# Effects of Wildlife Utilization and Grass Seeding Rates on Big Sagebrush Growth and Survival on Reclaimed Mined Lands

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**Abstract**: Ensuring Wyoming big sagebrush (*Artemisia tridentata* Nutt ssp. *wyomingensis* Beetle & Young) survival remains a challenge years after initial re-establishment on reclaimed mined lands. Wildlife utilization of big sagebrush can be a major factor influencing its survival. A wildlife-proof exclosure was erected on a portion of an existing sagebrush establishment research site initiated by Schuman and others (1998) in 1990 at the North Antelope/Rochelle Complex mine in northeastern Wyoming. Investigations focused on the effects of wildlife utilization of big sagebrush growth and survival as affected by grass seeding rates of the original study and the newly constructed exclosure. Results indicate no significant differences in big sagebrush density between grass seeding rates or inside versus outside the exclosure. Significantly greater leader growth of big sagebrush occurred inside compared to outside the exclosure. Mean leader length of big sagebrush inside the exclosure in April 2002, 10 months after construction, was 46.4 mm compared to 9.4 mm outside. Wildlife browsing occurred on 100 percent of the big sagebrush plants outside the exclosure in 2002. Utilization and mortality of the sagebrush plants was significantly higher at the lower grass seeding rates. Approximately 33 percent of the studied sagebrush plants outside of the exclosure died during the 15-month study period compared to 11 percent inside the exclosure. Findings of this study indicate that wildlife browsing on these sagebrush plants is significantly influencing their survival and growth.

## Introduction

Wyoming big sagebrush (*Artemisia tridentata* Nutt ssp. *wyomingensis* Beetle & Young), if present in premined ecosystems, is required to be re-established according to the Surface Mining Control and Reclamation Act of 1977 and the Wyoming Environmental Quality Act of 1973 (Wyoming Department of Environmental Quality, Land Quality Division 1996). The process of re-establishing this shrub has been difficult for reclamation specialists. In 1990, Schuman and others (1998) initiated a study to evaluate the effects of various topsoil management, mulch type, and grass seeding rate treatments on re-establishment of Wyoming big sagebrush. The direct-placed topsoil treatment produced a higher big sagebrush seedling density than stockpiled topsoil in the first 2 years of the study. They believed this was due to consistently higher soil moisture in direct-placed topsoil plots. Their study demonstrated the positive benefits of direct-placed topsoil compared to stockpiled topsoil and various mulch treatments on big sagebrush re-establishment at North Antelope Coal Mine south of Gillette, WY.

However, ensuring big sagebrush survival remains a challenge years after initial re-establishment. Reclamation specialists are exploring other potential impacts to big sagebrush survival beyond edaphic and vegetative factors. Impacts of wildlife browsing may be a major factor on big sagebrush survival for some mines. Newly reclaimed coal mined lands often provide young, highly palatable and nutrient-rich plant communities that attract wildlife species such as mule deer (*Odocoileus hemionus*), pronghorn antelope (*Antilocapra americana*), cottontail rabbits (*Sylvilagus audubonii baileyi*), and jackrabbits (*Lepus townsendii* and *Lepus californicus melanotis*). Big sagebrush is a major diet component of many wildlife species because it provides a critical source of winter browse and cover (Beetle 1960). Since adjacent native rangelands usually contain older, mature shrubs of lower palatability and nutrient value, wildlife are attracted to reclaimed areas supporting greater herbaceous vegetation. Cool-season grasses and some shrub species, including big sagebrush, generally dominate reclamation seeding mixtures. The restriction of public access and prohibited hunting on mine property provides an environment that encourages habitual wildlife utilization of these reclaimed areas.

To investigate the influence of wildlife utilization on big sagebrush growth and survival, a wildlife-proof exclosure was constructed on half of the original North Antelope study site to provide comparative data on browsed versus unbrowsed big sagebrush, therefore, providing data on browsing impacts.

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Browsing on vegetation can be positive, such as compensatory growth due to moderate use (McNaughton 1983), or negative, such as increased mortality from heavy use (Wambolt 1996).

Reclamation specialists have learned to successfully re-establish big sagebrush on reclaimed lands; however, developing successful management practices to ensure survival of these new seedlings must be addressed. Factors such as low seedling vigor, their inability to compete with herbaceous species, poor seed quality, and altered edaphic conditions can impact initial establishment and long-term survival of sagebrush (Cockrell and others 1995).When these factors are combined with intense wildlife browsing, sustaining big sagebrush re-establishment is challenging. Quantitative information on big sagebrush utilization and the effects of browsing impacts on long-term seedling survival are needed. Specific objectives of this project were to (1) determine long-term big sagebrush survival using data from the original study; (2) establish a new baseline data record of big sagebrush survival without wildlife influence using inside versus outside exclosure comparisons; (3) assess sagebrush density (plants $m^{-2}$) within various grass seeding rates, inside and outside the exclosure; (4) determine percent of big sagebrush plants browsed by grass seeding rates, inside and outside the exclosure; (5) examine seasonal (spring/summer, fall/winter) utilization rates of big sagebrush leader growth among grass seeding rates, inside/outside the exclosure; and (6) recommend potential management practices to enhance long-term big sagebrush survival on reclaimed mine lands.

