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SUITABILITY OF SHRUB ESTABLISHMENT ON WYOMING MINED LANDS RECLAIMED FOR WILDLIFE HABITAT

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ABSTRACT.—Restoring coal mined land to pre-mining shrub cover, density, height, community composition, and diversity to renew wildlife habitat quality is a priority for reclamation specialists. Long-term shrub reestablishment success on reclaimed mined land in Wyoming and suitability of these lands for wildlife habitat are unknown. Fourteen reclaimed study sites, 10 yr old or older, were selected on 8 mines in Wyoming to evaluate shrub reestablishment and wildlife habitat value for antelope (*Antilocapra americana*) and sage grouse (*Centrocercus urophasianus*). Five sites were categorized as fourwing saltbush (*Atriplex canescens*) sites and 9 as fourwing saltbush/big sagebrush (*A. canescens*/*Artemisia tridentata* spp. *wyomingensis*) sites. Published data describing antelope and sage grouse–preferred habitat requirements in sagebrush-grassland steppe ecosystems were used to evaluate shrub community value of sampled sites for wildlife habitat. Mean shrub canopy cover, density, and height for fourwing saltbush sites were 5.8%, 0.23 m^{-2}, and 41.6 cm, respectively, compared to 5.6%, 0.61 m^{-2}, and 31.1 cm for fourwing saltbush/big sagebrush sites. Two fourwing saltbush and 4 fourwing saltbush/big sagebrush sites provided sufficient cover for antelope, while 2 fourwing saltbush and 4 fourwing saltbush/big sagebrush sites were adequate for sage grouse. Only 1 fourwing saltbush/big sagebrush site provided high enough shrub densities for sage grouse. One fourwing saltbush and 7 fourwing saltbush/big sagebrush sites provided ample shrub heights for antelope, while 1 fourwing saltbush and 8 fourwing saltbush/big sagebrush sites were sufficient for sage grouse. One fourwing saltbush and 1 fourwing saltbush/big sagebrush site provided enough grass, forb, and shrub composition for antelope, while no site in either reclamation type was satisfactory for sage grouse. Shrub diversity was 3 times higher for fourwing saltbush/big sagebrush sites (0.984) than for fourwing saltbush sites (0.328). Individually, sites seeded with multiple shrub species had higher canopy cover, density, and diversity compared with single-species shrub seedings. Achieving premining shrub cover, density, height, community composition, and diversity within existing bond-release time frames is unrealistic, considering that some native shrublands require 30-60 yr to reach maturity.

Key words: disturbed land, sagebrush, fourwing saltbush, community diversity.

Shrub reestablishment on reclaimed mined lands continues to be a controversial topic among mining interests, regulatory agencies, environmental groups, and state and federal wildlife management agencies. Because many wildlife species utilize reclaimed mined lands, quality (height, cover, density, and diversity) of shrub reestablishment on these lands is important for achieving good wildlife habitat conditions. Information on long-term success of shrub reestablishment is needed to assess reclamation objectives for creating quality wildlife habitat, formulating future seed mixes for reclamation, and evaluating reclamation methodologies and regulations.

Shrub reestablishment practices in Wyoming on reclaimed mined land often emphasize Wyoming big sagebrush (*Artemisia tridentata* [Pursh] Nutt. ssp. *wyomingensis* [Beetle and Young]) due to its predominance in premining plant communities and importance for wildlife habitat. This important shrub provides yearlong habitat for antelope (*Antilocapra americana* [Ord.]) and sage grouse (*Centrocercus urophasianus* Bonaparte), 2 abundant and economically important game species in Wyoming. Although widely distributed across Wyoming and the Rocky Mountain West, big sagebrush is sometimes difficult to reestablish due to low seedling vigor, inability to compete with herbaceous species, poor seed quality, and altered edaphic conditions (Cockrell et al. 1995). The high cost and limited availability of big sagebrush seed further confounds its use in reclamation.

Fourwing saltbush (*Atriplex canescens* [Pursh] Nutt.) is a highly palatable, nutritious shrub used by wildlife and livestock for forage in all seasons (Long 1981). Additionally, it provides cover for game birds on arid rangeland (Shaw

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et al. 1984). The use of fourwing saltbush in reclamation was de-emphasized in recent years over concerns about low survival rates after planting and competitive exclusion of other shrub species (Moghaddam and McKell 1975, Booth 1985). Fourwing saltbush seedlings are sensitive to freezing and wet soil conditions that make them susceptible to a fungal disease (Plummer et al. 1966). However, fourwing saltbush is more tolerant to planting depth variations than big sagebrush, which probably explains its higher establishment success when drill-seeded in earlier reclamation programs (Hennessy et al. 1984).

A diverse mixture of shrub species provides habitat diversity, and wildlife prefer it over monocultures (Postovit 1981, Roberson 1984, Yoakum 1984a). Shrubs also provide critical forage and cover for a variety of wildlife (Postovit 1981, Cook 1984, Nydegger and Smith 1984, Roberson 1984, Ngugi et al. 1992). Antelope and sage grouse, species common to big sagebrush communities (Braun et al. 1977, Yoakum 1984b), should benefit from big sagebrush reestablishment success and subsequent improvement of habitat quality on reclaimed mined land.

HABITAT REQUIREMENTS

Habitat is defined as “the place where an organism lives, and includes both biotic and abiotic components” (Scalet et al. 1996). Terrestrial wildlife biologists most often evaluate habitat condition by assessing plant community characteristics. This paper focuses specifically on vegetative characteristics of shrub communities (e.g., shrub height, canopy cover, density, and diversity), which are important habitat parameters for antelope and sage grouse.

Preferred habitat characteristics for antelope and sage grouse were based on prior research conducted in sagebrush-grassland steppe ecosystems, since our study areas are in bunchgrass steppe and the western edge (ecotone) of the northern mixed-grass prairie (Hart 1994). These 2 major rangeland ecosystems described by Hart (1994) are dominated by big sagebrush and are consistent with vegetation characteristics of our study sites.

Desired habitat characteristics for antelope in sagebrush-grassland steppe ecosystems are summarized in Table 1. Antelope prefer open shrub habitat (5–20% cover) comprising 5–10 shrub species (Yoakum 1984b) and 10–30% forb cover (Kindschy et al. 1982). Cook (1984) reports similar antelope habitat requirements consisting of 13–30% shrub cover with 10–38% herbaceous cover. Optimum shrub heights for antelope are ≤38 cm (Sundstrom et al. 1973) and 38 cm (Yoakum 1984b), with a recommended range of 13–63 cm (Kindschy et al. 1982). Cook (1984) reported the ideal range of big sagebrush heights is 22–46 cm and suggested that big sagebrush heights <13 cm and >60 cm are less suitable for antelope. Preferred composition of grasses, forbs, and shrubs for antelope in Wyoming (Sundstrom et al. 1973) is 40–60%, 25–35%, and 5–20%, respectively (Table 1). Yoakum (1980) reported preferred composition as 50–70% grasses, 20–40% forbs, and 5–10% shrubs for central Oregon. Findings of these 5 studies are surprisingly similar in their definition of optimum big sagebrush requirements for antelope.

