing conditions will only allow for germination during certain years (Sabo et al. 1979, Young et al. 1990). Following germination, seedling establishment also requires a specific set of growing conditions (Booth et al. 1990). The combination of these influences allows for very slow recovery in the first years after burning. However, as more plants become established, seed production and dispersal increase dramatically, and germination and establishment of seedlings likely follow. Thus, a graphic analysis of recovery over time may appear similar to an exponential curve. The long-term observations of Wambolt and Payne 1995 and Harniss and Murray 1973 are further evidence of this apparent relationship between time since disturbance and reestablishment.

The absence of livestock grazing during the growing season may be another factor influencing the reestablishment of big sagebrush on the study area. Pechanec et al. (1954) indicated that heavy livestock grazing following disturbance led to greater sagebrush abundance in treated than untreated plots. The opposite may be true for disturbed sagebrush communities where there is little or no livestock grazing. Observations throughout the burned area indicate that grass abundance and vigor was extremely high, compared with similar unburned sites. This interspecific competition may have inhibited the establishment of big sagebrush seedlings.

Owens and Norton (1992) report that big sagebrush seedling establishment was inhibited by livestock trampling. Differing results would be expected under differing grazing intensities. Thus, big sagebrush seedling establishment as related to competition and trampling mortality may be difficult to predict.

Big Sagebrush Reestablishment by Taxon

For comparison among taxa, burned and unburned canopy cover, density, and production were combined into a ratio (burned/unburned), which represents the extent to which each subspecies has reestablished. For statistical comparisons, a combined variance term was calculated, and ratios were compared using t-tests (Fig. 5).

Wyoming big sagebrush reestablished to only 0.6% of its original canopy cover. Mountain and basin big sagebrush reestablished to 17% and 20% of their original canopy cover values, respectively. Wyoming big sagebrush reestablished to a lesser extent than mountain or basin big sagebrush ($P<0.002$ in both cases) as determined by canopy cover. Mountain and basin reestablishment by canopy cover were not different ($P<0.05$).

Mature Wyoming big sagebrush reestablished to only 2% of its original density. Mountain and basin big sagebrush reestablished to 12% and 16% of their original densities. According to density values, Wyoming big sagebrush reestablished to a lesser extent than mountain big sagebrush ($P<.03$), and basin big sagebrush ($P<.0001$). The density values for mountain and basin big sagebrush were not different ($P<0.05$).