## Study Area

North Antelope Coal Mine is located in the Powder River Basin in northeast Wyoming, approximately 100 km south of Gillette, WY. Elevation ranges from 1,220 to 1,520 m. Climate is characterized as semiarid, temperate, and continental. Average annual temperature is 7 °C with January the coldest month (–6 °C) and July the warmest month (22 °C). Annual precipitation is 339 mm (1978 to 2000 average), with the greatest precipitation occurring in April, May, and June (Schuman and Belden 2002). The frost-free growing season averages 133 days (Glassey and others 1955).

The project area is approximately 1.2 ha in size. Native soils are broadly classified as Haplargids, Natrargids, and Torrorthents. Loamy and clayey soil textures comprise much of the basin (Young and Singleton 1977). Fresh direct-placed topsoil used at the research site included a complex of Shingle (loamy, mixed, calcareous, mesic, shallow, Ustic Torrorthents) and Samsil (clayey, montmorillinitic, calcareous, mesic, shallow, Ustic Torrorthents) series (Schuman and others 1998).

Topography is characterized as plains and low-lying irregular hills. Vegetation consists of low-growing shrubs, forbs, and short to midgrasses, primarily cool-season perennials. Prior to mining, the native vegetation primarily consisted of western wheatgrass (*Pascopyrum smithii* (Rybd.) A. Love), needleandthread grass (*Stipa comata* Trin. and Rupr.), prairie junegrass (*Koeleria macrantha* L. Pers.), big sagebrush, sandberg bluegrass (*Poa secunda* Presl), six-weeks-grass [*Vulpia octoflora* (Walt.) Rydb.], and cheatgrass (*Bromus tectorum* L.) (Western Water Consultants and Bureau of Land Management 1998). Species seeded on the reclaimed area were a mixture of native cool-season perennial grasses (Schuman and others 1998), including "Rosana" western wheatgrass [*Pascopyrum smithii* (Rybd.) A. Love], "San Luis" slender wheatgrass [*Elymus trachycaulus* (Link) Gould ex Skinner], and "Critana" thickspike wheatgrass [*Elymus lanceolatus* (Scribner & J.G. Smith) Gold].

The predominant land use in the area is domestic livestock grazing and habitat for big game, predators, small mammals, upland game birds, and nongame birds.