Table 2 summarizes preferred habitat characteristics for sage grouse in sagebrush-grassland steppe ecosystems based on previous studies. Sage grouse in northeastern Wyoming prefer areas with an average big sagebrush density of 1.3 shrubs m^{-2} and an average shrub cover of 5.5% (Postovit 1981). For nesting, shrub patches with big sagebrush densities of 2.9 shrubs m^{-2} and 25% cover are recommended. Hulet et al. (1984) reported that nesting sage grouse in southern Idaho prefer areas having about 26% shrub cover, with big sagebrush comprising about 17% of the cover over a 9.3-m^2 area. In this same study he found that 62% of nests were under big sagebrush plants, 14% under three-tip sagebrush (*Artemisia tripartata* Rydb.), and 17% beneath antelope bitterbrush (*Purshia tridentata* [Pursh] DC.). Roberson (1984) in Utah, Braun et al. (1977) in Colorado, and Dobkin (1995) in Oregon found that wintering sage grouse prefer areas with 28%, ≥20%, and 25–40% shrub cover, respectively, while desired nesting habitat consists of 20–40%, 20–40%, and 15–25% shrub cover, respectively (Table 2).

Height of big sagebrush and other shrubs preferred by sage grouse varies by season and specific use. Postovit (1981) reported that sage grouse prefer big sagebrush heights of about 22 cm in winter and 18 cm in summer and fall. Where sage grouse nesting occurred, big sagebrush heights averaged about 27 cm. Hulet et al. (1984) reported the average shrub height

TABLE 1. Preferred habitat characteristics for antelope (*Antilocapra americana*) in shrub-grassland steppe ecosystems based on existing published literature.

Authority/Location	No. shrub species	Shrub height (cm)		Cover (%)		Composition (%)			
		Sage-brush	All shrubs	Forbs	Shrubs	Grass	Forb	Shrub	Sage-brush
Sundstrom et al. (1973), Wyoming	5[a]		≤38			40–60	25–35	5–15[b]	10–20
Cook (1984), Wyoming		22–46		10–38[c]	13–30				
Yoakum (1980), central Oregon						50–70	20–40	5–10	
Yoakum (1984b), Great Basin region	5–10		38 (mean)		5–20				
Kindschy et al. (1982)[d], SE Oregon, Great Basin region			13–63	10–30	5–20				
MINIMAL PREFERRED HABITAT REQUIREMENTS	5	22	13	10	5	40	20	5	10

[a]Preferred species include big sagebrush (*Artemisia tridentata*), sand sagebrush (*A. filifolia*), fringed sagebrush (*A. frigida*), silver sagebrush (*A. cana*), and Douglas rabbitbrush (*Chrysothamnus viscidiflorus*).
[b]All other shrub species, excluding big sagebrush (*A. tridentata*).
[c]Includes all herbaceous (grasses and forbs) cover.
[d]Optimum combination of percent cover and shrub height are 10–20% forb cover, 10–20% shrub cover, and 13–25 cm shrub height.

TABLE 2. Preferred habitat characteristics for sage grouse (*Centrocercus urophasianus*) in shrub-grassland steppe ecosystems based on existing published literature.

Authority/Location	Sagebrush density (no. m^{-2})	Shrub height (cm)		Shrub cover (%)	Composition (%)		
		Sagebrush	All shrubs		Grass	Forb	Shrub
Postovit (1981), NE Wyoming	1.3 (general) 2.9 (nesting)	26.6 (nesting) 18 (summer) 22 (winter)		5.5 (general) 25.0 (nesting)			
Hulet (1984), southern Idaho			46.7[a]	26.2[b]			
Roberson (1984), Great Basin, Utah		55.8 (winter)	17–79 (nesting)	20–40 (nesting) 28 (winter)			
Martin (1970), SW Montana					42.0	28.4	29.6
Braun et al. (1977), NW Colorado		17–79 (nesting)		20–50 (general) 20–40 (nesting) ≥20 (winter)			
Dobkin (1995), central Oregon				15–25 (nesting)[c] 25–40 (winter) 15–25 (brood)[d]			
MINIMAL PREFERRED HABITAT REQUIREMENTS	1.3 (general) 2.9 (nesting)	17 (nesting) 18 (summer) 22 (winter)	17 (nesting)	5.5 (general) 15 (nesting) 25 (winter) 15 (brood)	42.0	28.4	29.6

[a]Mean shrub height surrounding nests.
[b]Big sagebrush (*Artemisia tridentata*) should comprise 17.2% of total shrub cover.
[c]Should also include 20% residual herbaceous cover.
[d]Should also include 10–20% live herbaceous (grass and forb) cover.

surrounding sage grouse nests was 47 cm, while Roberson (1984) reported a range of 17–79 cm being optimum for nesting habitat. Braun et al. (1977) also suggested sagebrush heights of 17–79 cm for nesting sage grouse. During winter sage grouse utilized big sagebrush with an average height of 56 cm (Roberson 1984). Martin (1970), in southwestern Montana, is the only researcher to report preferred composition of grasses, forbs, and shrubs (42.0%, 28.4%, and 29.6%, respectively) for sage grouse.

The objectives of this study were to (1) evaluate shrub reestablishment on reclaimed mined lands in Wyoming seeded prior to 1985, (2) assess habitat suitability of these seedings for antelope and sage grouse based on prior research in sagebrush-grassland steppe ecosystems, and (3) develop recommendations for improving reclamation practices.

STUDY AREA DESCRIPTIONS

Fourteen pre-1985 reclaimed mine sites, 10–17 yr old, were selected from 8 mines in 4 geographic locations of Wyoming in 1994. Descriptions and locations of the 14 sample sites are summarized in Table 3.

Each site was classified as either a fourwing saltbush/grass (hereinafter called "fourwing") or a fourwing saltbush/big sagebrush/grass (hereinafter called "fourwing/sagebrush") reclamation type depending upon the original seed mixture of fourwing saltbush only or a fourwing saltbush/big sagebrush combination. Seed mixtures varied among sites, but fourwing saltbush and big sagebrush were the primary shrub species seeded (Table 4). Other shrub species in the seed mixtures included rubber rabbitbrush (*Chrysothamnus nauseosus* [Pall.] Britt.), broom snakeweed (*Gutierrezia sarothrae* [Pursh] Britt. & Rusby), fringed sagebrush (*Artemisia frigida* Willd.), winterfat (*Eurotia lanata* [Pursh] Howell, syn. *Krascheninnikova lanata* [Pursh] Mueese & Smith, syn. *Ceratoides lanata* [Pursh] Howell), greasewood (*Sarcobatus vermiculatus* [Hook.] Torr.), woods rose (*Rosa woodsii* Lindl.), Gardner's saltbush (*Atriplex gardnerii* [Moq.] Dietr.), silver sagebrush (*Artemisia cana* Pursh), and shadscale (*Atriplex confertifolia* [Torr. & Frem.] S.Wats.). Five fourwing and 9 fourwing/sagebrush sites were sampled.

