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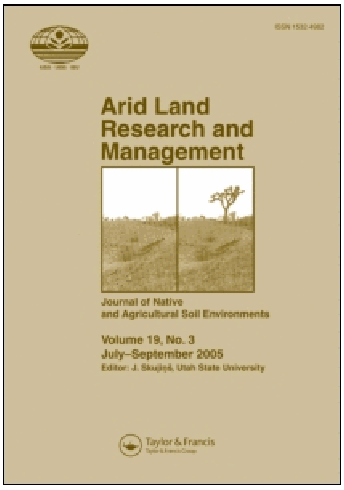

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Wildlife Impacts to Big Sagebrush on Reclaimed Mined Lands

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Wildlife browsing of Artemisia tridentata *ssp.* wyomingensis *(big sagebrush) on reclaimed coal mined land threatens long-term, sustainable reclamation success. A wildlife-proof exclosure was constructed in 2001 on a 10-year old* A. tridentata *ssp.* wyomingensis *reestablishment research site at North Antelope Coal mine in northeastern Wyoming to assess wildlife browsing impacts.* Artemisia tridentata *ssp.* wyomingensis *survival, growth, and plant community attributes (species richness, canopy cover, and diversity) were evaluated inside and outside the exclosure, across the original grass seeding rate treatments (0, 16, 32 kg PLS ha^{-1}). Long-term* A. tridentata *ssp.* wyomingensis *density decreased across all seeding rates from 1994 to 2002. Higher* A. tridentata *density, leader (shoot) growth, and canopy cover, along with lower mortality, occurred inside the exclosure across all seeding rates. Lower winter use, higher survival, and lower mortality of* A. tridentata *ssp.* wyomingensis *in the 32 compared to the 0 and 16 kg PLS ha^{-1} seeding rates suggest a beneficial relationship between* A. tridentata *ssp.* wyomingensis *survival and higher grass seeding rate. Approximately 33% mortality of marked* A. tridentata *ssp.* wyomingensis *plants occurred outside the exclosure.* Lepus townsendii campanius *(white-tailed jackrabbit),* L. californicus melanotis *(black-tailed jackrabbit),*

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and Sylvilagus audubonii baileyi *(cottontail rabbit) were identified as primary browsers of* A. tridentata. *Plant species richness, cover, and diversity decreased from 2001 to 2002, probably due to below average precipitation during the study. Defoliation of* A. tridentata *ssp.* wyomingensis *was severe, indicating the magnitude of impact from browsing wildlife. Post mining wildlife management and habitat manipulation on adjacent rangeland is suggested to ensure successful reclamation of coal mined lands.*

Keywords *Artemisia tridentata* ssp. *wyomingensis*, mining reclamation, wildlife browsing

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Post mining restoration of *Artemisia tridentata* Nutt ssp. *wyomingensis* Beetle and Young (Wyoming big sagebrush) on western USA coal mined land has been difficult. Low seedling vigor, inability to compete with herbaceous species, poor seed quality, and altered edaphic conditions can inhibit establishment and long-term survival of *A. tridentata* ssp. *wyomingensis* (Cockrell et al., 1995). Post mining reestablishment of *A. tridentata* ssp. *wyomingensis* is critical to suppress potential soil erosion, slow natural recruitment of less desirable shrub species, and enhance initial plant productivity (Hansen 1989; Stevenson et al., 1995; Whisenant, 1999; Cooper & MacDonald, 2000). It is also very important as a browse plant for big game and provides habitat for numerous small mammals and prairie birds, especially sage grouse (Long, 1981). In Wyoming, *A. tridentata* ssp. *wyomingensis*, if present before mining, must be reestablished 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).

Reclamationists have successfully reestablished *A. tridentata* ssp. *wyomingensis* through careful topsoil replacement and reseeding. In 1990, Schuman et al. (1998) demonstrated higher *A. tridentata* ssp. *wyomingensis* seedling density and establishment success using direct-placed (versus stockpiled) topsoil and mulching treatments at North Antelope Coal mine south of Gillette, Wyoming, USA. Other research has reported successful revegetation of *A. tridentata* ssp. *wyomingensis* using various seeding rates (Williams et al., 2002), varied grass seeding rates (Schuman et al., 1998; Williams et al., 2002), and diversified native plant seed mixes (Steward & Hansen, 1996). However, maintaining long-term survival and the desired density of *A. tridentata* ssp. *wyomingensis* from seedling to mature plant stages remains a challenge.

Newly reclaimed coal mine lands often provide young, highly palatable, and nutrient-rich plant communities that attract wildlife such as *Odocoileus hemionus* Rafinesque (mule deer), *Antilocapra americana* (Ord.) (pronghorn antelope), *Sylvilagus audubonii baileyi* (Baird) (cottontail rabbit), *Lepus townsendii campanius* Hollister (white-tailed jackrabbit), and *L. californicus melanotis* Mearns (black-tailed jackrabbit). Since adjacent rangelands consist of mature shrubs of lower palatability and nutrient value (Longhurst et al., 1968; Kelsey, 1984), wildlife are often attracted to reclaimed mined land. Additionally, public access restrictions and prohibited hunting on coal mine lands further encourages wildlife to habitually occupy these areas.