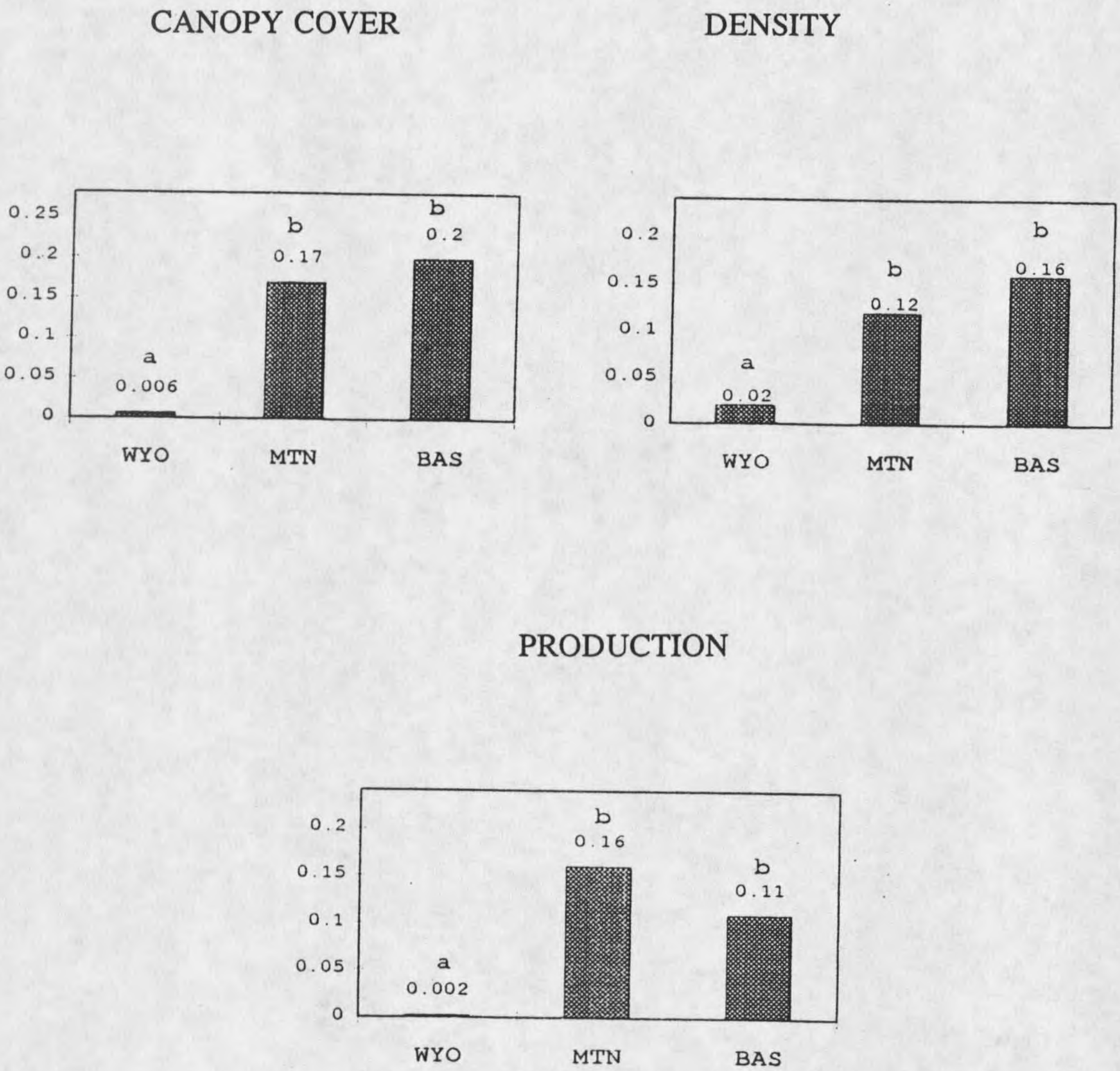
The density of young plants was not different ($P<0.05$) among the 3 subspecies of big sagebrush studied. From our observations, the density of young plants is probably not an accurate indicator of long-term establishment.

The density of young plants is a direct result of mature, seed-producing plants. Thus, one would expect the density of young plants to correlate with the density of mature plants. Actually, it is reasonable to expect that the density of young plants may be an exaggerated expression of the number of mature plants because of the large number of seeds produced by each mature plant.

However, the density of young plants is also strongly dependent on germination and seedling establishment, which differ among Wyoming, mountain, and basin big sagebrush depending on spring moisture and growing conditions (Sabo et al. 1979, Booth et al. 1990, Young et al. 1990). Big sagebrush is an opportunistic shrub. When growing conditions are favorable, seedlings flood the landscape. The number of seedlings that actually establish and reach maturity is a fraction of the number that may germinate. Thus, the density of young plants may reflect how recent growing conditions have favored germination of 1 subspecies over another, rather than actual establishment or recovery. In this study, density of young plants was not useful for determining the long-term response of big sagebrush to disturbance.

Wyoming big sagebrush reestablished to only 0.2% of its original production, while mountain and basin big sagebrush had reestablished to 16% and 11% of their original production. Wyoming big sagebrush reestablishment in terms of production was less than that of mountain big sagebrush ($P < 0.03$) as well as that of basin big sagebrush ($P < 0.04$). As with canopy cover and density results, reestablishment as measured by production for mountain and basin big sagebrush was not different ($p < 0.05$).

From these results, the null hypothesis that Wyoming mountain and basin big sagebrush would reestablish equally following disturbance is rejected. Wyoming big sagebrush reestablished to a lesser extent than mountain or basin big sagebrush. No difference was detected between the reestablishment of mountain and basin big sagebrush.



-- Numbers express ratio burned/unburned

-- Different letters above the value in each column are significantly different ($P < 0.05$)

-- WYO=Wyoming big sagebrush, MTN=mountain big sagebrush, BAS=basin big sagebrush

Figure 5. Canopy cover, density, and production ratios (burned/unburned) for 3 big sagebrush subspecies 19 years following wildfire near Gardiner, Montana measured during the summer of 1993.

Wyoming big sagebrush recovery may be slower because it occurs on drier, less productive sites. In addition, these microsites may be free of snow during a greater portion of the winter months, exposing Wyoming big sagebrush plants to greater browsing pressure. Although the burned area was fairly homogenous in terms of aspect and topography, mountain and basin big sagebrush plants were establishing on more north and east facing slopes, or in slight depressions, all of which would tend to hold more snow. Although these sites would be more productive which may result in greater interspecific competition, big sagebrush reestablishment tends to be greater, probably because of the protection from browsing animals.