Seed mixtures for the older fourwing sites (Black Thunder, Belle Ayr, Pathfinder, and Kemmerer #1) had generally higher grass seeding rates and lower shrub seeding rates than fourwing/sagebrush sites (Table 4). In addition, there were fewer shrub species in the mixture.

Seed mixtures for fourwing/sagebrush sites usually contained more big sagebrush seeds than fourwing saltbush seeds due to differences in seed number per kg. Wyoming big sagebrush has 4–5.4 million seeds per kg (Meyer 2000) while dewinged fourwing saltbush has 120,000 seeds per kg (Foiles 1974). Therefore, where big sagebrush and fourwing saltbush were both seeded at the same kg per ha pure-live-seed (pls) rate, 33–45 times more big sagebrush seeds were sown.

METHODS

We placed twenty 50-m transects equidistant across sample sites to evaluate shrub reestablishment. Transects were oriented perpendicular to the longest dimension of each site using a compass. Transect numbers were reduced on Belle Ayr (5) and WyoDak (10) sites because of the small size of available reclaimed area. Thirty transects were used at 1 Pathfinder site (the first studied). Preliminary sampling (Pathfinder site) indicated that 20 transects were adequate on larger sites to minimize data variance and ensure adequate representation of the revegetated areas.

Percent aerial cover of shrub species was obtained using the line-intercept method (Canfield 1941). Along each transect we recorded species canopy cover in centimeters and divided that by the transect total (5000 cm). Gaps in shrub canopy of ≤4 cm were considered part of the continuous canopy.

Shrub density, expressed as number per m^2, was determined by counting the number of individual species within a belt transect of 200 m^2 (4 m × 50 m). A 2-m rule, held perpendicular to the transect, was used as a guide when counting individual shrubs along each side of the transect (Pieper 1978). We included both seedlings and mature plants in density counts. Shrub height (cm) was also recorded for each species.

Shrub canopy cover and density by species was converted to relative cover and relative density. These values were summed for each species to provide an importance value used to identify community dominants (Curtis and McIntosh 1951). Relative cover was calculated by dividing absolute cover of each shrub species by total cover of all shrub species. Likewise, relative shrub density was calculated by dividing absolute density of each species by total shrub density for all species. A larger importance value identifies community dominants.

We used importance values of shrub species to calculate a Shannon-Wiener diversity index for each sample site (Krebs 1989). Higher diversity indices indicate greater shrub community diversity.

We determined percent composition of grasses, forbs, and shrubs at ground level using point-frame sampling techniques (Pieper 1978). Along each transect, a 10-point sampling frame was placed every 5 m (100 hits per transect) and the number of pin hits on grass, forb, and shrub canopy recorded. Percent composition by vegetation class was calculated by

TABLE 3. Descriptions and locations of sampled reclaimed mine sites to assess pre-1985 shrub establishment, 1994, Wyoming.

Company/Location	Site	Area (ha)	Seeding age in 1994	Reclamation type	Elevation (m)	Mean annual precipitation[a] (mm)	Mean annual temperature[a] (°C)	Mean frost-free period[b] (days)	Soil parent material[c]
NORTHEAST									
Black Thunder/ Thunder Basin Coal Co., Wright	1	26.3	13	Fourwing	1433	280	6.8	125	Tertiary sandstone, clay shale
Belle Ayr/Amax Coal West, Gillette	1	2.0	13	Fourwing	1433	422	6.8	125	Tertiary sandstone, clay shale
WyoDak/WyoDak Resource Corp., Gillette	1	4.5	12	Fourwing/big sagebrush	1341	422	6.8	125	Tertiary sandstone, clay shale
	2	6.5	10		1341	422	6.8	125	
CENTRAL									
Pathfinder/ Pathfinder Mines Corp., Shirley Basin	1	15.8	17	Fourwing	2195	244	4.1	100	Tertiary sandstone, clay shale
	2	21.4	12	Fourwing/big sagebrush	2195	244	4.1	100	
Dave Johnston/ Glenrock Coal Co., Glenrock	1	23.9	10	Fourwing/big sagebrush	1646	328	8.8	123	Cretaceous clay shale
SOUTH CENTRAL									
Seminoe I/Arch Minerals, Hanna	1	22.7	10	Fourwing	2012	261	5.5	106	Cretaceous clay shale
	2	7.7	10	Fourwing/big sagebrush	2012	261	5.5	106	Cretaceous clay shale
SOUTHWEST									
Kemmerer Coal/ Pittsburg & Midway Coal Mining Co., Kemmerer	1	36.4	14	Fourwing	2225	274	3.5	71	Carboniferous linestone
	2	13.0	13	Fourwing/big sagebrush	2225	274	3.5	71	
	3	37.6	13	Fourwing/big sagebrush	2225	274	3.5	71	clay shale, loamstones, Redbed sandstones
Bridger Coal/ Bridger Coal Co., Rock Springs	1	6.5	10	Fourwing/big sagebrush	2073	225	5.9	112	Cretaceous clay shale
	2	33.2	10	Fourwing/big sagebrush	2073	225	5.9	112	Cretaceous clay shale

[a]Owenby and Ezell (1992)
[b]Martner (1986)
[c]Young and Singleton (1977)

dividing hits of 1 vegetation type by total hits for all vegetation types.

Wildlife habitat quality of these reclaimed mined lands was assessed against habitat requirements for antelope and sage grouse. These species were selected because (1) both are abundant and economically important game species, (2) they represent a mammal and bird species having uniquely different habitat requirements, yet closely associated with surrounding sagebrush-grassland steppe ecosystems, and (3) habitat requirements of both species are published. Although other wildlife species are associated with these reclaimed sites, the absence of published habitat specifications limited their inclusion in this analysis.

RESULTS AND DISCUSSION

Canopy Cover

Shrub cover varied considerably between species and sites. Mean cover for the 5 fourwing sites ranged from 1.9% to 15.7% for all shrub species, with a mean of 5.8% (Table 5). For the 9 fourwing/sagebrush sites, mean cover ranged from 1.0% to 13.3%, with a mean of 5.6% (Table 6).

TABLE 4. Seeding year, method, plant species selected, and seeding rates (kg ha^{-2}) for study sites from 8 mines in 4 geographic locations of Wyoming.

