Vegetation Characteristics Across Part of the Wyoming Big Sagebrush Alliance

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Abstract

The Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis* [Beetle & A. Young] S.L. Welsh) alliance is the most extensive of the big sagebrush complex in the Intermountain West. This alliance provides critical habitat for many sagebrush obligate and facultative wildlife species and serves as a forage base for livestock production. There is a lack of information that describes vegetation cover values, characteristics, diversity, and heterogeneity of the Wyoming big sagebrush alliance. This study describes vegetation cover values and defines distinct associations for intact, late-seral Wyoming big sagebrush plant communities across part of its northwestern range. We sampled 107 Wyoming big sagebrush plant communities. Total herbaceous cover values were variable among sites with differences between sites exceeding 700%. Mean sagebrush cover was 12.3% with 90% of the sites producing 6% to 20% cover. Tall forb (> 18 cm) cover averaged 1.9% and 90% of the sites varied between 0.2% and 5.6% cover. Five associations delineated by dominant perennial bunchgrass species were identified: ARTRW8 (Wyoming big sagebrush)/PSSP6 (*Pseudoroegneria spicata* [Pursh] A. Löve, bluebunch wheatgrass), ARTRW8/ACTH7 (*Achnatherum thurberianum* [Piper] Barkworth, Thurber's needlegrass), ARTRW8/FEID (*Festuca idahoensis* Elmer, Idaho fescue), ARTRW8/HECO26 (*Hesperostipa comata* [Trin. & Rupr.] Barkworth, needle-and-thread), and ARTRW8/PSSP6–ACTH7 (a codominance of bluebunch wheatgrass and Thurber's needlegrass). Our results suggest when the vegetation cover values proposed for sage-grouse are applied as requirements at or above the stand level, they exceed the ecological potential of many of the sites sampled.

Resumen

La alianza de la artemisa grande de Wyoming (*Artemisia tridentata* ssp. *wyomingensis* [Beetle & A. Young] S.L. Welsh) es el complejo de artemisa mas extenso del oeste intermontano. Esta alianza proporciona hábitat crítico para muchas especies específicas y generalistas de artemisa y sirve como forraje básico para la producción ganadera. Existe muy poca información que describe el valor de la cobertura vegetal, características, diversidad, y heterogeneidad de la alianza de la artemisa grande. El presente estudio describe valores de cobertura vegetal y define las diferentes asociaciones en comunidades intactas de plantas serales de artemisa grande en el rango noroeste. Muestreamos 107 comunidades de plantas de artemisa grande de Wyoming. El total de los valores de cobertura herbácea fueron variables entre sitios con diferencias que excedían el 700%. La cobertura promedio de artemisa fue de 12.3% con un 90% de los sitios con un rango de cobertura entre 6% y 20%. La cobertura de hierbas altas (>18 cm) promedió 1.9% y el 90% de los sitios variaron en cobertura entre 0.2% y 5.6%. Se identificaron cinco asociaciones delineadas por especies perennes dominantes de pastos: ARTRW8 (Artemisa grande de Wyoming)/AGSP (*Agropyron spicatum* [Pursh] Schibn. & Smith, bluebunch wheatgrass), ARTRW8/STTH (*Stipa thurberiana* ajenjo, Thurber's needlegrass), ARTRW8/FEID (*Festuca idahoensis* Elmer, Idaho fescue), ARTRW8/STCO2 (*Stipa comata* Trin. & Rupr., needle-and-thread), and ARTRW8/AGSP-STTH (una co-dominancia de bluebunch wheatgrass and Thurber's needlegrass). Nuestros resultados sugieren que cuando los valores propuestos para sabio urogallo se aplican como requisitos promedio o por encima del mismo, estos exceden el potencial ecológico de muchos de los sitios muestreados.

Key Words: *Artemisia tridentata* spp. *wyomingensis*, cover potential, plant associations, vegetation cover, sage-grouse

INTRODUCTION

Big sagebrush (*Artemisia tridentata* Nutt.) communities make up one of the major plant complexes in the western United States (Küchler 1970; Miller et al. 1994; West and Young 2000). The Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis* [Beetle & A. Young] S.L. Welsh) alliance is the most extensive of the big sagebrush complex in the Intermountain West (Tisdale 1994). Since Euro-American settlement in the late 1800s, the Wyoming big sagebrush alliance has decreased from its historic range. Following World War II,

Research was funded in part by the US Department of Agriculture–Agricultural Research Service, Oregon State University, and Bureau of Land Management. The Eastern Oregon Agricultural Research Center is jointly funded by the US Department of Agriculture–Agricultural Research Service and Oregon State Agricultural Experiment Station.

Nomenclature follows Natural Resource Conservation Service. PLANTS Database. Available at: http://plants.usda.gov/index.html. Accessed 28 August 2006.

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Manuscript received 16 January 2006; manuscript accepted 3 September 2006.

Table 1. Connelly et al. (2000) vegetation cover values needed for productive greater sage-grouse habitat.