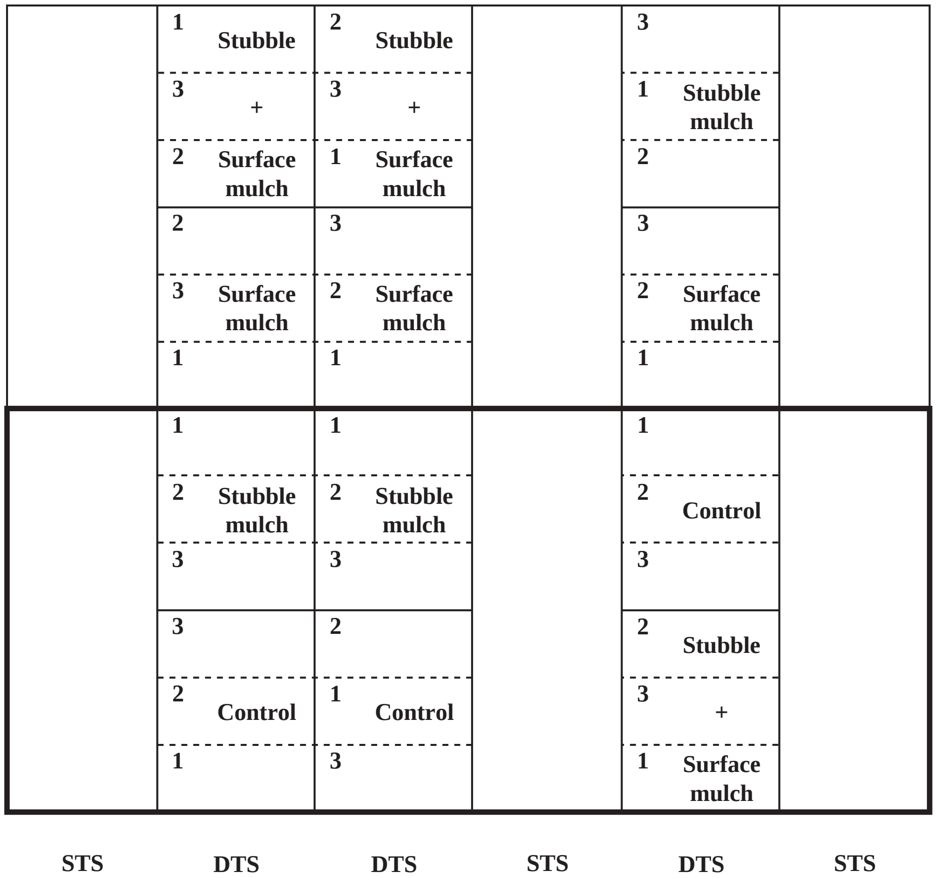
## Methods and Materials

### Experimental Design

The original big sagebrush re-establishment study design (Schuman and others 1998) initiated in August 1990 was used for this project and included the following treatments: topsoil management (fresh stripped/direct-placed and 5-year-old stockpiled topsoil), mulch type (stubble mulch, surface-applied straw mulch, stubble and surface-applied straw mulch, and no mulch), and grass seeding rate (no perennial grass seeded, 16 kg PLS [pure live seed] $ha^{-1}$, and 32 kg PLS $ha^{-1}$). All treatments were randomly assigned to a randomized block, split-split plot design with three replications (fig. 1). Topsoil treatment plots were 15 by 60 m with mulch subplots measuring 15 by 15 m and grass seeding rate sub-subplots measuring 15 by 5 m within each topsoil treatment main plot. Each of the four mulch types occurred within each of the three replications of fresh and stored topsoil treatments. The three grass seeding rates were randomly established within each of the four mulch treatments. Nine quadrats (1 $m^2$) were permanently staked in each of the grass seeding rate sub-subplots in three belts of three quadrats, lying in an east-west direction and located 1 m from the edge of each subplot.

In the original study, the direct-placed topsoil plots supported higher big sagebrush density than stockpiled topsoil in the first 2 years. Greater sagebrush seedling establishment in the direct-placed topsoil was due to consistently higher soil moisture observed in that treatment (Schuman and others 1998). Direct-placed topsoil also exhibits better chemical, physical, and biological properties than stockpiled topsoil (DePuit 1988; Stahl and others 1988; White and others 1989). The stockpiled topsoil treatment was excluded from this study because of the noted benefits of direct-placed topsoil. Stockpiled topsoil also no longer represented the original qualities because of the rapid inoculation by arbuscular mycorrhizae via wind and the many positive biogeochemical and physical changes that have occurred in the soil over 12 years.

Another addition to the original study was the construction of a wildlife-proof exclosure in June 2001 just prior to the first data collection. Exclosure dimensions are 90 by 30 m and 3.1 m tall, which enclosed half of each replicated direct-placed topsoil treatment plot. The same number of mulch treatment subplots and grass seeding rate sub-subplots were located inside and outside the exclosure. The exclosure fence was constructed of woven wire with 0.5 m




**Grass seeding rates:**

**1 = 0 kg PLS ha$^{-1}$**
**2 = 16 kg PLS ha$^{-1}$**
**3 = 32 kg PLS ha$^{-1}$**

**DTS = direct-placed topsoil**
**STS = stockpiled topsoil**
**Dark outline area = exclosure**
**Total Area = 90 x 60 m**

**Figure 1**—Study plot design including topsoil, mulch, and grass seeding rate treatments, North Antelope Coal Mine, Gillette, WY, 2001–2002.

high chicken wire extending along the ground surface to exclude rabbits and large rodents.

## Big Sagebrush Density

Two methods of determining big sagebrush density were used. Permanent quadrats established in 1992 (Schuman and others 1998) were sampled to determine long-term big sagebrush survival. The number of live big sagebrush plants was counted in each of nine permanent quadrats within each grass seeding rate sub-subplot. Density was reported as the mean number of plants m$^{-2}$ in each grass seeding rate inside and outside the exclosure.

Big sagebrush density was also assessed along a 2- by 12-m belt transect in each grass seeding rate sub-subplot, which provided another baseline record for evaluating big sagebrush survival inside and outside the exclosure. A 1-m$^2$ quadrat was placed alongside each belt transect, sagebrush plants were counted within the quadrat, then the quadrat was flipped to the next meter of the transect until all sagebrush plants were counted in the 24-m$^2$ area of the belt (12 m$^2$ on each side of the line). Density was summarized as the mean number of plants m$^{-2}$ in each grass seeding rate inside and outside the exclosure.

## Percent Browsed Big Sagebrush Plants

Within each grass seeding rate sub-subplot, four big sagebrush plants were selected near the outside corners of the permanent quadrats making a total of 144 plants (72 outside and 72 inside the exclosure). Each selected plant was marked by attaching a plastic locking zip tie at the base of the plant. Plant locations were mapped for easy relocation during subsequent sampling periods of the project. Each marked plant was inspected during sampling dates and recorded as browsed or unbrowsed to estimate percent of plants browsed.