These results coincide with those of Wambolt and Payne (1986), Blaisdell (1953), and Harniss and Murray (1973). Wambolt and Payne (1986) reported that 18 years following burning, Wyoming big sagebrush recovered to only 12% of levels measured on unburned sites. After 30 years, the same authors indicate that Wyoming big sagebrush abundance was not different on burned and unburned sites. Blaisdell (1953) reported that 12 years after a fire, mountain and basin big sagebrush had only recovered slightly. Thirty years following the same fire, Harniss and Murray (1973) found that mountain and basin big sagebrush had nearly recovered to their original abundance.

The previous discussion regarding different seedling germination and establishment among the 3 subspecies is another important consideration when interpreting the results. Growing conditions during certain years may encourage 1 subspecies over another. The more time the 3 subspecies are given to reestablish, the less the influence of seedling germination and establishment will have on overall recovery. Big sagebrush subspecies are adapted to inhabit certain types of environmental conditions, and eventually will reestablish themselves on certain sites. Thus, over a period of years, each subspecies will be afforded that set of environmental conditions to which it is best suited to begin reestablishment.

Wambolt (in press) reported on ungulate preference for the 3 big sagebrush taxa on this same winter range near Gardiner, Montana. According to his results, mountain big sagebrush was perferred over Wyoming big sagebrush, which was preferred over basin big sagebrush. Although ungulate use appeared to be heavy on all plants encountered in the burned area, the browsing impact did not apparently influence reestablishment as the most preferred taxon also exhibited greater reestablishment.

Rabbitbrush Recovery

Burned vs. Unburned

The rabbitbrush taxa have all exceeded their previous levels of abundance on the burned site (Table 7). Canopy cover and density of all rabbitbrush taxa were less in the unburned area than the burned area ($P<0.001$).

Canopy cover for threadleaf rubber rabbitbrush was 5.6% for the burned area and 0.60% for the unburned area. The density of threadleaf rubber rabbitbrush was 25 plants/m^2 in the burned area compared to 3.62 plants/m^2 in the unburned area.

Canopy cover values for mountain low rabbitbrush were 1.3% for the burned area and 0.10% for the unburned area. Mountain low rabbitbrush density was 11.2 plants/m^2 and 0.27 plants/m^2 in the burned and unburned areas respectively.

Narrowleaf low rabbitbrush canopy cover was 1.6% and 0.23% for the burned and unburned areas respectively. Densities of narrowleaf low rabbitbrush were 9.4 plants/m^2 in the burned area and 1.3 plants/m^2 in the unburned area.

Table 7. Density and canopy cover of 3 rabbitbrush taxa 19 years following wildfire near Gardiner, Montana measured during the summer of 1993.

	DENSITY (plants/m^2)		CANOPY COVER (%)	
TAXON*	BURNED	UNBURN.	BURNED	UNBURN.
NAUS	25.0	3.6	5.6	.60
LANC	11.2	.27	1.3	.10
STEN	9.0	1.3	1.6	.23

-- Within each parameter (canopy cover and density), all burned and unburned comparisons are different ($P<0.001$)

* NAUS=threadleaf rubber rabbitbrush, LANC=mountain low rabbitbrush, STEN=narrowleaf low rabbitbrush

The hypothesis that each of the rabbitbrush taxa would be equally abundant on burned area and unburned areas is rejected. All rabbitbrush taxa were more abundant on the burned area. These results are similar to Blaisdell (1953), Young and Evans (1974), and Wambolt and Payne (1986) who found that green rabbitbrush increased dramatically following fire. Unlike big sagebrush, green rabbitbrush plants have the ability to sprout from roots following disturbance (Young and Evans 1974). In addition, dynamic achene production and subsequent seedling establishment quickly result from the root sprouts. The observed response is a flush in rabbitbrush abundance immediately following a disturbance. Eventually, as observed by Harniss and Murray (1973) the rabbitbrush is replaced by the reestablishment of the dominant big sagebrush.

Although similar documentation does not exist for rubber rabbitbrush, the results of this study seem reasonable. Green and rubber rabbitbrush have similar abilities to sprout and produce abundant achenes following disturbance (Young and Evans 1974). Further evidence of this ability to produce achenes and establish seedlings was evident in that rabbitbrush occurred in extensive, dense patches as opposed to dispersed, individual plants.