Habitat	Sagebrush cover (%)	Sagebrush height (cm)	Grass–forb cover (%)	Grass–forb height (cm)	Area[1] (%)
Mesic breeding[2] sites	15–25	40–80	≥ 25[3]	> 18	> 80
Mesic brood-rearing sites	10–25	40–80	≥ 15	N/A	> 40
Mesic winter[4] sites	10–30	25–35	N/A	N/A	> 80
Arid breeding sites	15–25	40–80	≥ 15	> 18	> 80
Arid brood-rearing sites	10–25	40–80	≥ 15	N/A	> 40
Arid wintering[4] sites	10–30	25–35	N/A	N/A	> 80

[1]Percentage of habitat needed with suggested vegetation cover and height values.
[2]Lek attendance, nesting, and early brood rearing occur in breeding habitat.
[3]Perennial grass cover $> 15\%$ and forb cover $> 10\%$.
[4]Sagebrush cover and height values are for sagebrush above the snow.

Table 2. Bureau of Land Management et al. (2000) vegetation cover values needed for productive greater sage-grouse habitat.

Habitat	Sagebrush cover (%)	Sagebrush height (cm)	Grass–forb cover (%)	Grass–forb height (cm)	Area[1] (%)
Optimal nesting sites	15–25	40–80	≥ 25[2]	≥ 18	> 80
Optimal brood-rearing sites	10–25	40–80	≥ 25[2]	N/A	> 40
Suboptimal brood-rearing sites	≥ 14	40–80	≥ 15	N/A	> 40
Wintering sites	10–30	≥ 25–30[3]	N/A	N/A	> 80

[1]Percentage of habitat needed with suggested vegetation cover and height values.
[2]Perennial grass cover $> 15\%$ and forb cover $> 10\%$.
[3]Sagebrush height values are for sagebrush above the snow.

a large effort was made to reduce sagebrush in order to increase forage for domestic livestock (Young et al. 1981). Conversion to agricultural cropland and spread of nonnative weeds has also eliminated Wyoming big sagebrush communities from large areas. Miller and Eddleman (2000) speculate that a majority of the exotic annual grasslands dominated by cheatgrass (*Bromus tectorum* L.) in the Intermountain West were formerly Wyoming big sagebrush communities.

Research and land management agencies have placed a major emphasis on developing strategies to maintain remaining intact landscapes and restore degraded Wyoming big sagebrush communities. However, there is limited information describing the vegetation characteristics and potentials of the Wyoming big sagebrush alliance in intact, late-seral condition. Anderson and Inouye (2001) described vegetation characteristics on 47 Wyoming big sagebrush plots that had been undisturbed for 45 years, but their study was limited to the Idaho National Laboratory in southeastern Idaho and had experienced heavy livestock use in the past. Tisdale and Hironaka (1981), Passey et al. (1982), Jensen et al. (1990), and Kindschy (1992) also provide some description of this alliance, but their studies are restricted by small sample sizes and/or limited characterization of vegetation cover.

This lack of information on vegetation characteristics of Wyoming big sagebrush communities is of concern as management plans are developed and implemented. For example, recent disagreement has arisen over suggested vegetation cover values needed for productive sage-grouse habitat in management guidelines developed by Connelly et al. (2000) (Table 1) and Bureau of Land Management (BLM) et al. (2000) (Table 2). Vegetation cover values in the guidelines were developed from small-scale habitat studies and were not expected to be applied across all sagebrush communities. However, these vegetation cover values are being mistakenly interpreted as requirements and applicable to the stand, community, and landscape scales for all sagebrush communities. Rangeland ecologists and federal land managers are concerned that these vegetation cover values may exceed potentials of the Wyoming big sagebrush alliance when applied at the stand or larger scales.

The lack of adequate descriptions of vegetation characteristics makes it difficult to estimate the vegetation potentials of the Wyoming big sagebrush alliance and to develop useful management criteria that will assist land managers in protecting intact or restoring degraded Wyoming big sagebrush habitat. Management objectives also need to be tailored to the individual subspecies of the big sagebrush complex because of differing environmental characteristics influencing vegetation structure and composition, varying responses to grazing and other disturbances, and differing resistance to weed invasion (Beetle and Young 1965; Morris et al. 1976; Winward and Tisdale 1977; Hironaka 1978; McArthur and Plummer 1978; Blaisdell et al. 1982; Barker and McKell 1983).

The objectives of this study were to 1) determine the range of vegetation characteristics of intact, late-seral Wyoming big sagebrush communities in the northwest portion of the sagebrush biome that had been identified by the Bureau of Land Management as sage-grouse habitat (Bureau of Land Management-Burns Database 2004); 2) define distinct plant associations for this alliance within the area studied; and 3) compare vegetation characteristics of the Wyoming big sagebrush sites sampled to Bureau of Land Management et al. (2000) and Connelly et al. (2000) vegetation cover values for productive sage-grouse habitat.