A. tridentata ssp. *wyomingensis*, preferred by *O. hemionus* and *A. americana* for winter food and cover (Beetle, 1960; Johnson & Anderson, 1984), is not adapted to heavy browsing as evidenced in reduced plant vigor, impaired plant architecture, restricted resource allocation, reduced growth rate, lowered reproductive capacity (Maschinski & Whitman, 1989), and increased mortality (Wambolt, 1996) following excessive browsing. Heavy wildlife utilization of *A. tridentata* ssp. *wyomingensis* seedlings on reclaimed mined lands therefore may strongly influence vigor and survival.

Our hypothesis that wildlife browsing affected *A. tridentata* ssp. *wyomingensis* long-term survival, growth, and vigor was investigated by establishing a wildlife-proof exclosure in June 2001 around a portion of the original North Antelope Coal mine study site established by Schuman et al. (1998) in 1990 to provide comparative data on browsed versus unbrowsed *A. tridentata* ssp. *wyomingensis*. Study objectives were to: (1) determine long-term *A. tridentata* survival; (2) evaluate differences in *A. tridentata* ssp. *wyomingensis* growth inside and outside the exclosure; (3) assess differences in *A. tridentata* ssp. *wyomingensis* density between grass seeding rates, inside and outside the exclosure; (4) evaluate seasonal (spring/summer, fall/winter) utilization levels of *A. tridentata* ssp. *wyomingensis* leader (shoot) growth among grass seeding rates outside the exclosure; and (5) assess plant species richness, canopy cover, and diversity among grass seeding rates, inside and outside the exclosure.

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Study Area

North Antelope Coal mine (43° 30′ N; 105° 15′ W) is located in the Powder River Basin of northeast Wyoming USA, approximately 100 km south of Gillette. Elevation ranges from 1220 to 1520 m. Climate is semiarid, temperate, and continental with an average annual temperature of 7°C, January is the coldest month (−6°C) and July is the warmest month (22°C). Mean annual precipitation is 333 mm (1978–2002), mostly occurring in April, May, and June (Schuman & Belden, 2002). The frost-free growing season averages 133 days (Glassey et al. 1955).

Topography consists of plains and low lying irregular hills. Prior to mining, the vegetation consisted of *Pascopyrum smithii* (Rybd.) A. Love (western wheatgrass), *Stipa comata* Trin. and Rupr. (needle and thread grass), *Koeleria macrantha* L. Pers. (prairie junegrass), *Poa secunda* Presl (sandberg bluegrass), *Vulpia octoflora* (Walt.) Rydb (six-weeks grass), *Bromus tectorum* L. (cheatgrass), and *A. tridentata* ssp. *wyomingensis* (Western Water Consultants and Bureau of Land Management, 1998).

The study site comprises 1.2 ha of leveled coal mine spoil. Fresh direct-placed topsoil used in the study included a complex of Shingle (loamy, mixed, calcareous, mesic, shallow, Ustic Torrorthents) and Samsil (clayey, montmorillinitic, calcareous, mesic, shallow, Ustic Torrorthents) soil series (Schuman et al., 1998). Species seeded on the study area included *P. smithii* (Rybd.) A. Love 'Rosana' ('Rosana' western wheatgrass), *Elymus trachycaulus* (Link) Gould ex Skinner 'San Luis' ('San Luis' slender wheatgrass), and *Elymus lanceolatus* (Scribner & J.G. Smith) Gold 'Critana' ('Critana' thickspike wheatgrass) (Schuman et al., 1998). Predominant land use before mining was livestock grazing and wildlife habitat. Post mining land use is currently limited to wildlife habitat.

Methods and Materials

Experimental Design

This research was accomplished on an *A. tridentata* ssp. *wyomingensis* reestablishment study initiated by Schuman et al. (1998) in August 1990. Original treatments included 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}). Grasses were drill seeded in November 1991 into small grain stubble established in 1991. *Artemisia tridentata* ssp. *wyomingensis* was broadcast seeded in March 1992 at a rate of 2.63 kg PLS ha^{-1} across all treatments. All treatments were randomly located in a randomized block, split-split plot design with 3 replications (Figure 1). Topsoil treatment plots were 15 by 60 m with mulch subplots measuring 15 by 15 m and further split into 15 by 5 m grass seeding rate subplots. Nine quadrats (1 m^2) were permanently staked in each grass seeding rate subplot in 3 rows of 3 quadrats, arranged in an east-west direction and located 1 m from the subplot edge. Since no differences in *A. tridentata* ssp. *wyomingensis* plant density was found after 8 years (Schuman & Belden, 2002) between the stockpiled topsoil plots and direct haul topsoil treatments and various mulch type subplots we did not consider these treatments in our sampling scheme. These treatment plot/subplot delineations are shown in the plot