Since the first sampling period (June 2001) immediately followed exclosure construction, some browsing had occurred prior to exclosure erection. Therefore, percent browsed plants were calculated inside and outside the exclosure in June 2001. In fall 2001, a small hole in the exclosure was discovered and repaired. Therefore, rabbit presence and potential utilization of sagebrush leaders was possible inside the exclosure until September 2001.

## Big Sagebrush Leader Utilization

Differences in big sagebrush leader lengths of individually marked plants were evaluated to assess the degree of utilization. All leaders on marked plants were measured to the nearest 1 mm, and summarized as mean leader length per plant for each grass seeding rate inside and outside the exclosure. Nondistinctive leaders, such as those lacking woodiness or leaves extending from primary stems, were not considered leaders. Leader measurements excluded leaves extending from the terminal tip.

Big sagebrush leaders were measured in the spring and fall each year. Percent utilization was only calculated for the marked plants outside the exclosure because no browsing was observed inside the exclosure. The difference in mean leader length from spring to fall outside the exclosure provided percent summer utilization. Before new annual growth appeared the following spring, leader length was reassessed to provide the percent utilization during the late fall and winter period.

## Data Analysis

Differences ($P \leq 0.10$) in mean big sagebrush density from permanent quadrats and belt transects, percent big sagebrush plants browsed, mean leader length, and percent utilization were evaluated between grass seeding rates inside and outside the exclosure using analysis of variance (ANOVA). Mean separations were evaluated using Tukey's pairwise comparison test (experimentwise $P \leq 0.10$) (Krebs 1999).

# Results and Discussion

## Big Sagebrush Density

Big sagebrush density (plants $m^{-2}$), measured in the permanent quadrats, increased in 1993 and 1994 following the 1992 seeding, but declined during subsequent years across all grass seeding rates (fig. 2) and mulch treatments (Schuman and Belden 2002). Mean big sagebrush density was generally highest in the 0 kg PLS $ha^{-1}$ grass seeding rate across historical sampling years; therefore, percent survival was actually higher at the 16 and 32 kg PLS $ha^{-1}$ grass seeding rates.

Big sagebrush densities inside and outside the exclosure were combined (averaged) in both 2001 and 2002 to compare to previous years. Although there were no differences in big sagebrush density among grass seeding rates in 2001 or 2002, there was a consistent decline in big sagebrush density for grass seeding rates over time. Future studies should evaluate long-term grass seeding rate influences on big sagebrush density and survival inside the exclosure where wildlife influences will not be a factor.

When examining 2001–2002 data only, mean big sagebrush density within the belt transects was highest in the 32 kg PLS $ha^{-1}$ grass seeding rate inside the exclosure compared to other grass seeding rates, and significantly greater than the big sagebrush density in the same grass seeding rate outside of the exclosure (fig. 3). Big sagebrush density also exhibited a significant location by sample date interaction (fig. 4). Big sagebrush density was significantly higher inside

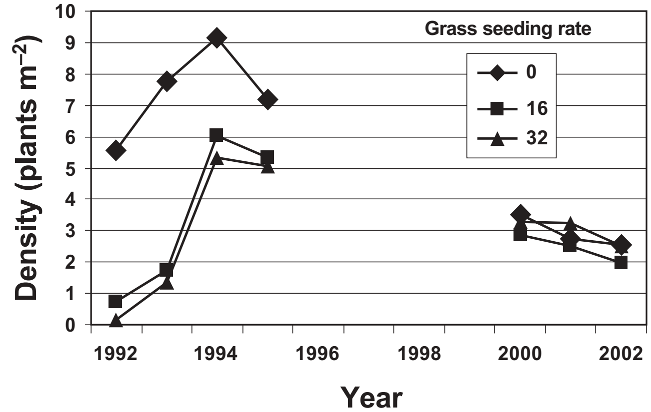
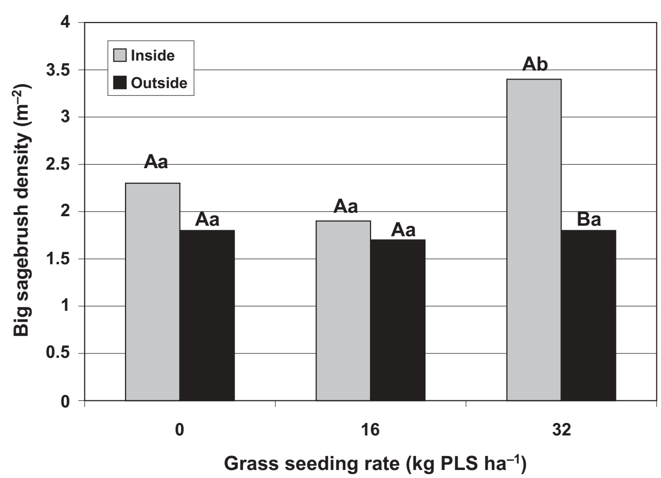



**Figure 2**—Historic and present mean big sagebrush density by grass seeding rates (kg PLS $ha^{-1}$) from permanent quadrat sampling, North Antelope Coal Mine, Gillette, WY.