METHODS

Study Area Description

Study sites were selected across an area encompassing about 50 000 km^2 in southeastern Oregon and northern Nevada. Study sites were in intact, late-seral Wyoming big sagebrush–bunchgrass communities. Sites were mainly in the High Desert and Humboldt ecological provinces with a few located in the western edge of the Snake River ecological province (Fig. 1). Long-term average annual precipitation at study sites is between 200 mm to 300 mm (Natural Resource Conservation

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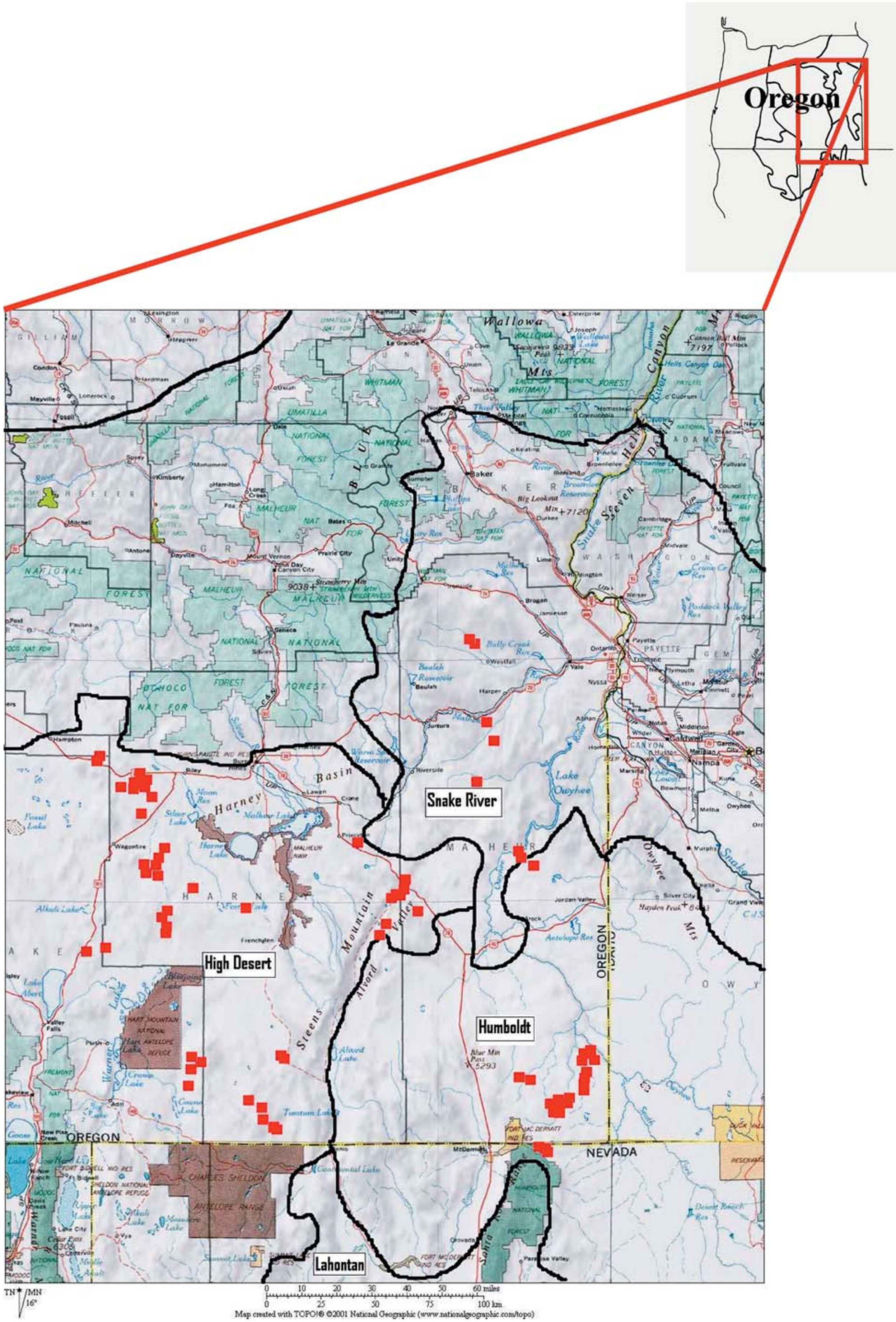
Figure 1. Study site locations ($n = 107$). Red squares represent areas where Wyoming big sagebrush sites were sampled. Ecological province boundaries (bold black lines) are derived from Anderson et al. (1998) and Bailey (1994).


Oregon
Snake River
High Desert
Humboldt
Lahontan
OREGON
NEVADA
OREGON
IDAHO
0 10 20 30 40 50 60 miles
0 25 50 75 100 km
TN MN 16°
Map created with TOPO!® ©2001 National Geographic (www.nationalgeographic.com/topo)

Service 1998). Annual precipitation amounts (from 1 October to 30 September) at weather stations within the study area were between 127% and 76% of the long-term average (30 years) in 2000–2001 and between 80% and 58% of the long-term average in 2001–2002 (Oregon Climate Service 2006). Elevation ranges from 986 m to 1804 m above sea level. Soils are variable across the study sites with the majority being various Aridisols and Mollisols, but there are some Andisols.