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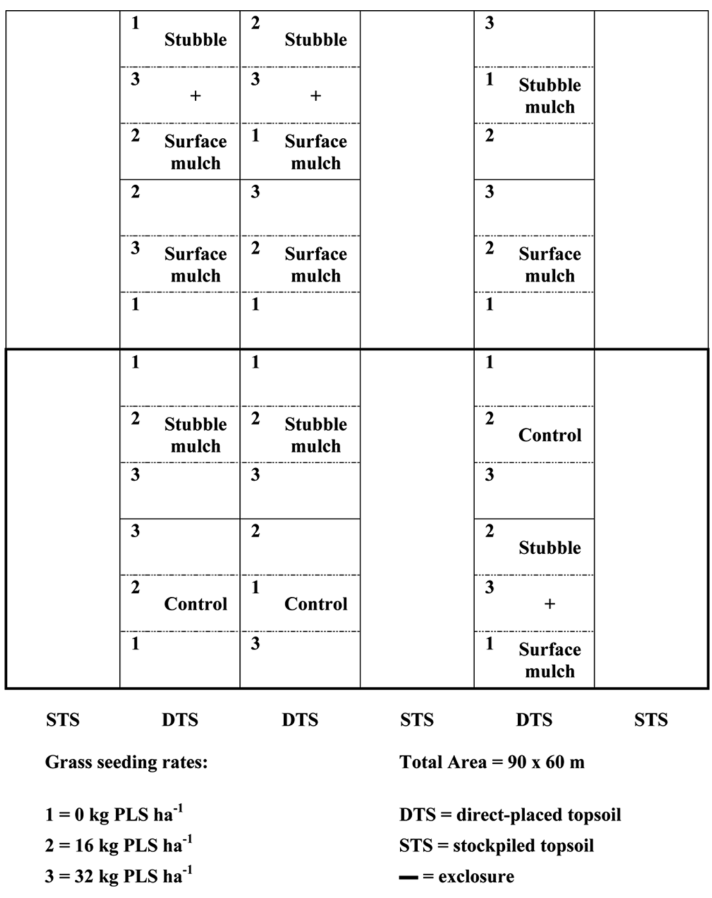

Figure 1. Field sampling design including topsoil plots, mulch subplots, and grass seeding rate sub-subplots. Only direct-placed topsoil plots and grass seeding rate subplots sampled across all mulch type subplots, North Antelope Coal mine, Gillette, Wyoming, USA, 2001–02.

diagram only for convenience of reference to the earlier research accomplished on these plots.

An additional permanent belt transect (2 by 12 m) was centrally located in each grass seeding rate subplot to evaluate current *A. tridentata* ssp. *wyomingensis* density and plant species composition. The wildlife-proof exclosure, constructed of woven wire just prior to initial data collection, is 90 by 30 m and 3.1 m tall. Fine-mesh (1.5 cm) wire 0.5 m high was installed around the exclosure and extended horizontally about 0.2 m along the ground surface to exclude *S. audubonii baileyi, L. townsendii campanius*, and *L. californicus melanotis*. This wire mesh was attached to the soil with wire brads. An equal number of grass seeding rate subplots (18) of each replication were located inside and outside the exclosure.

Vegetation Sampling

Artemisia tridentata ssp. *wyomingensis* density was determined in each of 9 original permanent quadrats per grass seeding rate, established by Schuman et al. (1998) in 1992, to evaluate long-term survival. Mean *A. tridentata* ssp. *wyomingensis* density (plants m^{-2}) was calculated for each grass seeding rate in 2001 and 2002, combining plots inside and outside the exclosure, to evaluate historical changes in shrub density.

To assess differences in short-term *A. tridentata* ssp. *wyomingensis* survival using the wildlife exclosure, density was evaluated along a 2 by 12 m permanent belt transect in each grass seeding rate, inside and outside the exclosure, by counting all *A. tridentata* ssp. *wyomingensis* plants within the 24 m^2 belt area. Mean density was evaluated in June and September 2001, and April and September 2002.

Four *A. tridentata* ssp. *wyomingensis* plants were selected in each grass seeding rate subplot and marked by attaching a yellow plastic locking zip tie to the plant base (144 total, 72 each inside and outside the exclosure). The number of browsed and unbrowsed marked plants was determined twice each year to determine percentage of plants browsed. Browsed *A. tridentata* ssp. *wyomingensis* leaders (lateral and terminal shoots) with clean knife-like cuts were attributed to *Lepus* ssp. and *S. audubonii baileyi*, while browsed *A. tridentata* ssp. *wyomingensis* leaders with rough, stripped characteristics were considered browsed by *O. hemionus* and *A. americana* (Hawthorne, 1983).

All leaders (browsed and unbrowsed) on marked plants were measured in late spring and fall each year, inside and outside the exclosure, to assess mean leader length per plant and within each grass seeding rate plot. Seasonal percent utilization was calculated for grass seeding rate plots outside the exclosure by comparing the difference in mean leader length from spring to fall (summer utilization) and from fall to the following spring (winter utilization).

Percent canopy cover of all plant species was estimated in June each year on all grass seeding rate subplots, inside and outside the exclosure, using a 10-pin point frame (Chambers & Brown, 1983) placed every 1.2 m along permanent 12 m line transects. The number of pin hits on plant species was divided by 100 (total hits per transect) to estimate percent canopy cover and characterize plant community composition.

A Shannon-Wiener plant diversity index ($\log_n$) was calculated for each grass seeding rate each year, inside and outside the exclosure, using proportional percent canopy cover to evaluate community heterogeneity (Whittaker, 1977; Krebs, 1999).

