Classification and Capabilities of Woody Sagebrush Communities of Western North America With Emphasis on Sage-Grouse Habitat

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Abstract—This paper deals with diversity, classification, and capabilities of different sagebrush (*Artemisia* spp.) communities. Capabilities of sagebrush communities in terms of production, plant diversity, potential for ground cover and sage-grouse (*Centrocercus urophasianus*) habitat are discussed. Reaction to fire and relationships with introduced annuals are also discussed for some communities.

Introduction

There are about 30 taxa of woody and semiwoody sagebrush (*Artemisia* spp.) in western North America. Many of these sagebrush taxa are community dominants that are highly specialized. They are high-resolution indicators of climate, geomorphic settings, soils, elevations, and other features of the environment. Ecotones between stands of different species of sagebrush are often narrow and even sharply abrupt. Ecotones between taxa of the same species are often wider, but these are also sometimes quite narrow.

Sagebrush taxa are often more site specific than many associated indicator species. Bluebunch wheatgrass (*Elymus spicatus*) and Idaho fescue (*Festuca ovina* var. *ingrata*) provide vivid examples. These are useful indicator plants in the sagebrush ecosystem. However, they are generalists compared to some of the sagebrush taxa. Respectively, these grasses are listed as indicator species in 9 and 11 sagebrush types, and they extend beyond the amplitude of sagebrush into grassland (Mueggler and Stewart 1980; Tisdale 1986), mountain brush, and some forested communities.

Hybrids and hybrid zones of sagebrush often indicate intermediate environments (Freeman and others 1999; Graham and others 1999; McArthur and Sanderson 1999b). Hybrid zones coupled with a propensity for development of polyploidy further increase the complexity of the sagebrush group (McArthur and Sanderson 1999a; McArthur and others 1981). With many highly specialized taxa, hybrid zones, and polyploidy, the sagebrush complex is highly diverse.

Classification of vegetation types inherently includes information useful in understanding capabilities of the land, and many classification works include management implications based on estimates or measurements of capabilities. Most classification of sagebrush vegetation types has been at local scales and based on different methods of data collection and ordination. Although a comprehensive and uniform classification would be useful, the work of the past provides considerable information about the sagebrush ecosystem. Classification works were relied upon heavily in preparing this paper. Units of sagebrush classification found in the literature include community types, plant associations, habitat types, and ecological units. Distinction of classification types used by different workers is not made in this paper. All methods of classification seem to be useful in helping to define the variability and capability of sagebrush systems. Recognizing differences in capabilities of sagebrush communities is important for restoration projects, management for desired condition, and other aspects of land management.

Evaluations of values for sage-grouse (*Centrocercus urophasianus*) habitat made in this paper are based on indicated capabilities of various sagebrush types in comparison with tables 1, 2, and 3 in Connelly and others (2000). In general Connelly and others (2000) indicated sage-grouse nest sites are associated with sagebrush with heights of 29 to 80 cm and crown cover of 15 to 38 percent. Characteristics needed for productive sage-grouse winter habitat include sagebrush with heights of 25 to 35 cm and crown cover of 10 to 30 percent. Characteristics needed for productive breeding and brood-rearing habitat include sagebrush with heights of 30 to 80 cm and crown cover of 15 to 25 percent for breeding habitat and 10 to 25 percent for brood-rearing habitat.

The majority of this paper is focused on Wyoming big sagebrush (*A. tridentata* ssp. *wyomingensis*), Vasey big sagebrush, and mountain big sagebrush (*A. t.* ssp. *vaseyana*) communities. These taxa are selected for greater discussion because of their comparatively wide distribution, the large area they cover, and their greater importance to sage-grouse than many of the other taxa.

In this paper common names of plants are not used in reference to classification. However, they are used in the text, and a list of scientific names including authors and corresponding common names is provided in tables 1 and 2. Symbols of plant taxa as listed by athe U.S. Department of

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Agriculture (2001) are also included in tables 1 and 2. Only indicator species of vegetation types are listed. Expanded lists are found in some of the works listed in the references section. For the most part, plant nomenclature in this paper follows that of Shultz (1986) for *Artemisia* and Welsh and others (1993) for other plant species.

References to production are generally based on standing crop (a measurement at one time of the year). Thus, plants that grow in spring and early summer then dry and wither away are often not well represented in production values. As used in this paper, ground cover includes the percentage of the ground surface covered by live plants, litter or plant residue, and rock. Bare soil and pavement of less than about 2 cm diameter are generally not considered ground cover. For the cited references, however, definitions of bare ground may vary among authors.

Artemisia arbuscula

This plant of western North America has been treated as a subspecies and as a variety of *A. tridentata*. However, it has been accepted at the species level by many Intermountain authors. Shultz (1986) recognized three subspecies in this complex and provided distribution maps for each. Winward and McArthur (1995) described a fourth subspecies. These are listed below. All plants of the complex are low, nonsprouting, wintergreen shrubs.

Artemisia arbuscula ssp. *arbuscula* Low Sagebrush

This plant is the most widespread taxon of the complex. It ranges from Washington to Wyoming and south to California and Utah.

Classification

Artemisia arbuscula ssp. *arbuscula*/Bunchgrass (*Elymus-Festuca*) (Hall 1973)

Artemisia arbuscula ssp. *arbuscula*/*Elymus spicatus* (Hironaka and others 1983: Jensen 1989; Mueggler and Stewart 1980; Nelson and Jensen 1987; Tew 1988; Zamora and Tueller 1973)

Artemisia arbuscula ssp. *arbuscula*/*Festuca idahoensis* (Hironaka and others 1983; Jensen 1989; Mueggler and

Table 1—Scientific name, codes, and common names of sagebrush type indicator plants: woody plants.