Site Selection

In February, March, and April of 2001 and 2002, BLM offices in Lakeview, Vale, and Burns, Oregon, and Winnemucca, Nevada, were contacted to obtain locations of Wyoming big sagebrush communities in high ecological, late-seral condition in the High Desert, Humboldt, and Snake River ecological provinces (Bailey 1994; Anderson et al. 1998). Local knowledge of BLM wildlife and rangeland experts, and ecological site inventory maps, were used to narrow down our initial search for intact, late-seral Wyoming big sagebrush sites. Sites were considered to be intact, late-seral sites if they met the following criteria: 1) the understory was dominated by large native perennial bunchgrasses and native forbs, 2) exotic species were a minor to nonexistent component, 3) there was evidence of limited historic and present livestock use based on criteria developed by Passey et al. (1982), 4) sites were dominated by mature stands of Wyoming big sagebrush (no recorded fire at sites for $>$ 50 years), and 5) no other disturbances were evident. Historic livestock grazing was light to nonexistent because sites were protected by steep slopes, cliffs, lava flows, fences, or other barriers, or were far ($>$ 3 km) from livestock watering sources. Every intact, late-seral site found was sampled, resulting in 107 sites included in this study. At each site a complete soil description was performed to determine the ecological site type (Natural Resource Conservation Service 1997). Vegetation measurements were compared to ecological site descriptions to ensure the sites' plant communities represented the historic "climax" plant communities. All sites included in our analysis met the requirements used for reference sites in rangeland health assessments (Pellant et al. 2005). In addition, we performed a range health assessment on each site to assure that departure of soil/stability, hydrologic function, and biotic integrity were none to slight based on the criteria in "Interpreting Indicators of Rangeland Health" (Pellant et al. 2005). Sites were located in identified sage-grouse habitat: 78 sites were in year-round occupied habitat and 29 sites were in occupied, seasonal-use-uncertain habitat (Bureau of Land Management–Burns database 2004). Thirty sites were within 2 km of a lek, 66 sites were within 5 km of a lek, and 99 sites were within 10 km of a lek (Bureau of Land Management–Burns database 2004). Sites were sampled from late May to the first of July to capture peak vegetation cover. We sampled sites with an array of different site characteristics (e.g., slope, elevation, aspect, soil, and dominant grass species) to represent variation across the Wyoming big sagebrush alliance and within plant associations.

Sampling

Fifty-six and 51 sites were sampled in 2001 and 2002, respectively. One representative, but randomly located 80 $\times$ 50 m plot (0.4 ha) was used to sample each site. Five 50-m transects, spaced at 20-m intervals, were deployed along the 80-m transect. Shrub canopy cover by species was measured by line intercept (Canfield 1941) and separated into live and dead components. Canopy gaps less than 15 cm were included in the canopy cover measurements. Fifty randomly selected sagebrush heights were measured in each plot. Herbaceous canopy cover was visually estimated by species inside 40 $\times$ 50 cm frames (0.2 m^2) located at 3-m intervals on each transect line (starting at 3 m and ending at 45 m), resulting in 15 frames per transect and 75 frames per plot. A species list was compiled within each 80 $\times$ 50 m plot.

Statistical Analysis

Descriptive statistics (means, medians, minimums, maximums, and standard errors) (S-PLUS 2000) were generated to summarize vegetation characteristics of sites. All means were reported with associated standard error. Means were considered to differ at $P < 0.05$ ($\alpha = 0.05$). For summaries, herbaceous cover was grouped into 5 functional groups: Sandberg bluegrass (*Poa sandbergii* Vasey), tall tussock perennial grass, annual grass, perennial forbs, and annual forbs. The purpose of using functional groups was to combine species that respond similarly to environmental perturbation and to reduce data to a simpler form for analysis and presentation (Boyd and Bidwell 2002). We tried to use hierarchical cluster analysis (PC-ORD 1999) to define associations, but were unsuccessful. Thus, dominant perennial bunchgrass species were used to group sites into distinct associations. Once associations were defined, parametric statistics were used to summarize the vegetation characteristics of each association. A multiple-response permutation procedure (MRPP) was used to test for homogeneity of species composition within associations (PC-ORD 1999). A MRPP was used because species composition consisted of too many response variables for parametric statistics. In a MRPP, the A statistic is the chance-correct within-group agreement (McCune and Grace 2002). A single A statistic is calculated for the entire data set. If A is > 0, then homogeneity is greater than expected by chance within groups. If all individuals within a group are identical then $A = 1$. If there is less agreement within groups than expected by chance, then $A < 0$. One-way analyses of variances (ANOVAs) were used to determine if differences in vegetation (functional groups and total herbaceous) mean cover values existed among associations and family-wise comparisons using the Tukey–Kramer method were used to determine which associations differed (S-PLUS 2000). Associations were treated as treatments in the 1-way ANOVAs. Year and its interaction with associations were not correlated with vegetation cover values ($P > 0.05$) and were not included in the ANOVA. Each site's vegetation cover values were compared to values that Bureau of Land Management et al. (2000) and Connelly et al. (2000) recommended for productive sage-grouse habitat. Tall forb cover ($>$ 18 cm) was estimated by including the cover of all forb species that reach $>$ 18 cm in height on late-seral Wyoming big sagebrush sites. Tall grass cover ($>$ 18 cm) was estimated by including Sandberg bluegrass and all other perennial grass cover. Sites were considered to meet the criteria if they produced all of the vegetation cover values suggested as needed for each type of

Table 3. Summary of herbaceous functional group[1] canopy cover values (%) across all sites measured.