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Wildlife Fecal Counts

Odocoileus hemionus and *A. americana* seasonal use of the plots outside the exclosure were evaluated by counting and removing fecal groups within the permanent belt transects in September 2001 and 2002, and April 2002 and 2003. Since *Lepus* ssp. and *S. audubonii baileyi* scatter fecal material, individual pellets were removed from transects and only presence/absence recorded.

Data Analysis

Differences in mean *A. tridentata* ssp. *wyomingensis* density from permanent quadrats and belt transects, percent *A. tridentata* ssp. *wyomingensis* plants browsed, mean leader length, percent utilization, vegetation cover, and plant diversity were assessed between grass seeding rates and year, inside and outside the exclosure using analysis of variance. Mean separations were determined using Tukey's pairwise comparison test (Krebs, 1999).

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Results

A. tridentata *ssp.* **wyomingensis** *Density*

Artemisia tridentata ssp. *wyomingensis* density increased from 1992 through 1994, but declined during subsequent years across all grass seeding rates (Figure 2). The larger increase observed in 1993 was the result of above normal precipitation that year (Schuman et al., 1998). Density was highest in the 0 kg PLS ha^{-1} grass seeding rate and lowest in the 32 seeding rate initially (1992), but by 2000, density was equivalent across all seeding rates. Therefore, long-term survival of *A. tridentata* ssp. *wyomingensis* was actually higher in the 16 and 32 kg PLS ha^{-1} seeding rates.

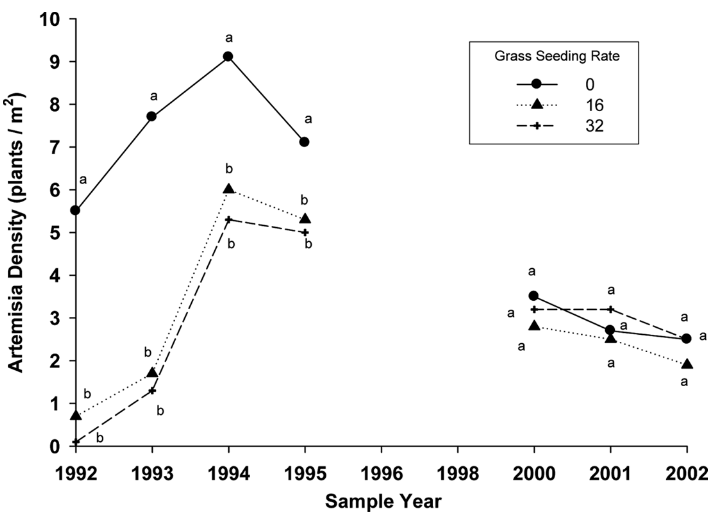

Figure 2. Long-term trend of *Artemisia tridentata* ssp. *wyomingensis* density by grass seeding rate (kg PLS ha^{-1}) from permanent quadrats, North Antelope Coal mine, Gillette, Wyoming, USA. (1992–1995 data are from Schuman et al., 1998). (Means within a year with different letters are significantly different; $P \leq 0.10$).

Initially high *A. tridentata* ssp. *wyomingensis* seedling density in the 0 seeding rate resulted in greater overall mortality, probably from intra-specific nutrient, space, and moisture competition (Schuman & Belden, 2002).

Artemisia tridentata ssp. *wyomingensis* density during 2001–02 was significantly higher ($F_{[2,48]} = 312.46$, $p < 0.001$) inside versus outside the exclosure in the 32 kg PLS ha^{-1} seeding rate (Table 1). Although not statistically significant, mean density values for *A. tridentata* ssp. *wyomingensis* were numerically greater in the 0 and 16 kg PLS ha^{-1} seeding rates inside versus outside the exclosure in 2001–02. With regard to the sample period, mean density across seeding rates was significantly higher ($F_{[3,48]} = 35.76$, $p < 0.001$) inside versus outside in April and September 2002. *Artemisia tridentata* ssp. *wyomingensis* density inside versus outside in June and September 2001 was not significantly different likely due to recent exclosure construction that year. With the exception of the 16 kg PLS ha^{-1} seeding rate in September 2001, mean density values for *A. tridentata* ssp. *wyomingensis* were higher across all seeding rates and sample periods inside versus outside the exclosure (Table 1).

During the study, 24 marked *A. tridentata* ssp. *wyomingensis* plants died outside the exclosure compared to 8 inside. The number of dead plants outside was lowest in the 32 (5) compared to the 0 (10) and 16 (9) kg PLS ha^{-1} grass seeding rates, suggesting a greater survival rate in the higher grass seeding rate plots over the 2 year sampling period.

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Percent **A. tridentata** *ssp.* **wyomingensis** *Browsed*

In June 2001, sampled 2 weeks after exclosure construction, the proportion of *A. tridentata* ssp. *wyomingensis* browsed was 32.3% outside compared to 33.3% inside, reflecting browsing pressure prior to exclosure construction. However, the proportion of *A. tridentata* ssp. *wyomingensis* plants browsed was significantly higher ($F_{[3,48]} = 478.21$, $p < 0.001$) outside versus inside the exclosure in September 2001 (100 and 8.3%, respectively) and 2002 (100 and 0%, respectively), and April 2002 (100 and 0%, respectively) across all seeding rates. Between June and September 2001, a single *S. audubonii baileyi* breached the exclosure, accounting for limited browsing of *A. tridentata*. Otherwise, browsing data indicate the exclosure to have been highly effective in excluding wildlife.