Sites	Area (ha)	Year(s) seeded	Seeding method[b]	Seeding rates (kg ha^{-2})[a] All grasses	All forbs	*Atca*[c]	*Artr*	*Chna*	*Eula*	Other shrubs
FOURWING										
Black Thunder	26.3	1981	D & B	21.3	—	1.1	—	—	—	—
Belle Ayr	2.0	1981	D	28.0	5.3	3.4	—	0.1	1.1	*Rowo* = 0.1, *Save* = 0.1
Pathfinder	15.8	1977	D	Unk.	Unk.	2.2	—	—	—	—
Seminoe I	22.7	1984	Unk.	16.8	—	1.7	—	0.6	0.6	*Save* = 0.6, *Atco* = 1.7
Kemmerer #1	36.5	1980	D	15.7	—	2.2	—	—	—	—
FOURWING/BIG SAGEBRUSH										
WyoDak #1	4.5	1982	D & B	15.1	0.6	1.1	0.6	3.4	2.2	*Atga* = 3.4, *Arca* = 0.6
WyoDak #2	4.5	1984	D & B	16.1	0.6	5.6	0.6	3.4	—	*Atga* = 3.4
Pathfinder	21.5	1982	D	15.1	2.2	2.2	1.1[d]	—	1.1	—
Dave Johnston	23.9	1981	D & B	20.2	1.1	0.6	0.6	—	0.6	*Chvi* = 2.2, *Arca* = 0.6
Seminoe I	7.7	1984	D	16.8	—	1.7	0.3	0.6	0.6	*Save* = 0.6, *Atco* = 0.6
Kemmerer #2	3.0	1980	D	15.7	—	2.2	0.3	—	—	—
Kemmerer #3	37.7	1981	D	15.7	—	2.2	0.3	—	—	—
Bridger Coal #1	6.5	1981	D & B	19.5	2.8	—	—	0.6	1.7	—
		1984[e]		24.4	6.7	2.2	—	1.1	1.1	*Atga* = 2.2, *Arfr* = 1.1
		1984[e]		—	—	—	3.9	1.1	2.2	*Atga* = 5.6, *Arfr* = 3.4, *Atco* = 0.6
Bridger Coal #2	33.2	1980	B	13.4	—	0.6	—	—	—	—
		1981		19.5	2.8	—	—	0.6	1.7	—
		1984[e]		29.1	5.6	—	2.2	—	1.1	*Atga* = 1.1
		1984[e]		—	—	—	3.9	1.1	2.2	*Atga* = 5.6, *Arfr* = 3.4, *Atco* = 0.6

[a]Pure live seed (pls) unless otherwise noted
[b]D = drilled, B = broadcasted
[c]Plant symbols: *Arca* = *Artemisia cana*, *Arfr* = *Artemisia frigida*, *Artr* = *Artemisia tridentata*, *Atca* = *Atriplex canescen*, *Atco* = *Atriplex confertifolia*, *Chna* = *Chrysothamnus nauseosus*, *Chvi* = *Chrysothamnus viscidiflorus*, *Eula* = *Eurotia lanata*, *Rowo* = *Rosa woodsii*, *Save* = *Sarcobatus vermiculatus*
[d]Bulk seed, not pls
[e]Interseeded on same plot, different year(s) from original seeding

TABLE 5. Summary of shrub plant community characteristics for fourwing saltbush/grass reclaimed mined sites.

Site	Mean height (cm)	Mean cover[a] (%)	Mean density (plants m^{-2})	Importance value	Diversity index
BLACK THUNDER					0.033
Artemisia tridentata	11.0		≤0.01	≤ 0.01	
Atriplex canescens	71.7 ± 19.8[b]	5.3 ± 0.4	0.10 ± 0.04	2.00	
All shrubs	41.4[c] ± 20.1	5.3[d]	0.10[d]		
BELLE AYR					0.060
Atriplex canescens	74.3 ± 23.2	1.9 ± 0.3	0.14 ± 0.07	1.99	
Eurotia lanata	34.0 ± 2.8		≤0.01	0.01	
All shrubs	54.1 ± 23.7	1.9	0.14		
PATHFINDER					0.053
Artemisia tridentata	10.5 ± 2.4		≤0.01	0.01	
Atriplex canescens	41.1 ± 16.8	2.7 ± 0.4	0.12 ± 0.09	1.99	
All shrubs	25.8 ± 17.0	2.7	0.12		
SEMINOE I					1.428
Artemisia tridentata	11.6 ± 10.4	≤0.1	0.01	0.12	
Atriplex canescens	65.7 ± 24.9	2.5 ± 0.3	0.06 ± 0.04	1.43	
Chrysothamnus spp.	28.1 ± 10.1		≤0.01	0.02	
Gutierrezia sarothrae	35.9 ± 10.8	≤0.1	≤0.01	0.03	
Atriplex confertifolia	37.3 ± 12.7	0.2 ± 0.2	0.01	0.14	
Sarcobatus vermiculatus	87.0 ± 30.5	0.6 ± 0.6	0.01	0.25	
All shrubs	44.3 ± 30.4	3.4	0.09		
KEMMERER #1					0.066
Artemisia tridentata	27.7 ± 9.7		≤0.01	≤0.01	
Atriplex canescens	51.5 ± 24.6	15.7 ± 0.5	0.69 ± 0.17	1.99	
Gutierrezia sarothrae	23.9 ± 7.7		0.01	0.01	
Atriplex confertifolia	14.3 ± 13.3		≤0.01	≤ 0.01	
Sarcobatus vermiculatus	94.0		≤0.01	≤0.01	
All shrubs	42.3 ± 24.9	15.7	0.70		
MEAN (ALL SITES)	41.6	5.8	0.23		0.328

[a]From line-intercept sampling techniques (Canfield 1941)
[b]Standard deviation
[c]Mean of mean shrub species heights
[d]Sum of mean shrub species cover and density

Fourwing saltbush was clearly the major component of canopy cover on fourwing sites (Table 5). Although big sagebrush was not included in the original seed mixture of these sites (Table 4), it occurred at Black Thunder, Pathfinder, Seminoe I, and Kemmerer #1 (Table 5). Big sagebrush apparently immigrated and successfully colonized these sites, presumably from adjacent native plant communities.

On 6 fourwing/sagebrush sites (WyoDak #1, WyoDak #2, Dave Johnston, Seminoe I, Kemmerer #2, and Bridger Coal #1), big sagebrush was the largest contributor to overall shrub canopy cover (Table 6). However, Pathfinder, Kemmerer #3, and Bridger Coal #2 (fourwing/sagebrush) sites were dominated by fourwing saltbush. Fourwing saltbush was originally included in the seed mixture of these sites.