Statistic	POSA (%)	PG (%)	AG (%)	PF (%)	AF (%)	Total herb (%)
Mean	5.39	12.19	0.61	4.13	0.59	22.91
Median	5.28	10.85	0.05	3.61	0.37	21.92
Minimum	0.0	4.5	0.0	0.0	0.02	5.9
Maximum	13.21	28.3	9.8	11.9	5.6	46.5
Standard error	0.23	0.45	0.14	0.27	0.07	0.66

[1]POSA indicates Sandberg bluegrass; PG, tall tussock perennial grass; AG, annual grass; PF, perennial forb; AF, annual forb; and total herb, total herbaceous material.

Table 4. Summary of shrub canopy cover values (%) for all sites measured.

Statistic	Live sagebrush (%)	Dead sagebrush (%)	Other shrub (%)	Total live[1] (%)	All shrub[2] (%)
Mean	12.3	3.9	1.1	13.4	17.3
Median	11.9	3.5	0.4	12.3	17.0
Minimum	3.2	0.6	0.0	4.8	8.6
Maximum	25.5	11.5	8.4	26.9	35.5
Standard error	0.41	0.22	0.17	0.43	0.47

[1]Total live cover is the combination of live sagebrush cover and live other shrub cover.
[2]All shrub cover is the combination of live and dead sagebrush cover and all other shrub cover.

sage-grouse habitat (Bureau of Land Management et al. 2000; Connelly et al. 2000).

RESULTS AND DISCUSSION

Summary of Vegetation Characteristics

Herbaceous Cover. Herbaceous vegetation cover was variable across the 107 sites (Table 3). Tall tussock perennial grass and total herbaceous cover varied more than 6- and 7-fold, respectively, among sites. Tall tussock perennial grass accounted for 53% of the total herbaceous cover across all sites sampled. Annual grass cover was low to nonexistent. Perennial forb cover accounted for less than 20% of the total herbaceous cover across the sites. Tall (> 18 cm) forb cover averaged 1.9% ± 0.20% (Fig. 2). The functional group cover values reported by Anderson and Inouye (2001) and Kindschy (1992) were within the range measured in this study. Anderson and Inouye (2001) reported 0.13% Sandberg bluegrass, 5.5% perennial grass, and 2.85% perennial forb average cover values for 47 Wyoming big sagebrush plots in southeastern Idaho that had not been grazed or otherwise disturbed for 45 years. In southeastern Oregon, Kindschy (1992) reported a Wyoming big sagebrush/bluebunch wheatgrass (*Pseudoroegneria spicata* [Pursh] A. Löve) community in a kipuka (land surrounded by lava) with 5.2% sagebrush, 3.6% Sandberg bluegrass, 7.6% perennial forb, and 24.6% perennial grass cover.

Shrub Cover. Shrub canopy cover was also variable across the sites sampled (Table 4). Ninety percent of sites had sagebrush canopy cover between 6% and 20% (Fig. 3). Wyoming big sagebrush canopy cover values from our sites were similar to values reported by West and Hassan (1985), Doescher et al. (1986), Kindschy (1992), and Goodrich et al. (1999) (Table 5).

Wyoming Big Sagebrush Association Classification. Species composition was represented by 238 plant species including 17 shrub, 2 tree, 19 perennial grass, 5 annual grass, 127 perennial forb, and 68 annual forb species. Cluster analysis by species composition did not group plant communities into distinguishable associations. The National Vegetation Classification Standard (The Nature Conservancy 1994) defines an association as a physiognomically uniform group of vegetation stands that share one or more diagnostic (dominant, differential, indicator,

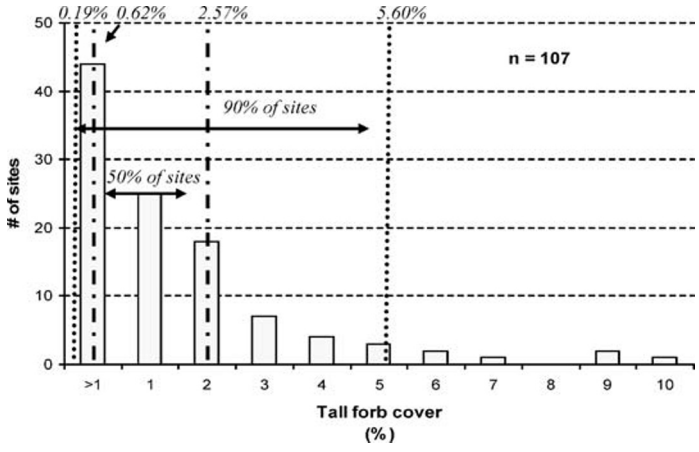


Figure 2. The number of Wyoming big sagebrush sites that produced certain quantities of tall forb cover. The area between the dotted lines contains the cover values for 90% of the sites. The area between the dashed lines contains the cover values for 50% of the sites.