During 2002, *Lepus* ssp. and *S. audubonii baileyi* were the primary browsers of *A. tridentata* ssp. *wyomingensis* across all grass seeding rates outside the exclosure as determined by severed leader characteristics (Figure 3) and fecal counts. Fecal material from *Lepus* ssp. and *S. audubonii baileyi* were observed in all seeding rates outside the exclosure. The high percentage of fecal evidence from these species and the wildlife survey data collected by mine personnel (Scott Belden, personal communication) indicate that browsing was predominately due to *Lepus* ssp. and *S. audubonii baileyi*. Clark and Stromberg (1987) also found that *S. nuttallii grangeri* and *S. aububonii baileyi* feed primarily on herbaceous vegetation and bark/buds (leaders) of *Artemisia tridentata.* Fecal groups from *O. hemionus* and *A. americana* were less abundant than anticipated, ranging from 0.05–0.10 m^{-2} across grass seeding rates outside the exclosure.

Leader Growth and Utilization

Mean annual leader growth during 2001–02 was significantly greater ($F_{[2,48]} = 4.63$, $p = 0.06$) inside versus outside the exclosure for all grass seeding rates (Table 2).

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Table 1. Mean density (plants m^{-2}) of *Artemisia tridentata* ssp. *wyomingensis* within belt transects by grass seeding rate (kg PLS ha^{-1}) inside and outside the exclosure, North Antelope Coal mine, Gillette, Wyoming, USA, 2001 and 2002

	Inside				Outside			
Grass seeding rate	0	16	32	Mean	0	16	32	Mean
June 2001	2.4 (1.3)[1]	2.0 (1.5)	3.6 (1.3)	2.7 a[2]	2.2 (1.5)	2.0 (1.4)	2.1 (1.1)	2.1 a
September 2001	2.4 (1.2)	2.0 (1.5)	3.4 (1.3)	2.6 a	2.2 (1.3)	2.1 (1.4)	2.1 (1.0)	2.1 a
April 2002	2.2 (1.2)	1.8 (1.4)	3.4 (1.2)	2.5 a	1.5 (1.1)	1.4 (0.8)	1.7 (1.0)	1.5 b
September 2002	2.1 (1.0)	1.9 (1.5)	3.3 (1.3)	2.4 a	1.3 (1.1)	1.3 (0.9)	1.4 (0.9)	1.3 b
Mean	2.3 a[3]	1.9 a	3.4 a		1.8 a	1.7 a	1.8 b	

[1]Standard error.
[2]Means in same row with same letter are not significantly different (ANOVA; Tukey's pairwise comparisons, $\alpha = 0.10$).
[3]Comparisons within grass seeding rates, inside versus outside the exclosure.

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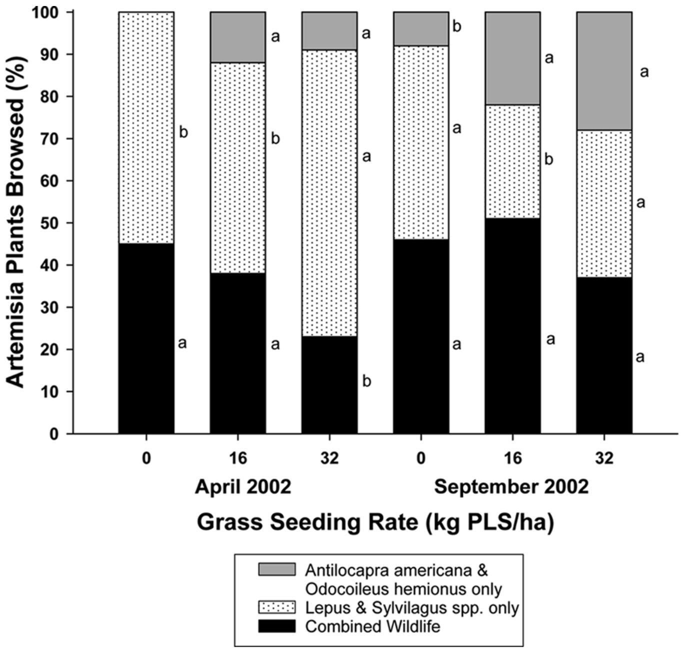

Figure 3. Percent of *Artemisia tridentata* ssp. *wyomingensis* browsed by wildlife in each grass seeding rate outside the exclosure in April and September, 2002, North Antelope Coal mine, Gillette, Wyoming, USA. (Means within a sample date with different letters are significantly different: $P \leq 0.10$; note: no plants were browsed by *Antilocapra americana* and *Odocoileus hemionus* on April 2002 sampling; the "combined wildlife" designation in the legend means that it was not possible to distinguish between *Antilocapra americana, Odocoileus hemionus, Sylvilagus audubonii baileyi, and Lepus* spp. *browsing).*

With regard to sample period, mean leader length across seeding rates was significantly greater ($F_{[3,48]} = 18.61$, $p = 0.002$) inside versus outside in all sample periods. With the exception of the 32 kg PLS ha^{-1} grass seeding rate in June 2001, leader growth inside the exclosure was greatest in the 32 kg PLS ha^{-1} grass seeding rate across all sample periods. Further, leader lengths progressively increased on all grass seeding rates across sample periods inside the exclosure except for the 0 and 16 kg PLS ha^{-1} grass seeding rates in September 2001. Outside the exclosure, leader lengths progressively decreased on all grass seeding rates from June 2001 to April 2002. However, leader lengths were greatest in September 2002 across all grass seeding rates outside the exclosure (Table 2). Mean monthly precipitation for August and September 2001 was 23 mm, but 51 mm in 2002 (Table 3), which partially explains the increased leader growth observed across grass seeding rates outside the exclosure in September 2002.