Scientific name	Code	Common name
Artemisia arbuscula Nutt. ssp. *arbuscula*	ARARA	Low sagebrush
Artemisia arbuscula ssp. *longicaulis* Winward & McArthur	ARARL3	Lahontan sagebrush
Artemisia arbuscula ssp. *thermopola* Beetle	ARART	Cleftleaf sagebrush, hotsprings sagebrush
Artemisia bigelovii Gray	ARBI3	Bigelow sagebrush
Artemisia cana Pursh ssp. *cana*	ARCAC5	Plains silver sagebrush
Artemisia cana ssp. *bolanderi* (A. Gray) Ward	ARCAB3	Sierra silver sagebrush
Artemisia cana ssp. *viscidula* (Osterh.) Beetle	ARCAV2	Mountain silver sagebrush
Artemisia filifolia Torrey	ARFI2	Sand sagebrush
Artemisia frigida Willd.	ARFR4	Fringed sagebrush
Artemisia longiloba (Osterh.) Beetle	ARLO9	Alkali sagebrush, early sagebrush
Artemisia nova A. Nels. var. *nova*	ARNO4	Black sagebrush
Artemisia nova var. *duchesnicola* Welsh & Goodrich	ARNOD	Red clay sagebrush
Artemisia papposa S. F. Blake & Cronquist	ARPA16	Owyhee sagebrush
Artemisia pedatifida Nutt.	ARPE6	Birdsfoot sagebrush
Artemisia porteri Cronq.	ARPO5	Porter sagebrush
Artemisia pygmaea A. Gray	ARPY2	Pygmy sagebrush
Artemisia rigida (Nutt.) A. Gray	ARRI2	Scabland sagebrush; stiff sagebrush
Artemisia rothrockii A. Gray	ARRO4	Rothrock sagebrush
Artemisia spinescens D. C. Eaton	ARSP5	Bud sagebrush, budsage
Artemisia tridentata ssp. *parishii* (A. Gray) Hall & Clements	ARTRP2	Parish big sagebrush
Artemisia tridentata ssp. *spiciformis* (Osterh.) Kartesz & Gandhi	ARTRS2	Spiked big sagebrush, subalpine big sagebrush
Artemisia tridentata ssp. *tridentata*	ARTRT	Basin big sagebrush
Artemisia tridentata ssp. *vaseyana* var. *pauciflora* Winward & Goodrich	ARTRP4	Mountain big sagebrush
Artemisia tridentata ssp. *vaseyana* (Rydb.) Beetle var. *vaseyana*	ARTRV	Vasey big sagebrush
Artemisia tridentata ssp. *wyomingensis* Beetle & Young	ARTRW8	Wyoming big sagebrush
Artemisia tridentata ssp. *xericensis* Rosentreter and Kelsey	ARTRX	Xeric big sagebrush
Artemisia tripartita Rydb. ssp. *tripartita*	ARTRT2	Threetip sagebrush
Artemisia tripartita ssp. *rupicola* Beetle	ARTRR4	Wyoming threetip sagebrush
Atriplex confertifolia (Torr. & Frem) Wats.	ATCO	Shadscale
Chrysothamnus nauseosus (Pallas) Britt.	CHNA2	Rubber rabbitbrush
Grayia spinosa (Hook.) Moq.	GRSP	Spiny hopsage
Purshia tridentata (Pursh) DC.	PUTR2	Bitterbrush
Sarcobatus vermiculatus (Hook.) Torr.	SAVE4	Greasewood
Symphoricarpos occidentalis Hook.	SYOC	Wolfberry
Symphoricarpos oreophilus Gray	SYOR	Mountain snowberry

Table 2—Scientific name, symbols, and common names of sagebrush type indicator plants: graminoids.

Scientific name	Symbol	Common name
Bouteloua gracilis (H.B.K.) Lag. ex Steudel	BOGR	Blue gramma
Bromus carinatus H. & A.	BRCA5	Mountain brome
Carex geyeri F. Boott	CAGE2	Elk sedge
Deschampsia cespitosa (L.) Beauv.	DECE	Tufted hairgrass
Elymus cinereus Scribn. & Merr.	ELCI2	Basin wildrye
Elymus elymoides (Raf.) Swezey	ELEL5	Bottlebrush squirreltail
Elymus lanceolatus (Scribn. & Sm.) Gould	ELLA3	Thickspike wheatgrass
Elymus salinus Jones	ELSA	Salina wildrye
Elymus smithii (Rydb.) Gould	ELWM3	Western wheatgrass
Elymus spicatus (Pursh) Gould	ELSP3	Bluebunch wheatgrass
Elymus trachycaulus (Link.) Gould ex Shinn.	ELTR7	Slender wheatgrass
Festuca ovina L. var. *ingrata* Hackel ex Beal (*Festuca idahoensis* Elmer)	FEOVI	Idaho fescue
Festuca ovina var. *rydbergii* St. Yves	FEOVR	Sheep fescue
Festuca scabrella Torr.	FESC	Rough fescue
Festuca thurberi Vasey	FETH	Thurber fescue
Koeleria macrantha (Ledeb.) Schultes	KOMA	June grass
Leucopoa kingii (Wats.) W. A. Weber	LEKI2	Spike fescue
Poa fendleriana (Stuedel) Vasey	POFE	Muttongrass
Poa pratensis L.	POPR	Kentucky bluegrass
Poa secunda Presl	POSE	Sandberg bluegrass
Sporobolus cryptandrus (Torr.) Gray	SPCR	Sand dropseed
Stipa comata Trin. & Rupr. var. *comata*	STCOC2	Needle-and-thread grass
Stipa comata var. *intermedia* Scribn. & Tweedy	STCOI	Mountain needle-and-thread grass
Stipa hymenoides R. & S.	STHY6	Indian ricegrass
Stipa lettermanii Vasey	STLE4	Letterman needlegrass
Stipa nelsonii Scribn.	STNE3	Columbia needlegrass
Stipa richardsonii Link	STRI2	Richardson needlegrass
Stipa thurberiana Piper	STTH2	Thurber needlegrass
Trisetum spicatum (L.) Richter	TRSP2	Spike trisetum

Stewart 1980; Nelson and Jensen 1987; Volland 1976; Zamora and Tueller 1973)

Artemisia arbuscula ssp. *arbuscula*/*Festuca idahoensis*/*Poa secunda* (Nelson and Jensen 1987)

Artemisia arbuscula ssp. *arbuscula*/*Stipa thurberiana* (Zamora and Tueller 1973)

Artemisia arbuscula ssp. *arbuscula*/*Purshia tridentata*/*Agropyron spicatum* (Zamora and Tueller 1973)

Of the plants recognized above as indicator species of classification units within the low sagebrush type, all likely have broader ecological amplitude than does low sagebrush. This taxon appears to be the most specialized of any of the associates listed above.