As documented in Beverlin and Wambolt (1990), stickyleaf low rabbitbrush (Chrysothamnus viscidiflorus [Hook.] Nutt. viscidiflorus viscidiflorus) is present in the Gardiner area. However this taxon was rarely encountered in sampling this particular study area.

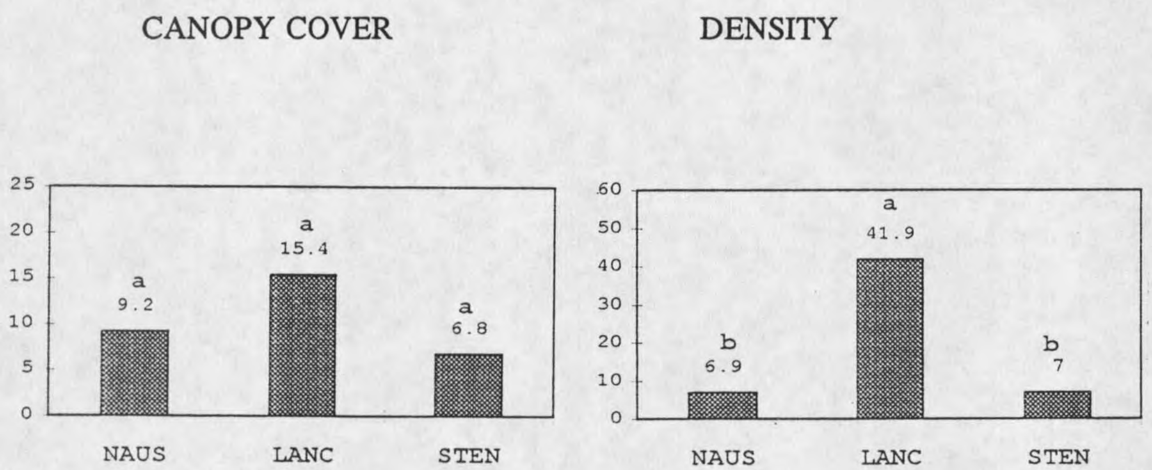
Grey horsebrush was also present on the study area. Blaisdell (1953) found that this species had reestablished to a greater extent than green rabbitbrush following fire. Although a trace of this species was observed within the perimeter of the burn, reestablishment was too small to measure.

Rabbitbrush Reestablishment by Taxon

For comparison among taxa, burned and unburned values were combined into a ratio (burned/unburned), which represents the extent to which each subspecies has recovered (Fig. 6). For statistical comparisons, a combined variance term was calculated, and ratios were compared using t-tests. Because the numerator was greater than the denominator for all rabbitbrush taxa, the ratio represents the number of times greater the burned value was than the unburned value, rather than a percentage as expressed above with the big sagebrush taxa.

Burned/unburned ratios of canopy cover yielded 15.4 for mountain low rabbitbrush, 9.2 for threadleaf rubber rabbitbrush, and 6.8 for narrowleaf low rabbitbrush. These canopy cover values were not different (P>0.05).

The mountain low rabbitbrush density ratio of burned/unburned was 41.9, which was greater (P<0.02 in both cases) than the threadleaf rubber rabbitbrush density ratio of 6.9 and the narrowleaf low rabbitbrush density ratio of 7.0. The density of threadleaf rubber rabbitbrush and narrowleaf low rabbitbrush were not different (P<0.05).



-- Values express ratio burned/unburned

-- Different letters above the value in each column represent a significant difference (P<0.05)

-- NAUS=threadleaf rubber rabbitbrush, LANC=mountain low rabbitbrush, STEN=narrowleaf low rabbitbrush

Figure 6. Canopy cover and density of 3 rabbitbrush taxa 19 years following wildfire near Gardiner, Montana measured during the summer of 1993.

Based on canopy cover measurements, no difference was detected for reestablishment among the 3 rabbitbrush taxa ($P < 0.05$). However, difference in density indicates that mountain low rabbitbrush had reestablished to a greater extent than threadleaf rubber rabbitbrush and narrowleaf low rabbitbrush ($P < 0.02$). No difference was detected between threadleaf low rabbitbrush and narrowleaf low rabbitbrush according to density ($P < 0.05$).