Mean seasonal utilization of *A. tridentata* ssp. *wyomingensis* leader growth during 2001–02 was significantly greater ($F_{[2,12]} = 3.87$, $p = 0.05$) during winter compared to summer across all grass seeding rates. Winter utilization was greatest in the 0 (53.7%) compared to the 16 (43.2%) and 32 (23.6%) kg PLS ha^{-1} grass seeding rates. Summer utilization for the same period was 20.7% in the 0, 14.9% in the 16, and 20.1% in the 32 kg PLS ha^{-1} grass seeding rates.

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Table 2. Mean leader length (mm) of marked *Artemisia tridentata* ssp. *wyomingensis* plants by grass seeding rate (kg PLS ha^{-1}) inside and outside the exclosure, North Antelope Coal mine, Gillette, Wyoming, USA, 2001 and 2002

	Inside				Outside			
Grass seeding rate	0	16	32	Mean	0	16	32	Mean
June 2001	37.5 (16.2)[1]	28.4 (8.6)	37.2 (10.3)	34.4 a[2]	19.8 (8.1)	20.2 (8.4)	17.5 (9.3)	19.2 b
September 2001	33.8 (21.9)	24.7 (12.1)	44.3 (15.7)	34.2 a	15.8 (7.8)	16.8 (8.3)	13.8 (5.8)	15.5 b
April 2002	47.0 (18.2)	43.7 (13.8)	48.6 (18.0)	46.4 a	7.6 (5.7)	10.1 (5.9)	10.6 (9.2)	9.4 b
September 2002	62.1 (24.2)	61.1 (10.9)	63.4 (20.2)	62.2 a	23.2 (23.9)	23.4 (5.1)	22.9 (14.3)	23.1 b
Mean	45.1 a[3]	39.5 a	48.4 a		16.6 b	17.6 b	16.2 b	

[1]Standard error.
[2]Means in same row with same letter are not significantly different (ANOVA; Tukey's pairwise comparisons, $\alpha = 0.10$).
[3]Comparisons within grass seeding rates, inside versus outside the exclosure.

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Table 3. Summary of monthly precipitation (mm) from 1991 to 2002, North Antelope Coal mine, Gillette, Wyoming, USA[1]

	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
January	N/A[2]	0.0	0.0	2.0	0.5	0.3	2.3	4.1	0.0	6.6	11.9	0.0
February	N/A	6.9	3.8	1.5	6.6	2.3	7.4	10.2	0.0	6.1	13.2	0.5
March	N/A	31.5	14.7	4.1	9.7	5.6	2.5	34.3	14.0	9.4	2.0	1.0
April	N/A	7.6	64.8	27.9	20.1	15.7	33.3	21.8	44.2	71.6	52.6	19.3
May	55.9	22.6	59.4	28.7	89.4	4.6	62.7	55.1	27.4	57.4	9.9	62.0
June	91.4	64.3	141.5	83.6	72.1	13.5	44.7	71.9	117.6	32.8	45.0	16.5
July	15.8	77.5	97.0	49.3	16.8	13.7	113.8	43.7	34.5	40.1	72.9	20.8
August	38.6	29.5	101.3	8.1	0.3	14.2	19.8	7.9	1.5	5.8	30.5	72.1
September	2.5	17.5	22.9	12.2	2.3	22.4	18.8	0.0	42.7	18.8	15.0	29.5
October	0.5	4.1	23.6	54.9	19.6	1.3	23.6	0.8	2.8	31.0	18.8	9.4
November	0.0	8.9	3.6	5.8	1.0	2.5	0.0	0.0	2.0	3.6	6.4	7.6
December	0.0	11.9	1.0	0.5	0.0	2.3	18.0	0.0	1.5	2.0	3.3	3.6
Total	204.7	282.2	533.6	278.6	238.3	98.3	347.0	249.7	288.3	285.2	281.4	242.3
% Avg Annual	—	85	160	84	72	30	104	75	87	85	85	73

[1]Long-term (1978–2002) average annual precipitation 333 mm (S.E. Belden 2003, North Antelope Coal, Gillette, WY, personal communication).
[2]No data available.

Plant Community Characteristics

Percent Cover

Mean vegetation cover across all grass seeding rates, inside and outside the exclosure, was significantly greater ($F_{[1,24]} = 30.16$, $p = 0.071$) in 2001 (47.2% ± 1.6 SE) than in 2002 (29.9% ± 1.4 SE). A significant ($F_{[1,24]} = 68.28$, $p = 0.03$) decrease in mean grass cover was observed from 2001 (35.8% ± 1.6 SE) to 2002 (19.3% ± 1.5). There were no differences in mean forb cover (10.2% ± 0.5 SE, 2001; 9.1% ± 0.5 SE, 2002) or shrub cover (1.1% ± 0.2 SE, 2001; 1.5% ± 0.6 SE, 2002) between years. Mean total precipitation in 2001 (281 mm) and 2002 (242 mm) was less than the long-term (1978–2002) average of 333 mm for this area (Table 3), which probably accounts for decreased grass cover between years.