Habitat and Capabilities

Low sagebrush forms stands below the pinyon-juniper (*Pinus-Juniperus*) belt, within this belt, and well above it. Stands in the Toiyabe Range of Nevada extend up to 3,200 m elevation or higher (Goodrich 1981) and up to 3,900 m in the White Mountains of California (Mozingo 1987). Perhaps low sagebrush is less common below the pinyon-juniper belt than is black sagebrush (*A. nova*).

Low sagebrush is often an indicator of soils with clay subsurface horizons or bedrock within 8 to 33 cm of the surface (Fosberg 1963; Summerfield and Peterson 1971). This plant is sometimes found where restrictive soil horizons cause water to stand on the surface in late winter and spring, during which time the soils are poorly aerated (Hironaka 1963). The restrictive soil layers also tend to reduce water-holding capacity in summer. The soil features associated with low sagebrush indicate a habitat with potential for soil saturation in spring and drier conditions in summer than are typical for big sagebrush.

Sabinske and Knight (1978) found low sagebrush on gravelly soils without a restrictive horizon in Wyoming. In the mountain ranges of central Nevada, low sagebrush occupies shallow, rocky, well-drained soils as well as those with heavy clay horizons (Goodrich 1981).

Low sagebrush is highly competitive on sites where it is well adapted. It will reestablish from seed after disturbance, but it does not sprout. Comparatively low productivity and other site features indicate difficulty and low economic return for restoration and forage improvement projects in this type. Such projects should be planned and conducted carefully (Johnson 1987; Winward 1980). Low-elevation stands can be expected to be vulnerable to displacement by cheatgrass (*Bromus tectorum*). High-elevation stands are likely to be more resistant.

Annual production of between 392 to 728 kg/ha (350 to 650 lbs/acre) has been reported for low sagebrush communities (Hall 1973; Jensen 1989; Nelson and Jensen 1987; Tew 1988). Volland (1976) listed a mean of 200 kg/ha (179 lbs/acre) for sites in fair condition in the pumice zone of Oregon.

As implied by its common name, low sagebrush is short in stature. Height of low sagebrush is commonly 20 to 40 cm and less commonly from 10 to 50 cm (Cronquist 1994;

Harrington 1954; Welsh and others 1993). In four habitat types in Nevada, maximum height of low sagebrush is between 11 to 19 cm and crown cover is between 12 to 16 percent (Zamora and Tueller 1973).

Hall (1973) listed 13 percent surface rock, 10 percent erosion pavement, and 16 percent bare ground for a low sagebrush/bunchgrass type in Oregon and Washington. Tables in Tew (1988) indicate ground surface with an average of 21 percent bare soil, 42 percent vegetation and litter, and the remaining 37 percent rock and pavement. Volland (1976) listed 11 percent rock and 42 percent bare ground and pavement for a type in fair condition in the pumice zone of Oregon.

Low sagebrush sites of low and moderate productivity are indicated to lack the capability to meet the requirements of shrub height and percent crown cover for sage-grouse nesting habitat. Some of the more productive sites might provide moderate value nesting habitat. However, the crowns of low sagebrush are often in contact with the ground or close enough to the ground to obstruct sage-grouse nesting.

Low sagebrush sites dry rapidly in early summer. This indicates moderate-value brooding habitat in the spring and low value in summer and fall. Small stands of low productivity likely provide high-value strutting habitat especially where they are mixed with stands of big sagebrush (*Artemisia tridentata*). On windswept areas low sagebrush might provide high-value winter forage. However, snow can be expected to cover shrubs of this community on flat and concave areas before shrubs of big sagebrush are covered.

Artemisia arbuscula ssp. *longicaulis* Lahontan Sagebrush

This plant is known from western Nevada, southern Idaho, and eastern California where the old shorelines of Pleistocene Lake Lahontan are one of the centers of its current distribution (Winward and McArthur 1995).

Apparently this taxon has not been included in published vegetation type classifications. It is interspersed with salt desert shrub species including shadscale. It is also associated with Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*), black sagebrush, and low sagebrush. The most common understory species include bluebunch wheatgrass, Thurber needlegrass (*Stipa thurberiana*), desert needlegrass (*Stipa speciosa*), Indian ricegrass (*S. hymenoides*), bottlebrush squirreltail (*Elymus elymoides*), and Sandberg bluegrass (*Poa sandbergii*) (Winward and McArthur 1995). The value of Lahontan sagebrush to sage-grouse is likely similar to that of other taxa of the *A. arbuscula* complex.

Artemisia arbuscula ssp. *thermopola* Cutleaf Sagebrush

This plant ranges from central Idaho to western Wyoming and south to northern Utah. It is restricted to areas adjacent to those occupied by *A. tripartita*, which perhaps hybridized with *A. arbuscula* to form *A. a. thermopola* (Beetle 1960; Shultz 1984).

Classification

Artemisia arbuscula thermopola/Festuca idahoensis (Hironaka and others 1983)

Habitat and Capabilities

Habitat includes ridgetops and glacial outwash areas that are thinly mantled, poorly drained, and usually within forest openings. Soils are shallow and have a strongly developed clay horizon (Hironaka and others 1983). Low stature of shrubs and herbaceous species can be expected to be inherent to stands of cutleaf sagebrush. K. Johnson (1987) listed this as a spreading, lax shrub up to 30 cm tall.

Value for sage-grouse likely depends upon the size of forest openings in which stands are found. Smaller openings can be expected to have lower value than larger openings. Low site productivity indicates that stature and crown cover of cutleaf sagebrush will be of low value for nesting habitat. Soil and habitat features listed by Hironaka and others (1983) indicate early drying of herbaceous species and thus low value for brooding habitat. Windswept knolls might provide moderate- to high-value breeding and winter habitat where these are adjacent to stands of big sagebrush.

Shallow soils and poor drainage indicate low productivity. Restoration projects can be expected to be of low success due to the short growing season and water stress occurring during the seedling establishment stage (Hironaka and others 1983).