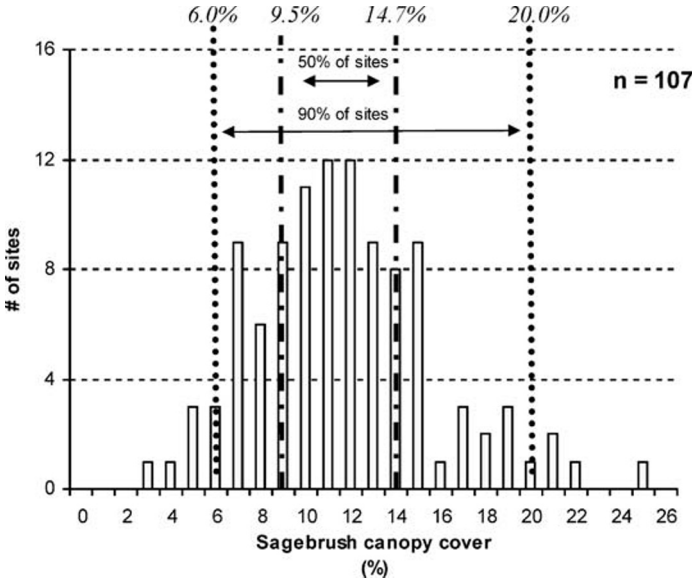


Figure 3. The number of Wyoming big sagebrush sites that produced a given quantity of sagebrush cover. The area between the dotted lines contains the cover values for 90% of the sites. The area between the dashed lines contains the cover values for 50% of the sites.

Table 5. Wyoming big sagebrush association stand cover values previously reported.

Association[1]	Sagebrush cover	Location	Reference
ARTRW8/FEID	7–25%	Eastern Oregon	Doescher et al. 1986
ARTRW8/HECO26	0.3–22%	Utah	Goodrich et al. 1999
ARTRW8/PSSP6	5.2–7%	Jordan Crater kipukas	Kindschy 1992
ARTRW8/ACTH7	4–13%	EOARC[2] Burns, Oregon	File Data
ARTRW8/FEID	5–22%	EOARC Burns, Oregon	File Data
ARTRW8/PSSP6	6.5% mean	Mill, Utah	West and Hassan 1985

[1]ARTRW8 indicates Wyoming big sagebrush; FEID, Idaho fescue; HECO26, needle-and-thread grass; PSSP6, bluebunch wheatgrass; and ACTH7, Thurber's needlegrass.
[2]EOARC indicates Eastern Oregon Agricultural Research Center.

or character) overstory and understory species. Though different groupings were defined, none could easily be recognized in the field and no indicator species were consistently present or exclusive for any of the groups. However, some clustering of sites did result from the occurrence of dominant perennial bunchgrasses. Passey et al. (1982) reported similar difficulties with classifying vegetation groups with cluster analysis. Therefore, associations within the Wyoming big sagebrush alliance were delineated by understory dominance. This identified 5 associations based on dominant late-seral perennial bunchgrass species.

The following Wyoming big sagebrush (ARTRW8) alliance plant associations were identified: ARTRW8 (Wyoming big sagebrush)/PSSP6 (*Pseudoroegneria spicata* [Pursh] A. Löve, bluebunch wheatgrass), ARTRW8/ACTH7 (*Achnatherum thurberianum* [Piper] Barkworth, Thurber's needlegrass), ARTRW8/FEID (*Festuca idahoensis* Elmer, Idaho fescue), ARTRW8/HECO26 (*Hesperostipa comata* [Trin. & Rupr.] Barkworth, needle-and-thread), and ARTRW8/PSSP6–ACTH7 (a codominance of bluebunch wheatgrass and Thurber's needlegrass). This classification was similar to previous systems. The habitat types described by Hironaka et al. (1983) for southern Idaho included ARTRW8/PSSP6 and ARTRW8/ACTH7. Dissimilar to our classification, they found ARTRW8/POSA (Sandberg bluegrass) and ARTRW8/ELEL5 (*Elymus elymoides* [Raf.] Swezey, squirreltail) habitat types and considered mixtures of Thurber's needlegrass with bluebunch wheatgrass to be members of the ARTRW8/PSSP6 habitat type. Hironaka et al. (1983) also did not identify ARTRW8/FEID or ARTRW8/HECO26 habitat types. Our sampling was limited to late-seral Wyoming big sagebrush communities; thus, we did not report any ARTRW8/ELEL5 or ARTRW8/POSA associations, because we did not sample communities dominated by lower-seral perennial bunchgrasses. Doescher et al. (1986) identified and described the ARTRW8/FEID habitat type in eastern Oregon, and Passey et al. (1982) reported an ARTRW8/FEID community in their survey. Passey et al. (1982) also identified ARTRW8/PSSP6 and ARTRW8/ACTH7 communities. The discrepancies between our classification and others should be expected because of differences among the regions where they were developed. The surveys performed by Hironaka et al. (1983) and Passey et al. (1982) did not extend into eastern Oregon, and Doescher et al. (1986) only described one habitat type.

When referring to the association, only the dominant perennial grass code will be used in the remainder of this section. The PSSP6 association appears to be the most abundant intact, late-seral Wyoming big sagebrush/bunchgrass association in the region, and was represented by 63 sites sampled. Other associations sampled included 16 ACTH7, 14 FEID, 7 HECO26, and 7 PSSP6–ACTH7 sites.