**Figue 3**—Mean density of big sagebrush along belt transects by grass seeding rates inside and outside the exclosure, North Antelope Coal Mine, Gillette, WY, 2001–2002 (means within a grass seeding rate across locations with the same uppercase letter are not significantly different; means within a location across grass seeding rates with the same lower case letter are not significantly different, $P \leq 0.10$).

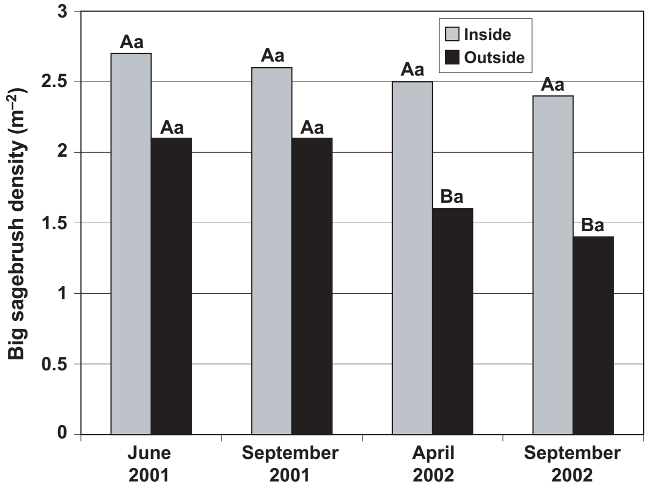



**Figure 4**—Density of big sagebrush along belt transects by sampling date inside and outside the exclosure, North Antelope Coal Mine, Gillette, WY, 2001–2002 (means within a sampling date across locations with the same uppercase letter are not significantly different; means within a location across sampling dates with the same lowercase letter are not significantly different, $P \leq 0.10$).

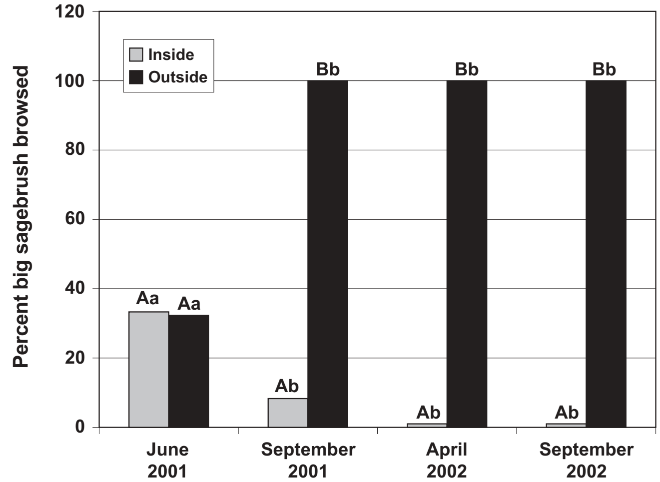



**Figure 5**—Percent big sagebrush plants browsed by sampling date inside and outside the exclosure, North Antelope Coal Mine, Gillette, WY, 2001–2002 (means within a sampling date across locations with the same uppercase letter are not significantly different; means within a location across sampling dates with the same lowercase letter are not significantly different, $P \leq 0.10$).

the exclosure compared to outside of the exclosure in April and September 2002. No differences in density were observed inside the exclosure versus outside of the exclosure in 2001, which was anticipated since the exclosure was not constructed until June 2001.

Big sagebrush density was positively affected by wildlife exclusion 10 months (April 2002) after construction of the exclosure. Big sagebrush density outside the exclosure decreased more rapidly than inside, as evidenced by the number of dead marked plants during the study. Eight marked sagebrush plants inside the exclosure died compared to 24 plants outside of the exclosure. Mortality outside of the exclosure, among the marked plants, was 42 percent in the 0 kg PLS ha$^{-1}$ grass seeding rate, 38 percent in the 16 kg PLS ha$^{-1}$ grass seeding rate, and only 21 percent in the 32 kg PLS ha$^{-1}$ grass seeding rate. Schuman and Belden (2002) also reported significantly greater sagebrush plant mortality in the 0 and 16 kg PLS ha$^{-1}$ compared to the 32 kg PLS ha$^{-1}$ grass seeding rate on these plots after 8 years. They hypothesized that this might be due in part to intraspecific competition and some sort of protective mechanism of the grass plants. Owens and Norton (1992) also reported that basin big sagebrush (*Artemisia tridentata* ssp. *tridentata*) seedlings experienced the greatest mortality in unsheltered areas of the landscape.