The conflicting results found between canopy cover and density were likely caused by error in using total density counts to measure establishment as discussed above with respect to big sagebrush seedlings; i.e., counting all plants establishing on a site may result in incorrect conclusions regarding actual reestablishment because the number of seedlings that survive to maturity is only a fraction of those that germinate. Adding to these difficulties, young and mature rabbitbrush plants could not be distinguished in the field. Apparently, as a result of heavy ungulate browsing, all rabbitbrush plants were quite compact in shape and had very little woody tissue above ground level, making them appear to be half-shrubs.

Because of this, canopy cover likely was the more reliable measure of rabbitbrush establishment. Thus, the 3 rabbitbrush taxa have apparently not reestablished to a different extent since the wildfire.

Rabbitbrush is probably more reliant on opportunistic reestablishment than big sagebrush, as it dominates the plant community at an earlier seral stage after disturbance. As the plant community matures successionally, rabbitbrush is one of the first shrubs to recolonize a disturbed site. Big sagebrush should eventually out-compete the rabbitbrush taxa, again becoming the dominant shrub in the community (Harniss and Murray 1973).

Big Sagebrush/Rabbitbrush Relationships

The original intent of this portion of the study was to correlate big sagebrush and rabbitbrush data to identify which taxa occupied similar types of sites. In the unburned area rabbitbrush was present, but only as isolated, widely distributed groups of plants. The same was true for big sagebrush reestablishing on the burned area. Thus, there would not have been an adequate number of plants for a comparison in the unburned areas, in the case of rabbitbrush, or burned areas, in the case of big sagebrush.

General observations indicated that narrowleaf low rabbitbrush tended to occur with Wyoming big sagebrush on drier, south and west facing slopes. Conversely, mountain low rabbitbrush tended to inhabit more moist, north and east facing slopes with mountain big sagebrush. Threadleaf rubber rabbitbrush was a more widespread shrub, and did not tend to occur in one habitat type over another.

Data from the 12 sites used for the first section of this study did not support these general observations. On these sites each of which was clearly dominated by one of the subspecies of big sagebrush, rabbitbrush generally was more common on the drier, south and west facing slopes with relatively less vegetative production or where introduced species dominated the understory vegetation. The only sites that contained more than 1 plant per $60m^2$ were the Travertine Wyoming big sagebrush, Eagle Cr. mountain big sagebrush, and Reese Cr. basin big sagebrush sites (for site conditions, see Table 2).

CHAPTER 5

SUMMARY AND MANAGEMENT IMPLICATIONS

Sagebrush manipulation remains a contentious issue within and among land management agencies and with the public. In Montana, this issue may be of particular importance with regard to the welfare of mule deer, elk, and many other wildlife species that inhabit sagebrush habitat types in the Gardiner basin along the northern border of Yellowstone National Park (YNP). In this area, winter range is of great concern as it provides a limited habitat for wintering ungulates (Houston 1982, Farnes 1991, Wambolt in press).

Under YNP policy of "natural regulation" of wildlife populations, severe winter periods are expected to play a significant role in limiting populations. The Montana Department of Fish, Wildlife, and Parks conducts elk hunts between October and February each year, but the overall impact of these hunts on the total population is minimal. Consequently, the relatively high number of overwintering ungulates, particularly elk, has long term impacts on the browse species of the winter range (Wright and Thompson 1935, Kay 1990, Chadde and Kay 1991, Patten 1993, Fortney and Wambolt 1995, Hoffman and Wambolt in press, Keigley, R.B. pers. comm., Wambolt in press). The heavy utilization that often occurs during the non-growing season is more injurious to shrubs than herbaceous species. This impact is magnified during severe winters through increased utilization levels (Wambolt in press).

Big sagebrush taxa on my study area are self-perpetuating, ie., as older plants die off, younger ones take their place (Lomasson 1948, Mueggler and Stewart 1980, and Wambolt 1994). This concept is complemented by the fact that sagebrush taxa are dominants in a number of habitat types (climax vegetation). For big sagebrush habitat types, the climax community produces the most vegetative biomass (Harniss and Murray 1973, Mueggler and Stewart 1980). Therefore, not surprisingly, Harniss and Murray (1973) found that fire decreases total vegetative productivity. Wildfire is not a frequent occurrence in sagebrush habitat types (Whisenant 1990), and periodic burning is not required to provide an adequate forage base for wintering ungulates that have evolved a browsing habit. Indeed, burning non-sprouting palatable shrubs will reduce forage for browse-dependent wildlife species. The reduction of browse will vary with many different factors including the level of ungulate stocking.