With regard to the exclosure, shrub (primarily *A. tridentata* ssp. *wyomingensis*) cover was significantly higher ($F_{[1,24]} = 8.58$, $p = 0.09$) inside (2.5% ± 0.8 SE) versus outside (0.6% ± 0.3 SE) across all grass seeding rates in 2002, but not in 2001 (1.2% ± 0.3 SE, inside; 1.0% ± 0.2 SE, outside). There were no differences inside versus outside in grass cover in 2001 (35.6% ± 3.1 SE, inside; 36.1% ± 1.6 SE, outside) and 2002 (20.2% ± 2.1 SE, inside; 18.4% ± 2.6 SE, outside) or forb cover in 2001 (9.3% ± 0.5 SE, inside; 11.1% ± 0.3 SE, outside) and 2002 (9.1% ± 0.9 SE, inside; 9.1% ± 0.6 SE, outside). Likewise, there were no differences in grass, forb, or shrub cover between grass seeding rates, inside versus outside, in either 2001 or 2002.

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Species Richness and Diversity

Plant species richness decreased from 2001 to 2002, both inside and outside the exclosure. Mean species richness inside the exclosure was 12.3 (±1.5 SE) in 2001 compared to 8.3 (±1.5 SE) in 2002, while richness outside the exclosure declined from 13.7 (±1.5 SE) in 2001 to 6.7 (±0.6 SE) in 2002. The disappearance of many forb species in 2002, probably due to drought conditions (Table 3), was the major difference in shifts of species richness. There were no differences in species richness between grass seeding rates or inside versus outside the exclosure in either year.

Although not statistically significant, plant diversity indices were always higher inside the exclosure for each grass seeding rate in 2001 and 2002, except for the 0 grass seeding rate in 2001. Mean diversity indices in 2001 were 0.67, 0.66, and 0.72 inside and 0.70, 0.64, and 0.63 outside for the 0, 16, and 32 kg PLS ha^{-1} grass seeding rates, respectively. In 2002, mean diversity indices were 0.52, 0.46, and 0.50 inside and 0.41, 0.41, and 0.38 outside for the 0, 16, and 32 kg PLS ha^{-1} grass seeding rates, respectively. There were no significant differences in diversity indices between grass seeding rates.

Discussion

Greater *A. tridentata* ssp. *wyomingensis* density, leader growth, cover, plant diversity, and lower mortality and proportion of plants browsed inside versus outside the wildlife exclosure clearly illustrate the magnitude of wildlife impacts on *A. tridentata* ssp. *wyomingensis* and the overall plant community. More notable, however, was the rapid response of *A. tridentata* ssp. *wyomingensis* leader growth following protection (exclosure) from wildlife use. *Artemisia tridentata* ssp. *wyomingensis* leader growth substantially increased inside and decreased outside the exclosure across all grass seeding rates during the study. In Yellowstone National Park, Wambolt and Sherwood (1999) reported *A. tridentata* density 2 times greater inside versus outside a winter range exclosure after 32 years of protection from *Cervus elaphus* Linnaeus (elk) and *O. hemionus*. McArthur et al. (1988) found significant *O. hemionus*-induced declines in *A. tridentata* ssp. *vaseyana* Rydb. (Beetle) (mountain big sagebrush) cover and survival outside a deer fence in Utah.

In our study, grass seeding rate influenced short-term growth and long-term survival of *A. tridentata* ssp. *wyomingensis*. Lower winter utilization of leader growth, higher long-term survival, and lower mortality of marked plants in the 32 kg PLS ha^{-1} grass seeding rate, along with progressive deterioration of survival, increased mortality, and higher utilization in the 0 and 16 kg PLS ha^{-1} grass seeding rates (Figure 4), suggest a beneficial relationship between *A. tridentata* ssp. *wyomingensis* long-term establishment success and grass seeding rate. Schuman and Belden (2002) also reported significantly greater *A. tridentata* ssp. *wyomingensis* mortality in the 0 and 16 compared to the 32 kg PLS ha^{-1} grass seeding rate on these plots after 8 years. They suggested that herbaceous plant cover may thwart browsing attempts of *A. tridentata* ssp. *wyomingensis* seedlings. Owens and Norton (1992) found that *A. tridentata* ssp. *tridentata* (Beetle & Young) Welsh (basin big sagebrush) seedlings sheltered by other plants experienced less mortality than those growing in unprotected interspace. However, the specific ecological relationship between long-term *A. tridentata* ssp. *wyomingensis* survival and grass seeding rate in this study is unclear.