The MRPP analysis indicated that delineating associations by dominant perennial bunchgrass species successfully grouped similar sites together. Species composition within associations, after excluding dominant perennial bunchgrass species, was more homogenous than expected by chance ($A = 0.0325$). Thus, within an association, species composition was similar, whereas species composition varied among the 5 associations ($P < 0.0001$). Inclusion of the dominant perennial bunchgrass species in the analysis increased homogeneity within associations ($P < 0.0001$, $A = 0.1968$). The classification of the Wyoming big sagebrush alliance by dominant perennial grass was appropriate, simple, and useful. The historic classification of rangelands (habitat types, cover types, range sites, etc.) by dominant shrub and dominant perennial grass species is a valid means of delineating associations in the Wyoming big sagebrush alliance.

Association Vegetation Characteristics. Functional group cover values differed among associations (Table 6). Tall tussock

Table 6. Mean percentage of cover of functional groups by association with standard error.[1]

	Association				
Functional groups	PSSP6 $n = 63$ (%)	ACTH7 $n = 16$ (%)	HECO26 $n = 7$ (%)	FEID $n = 14$ (%)	PSSP6–ACTH7 $n = 7$ (%)
Sandberg bluegrass	6.0 ± 0.27 c	4.8 ± 0.37 bc	1.6 ± 0.78 a	4.5 ± 0.39 b	6.7 ± 1.23 c
Tall tussock perennial grass	11.9 ± 0.46 b	8.8 ± 0.36 a	11.0 ± 1.97 ab	19.4 ± 1.20 c	9.4 ± 0.88 a
Annual grass	0.8 ± 0.22 b	0.4 ± 0.24 ab	0.8 ± 0.22 b	0.02 ± 0.01 a	0.7 ± 0.27 b
Perennial forb	4.8 ± 0.36 c	2.5 ± 0.42 b	0.3 ± 0.09 a	4.4 ± 0.44 c	5.0 ± 1.20 c
Annual forb	0.6 ± 0.11 ab	0.8 ± 0.18 ab	0.2 ± 0.06 a	0.4 ± 0.10 ab	0.4 ± 0.04 b
Total herbaceous	24.1 ± 0.77 b	17.1 ± 0.86 a	13.9 ± 2.44 a	28.7 ± 1.26 c	22.1 ± 2.12 abc
Wyoming big sagebrush	12.0 ± 0.48 ab	13.5 ± 0.91 ab	9.9 ± 2.28 a	11.1 ± 0.90 ab	16.8 ± 2.44 b

[1]Different lower case letters indicate significant ($\alpha = 0.05$) differences among associations by functional group.

Table 7. Number and percentage of intact, late-seral Wyoming big sagebrush sites by association that met the guidelines' vegetation cover values needed for productive sage-grouse habitat.

		BLM et al. (2000) guidelines				Connelly et al. (2000) guidelines			
Association	No. of sites	Nesting sites	Optimal brood-rearing sites	Suboptimal brood-rearing sites	Wintering sites	Mesic breeding	Arid breeding	Brood-rearing	Wintering sites
PSSP6[1]	63	0 (0%)	0 (0%)	21 (33%)	43 (68%)	0 (0%)	12 (19%)	43 (68%)	43 (68%)
ACTH7	16	0 (0%)	0 (0%)	3 (19%)	15 (93%)	0 (0%)	2 (13%)	9 (56%)	15 (93%)
HECO26	7	0 (0%)	0 (0%)	0 (0%)	3 (43%)	0 (0%)	0 (0%)	1 (14%)	3 (43%)
FEID	14	0 (0%)	0 (0%)	3 (21%)	9 (64%)	0 (0%)	1 (7%)	9 (64%)	9 (64%)
PSSP6/ACTH7	7	0 (0%)	0 (0%)	5 (71%)	5 (71%)	0 (0%)	4 (57%)	5 (71%)	5 (71%)
Total	107	0 (0%)	0 (0%)	32 (30%)	75 (70%)	0 (0%)	19 (18%)	68 (64%)	75 (70%)

[1]PSSP6 indicates bluebunch wheatgrass; ACTH7, Thurber's needlegrass; HECO26, needle-and-thread grass; and FEID, Idaho fescue.

perennial grass cover of the FEID association was almost twice that of any of the other associations. Sandberg bluegrass cover was less in the HECO26 association than the other associations. The HECO26 association also had the lowest perennial forb cover among plant associations. Annual grass cover differed between several associations, but was generally very low. Annual grass cover was composed mainly of cheatgrass (*Bromus tectorum* L.), though native annual grasses (*Vulpia* sp.) were also present on several sites. Cheatgrass presence on these undisturbed areas may be a threat if a fire disturbance occurs, especially in the ACTH7 association because Thurber's needlegrass is negatively impacted by fire (Wright and Klemmedson 1965; Uresk et al. 1976).

Total herbaceous cover values were variable within and among plant associations. Total herbaceous cover was significantly different among many of the associations (Table 6). The FEID association had the greatest mean total herbaceous cover (28.7% ± 1.3%), followed in order by the PSSP6 (24.1% ± 0.8%), PSSP6–ACTH7 (22.12% ± 2.1%), ACTH7 (17.1% ± 0.9%), and HECO26 (13.9% ± 2.4%) associations. The HECO26 association produced less than half the herbaceous cover of the FEID association. Grouping the Wyoming big sagebrush alliance into associations for management purposes is supported by differences in associations' ability to produce herbaceous cover. Differences in vegetation characteristics among associations suggest management should be tailored to individual associations or be constrained by the least resilient association within a management unit. For example, ACTH7, PSSP6, and PSSP6–ACTH7 associations are found in a mosaic across the landscape; however, the dominant perennial bunchgrass species respond differently to fire. Thurber's needlegrass is negatively impacted by fire (Wright and Klemmedson 1965; Uresk et al. 1976), whereas bluebunch wheatgrass may remain unchanged (Peek et al. 1979) or increase after fire (Uresk et al. 1976).