My results, together with past studies, indicate that responses to fire will vary greatly across the range of biotic and abiotic conditions found within and among big sagebrush habitat types on the northern range. This is confounded by the apparent difference in response among the subspecies of big sagebrush.

On the Northern Yellowstone Winter Range, big sagebrush provides particularly important cover and forage for mule deer and elk (McNeal 1984, Wambolt and McNeal 1987, Wambolt in press). My results and Wambolt (in press) suggest that big sagebrush comprises a significant proportion of mule deer diets. Although elk utilize big sagebrush to a lesser extent, sagebrush may provide a forage resource that is higher in nutrients than others available during the winter (Welch and McArthur 1979, Striby et al. 1987).

Along with most other browse species on the Northern Yellowstone Winter Range (Wright and Thompson 1935, Kay 1990, Chadde and Kay 1991, R.B. Keigley pers. comm.), the big sagebrush component of shrub/grass habitat types is declining (Wright and Thompson 1935, Patten 1993, Fortney and Wambolt 1995, Hoffman and Wambolt in press, Wambolt in press). Therefore, browsing pressure can further inhibit big sagebrush reestablishment following disturbances like fire (Fortney and Wambolt 1995). Browsing is likely one reason for the insignificant reestablishment of all 3 big sagebrush subspecies in the 1974 wildfire. Ultimately, herbivore numbers will have to be reduced from the highest levels realized over time for browse species to persist even at their currently reduced abundance on the Northern Yellowstone Winter Range. Currently, there is no known substitute for this course of action.

If the goal of sagebrush manipulation is to encourage establishment and production of grass and forb species for a period of time, burning may obtain the desired condition. However, caution should be used with fire because certain grass species may be damaged by burning (Jorgenson 1990), particularly Idaho fescue which is an important subdominant in the Gardiner basin (McNeal 1984).

However, if the ultimate goal is to provide winter forage and cover for mule deer and elk, the results of this investigation and companion studies (Fortney and Wambolt 1995, Hoffman and Wambolt in press, Wambolt in press) indicate burning will likely result in an overall decrease in winter range carrying capacity for a period of time until sagebrush reestablishment. This consideration is especially important on the Northern Yellowstone Winter Range, where browse has been heavily impacted by ungulate use. In this case, vegetative manipulation amounts to an additional stress (Wambolt and Payne 1986) on non-sprouting browse species that are already decreasing. Unfortunately, even if big sagebrush does reestablish following vegetative manipulation, it will not provide any benefits for browse-dependent ungulates that were not present in the pre-fire community.

Management decisions regarding the manipulation of big sagebrush habitat types will likely always be a source of conflict. As with all decisions of this type, final implementation depends on the objectives for the area. More importantly, once these objectives are identified, the environmental conditions must be adequately considered. In the Gardiner basin and similar areas that place a high priority on mule deer and elk (as well as antelope) habitat, it is certain that management should promote browse species and species that furnish security and thermal cover. Big sagebrush clearly falls within this realm. Fire will not promote a non-sprouting shrub like big sagebrush. Thus, promotion of these taxa must be through control of animal numbers. This will ensure the survival of older, more productive plants (Wambolt et al. 1994) and productive continuity in the existing plant community through uninterrupted establishment of new sagebrush plants.

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APPENDIX -- Big Sagebrush Production Equations

Table 8. Big sagebrush forage production equations and minimum crown diameters (MCD), from Creamer (1991).

Low use Wyoming big sagebrush:

$$\ln(F) = .322 + .048(MJ) + .017(AC) - .0003(C1)$$

MCD=36cm

High use Wyoming big sagebrush:

$$\ln(F) = .669 + .008(MJ) + .029(AC) + .028(HT)$$

MCD=23cm

Low use mountain big sagebrush:

$$\ln(F) = .647 + .034(MJ) + .031(AC) - .0002(C1)$$

MCD=23cm

High use mountain big sagebrush:

$$\ln(F) = .489 + .037(MJ) + .050(AC) - .0003(C1)$$

MCD=22cm

Low use basin big sagebrush:

$$\ln(F) = 2.37 + .008(MJ) + .020(AC)$$

MCD=28cm

High use basin big sagebrush:

$$\ln(F) = 2.18 + .004(MJ) + .027(AC) + .004(HT)$$

MCD=24cm

Equation parameter abbreviations: F=Forage (g), MJ=Major axis (cm), AC=Average cover (cm), C1=Circular area (cm^2), HT=Height (cm).