Artemisia bigelovii Bigelow Sagebrush

Bigelow sagebrush is known from California east to Colorado and Texas. Habitat includes rimrock, cliff faces, canyons, and ravines within the desert shrub and pinyon-juniper belts. Shrubs are commonly 10 to 30 cm tall with the flower stalks often equal to or greater than the length of the woody stems. The flower stalks die back each year.

The stature and growth form of Bigelow sagebrush is not conducive to sage-grouse nesting. Sage-grouse generally show low selectivity for the habitat of this plant. Where stands of Bigelow sagebrush are adjacent to big sagebrush stands, it might be used by sage-grouse as winter forage or sparingly at other times of the year.

Artemisia cana ssp. *bolanderi* Bolander Silver Sagebrush

Bolander silver sagebrush is primarily a plant of the Sierra Nevada Mountains of California. It extends into Oregon and barely into Nevada.

Habitat and Capabilities

This shrub occurs along streams and in snow catchment basins on granitic soils (Shultz 1986). Its value as sage-grouse habitat is likely similar to that of mountain silver sagebrush (*A. cana* ssp. *visicidula*). However, prolonged flooding of some sites likely limits the values of this type for

sage-grouse habitat. The plant is known from the margin of the range of sage-grouse.

Artemisia cana ssp. *cana* Plains Silver Sagebrush

Plains silver sagebrush ranges from Montana and North Dakota south to northern Colorado and western Nebraska. As indicated by its common name, this is a plant of the plains and it is mostly found east of the Continental Divide. However, outlier populations have been found in Sweetwater County, Wyoming; Daggett County, Utah; and in Moffat County (Yampa River Valley) and Rio Blanco County, Colorado, on the west side of the Continental Divide.

Classification

Artemisia cana ssp. *cana*/*Elymus smithii* (Johnston [1987] listed several references for the Plains.)
Artemisia cana ssp. *cana* / *Symphoricarpos occidentalis* / *E. smithii* (Johnston [1987] listed three references for North Dakota.)
Artemisia cana ssp. *cana* / *Elymus cinereus* (Thatcher 1959)

Habitat and Capabilities

Plains silver sagebrush is most common on deep, well-drained soils on alluvial flats and terraces along watercourses (Walton and others 1986). This is well demonstrated in the distribution map by Beetle (1960) where the distribution of this plant is represented by linear lines following watercourses. It extends beyond watercourses especially on sandy soils (Thatcher 1959). Although not requiring a high water table, plains silver sagebrush can tolerate a water table within the rooting zone. Thatcher (1959) found it on soils with pH between 6.6 and 8.5 with most sites having a pH of above 7.4; he did not find it on heavy-textured soils regardless of topographic position. In Albany County, Wyoming, Thatcher (1959) found plains silver sagebrush from about 18 to 102 cm tall with shorter plants on upland sites. Within its range, it is capable of growing up to 1.5 m tall (Walton and others 1986) on better sites.

Stature of plains silver sagebrush indicates high value for sage-grouse for nesting and for winter habitat. This shrub is capable of forming dense stands (Walton and others 1986), which indicates high value for nesting habitat. However, the crown-form of plains silver sagebrush might not be of equal value to that of Vasey big sagebrush or Wyoming big sagebrush. The plains habitat indicates productive understory communities. Where stands occur with sufficient shrub crown cover, plains silver sagebrush might be expected to provide yearlong, high-value habitat for sage-grouse. However, linear stands of this plant might not have as high a value as do broad areas covered by Wyoming big sagebrush.

Artemisia cana Pursh ssp. *viscidula* Mountain Silver Sagebrush

Mountain silver sagebrush ranges from western Montana south to Nevada and Colorado.

Classification

Artemisia cana Pursh ssp. *viscidula* / *Deschampsia cespitosa* (Padgett and others 1989)
Artemisia cana Pursh ssp. *viscidula* / *Elymus trachycaulus* (Bramble-Brodahl 1978; Tew 1988)
Artemisia cana Pursh ssp. *viscidula* / *Festuca idahoensis* (Bramble-Brodahl 1978; Hironaka and others 1983; Youngblood and others 1985)
Artemisia cana Pursh ssp. *viscidula* / *Festuca ovina* (Padgett and others 1989; Tew 1988)
Artemisia cana Pursh ssp. *viscidula* / *Festuca thurberi* (Francis 1983; Johnston [1987] listed six references for Colorado; Tew 1988)
Artemisia cana Pursh ssp. *viscidula* / *Poa pratensis* (Padgett and others 1989; Youngblood and others 1985)
Artemisia cana Pursh ssp. *viscidula* / *Symphoricarpos oreophilus* / *Elymus trachycaulus* (Tew 1988)

Habitat and Capabilities

This is a plant of montane valleys where it is commonly associated with riparian communities. Soils of some communities show evidence of seasonally high water tables (Padgett and others 1989). Communities of mountain silver sagebrush often form between wetlands of sedges (*Carex* spp.) and willows (*Salix* spp.) and uplands of big sagebrush, aspen (*Populus tremuloides*), and coniferous forests. Occasionally, mountain silver sagebrush forms stands on upland sites well removed from riparian communities.

In the cool and moist setting of mountain silver sagebrush communities, cool season graminoids are highly productive. Tables from Tew (1988) from central Utah show total herbage production ranges from 858 kg/ha (855 lbs/acre) for the low end of an *A. c. viscidula* / *Festuca ovina* type to 1,919 kg/ha (1,713 lbs/acre) for an *A. c. viscidula* / *Festuca thurberi* type. With high production, potential for ground cover is also high. Tables from Tew (1988) indicate potential ground cover ranges from 84 to 97 percent with an average of 92 percent.

Mountain silver sagebrush is a multiple-stemmed shrub with capacity to sprout from the root crown. Although the leaves of mountain silver sagebrush persist though some or all of the winter, they dry upon freezing and many fall.

Common grasses include those listed above as vegetation type indicators. Succulent forbs including dandelion (*Taraxacum officinale*), longfoot clover (*Trifolium longipes*), yarrow (*Achillea millefolium*), and everywhere aster (*Aster chilensis*) are often present, and they likely increase with heavy, persistent livestock grazing.