Unlike the herbaceous functional groups, Wyoming big sagebrush cover among associations rarely differed (Table 6). Wyoming big sagebrush cover was greater in the PSSP6–ACTH7 than in the HECO26 association ($P < 0.05$), but did not differ among the other associations ($P > 0.05$).

Sage-Grouse Guidelines. The sites sampled in this study varied in their ability to meet the suggested vegetation cover values from the guidelines (Bureau of Land Management et al. 2000; Connelly et al. 2000) at or above the stand level for the different types of sage-grouse habitat (Table 7). The number of sites that did not meet the recommended vegetation cover values indicate these cover values exceed the potential of a significant portion of the Wyoming big sagebrush alliance. Therefore, the vegetation cover values for specific types of sage-grouse habitat should not be applied across the entire Wyoming big sagebrush alliance in our study area. No sites met the nesting or optimum brood-rearing habitat vegetation cover values suggested by Bureau of Land Management et al. (2000). Mesic and arid breeding vegetation cover values suggested by Connelly et al. (2000) were met by 0% and 18% of the sites, respectively. Although sites may be capable of producing high vegetation cover values in one functional group, it is highly improbable that they would produce the suggested cover values across several functional groups. Because precipitation across the study area ranged from slightly above average to below average during the study, more sites may have produced the cover values from the guidelines if precipitation had been greater and the reverse may have occurred if precipitation was less. However, the guidelines (Bureau of Land Management et al. 2000; Connelly et al. 2000) do not address the issue of vegetation cover variability that may occur as a result of interannual climate variation. The vegetation cover values were not developed to be used as requirements for all sagebrush communities and our results indicate that it would be a mistake to apply them as such. If the vegetation cover values from the guidelines are going to be applied as requirements at or above the stand level to manage the Wyoming big sagebrush alliance, they need to be adjusted to better match the ecological potentials of this alliance.

MANAGEMENT IMPLICATIONS AND CONCLUSIONS

We found a high degree of heterogeneity in vegetation characteristics within the Wyoming big sagebrush alliance. The variability in ecological potential among sites is probably the result of the range of effective moisture that can support this alliance. Identification of associations within the Wyoming big sagebrush alliance elucidates the ecological potential and vegetation characteristics across this alliance. Management that recognizes these differences within this alliance will develop more realistic goals for the restoration or maintenance of vegetation structure and composition. Defining associations by dominant perennial bunchgrass species is a practical classification of the Wyoming

big sagebrush alliance that improves management by grouping sites with similar vegetation characteristics and potentials.

The sage-grouse guidelines (Bureau of Land Management et al. 2000; Connelly et al. 2000) could be improved by specifying the scale at which monitoring should occur. Defining criteria for selecting sites and developing a monitoring protocol would also improve the guidelines. Determining the percentage or amount of the total area needed for each type of sage-grouse habitat would also improve the applicability of the guidelines to land managers. The vegetation cover values for productive sage-grouse habitat from the guidelines (Bureau of Land Management et al. 2000; Connelly et al. 2000) may be appropriate for management at a scale that is finer then what we measured. Sites sampled probably contained patches of higher cover if measured at a fine scale. However, the guidelines (Bureau of Land Management et al. 2000; Connelly et al. 2000) were not developed nor should they be used as criteria to manage the entire Wyoming big sagebrush alliance at or above the stand level. The inability of Wyoming big sagebrush sites to meet some of the vegetation cover values suggested for productive sage-grouse habitat at the stand level indicates that surveys of other sagebrush species and subspecies need to occur to prevent disagreement and conflict over their potentials. Critical to our region would be surveys of the mountain big sagebrush (*Artemisia tridentata* Nutt. ssp. *vaseyana* [Rydb.] Beetle), basin big sagebrush (*Artemisia tridentata* Nutt. ssp. *tridentata*), and low sagebrush (*Artemisia arbuscula* Nutt.) alliances.

Any attempt to develop vegetation requirements for the sagebrush biome should include the potential range of vegetation characteristics across the Wyoming big sagebrush alliance. Our survey of the vegetation characteristics of the Wyoming big sagebrush alliance in the High Desert, western Snake River, and Humboldt ecological provinces provides information that can be used for this purpose. The scales at which studies were conducted to develop management guidelines and the scales at which they will be applied should also be carefully scrutinized.

ACKNOWLEDGMENTS

The authors are grateful to the Burns, Lakeview, Vale, and Winnemucca Bureau of Land Management districts for their help in locating intact, late-seral Wyoming big sagebrush communities and for providing land for the research. Reviews of this manuscript by Chad Boyd, Michael Gregg, and Christian Hagen were greatly appreciated. We also thank the anonymous reviewers for their constructive criticism and suggestions. We would also like to thank the student summer range technicians for assisting with data collection.

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