When comparing percent shrub cover to preferred habitat requirements, we found that only fourwing sites at Black Thunder and Kemmerer #1 provided cover needs of antelope, 5.3% and 15.7%, respectively (Tables 1, 5). Total shrub cover on fourwing/sagebrush sites at WyoDak #1 and #2 and Bridger Coal #1 and #2 was marginally adequate when considering minimal preferred habitat requirements of 5% (Tables 1, 6). Based on Cook's (1984) guidelines for Wyoming, only the Kemmerer #1 fourwing site and Bridger Coal #2 fourwing/sagebrush site had enough cover for antelope when considering total shrub cover (Tables 1, 5, 6).

With regard to sage grouse habitat, Kemmerer #1 and Black Thunder fourwing sites offered enough canopy cover (15.7% and 5.3%, respectively) to meet requirements for general use (Tables 2, 5). But, since both sites were dominated by fourwing saltbush and sage grouse are closely associated with big sagebrush, habitat characteristics of the Kemmerer #1 and Black Thunder fourwing sites are

Table 6. Summary of shrub plant community characteristics for fourwing saltbush/big sagebrush/grass reclaimed mined sites.

Site	Mean height (cm)	Mean cover[a] (%)	Mean density (plants m^{-2})	Importance value	Density index
WYODAK #1					0.857
Artemisia tridentata	64.1 ± 31.1[b]	7.4 ± 0.4	0.45 ± 0.3	1.65	
Atriplex canescens	13.0		≤0.01	≤0.01	
Artemisia frigida	14.1 ± 10.0	≤0.1	0.08 ± 0.1	0.14	
Eurotia lanata	28.7 ± 19.5		≤0.01	≤0.01	
Artemisia cana	28.5 ± 14.8	0.4 ± 0.6	0.11 ± 0.2	0.21	
All shrubs	29.7[c] ± 32.2	7.8[d]	0.64[d]		
WYODAK #2					0.940
Artemisia tridentata	32.9 ± 12.7	4.7 ± 0.4	0.37 ± 0.3	1.43	
Artemisia frigida	17.0 ± 8.8	0.9 ± 0.2	0.24 ± 0.1	0.55	
Chrysothamnus spp.	64.0		≤0.01	≤0.01	
Gutierrezia sarothrae	16.2 ± 4.9		0.01	0.02	
Rosa woodsii	84.0		≤0.01	≤0.01	
All shrubs	39.1 ± 13.7	5.6	0.62		
PATHFINDER					0.731
Artemisia tridentata	10.0 ± 4.0	≤0.1	0.03	0.20	
Atriplex canescens	50.7 ± 25.1	4.0 ± 0.5	0.11 ± 0.1	1.74	
Artemisia frigida	7.3 ± 3.8		≤0.01	0.01	
Eurotia lanata	22.0 ± 11.6		0.01	0.04	
Chrysothamnus spp.	6.4 ± 2.3		≤0.01	0.01	
Atriplex confertifolia	37.0 ± 4.5	0.1	≤0.01	0.01	
All shrubs	22.2 ± 27.7	4.1	0.15		
DAVE JOHNSTON					1.398
Artemisia tridentata	19.9 ± 6.9	0.6 ± 0.1	0.16 ± 0.1	0.90	
Atriplex canescens	20.2 ± 9.9	≤0.1	≤0.01	0.02	
Artemisia frigida	9.5 ± 5.6	0.3 ± 0.1	0.31 ± 0.2	0.93	
Eurotia lanata	23.4 ± 19.8	0.1 ± 0.1	0.04	0.16	
Chrysothamnus spp.	20.5 ± 7.8		≤0.01	≤0.01	
Gutierrezia sarothrae	23.0 ± 12.7		≤0.01	≤0.01	
All shrubs	19.4 ± 10.5	1.0	0.51		
SEMINOE I					1.116
Artemisia tridentata	46.1 ± 26.8	2.2 ± 0.3	0.17 ± 0.2	1.49	
Atriplex canescens	82.3 ± 28.3	0.7 ± 0.4	0.01	0.27	
Chrysothamnus spp.	32.9 ± 27.6	0.3 ± 0.2	0.03	0.24	
Gutierrezia sarothrae	35.7 ± 4.5		≤0.01	0.01	
Sarcobatus vermiculatus	25.3 ± 31.1		≤0.01	0.01	
All shrubs	44.5 ± 28.8	3.2	0.21		

probably undesirable for sage grouse (Table 5). Only 1 fourwing site, Kemmerer #1, had sufficient cover for sage grouse nesting and brood rearing (Tables 2, 5). No site supported enough winter cover for sage grouse.

Fourwing/sagebrush sites at WyoDak #1 and #2 and Bridger Coal #1 and #2 also had enough canopy cover for general use by sage grouse (Tables 2, 6). However, only 1 fourwing/sagebrush site, Bridger Coal #2, provided enough shrub cover for nesting and brood rearing (Tables 2, 6). No site provided enough winter cover for sage grouse.

Shrub cover is an extremely important component of wildlife habitat quality. These study sites, with the exception of Kemmerer #1 fourwing and Bridger Coal #2 fourwing/sagebrush sites, provided only minimal cover for antelope and sage grouse. Shrub reclamation guidelines in Wyoming focus solely on shrub density to evaluate successful reclamation. Research findings (Postovit 1981, Cook 1984, Nydegger and Smith 1984, Roberson 1984) emphasize that shrub cover is equally as important as shrub density when evaluating reclaimed mined land for wildlife habitat and should be considered to provide a full assessment of the reclaimed site in meeting wildlife habitat needs.

Table 6. Continued.

Site	Mean height (cm)	Mean cover[a] (%)	Mean density (plants m^{-2})	Importance value	Density index
KEMMERER #2					0.133
Artemisia tridentata	59.9 ± 25.3	2.2 ± 0.4	0.09 ± 0.1	1.97	
Amelanchier alnifolia	14.0		≤0.01	0.01	
Chrysothamnus spp.	37.5 ± 10.6		≤0.01	0.02	
Gutierrezia sarothrae	24.0 ± 7.0	≤0.1	≤0.01	≤0.01	
All shrubs	33.9 ± 25.6	2.2	0.09		
KEMMERER #3					0.777
Artemisia tridentata	41.9 ± 20.8	0.4 ± 0.6	0.02	0.19	
Atriplex canescen	64.9 ± 28.4	4.3 ± 0.4	0.18 ± 0.2	1.72	
Chrysothamnus spp.	31.4 ± 10.5	0.2 ± 0.2	0.01	0.07	
Gutierrezia sarothrae	16.4 ± 3.5		≤0.01	0.01	
Artemisia tripartata	18.3 ± 4.3		≤0.01	0.01	
All shrubs	34.6 ± 29.1	4.9	0.21		
BRIDGER COAL #1					1.505
Artemisia tridentata	34.6 ± 15.6	4.1 ± 0.4	1.71 ± 1.0	1.39	
Atriplex canescens	38.5 ± 24.7	0.5 ± 0.4	0.02	0.07	
Eurotia lanata	19.2 ± 10.0	≤0.1	≤0.01	≤0.01	
Chrysothamnus spp.	18.2 ± 15.4	0.1	0.02	0.03	
Gutierrezia sarothrae	21.4 ± 12.7	≤0.1	0.01	0.01	
Atriplex confertifolia	36.3 ± 15.3	0.6 ± 0.3	0.02	0.08	
Atriplex gardnerii	11.8 ± 5.7	2.0 ± 0.3	0.12 ± 0.1	0.30	
Sarcobatus vermiculatus	43.7 ± 36.5	0.9 ± 0.3	0.02	0.12	
All shrubs	28.0 ± 19.3	8.3	1.92		
BRIDGER COAL #2					1.398
Artemisia tridentata	32.9 ± 14.5	1.4 ± 0.4	0.77 ± 0.6	0.80	
Atriplex canescens	55.4 ± 41.5	10.7 ± 0.7	0.27 ± 0.1	1.05	
Chrysothamnus spp.	21.3 ± 11.0		0.01	0.01	
Gutierrezia sarothrae	16.2 ± 12.1	≤0.1	≤0.01	0.01	
Atriplex confertifolia	29.8 ± 17.7	0.8 ± 0.6	0.04	0.09	
Atriplex gardnerii	13.2 ± 11.5	0.4 ± 0.2	0.02	0.04	
All shrubs	28.1 ± 33.7	13.3	1.11		
MEAN (ALL SITES)	31.1	5.6	0.61		0.984