Many stands of mountain silver sagebrush are likely too wet or snow covered to be of more than low-value nesting habitat for sage-grouse. Many are at elevations of deep snow accumulations in winter where low value for winter habitat is indicated. Drying and deciduous leaves indicate mountain silver sagebrush has low value for winter forage for sage-grouse. Crowns of mountain silver sagebrush are typically thin and ascending compared to the dense, spreading crowns of Vasey big sagebrush and Wyoming big sagebrush. This is likely a limiting factor in value for sage-grouse nesting habitat.

Presence of succulent forbs and proximity to water and meadows indicate high value for brood-rearing habitat for sage-grouse. This seems especially so where mountain silver sagebrush stands are adjacent to, or near to, stands of big sagebrush. Where mountain silver sagebrush communities are adjacent to stands of big sagebrush, value for sage-grouse is indicated to be higher than where they are surrounded by coniferous forests.

High elevation, cool climate, relatively high annual precipitation, and high productivity of aggressive perennials indicate high resistance to invasion of cheatgrass.

Artemisia filifolia Sand Sagebrush

This is a plant of the western Great Plains and Colorado Basin from eastern Wyoming and South Dakota, south to Arizona and New Mexico and extending into Texas and Mexico.

Classification

Artemisia filifolia / *Andropogon hallii* (Johnston [1987] listed two references for the Comanche and Cimarron National Grasslands.)

Artemisia filifolia / *Sporobolus cryptandrus-Bouteloua gracilis* (Johnston [1987] listed a reference for the Comanche National Grasslands.)

Habitat and Capabilities

Sand sagebrush is most common on sandy soil including dunes. The plants are from 50 to 150 cm tall, and they have a stature that would indicate favorable cover for sage-grouse. However, due to the sparse, filiform leaves, the crowns of sand sagebrush provide a thin cover. Shrub density in communities of sand sagebrush is also sometimes rather low.

Features of this shrub and its communities indicate low value for sage-grouse at any time of the year. The distribution of sand sagebrush is mostly at the margin and well beyond the current and historic range of sage-grouse. This could indicate sage-grouse did not find suitable habitat in sand sagebrush communities during their evolutionary history.

Artemisia frigida Fringed Sagebrush

This subshrub ranges from Alaska to the Atlantic and south to Arizona and Kansas. It is a characteristic species of the high plains of central North America, and it is disjunct in Siberia (Cronquist 1994; Welsh and others 1993).

Classification

Artemisia filifolia / *Elymus spicatus* (Francis 1983; Tew 1988)

Although Baker and Kennedy (1985) did not formally recognize a fringed sagebrush association, they did note the presence of this plant in a bluebunch wheatgrass/cushion plant community of rocky, wind-exposed summits.

Habitat and Capabilities

Fringed sagebrush is a subshrub that dies back to near the base in winter in most locations. Where it is a dominant or codominant, it often indicates windswept sites. It often grows as a minor component in many communities in more protected sites. Fringed sagebrush can readily pioneer disturbed sites, and it occurs through all successional stages including climax (Wambolt and Frisina 2002).

Stature and crown cover of fringed sagebrush rarely, if ever, meet the needs of sage-grouse for nesting, brood-rearing, or wintering. Where stands of fringed sagebrush are adjacent to those of big sagebrush, they might be used as strutting grounds. Windswept areas might provide winter forage. As fringed sagebrush dies back in winter, availability of active leaves can be expected to decrease. However, the lower leaves remain green throughout winter. Where these leaves are not covered by snow, they can be expected to be of some value to sage-grouse in winter.

Artemisia longiloba Early Sagebrush, Longleaf Sagebrush, Alkali Sagebrush

Early sagebrush ranges from extreme southeastern Oregon to western Wyoming and south to Nevada and Colorado. Early sagebrush has been treated as a part of the *A. arbuscula* complex. However, unlike taxa of the *A. arbuscula* complex, this plant flowers in late spring and early summer instead of fall. The difference in flowering period seems to indicate considerable phylogenetic distance from *A. arbuscula*. *Artemisia longiloba* also differs from the *A. arbuscula* complex in habitat and, to some extent, in geography. Recognition at the species level is consistent with treatments by Welsh and others (1993) and Wambolt and Frisina (2002).

Classification

Artemisia longiloba/Elymus spicatus (Bramble-Brodahl 1978; Robertson and others 1966)

Artemisia longiloba/Festuca idahoensis (Bramble-Brodahl 1978; Hironaka and others 1983; Nelson and Jensen 1987; Zamora and Tueller 1973)

Artemisia longiloba / *Poa secunda* (Francis 1983)

Habitat and Capabilities

Habitat includes fine-textured soils derived from alkaline shales in clay basins and in mountains (Schultz 1986; Wambolt and Frisina 2002). It was found only on claypan soils in Idaho (Hironaka and others 1983), on the Humboldt National Forest, Nevada (Nelson and Jensen 1987), and at North Park, Colorado (Robertson and others 1966). Soil features indicate curing of herbaceous plants in late spring or early summer.

Francis (1983) recorded only 24 plant species per stand in an early sagebrush type in Colorado compared to 30 to 40 species in Wyoming big sagebrush types and 55 to 67 species in Vasey big sagebrush types. Zamora and Tueller (1973) listed maximum shrub height at 24 cm and shrub crown

cover at 19 percent for a habitat type in northern Nevada. Average annual production of 504 kg/ha (450 pounds/acre) (Nelson and Jensen (1987) and 572 kg/ha (510 pounds/acre) (Robertson and others 1966) have been reported for northeastern Nevada and northern Colorado, respectively.

Productivity, succulence of summer herbage, shrub height, and crown cover of most early sagebrush stands indicate relatively low value for sage-grouse nesting, brooding, and wintering habitat. Small stands might provide moderate to high-value strutting habitat, especially where they are adjacent to larger stands of big sagebrush. Windswept sites might provide some forage in winter. Heavy clay subsoil and shallow depth to bedrock limit the potential for management (Nelson and Jensen 1987).

Artemisia nova Black Sagebrush

This nonsprouting, evergreen, low shrub ranges from Oregon to Montana and south to eastern California and north-central New Mexico.