## Percent Browsed Big Sagebrush Plants

Percent of big sagebrush plants browsed exhibited a significant interaction between location (inside versus outside exclosure) and sample date (fig. 5). There were no differences in the degree of big sagebrush plants browsed inside versus outside the exclosure in June 2001 due to the recent exclosure construction. However, percent of big sagebrush browsed decreased inside the exclosure from June 2001 to September 2002. Browsing inside the exclosure on the June 2001 sampling date occurred prior to construction of the exclosure about 10 days before the sampling date. All marked plants outside the exclosure exhibited browsing regardless of grass seeding rate. Across all grass seeding rates, April 2002 browsing data suggest that rabbits rather than big game were the primary browsers of the big sagebrush plants. However, the September 2002 browsing data indicate that big game and rabbit browsing was nearly equal. It is important to remember that identifying the browsing animal is limited to the most recent browser, because if a plant was browsed by big game and then browsed by a rabbit the data would only indicate it was browsed by a rabbit because of the methodology.

## Utilization

Big sagebrush leader length exhibited a significant location by grass seeding interaction (fig. 6). Mean leader length was significantly greater in the 32 kg PLS ha$^{-1}$ grass seeding rate compared to the lower grass seeding rates. This response cannot be explained. However, leader lengths were greater inside of the exclosure compared to outside the exclosure for all grass seeding rates. There were no differences in leader lengths among grass seeding rates outside of the exclosure. Big sagebrush leader length was also greater inside the exclosure for all sample dates (fig. 7). Big sagebrush leader length responded to the protection provided by the exclosure. Leader length inside the exclosure continued to increase, while unprotected plants outside the exclosure exhibited dramatic decreases in leader length due to wildlife browsing. Big sagebrush survival outside of the exclosure is threatened by continued intense wildlife utilization.

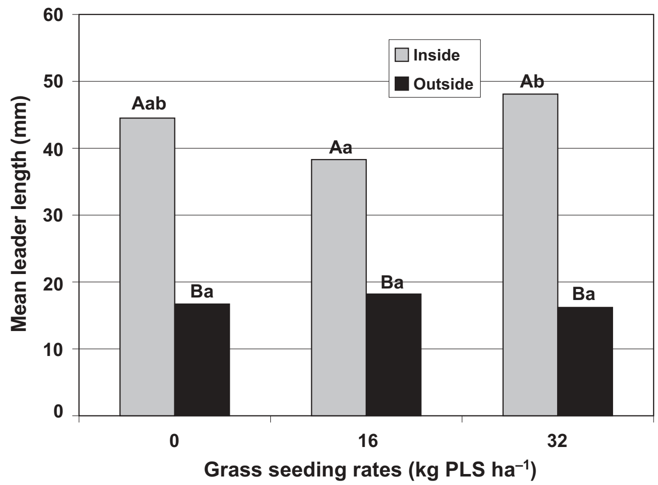



**Figure 6**—Mean leader length of marked big sagebrush by grass seeding rates inside and outside the exclosure, North Antelope Coal Mine, Gillette, WY, 2001–2002 (means within a grass seeding rate across locations with the same uppercase letter are not significantly different; means within a location across grass seeding rates with the same lower case letter are not significantly different, P ≤ 0.10).

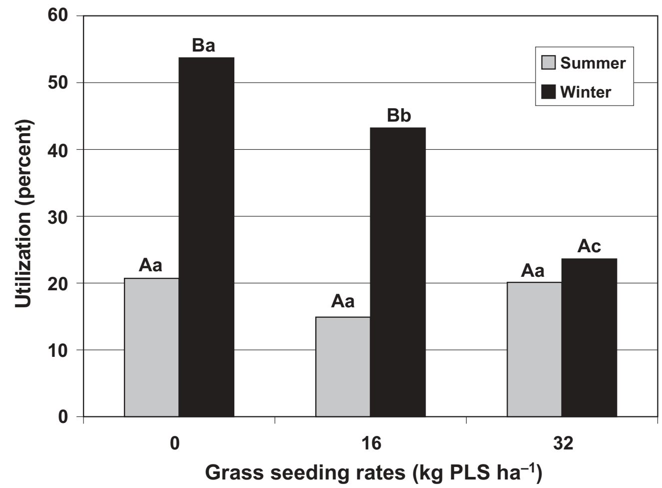



**Figure 8**—Seasonal percent utilization of marked big sagebrush plants by grass seeding rates outside the exclosure, North Antelope Coal Mine, Gillette, WY, 2001–2002 (means within a grass seeding rate across season with the same uppercase letter are not significantly different; means within a season across grass seeding rates with the same lower case letter are not significantly different, P ≤ 0.10).