[a]From line-intercept sampling techniques (Canfield 1941)
[b]Standard deviation
[c]Mean of mean shrub species heights
[d]Sum of mean shrub species cover and density

Density

Densities among dominant shrub species varied considerably between and among reclaimed mine sites, while densities of subdominant species were consistently low. Densities for all shrubs in the 5 fourwing sites ranged from 0.09 m^{-2} to 0.70 m^{-2}, with a mean of 0.23 m^{-2} (Table 5). For the 9 fourwing/sagebrush sites, densities for all species ranged from 0.09 m^{-2} to 1.92 m^{-2}, with a mean of 0.61 m^{-2} (Table 6).

Fourwing saltbush displayed the highest density of any shrub species on fourwing sites (Table 5), while big sagebrush density was highest among all shrub species on fourwing/sagebrush sites except Pathfinder, Dave Johnston, and Kemmerer #3 (Table 6). Fourwing saltbush densities were greater on Pathfinder and Kemmerer #3 sites, while fringed sagebrush had the highest density on the Dave Johnston site (Table 6).

No site within the fourwing reclamation type exhibited the minimal big sagebrush density required by sage grouse. Only 1 site in the fourwing/sagebrush reclamation type, Bridger Coal #1, had sufficient big sagebrush densities (1.92 m^{-2}) for sage grouse (Table 6). However, >90% of big sagebrush plants measured at Bridger Coal #1 were seedlings <10 cm in height and therefore did not represent high-quality sage grouse habitat at that time. If this plant density persists over time, it should then produce desirable habitat.

Shrub Height

Shrub heights varied greatly between species within and among study sites. Mean shrub heights for all species on 5 fourwing sites ranged from 25.8 to 54.1 cm, with an overall mean of 41.6 cm (Table 5). For 9 fourwing/sagebrush sites, mean shrub heights for all species were 19.4–44.5 cm, with an overall mean of 31.1 cm (Table 6). Mean heights of big sagebrush varied from 10.0 to 64.1 cm, while fourwing saltbush heights ranged from 13.0 to 82.3 cm across sites.

Big sagebrush heights at Kemmerer #1 averaged 27.7 cm (Table 5). All other fourwing sites had big sagebrush heights <22 cm recommended for antelope (Table 1). Among fourwing/sagebrush sites, 7 of 9 had mean big sagebrush heights greater than the preferred height, but 5 of those sites were within Cook's (1984) optimum range of 22–46 cm (Tables 1, 6).

Kemmerer #1 was the only fourwing site providing sufficient big sagebrush height (27.7 cm) to offer nesting and summer or winter habitat for sage grouse (Tables 2, 5). Eight of 9 fourwing/sagebrush sites provided sufficient nesting (17 cm) and summer (18 cm) habitat for sage grouse (Tables 2, 6). Seven of 9 fourwing/sagebrush sites provided sufficient big sagebrush heights for winter habitat. Only the Pathfinder site, with a mean big sagebrush height of 10 cm, did not meet the minimal height for sage grouse.

Vegetative Composition

Grasses dominated the vegetative composition on all fourwing and fourwing/sagebrush sites except Bridger Coal #2 site (Table 7). Considering that 67% of the total antelope population in North America occupies grasslands and highest antelope densities occur on grasslands (Yoakum 1978), these reclaimed mine sites may be important for antelope from a vegetation composition standpoint. Yoakum (1984a) reported that Bear Valley in central Oregon supported the highest antelope doe: fawn ratios of anywhere in the state after herbicides and mechanical practices changed pretreatment grass composition from 10–40% to 50–70%. However, for sage grouse requiring higher percentages of forbs and shrubs (Table 2), these reclaimed mine sites are less desirable.

Despite high grass seeding rates on all study sites (Table 4), Booth et al. (1999) found no correlation between shrub density and grass seeding rates. Schuman et al. (1998) also reported no differences in big sagebrush seedling density when grasses were seeded at 16 and 32 kg ha^{-1} pls. However, big sagebrush seedling density was significantly greater when seeded without grass.

When evaluating mean percent vegetative composition of fourwing sites against preferred standards of 40% grasses, 20% forbs, and 5% shrubs for antelope (Table 1), we found that only Pathfinder satisfies antelope habitat requirements (Table 7). Likewise, of fourwing/sagebrush sites, only WyoDak #1 had sufficient vegetation composition preferred by antelope. The absence of forbs in all sampled revegetated communities is the primary factor contributing to an unbalanced vegetation composition. No fourwing or fourwing/sagebrush site met the minimal preferred composition of 42.0% grasses, 28.4% forbs, and 29.6% shrubs for sage grouse (Table 2).

Importance Values

Importance values provide a quantitative approach to identify plant community dominants (Curtis and McIntosh 1951). Dominant species highly preferred by wildlife for food and cover enhance wildlife habitat quality.

Fourwing sites were dominated by fourwing saltbush with importance values ranging from 1.43 to 1.99 (Table 5), while other shrub species were subdominants. Among 9 fourwing/sagebrush sites, big sagebrush dominated WyoDak #1 and #2, Seminoe I, Kemmerer #2, and Bridger Coal #1 sites with importance values of 1.65, 1.43, 1.49, 1.97, and 1.39, respectively (Table 6). Fourwing saltbush dominated Pathfinder, Kemmerer #3, and Bridger Coal #2 sites and exhibited importance values of 1.74, 1.72, and 1.05, respectively. The Dave Johnston site reflected a shrub community dominated equally by fringed sagebrush and big sagebrush with importance values of 0.93 and 0.90, respectively.