Classification

Artemisia nova/*Bouteloua gracilis* (Tew 1988)
Artemisia nova/*Elymus spicatus* (Baker and Kennedy 1985; Hironaka and others 1983; Nelson and Jensen 1987; Tew 1988; Thatcher 1959; Zamora and Tueller 1973)
Artemisia nova/*Festuca idahoensis* (Hironaka and others 1983)
Artemisia nova/*Stipa comata* (Baker and Kennedy 1985; Zamora and Tueller 1973)
Artemisia nova/*Stipa hymenoides* (Nelson and Jensen 1987; Zamora and Tueller 1973)
Artemisia nova/*Atriplex confertifolia*/*Elymus elymoides* (Nelson and Jensen 1987)

Habitat and Capabilities

Black sagebrush has a rather wide elevational range that includes valleys within the cold desert shrub belt to slopes and ridges of mountains up into the lower end of the coniferous forest belt. It is noted to extend from 1,524 to 3,353 m in California (Munz 1959). Its extension upslope into montane areas is often facilitated by calcareous substrates.

Soils of black sagebrush communities are often basic and shallow or rocky or both. Compared to soils of big sagebrush taxa, soils of black sagebrush communities often have the lowest water-holding capacity, organic matter, and nitrogen content, and the thinnest mollic epipedons (Jensen 1990). In cold desert areas, soils can be expected to be without mollic epipedons.

Cold Desert Stands—Stands of black sagebrush in the cold desert shrub belt appear to be highly competitive with other native plants, and they appear to be long-persistent with little potential for displacement by other shrubs. However, in some areas black sagebrush is highly selected by ungulates, and heavily browsed stands are thinned and replaced by shrubs more resistant to grazing (Clary 1986; Holmgren and Hutchings 1972; Hutchings and Stewart 1953). With the introduction of cheatgrass, cold desert stands of black sagebrush are highly subject to conversion to cheatgrass systems. Replacement or displacement of black sagebrush stands in cold desert shrub systems can be expected to be long-persistent with low potential for recovery of sagebrush.

Crown cover of black sagebrush in stands of the cold desert belt is often limited to less than 15 percent by the low capacity of these sites to support vegetation. Height of black sagebrush in cold desert areas is mostly less than 25 cm. Cold desert shrub communities inherently have low potential for perennial forbs. Limitations are mostly a function of precipitation, which is commonly as low as 15 to 18 cm/year. Depending on amount and timing of precipitation, forbs might flourish in some years and be essentially absent in others.

Canopy cover and height of black sagebrush in cold desert areas and low presence of succulent forbs indicate low (or no) value for sage-grouse for nesting and brooding. Some stands might have moderate value in winter, or other times of the year, if they are adjacent to stands of Wyoming big sagebrush.

Artemisia nova var. *duchesnicola* (red clay sagebrush) is endemic to the Duchesne River Formation in the Uinta Basin in northeastern Utah (Welsh and Goodrich 1995). Plants of this taxon are restricted to the cold desert shrub environment. The discussion of values for the cold desert shrub belt of black sagebrush are applicable to communities of red clay sagebrush.

Disturbances that reduce black sagebrush in cold desert systems can be expected to be long-persistent, and recovery of black sagebrush can be expected to be slow. Risk of long-term loss of black sagebrush is high in cold desert areas compared to montane stands.

Stands Within the Pinyon-Juniper Belt—Stands of black sagebrush are common within the pinyon pine (*Pinus* spp.) and juniper (*Juniperus* spp.) belt where they are clearly seral to pinyon-juniper. Pinyon-juniper trees have advanced into many black sagebrush communities in the past several decades. Degree of displacement depends on time since disturbance and other factors. Stands within the pinyon-juniper belt are also highly vulnerable to conversion to cheatgrass-driven communities. Although black sagebrush is highly sensitive to fire, the long-term maintenance of black sagebrush within the pinyon-juniper belt requires periodic fires to reduce conifer encroachment. The potential for cheatgrass invasion greatly complicates management of black sagebrush communities within the pinyon-juniper belt in many areas.

Value of black sagebrush stands within the pinyon-juniper belt for sage-grouse is dependent on fire or other disturbance that reduces pinyon-juniper cover. Height and crown cover of black sagebrush on better sites in the pinyon-juniper belt are often within the limits indicated by Connelly and others (2000) for at least winter habitat. However, capability for height and crown cover decreases as site potential decreases. Sites of low to moderate potential for sagebrush cover have low value for sage-grouse nesting. These limitations also indicate low value for winter habitat except where stands are adjacent to more productive sagebrush sites. Early drying of herbaceous plants in summer indicates low value for brood rearing.

Montane Stands—Stands of black sagebrush above the pinyon-juniper belt are often quite stable but they are sometimes vulnerable to displacement by Douglas-fir (*Pseudotsuga menziesii*) and other conifers. These stands appear to be more resistant to displacement by cheatgrass than those of lower elevations.

Black sagebrush can be highly competitive in montane stands. At two sites on the Tavaputs Plateau (Ashley National Forest [ASNF] 67-26, 68-1) stands of black sagebrush were plowed and seeded with crested wheatgrass (*Agropyron cristatum*) and other aggressive introduced species. Where protected from livestock and lagomophs, black sagebrush returned to pretreatment status within 20 years, and essentially displaced the seeded grasses.

At another site (ASNF 45-6) on the Uinta Mountains, Ashley National Forest, black sagebrush was sprayed with 2,4-D. Percent sagebrush kill was high and grass production increased 3.2 times over what it was prior to treatment and in the control. At 14, 19, and 23 years post treatment, crown cover of black sagebrush was measured at 5, 12, and 17 percent, respectively. At 23 years post treatment, crown cover in the treated area equaled that of the control.

Black sagebrush does not sprout after fire. However it is capable of vigorous seedling establishment following fire. Montane stands of black sagebrush on the Tavaputs Plateau have returned to pretreatment crown cover within about 20 years after burning.