Seasonal utilization of marked sagebrush plants outside the exclosure exhibited a significant interaction between grass seeding rate and sample period (fig. 8). Summer wildlife utilization was consistent across grass seeding rates. However, winter utilization was significantly lower in the 32 kg PLS ha$^{-1}$ grass seeding rate compared to both the 16 and 0 kg PLS ha$^{-1}$ grass seeding rates. There was also significantly greater wildlife utilization in the winter compared to the summer period in the 0 and 16 kg PLS ha$^{-1}$ grass seeding rates. The lower wildlife utilization during the winter months as grass seeding rate increased agrees with the sagebrush survival data presented by Schuman and Belden (2002) after 8 years, and also agrees with the survival and mortality data presented here 10 years after establishment (fig. 9). It appears that several things may be influencing the response sagebrush are exhibiting on this site. Austin and others (1994) evaluated the effects of deer and horse browsing on transplanted Wyoming big sagebrush survival. They found that plantings resulting in densities of 0.08 and 0.44 sagebrush plants m$^{-2}$ were not influenced by the animals. However, the plant densities at our study site were severalfold higher and may have resulted in intraspecific competition for space, water, and nutrients. Owens and Norton (1994) found that sagebrush seedlings sheltered by other plants experienced less mortality than those growing in unprotected spaces. Based on their findings and those of Schuman and Belden (2002) it appears there are likely several factors affecting sagebrush survival on this reclaimed mined land. It is obvious from the significantly higher survival, lower mortality, and reduced wildlife utilization (fig. 9) of big sagebrush at the higher grass seeding rates that this is not a random response even though we cannot fully explain it.

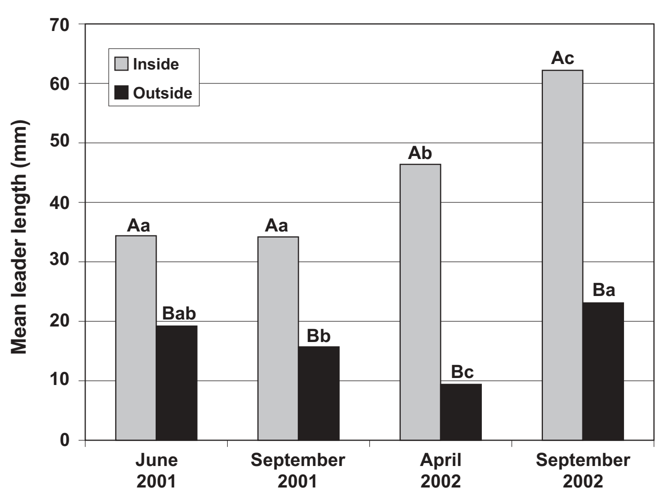



**Figure 7**—Mean leader length of marked big sagebrush plants by sampling period inside and outside the exclosure, North Antelope Coal Mine, Gillette, WY, 2001–2002 (means within a sampling date across locations with the same uppercase letter are not significantly different; means within a location across sampling dates with the same lowercase letter are not significantly different, P ≤ 0.10).

Greater winter utilization was anticipated because browsing preference by big game (Craven 1983b; Schemnitz 1982; Welch and others 1981) and rabbits (Anderson and Shumar 1986; Craven 1983a; Knight 1982) intensify during the winter. Big sagebrush is a “starvation food” or necessary dietary component of winter months when nothing else is available (Welch and others 1981). Partial or complete defoliation of sagebrush leaders will not adversely affect growth,

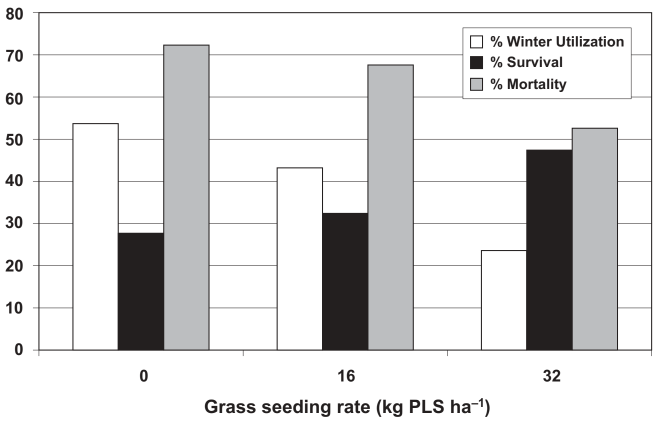



**Figure 9**—Relationship between percent winter utilization (2002), survival, and mortality of big sagebrush plants, North Antelope Coal Mine, Gillette, WY, 1994–2002.

vigor, and survival if leaf primordia and twigs are undamaged (Kelsey 1984). However, defoliation in our study was much more severe with considerable twig and primordia damage. Wildlife contributed to the death of about 33 percent of the marked sagebrush plants outside of the exclosure within 15 months.