According to Sundstrom et al. (1973), preferred shrub species for antelope in Wyoming sagebrush-grassland steppe ecosystems are big sagebrush, sand sagebrush (*Artemisia filifolia*),

TABLE 7. Mean vegetative composition (%) of fourwing saltbush/grass and fourwing saltbush/big sagebrush/grass reclaimed mine sites.

Site	Mean composition (%)		
	Grass	Forb	Shrub
FOURWING SALTBUSH/GRASS			
Black Thunder (20)[a]	82.9 ± 20.4[b]	0.4 ± 1.4	16.7 ± 20.4
Belle Ayr (5)	94.2 ± 7.1	5.0 ± 5.6	0.8 ± 1.8
Pathfinder (20)	67.9 ± 15.4	23.5 ± 16.2	8.6 ± 16.1
Seminoe I (20)	87.9 ± 16.8	0.0	12.1 ± 16.8
Kemmerer #1 (20)	56.9 ± 23.5	0.3 ± 1.2	42.8 ± 23.7
MEAN (ALL SITES)	77.9	5.8	16.2
FOURWING SALTBUSH/BIG SAGEBRUSH/GRASS			
WyoDak #1 (10)	48.5 ± 12.5	33.3 ± 15.7	18.2 ± 17.8
WyoDak #2 (10)	70.1 ± 19.3	15.9 ± 14.3	14.0 ± 17.0
Pathfinder (30)	87.0 ± 19.4	9.3 ± 16.2	3.7 ± 11.7
Dave Johnston (20)	92.8 ± 9.8	2.8 ± 4.6	4.4 ± 8.7
Seminoe I (20)	91.8 ± 11.8	3.6 ± 6.9	4.6 ± 9.9
Kemmerer #2 (20)	92.7 ± 11.9	1.2 ± 2.0	6.1 ± 10.8
Kemmerer #3 (20)	77.4 ± 25.4	5.7 ± 11.7	11.9 ± 18.4
Bridger Coal #1 (20)	45.3 ± 24.4	9.8 ± 13.6	44.9 ± 22.5
Bridger Coal #2 (20)	41.8 ± 24.6	8.0 ± 22.3	50.2 ± 25.6
MEAN (ALL SITES)	71.9	10.0	17.6

[a]Number of transects sampled, 100 points per transect
[b]Standard deviation

fringed sagebrush, silver sagebrush (*Artemisia cana*), and Douglas rabbitbrush (*Chrysothamnus viscidiflorus*; Table 1). Four of 5 fourwing sites had only 1 of these preferred shrub species, big sagebrush (Table 5). In comparison, 4 fourwing/sagebrush sites had 3 preferred species and 5 sites had 2 preferred species (Table 6). Clearly, fourwing/sagebrush sites offered more preferred shrub species in the community.

From the standpoint of wildlife habitat quality, sites dominated by big sagebrush are especially important for sage grouse and antelope because this shrub species provides both yearlong food and cover for these wildlife species. In contrast, fourwing saltbush does not provide as much cover as big sagebrush, but it does furnish highly palatable, nutritious forage needed by big game. Cook (1972) reported that average protein content for big sagebrush, when evaluated over 4 seasons, was 11.2%. Goodin (1979) reported mean protein content of fourwing saltbush at 19.0% in a 2-yr greenhouse study, asserting that crude protein levels were comparable to alfalfa (*Medicago sativa*). Palatability of fourwing saltbush is good for several species of wildlife, with a digestibility of 63.5% (Northington and Goodin 1979). Based on these criteria, WyoDak #1 and #2, Seminoe I, Kemmerer #2, Bridger Coal #1, and Dave Johnston sites are probably more important for cover provided to sage grouse and antelope since big sagebrush dominates the plant community composition. However, fourwing-dominated sites are valued for highly palatable, nutritious forage provided to big game species.

Diversity Indices

Shannon-Wiener diversity indices averaged 3 times higher on fourwing/sagebrush sites than on fourwing sites. Diversity indices on fourwing sites ranged from 0.033 to 1.428, with a mean of 0.328 (Table 5), and ranged from 0.133 to 1.505 on fourwing/sagebrush sites, with a mean of 0.984 (Table 6). This difference is attributed to more shrub species in the original seed mixtures of fourwing/sagebrush sites compared to fourwing sites (Tables 4, 5, 6).

An individual site analysis showed that 4 fourwing sites had the lowest diversity indices of all 14 study sites, while 8 fourwing/sagebrush sites reflected the highest diversity indices (Fig. 1). Only the Kemmerer #2 fourwing/sagebrush site and Seminoe I fourwing site displayed inconsistent patterns in diversity compared to other sites. Different initial seed mixtures probably resulted in community diversity differences between fourwing and fourwing/sagebrush sites.

Numerous research studies have shown that reduction in big sagebrush and other rangeland plants by burning, plowing, or 2,4-D applications results in decreases of wildlife species richness, presumably due to decreases in plant species richness. Schroeder and Sturges (1975), McAdoo and Klebenow (1978), and Castrale (1982) reported decreases in nongame bird species abundance as a result of burning or plowing big sagebrush steppe. Sage grouse are negatively impacted by drastic reductions in big sagebrush cover and density by any method (Martin 1970, Wallestad and Pyrah 1974, Swenson et al. 1987). Small mammal species abundance also decreases when big sagebrush and other rangeland plants are reduced (Cook 1959, Johnson and Hansen 1969, Gashwiler 1970, Crowner and Barrett 1979). However, Johnson et al. (1996) reported that small mammal community diversity is positively correlated with plant community diversity. Considering these research findings, the graphical representation of diversity indices in Figure 1 indicates that higher shrub diversity on fourwing/sagebrush sites may provide more desirable wildlife habitat quality.

CONCLUSIONS AND RECOMMENDATIONS

This study evaluated long-term (>10 yr) shrub reestablishment success of pre-1985 reclamation practices and offers information to enhance wildlife habitat and improve shrub establishment and productivity in future reclamation. Sites selected for this investigation are representative of pre-1985 era reclamation methodologies and levels of success. These sites demonstrate both reclamation inadequacies and successes which should be considered in future reclamation efforts.

Individual shrub species canopy cover on all sampled sites within the bunchgrass steppe and those located on the western edge of the northern mixed-grass prairie (Hart 1994) was low, rarely exceeding 5%, when evaluated against shrub cover recommendations for antelope in sagebrush-grassland steppe ecosystems. Since our sites more closely resemble the sagebrush-grassland ecosystem described by Yoakum (1984a, 1984b) rather than shortgrass prairie, his cover recommendations for the sagebrush-grassland ecosystem were used to evaluate our study sites for antelope.