Greater winter utilization was anticipated since preference for *A. tridentata* ssp. *wyomingensis* by *A. americana* and *O. hemionus* (Welch et al., 1981; Craven, 1983a; Schemnitz, 1983), and *Lepus* ssp. and *S. audubonii bailey* (Craven, 1983b; Knight, 1983; Anderson & Shumar, 1986) intensifies during winter. However, the magnitude

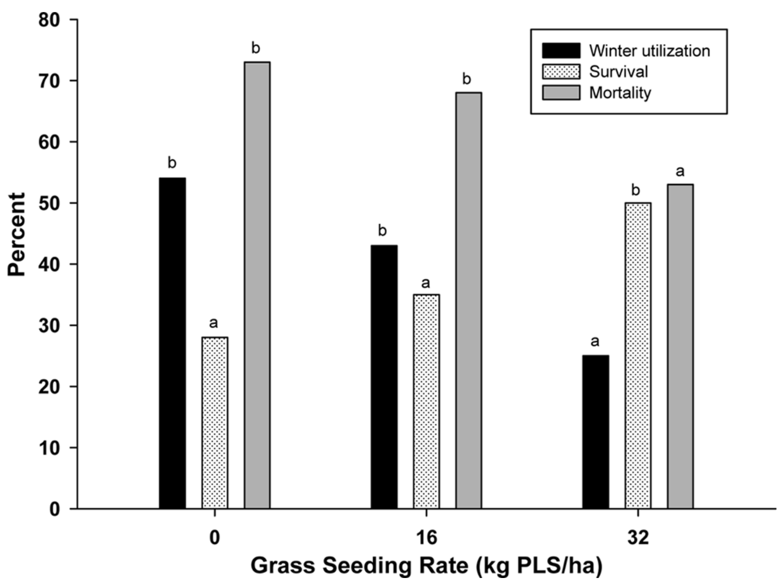

Figure 4. Relationship between percent winter utilization, survival, and mortality of *Artemisia tridentata* ssp. *wyomingensis* across grass seeding rates, North Antelope Coal mine, Gillette, Wyoming, USA, 2001–2002. (Means within winter utilization, survival or mortality across grass seeding rates with different letters are significantly different; $P \leq 0.10$).

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of *A. tridentata* ssp. *wyomingensis* browsing by *Lepus* ssp. and *S. audubonii bailey* was greater than anticipated. Partial or complete defoliation of *A. tridentata ssp. wyomingensis* leaders will not adversely affect growth, vigor, and survival if leaf primordial and twigs are undamaged (Kelsey, 1984). However, defoliation in our study was much more severe with considerable twig and leaf primordial damage. Wildlife browsing contributed to the death of 33% marked *A. tridentata* ssp. *wyomingensis* plants outside the exclosure within 15 months.

Below-average annual precipitation during our study most likely caused reduced plant species richness, cover, and diversity, therefore, possibly enhancing greater wildlife browsing of *A. tridentata* ssp. *wyomingensis*. Further, declining vegetation cover from 2001 to 2002, primarily due to reduced grass cover, coincides with data reported by Owens and Norton (1992) and supports the hypothesis of Schuman and Belden (2002) that greater protective herbaceous cover may reduce browsing intensity of *A. tridentata* seedlings. Continual intensive wildlife utilization threatens long-term survival of *A. tridentata* ssp. *wyomingensis* of this reclaimed mine site.

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Implications and Reclamation Recommendations

Successful establishment and maintenance of *Artemisia tridentata* ssp. *wyomingensis* on reclaimed mine lands in Wyoming is important to provide adequate wildlife habitat value. However, wildlife densities are impeding successful long-term survival and growth of *A. tridentata* ssp. *wyomingensis* at North Antelope Coal mine. Proactive wildlife management and habitat manipulation may be necessary to achieve successful reclamation on this site. Without proper post reclamation management, *A. tridentata* ssp. *wyomingensis* density could decline to less than 1 plant m^{-2} on this site and not meet the required density for bond release (Wyoming Department of Environmental Quality, Land Quality Division, 1996). Palatability of *A. tridentata* ssp. *wyomingensis and A. tridentata vaseyana* (mountain big sagebrush) is greater than that of *A. tridentata tridentata* (basin big sagebrush) (Long, 1981).

Reclamation specialists should consider post mining management practices to reduce wildlife impacts. Habitat on adjacent, native rangeland may be improved to attract wildlife away from reclamation sites, possibly enhancing *A. tridentata* ssp. *wyomingensis* survival. Prescribed burning and other treatments commonly reduce cover on native rangelands, encourage new plants, and improve herbaceous plant production. These practices improve forage quality and increase plant diversity (Bainter, 1982; Emmerich, 1982), which may enhance wildlife distribution.

However, improving wildlife distribution by enhancing adjacent rangeland habitat may not be enough. Where feasible, wildlife population management may be necessary. Allowing limited harvest (hunting) under strictly supervised situations, where compatible with the mine environment and safety considerations, may be a viable management option. If hunting is undesirable, nonlethal animal damage control practices (fireworks, propane zon guns, smell/taste repellants) may be effective (Craven, 1983a; Schemnitz, 1983). To discourage *Lepus* ssp. and *S. audubonii bailey*, erecting raptor roosts, and reducing the number of rockpiles near reclaimed sites may be helpful.

Evaluating and managing wildlife impacts is necessary for all mines trying to restore *A. tridentata* ssp. *wyomingensis* following mining. Holistic wildlife and habitat management practices must be considered in a post reclamation resource management strategy. Reducing wildlife browsing impacts on *A. tridentata* ssp.

wyomingensis should promote more successful reclamation and improve wildlife habitat on mined lands.

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