Crown cover of black sagebrush in stands at the upper edge of the pinyon-juniper belt and above have been measured at 27 percent (ASNF 68-1) and 28 percent (ASNF 68-69) at sites where use by wild ungulates has been minor. In the absence of livestock or at low levels of livestock use, but with mule deer (*Odocoileus hemionus*) concentrations in winter, crown cover has been measured at 15 to 18 percent (ASNF 4-4; 45-6U). At high concentrations of mule deer and elk (*Cervus elaphus*), crown cover was 11 percent (ASNF 32-64).

Shrubs of black sagebrush in the pinyon-juniper belt and above are 20 to 30 cm, and less commonly to 50 cm tall. Forbs are more common in montane stands than in cold desert stands. However, number of forbs and abundance of forbs are commonly much lower than in mountain big sagebrush communities.

The short stature of black sagebrush and lower abundance of forbs indicates that stands of this shrub have lower value than stands of mountain big sagebrush for sage-grouse nesting and winter habitat. The crowns are often in contact with the ground or close enough to the ground to obstruct sage-grouse nesting. However, some stands of black sagebrush do have height and crown cover features that meet the requirements indicated by Connelly and others (2000) for nesting and winter habitat for sage-grouse. Some windswept ridges supporting short and scattered plants of sagebrush have been found to be highly selected by sage-grouse as winter-feeding areas (Gullion 1964).

Artemisia papposa Owyhee Sagebrush

This half-shrub ranges from the northern margin of the Snake River Plain in Idaho to adjacent Nevada and Oregon. It is limited in height to 5 to 15 cm, and the woody stems are commonly only half this height. Features of this plant indicate little, if any, value for sage-grouse nesting, brood rearing, or wintering. Where stands of Owyhee sagebrush are adjacent to stands of big sagebrush, they might provide strutting habitat and some forage. Herbaceous plants in Owyhee sagebrush communities can be expected to dry in early summer, and they likely have low value for sage-grouse in summer.

Artemisia pedatifida Birdsfoot Sagebrush

This dwarf half-shrub ranges from Wyoming and southwestern Montana to Colorado. It is limited in height to 5 to 15 cm. Value for sage-grouse habitat is likely similar to that of Owyhee sagebrush discussed above.

Artemisia porteri Porter Sagebrush

This is another dwarf half-shrub limited to less than 20 cm tall. It is a narrow endemic of barren clay hills in Fremont County, Wyoming (Dorn 1992). The habit and habitat of this plant indicate low value for sage-grouse except where stands are adjacent to stands of big sagebrush.

Artemisia pygmaea Pygmy Sagebrush

Pygmy sagebrush is mostly limited to the Great Basin and the Uinta Basin, mostly in Nevada and Utah, with the margins of its range reaching into Arizona and Colorado. It is mostly confined to geologic strata that weather to semibarrens. It is an indicator of inherently semibarren, low productive sites. It is sometimes associated with narrowly endemic plants.

Stature of this plant is short enough that it has little, if any, value as cover for sage-grouse at any season of the year. It is indicative of sites of inherently low, scattered plants where rock, pavement, and bare ground dominate the soil surface. It is often associated with pinyon and juniper where the presence of trees also limits its value for sage-grouse. Forage value of pygmy sagebrush for sage-grouse is apparently unknown.

Sites occupied by pygmy sagebrush are not recommended for forage improvement projects. Reclamation of disturbed stands can be expected to be slow and difficult. The badland habitat indicates low potential for cheatgrass to form closed stands. However, cheatgrass can be expected to grow in the habitat of pygmy sagebrush.

Artemisia rigida Scabland Sagebrush, Rigid Sagebrush, Stiff Sagebrush

This sprouting, deciduous shrub ranges from southeastern Washington and northeastern Oregon to western Idaho

and northwestern Montana where it grows on basalt scablands of the Columbia Basin (Schultz 1986; Wambolt and Frisina 2002).

Classification

Artemisia rigida/*Poa sandbergii* (Hall 1973; Hironaka and others 1983; Tisdale 1986)

Habitat and Capabilities

Scabland sagebrush is the primary woody *Artemisia* of the Palouse grasslands (Hironaka and others 1983). It typically grows on a thin mantle of soil, underlain by basalt bedrock. The soil is commonly saturated in winter and spring, frequently enough to preclude establishment of other woody sagebrush species. The scabland habitat supports a relatively sparse cover of vegetation (Hironaka and others 1983). Hall (1973) listed 232 kg/ha (207 lbs/acre) herbage production, 5 percent surface rock, 18 percent erosion pavement, 20 percent bare ground, and soil depth of 8 to 25 cm with stoniness commonly of 25 to 60 percent for a community type in Oregon and Washington.

Cronquist (1994) described scabland sagebrush with a height of (20) 30 to 60 cm and with capability to sprout from the roots. This shrub is deciduous and drops all of its leaves in winter (Hironaka and others 1983).

Stature of the plant indicates moderate value for sage-grouse nesting. However, the scabland habitat indicates relatively low percent crown cover of sagebrush. Hall (1973) reported that cover for this sagebrush ranged from 5 to 20 percent. Tisdale (1986) found that foliar cover averaged 12 percent with no other shrubs in high-elevation communities of scabland sagebrush. He also found 11 species of perennial forbs occurring on more than one-half of the sites. On low-elevation sites with soils only 7 to 10 cm deep, Tisdale (1986) found sparse cover of scabland sagebrush and poor representation of forbs. The crowns of scabland sagebrush seem to be somewhat less spreading and not as dense as mountain big sagebrush or Wyoming big sagebrush. This also indicates lower value for nesting habitat for sage-grouse.

The scabland habitat indicates early summer drying of succulent plants. This feature suggests low value for nesting and brood rearing of sage-grouse. The deciduous feature of the plant makes this sagebrush of little value as winter forage for sage-grouse. In Idaho, scabland sagebrush forms a mosaic with other sagebrush types (Hironaka and others 1983). In this setting stands of this shrub likely provide strutting habitat.

The scabland habitat indicates difficulty and low returns for forage improvement and reclamation projects. Features of the type that indicate management limitations include severe moisture saturation during winter and severe frost heaving (Hall 1973; Hironaka and others 1983).

The sprouting capability of scabland sagebrush indicates high value of this shrub for reclamation where cheatgrass and high fire frequencies have altered structure and function of plant communities. However, high fidelity of this plant for basalt scablands indicates seedings beyond its rather narrow ecological amplitude are not likely to succeed.