Rather than reclamation practices, the greater time required by shrub species to reach maximum canopy cover (Lommasson 1948) and possible browsing-induced mortality of big sagebrush from wild herbivores (McArthur et al. 1988, Bilbrough and Richards 1993) may account for low canopy cover on our sample sites. Although shrub utilization by wild herbivores was not a focus of this study, reclamation specialists may need to consider intensifying wildlife damage control programs on newly reclaimed areas, if browsing appears heavy, to enhance and successfully achieve shrub cover requirements.

Shrub densities were also considered low when evaluated against an extrapolation of the reclamation regulation of 1 shrub m^{-2} on 20% of the land (Federal Register 1996). These data and information reported by Booth et al. (1999) also indicate that more shrub species in the initial seed mixture improved shrub density. Some fourwing/sagebrush sites displayed encouraging signs of increased shrub densities by the presence of an age-stratified population.

Shrub heights on fourwing/sagebrush sites were sufficient for both antelope and sage grouse, even providing enough winter cover for sage grouse. In contrast, shrub heights on fourwing sites were below minimal requirements for both antelope and sage grouse.

The preferred compositions of grasses, forbs, and shrubs for antelope and sage grouse were below minimal requirements on both reclamation types, due primarily to the absence of forbs. Original seed mixtures, which consisted principally of grass and shrub species with minimal forbs (Table 4), probably explain the existing composition on reclaimed sites. However, Schuman et al. (1998) have shown that big sagebrush establishment is significantly enhanced by limiting competition from herbaceous species.

Higher diversity indices on fourwing/sagebrush sites indicated that more species in the initial seed mixture enhanced plant community diversity, a highly desired characteristic for optimum wildlife habitat. Sites where more shrub species were included in the initial seed mixture appeared to be progressing toward pre-mining vegetation conditions faster than sites with fewer seeded shrub species.

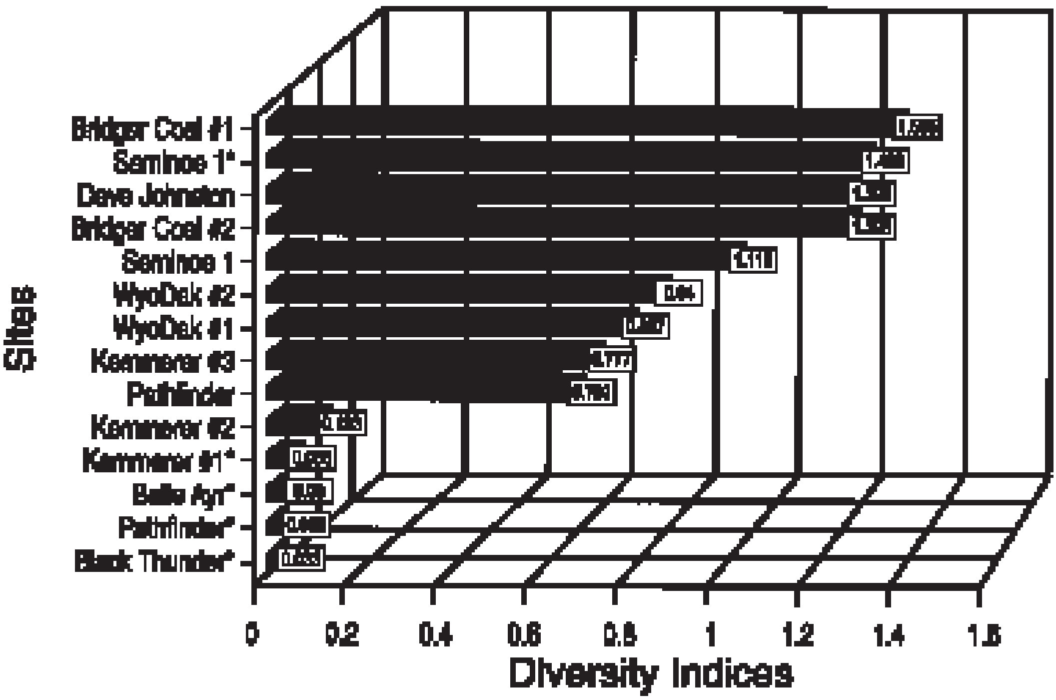

Fig. 1. Diversity indices for fourwing saltbush/grass (denoted by *) and fourwing saltbush/big sagebrush/grass reclaimed mined sites, 1994, Wyoming.

Inclusion of multiple species in the initial seeding mixture also enhanced overall cover, density, and diversity in reclaimed plant communities, all important components of quality wildlife habitat. However, with regard to antelope and sage grouse, less than optimal shrub canopy cover, density, plant community composition, and diversity on these study sites suggest that a long time period or improved cultural methods will be required for reclaimed shrub communities to achieve desired wildlife habitat characteristics similar to native sagebrush-grassland steppe ecosystems. Bond-release criteria requiring the reclaimed shrub community to be similar to pre-mine conditions within the 10-yr bonding period for this region are unrealistic. Native shrub communities may require 30–60 yr to develop through natural successional processes (Lommasson 1948).

If one objective of mined land reclamation is to restore disturbed land to pre-mining conditions for wildlife habitat, then shrub density standards alone will not satisfy this objective. Other characteristics of wildlife habitat, such as shrub canopy cover, shrub height, community composition, and plant diversity, must be considered.

Comparisons of on-site shrub establishment characteristics with published information on habitat requirements of antelope and sage grouse were not intended to provide specific benchmarks for evaluating reclamation success, but rather to provide an initial, broad assessment of wildlife habitat quality where none previously existed. There are no studies that relate quantitative wildlife population characteristics (e.g., species richness, abundance, density, diversity) to reclaimed mined land plant community features (e.g., species richness, canopy cover, density, standing crop biomass, diversity).

There are a number of interrelated biotic and abiotic environmental factors responsible for establishment and development of plant communities on reclaimed mined lands and, subsequently, wildlife use of these areas. These include site potential for vegetation development, original reclamation seeding mixtures, successional processes, disturbance factors (e.g., grazing, fire), and post-seeding management practices. For these reasons conclusions drawn from data in this study are limited to precursory evaluations of shrub community characteristics for antelope and sage grouse habitat quality. However, results from this study justify the need for future research quantifying the relationship of wildlife population dynamics to reclaimed plant community characteristics.

Future research should relate specific wildlife population sample data (e.g., species richness, abundance, density, diversity) to various parameters of reclaimed mined land plant communities (e.g., species richness, canopy cover, density, standing crop biomass, diversity) to better understand the function of these areas as habitat for wildlife populations. Other indirect wildlife use data, such as pellet counts, forage utilization measurements, and fecal analysis for food habits information, should be included to further clarify the importance of reclaimed mined land for wildlife habitat value. Additional research is also needed to prescribe initial seeding practices and post-seeding management techniques that enhance wildlife habitat quality on these reclaimed areas.

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