For reclamation sites to provide adequate wildlife habitat, big sagebrush must be successfully established and maintained. Big sagebrush is included in the reclamation seed mix to satisfy State and Federal regulations for shrub reestablishment and land use. However, the intended land use (wildlife habitat) seems to be the very reason for threatened big sagebrush survival at this site. Our data indicate that high wildlife densities are impeding the successful long-term establishment and growth of the big sagebrush component of the reclaimed site. Both wildlife management and habitat manipulation may be necessary for successful reclamation of this site. Without proper wildlife and habitat management, big sagebrush densities could decline to less than 1 plant m$^{-2}$ on these reclaimed areas, and not meet the required density for bond release (Wyoming Department of Environmental Quality, Land Quality Division 1996).

## Management Implications

Because intense wildlife utilization has been shown to reduce big sagebrush survival on some mine sites, reclamation specialists should consider management practices to reduce wildlife herbivory impacts. Habitats on adjacent, native rangeland may be improved to attract wildlife away from reclamation sites, possibly enhancing big sagebrush survival. Prescribed burning, mechanical practices (mowing, roto-beating), and other treatments of adjacent native big sagebrush-dominated rangeland that increase herbaceous plant production, improve forage quality, and enhance plant diversity may help distribute wildlife. Interseeding perennial grasses and forbs, combined with management of overmature big sagebrush stands, could improve adjacent native landscape condition and improve big sagebrush survival on reclaimed areas by increasing wildlife distribution.

Improving wildlife distribution and enhancing rangeland forage quality may not be enough. Therefore, wildlife population management may also be necessary at some mines. Wildlife are attracted to reclamation areas for foraging on freshly seeded plant species, including big sagebrush seedlings. In addition, wildlife are provided protection from human disturbance by restricted public access and prohibition of hunting within the mine permit area. Wildlife populations might be better managed on theses reclaimed areas if mining companies would consider allowing limited harvesting (hunting) by methods compatible with the mine environment and considerations.

Evaluating the impacts of wildlife browsing on big sagebrush survival is necessary for all mines trying to reestablish big sagebrush and other shrub species. This study has additional value as a demonstration site for illustrating long-term differences between browsed (outside exclosure) and unbrowsed (inside exclosure) big sagebrush years after project completion. Recommendations to reduce wildlife browsing impacts on big sagebrush, as a byproduct of this research, will hopefully result in more successful reclamation by mining companies and provide improved wildlife habitat.

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# Field Trips

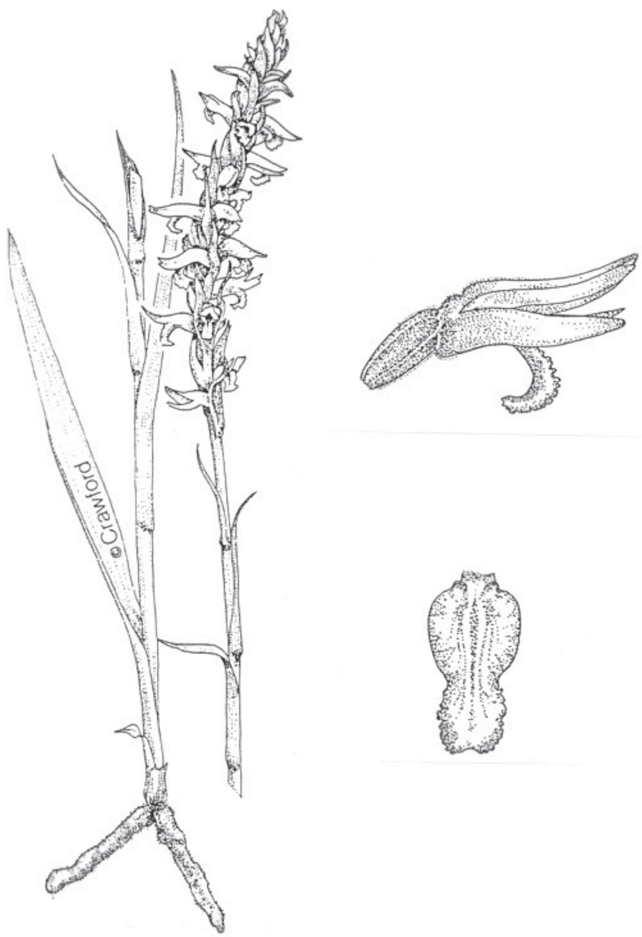


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Illustration on the reverse side is by Carolyn Crawford. In: Fertig, W.; Refsdal, C.; Whipple, J. 1994. Wyoming rare plant field guide. Cheyenne: Wyoming Rare Plant Technical Committee. Available at: http://www.npwrc.usgs.gov/resource/distr/others/wyplant/species.htm (Accessed 12/18/03).