Artemisia rothrockii Rothrock Sagebrush

As treated by Shultz (1986), Rothrock sagebrush is endemic to the southern Sierra Nevada and San Bernardino Mountains of California where it is found in high-elevation silt basins and on rocky slopes. This places Rothrock sagebrush, in a strict sense, beyond the range of sage-grouse. References to Rothrock sagebrush in the Intermountain West are likely based on specimens of spiked big sagebrush (*A. tridentata* ssp. *spiciformis*), because habit and habitat features of Rothrock sagebrush are somewhat similar to those of spiked big sagebrush.

Adaptation to moist conditions, a strong tendency to root-sprout, large heads, and small amounts of pubescence on the involucres suggest a close relationship to *A. cana* (Ward 1953). The origin of Rothrock sagebrush is perhaps similar to that of spiked big sagebrush, but perhaps with Bolander silver sagebrush, rather than mountain silver sagebrush, being one of the parent taxa.

Artemisia spinescens Bud Sagebrush

This is a plant of cold desert areas from Oregon to Montana and south to California and New Mexico. The shrubs are commonly 5 to 30 cm tall and rarely taller. Bud sagebrush is commonly associated with other desert shrubs, but occasionally it forms small stands where it is the dominant shrub. Cold desert shrub communities typically have relatively few forb species, and these are mostly annuals that flourish in some years and are essentially absent in others, depending on the amount and season of precipitation. These communities are commonly of low stature and plant density.

The height and form of bud sagebrush and the communities in which it is found indicate low value for sage-grouse. Where bud sagebrush is adjacent to stands of big sagebrush, it likely provides high-value forage for sage-grouse in spring and early summer. Stands of bud sagebrush might be used as strutting grounds, particularly where they are adjacent to stands of big sagebrush.

Artemisia tridentata ssp. *parishii* Parish Big Sagebrush

Parish big sagebrush is restricted to the costal ranges and cismontane region of California. Features of this taxon and its communities are quite similar to those of basin big sagebrush. Features ascribed to Parish big sagebrush might be found at random over much of the range of basin big sagebrush. Perhaps additional work will indicate *A. t.* ssp. *parishii* should be reduced to synonymy. If a distinct taxon, Parish big sagebrush is known from outside the range indicated for sage-grouse.

Artemisia tridentata ssp. *spiciformis* Spiked Big Sagebrush, Snowfield Big Sagebrush

Plants of this taxon are of apparent hybrid origin with mountain silver sagebrush and montane taxa of big sagebrush being the apparent parents. Some variation in populations of spiked big sagebrush could be a function of different parent taxa on the big sagebrush side. Features of silver sagebrush include numerous fine stems, large heads, and ability to sprout. Features of big sagebrush include lobed leaves and upland habitat.

Generally there are fewer flower heads per inflorescence in spiked big sagebrush than is common in the suggested parent taxa. Flower heads of spiked big sagebrush are often larger than those of either mountain silver sagebrush or other taxa of the big sagebrush complex, and in most populations there are more flowers per head. When transplanted at low elevations, plants of spiked big sagebrush have come to full flower by the end of May and first of June (McArthur and Goodrich 1984). This is a feature not shared by either silver sagebrush or other taxa of big sagebrush.

This taxon has been confused with Rothrock sagebrush that Shultz (1986) considered endemic to California. References to Rothrock sagebrush outside California, including Bramble-Brodahl (1978), are based on spiked big sagebrush. Vegetation types outside California listed under Rothrock sagebrush are included in the following list for spiked big sagebrush. Spiked big sagebrush has also been confused with Vasey big sagebrush. Osterhout's *Artemisia spiciformis*, based on his type specimen, clearly describes plants with a few large heasds per inflorescence. Beetle's concept of *Artemisia tridentata* ssp. *vaseyana* forma *spiciformis* is based, at least in part, on Vasey or subalpine big sagebrush. Vegetation types of Hironaka and others (1983) listed under spiked big sagebrush follow Beetle's concept and are treated in this paper under Vasey or subalpine big sagebrush.

Spiked big sagebrush is a sprouting, evergreen shrub that ranges from southern Idaho to western Wyoming and southwestern Montana and south to California, Nevada (Ruby Mountains), and Colorado. In Utah it is mostly confined to basic substrates.

Classification

Artemisia tridentata ssp. *spiciformis*/*Elymus trachycaulus* (Tart 1996)

Artemisia tridentata ssp. *spiciformis*/*Trisetum spicatum* (Tart 1996)

Artemisia tridentata ssp. *spiciformis*/mountain forb (Bramble-Brodahl 1978)

Habitat and Capabilities

Habitat of spiked big sagebrush typically includes open slopes and openings within the coniferous forest belt. Populations of this plant extend upward to treeline and approach alpine conditions. It is known from 2,680 to 3,350 m elevation in Utah (Welsh and others 1993). It is capable of withstanding longer duration of snow cover than are other taxa of big sagebrush. The common name of snowfield big sagebrush is comparatively well applied to many populations of this taxon. The capacity to sprout appears to be a factor in the ability to occupy areas of deeper snow cover.

Some associated species also indicate high elevation, snow-persistent sites. These include slender wheatgrass, mountain brome (*Bromus carinatus*), and yellowbrush (*Chrysothamnus viscidiflorus* var. *lanceolatus*). High elevation and cold climate indicate high resistance of these communities to invasion by cheatgrass.

Although height and crown cover of spiked big sagebrush and some features of spiked big sagebrush communities indicate high-value habitat for sage-grouse, the elevation of many populations of this taxon are such that they are not snow-free until after the nesting season of sage-grouse. Stands of this sagebrush are typically covered with too much snow in winter to provide winter habitat. Thus, their value for sage-grouse can be limited primarily to the summer season. The abundance of succulent vegetation during much of the summer suggests potential for high-value summer habitat. However, sage-grouse are not likely to reach some of the higher elevation populations of spiked big sagebrush at any season of the year.

Artemisia tridentata ssp. *tridentata* Basin Big Sagebrush

Basin big sagebrush ranges from southern British Columbia to southwestern North Dakota and south to Baja California and northern New Mexico. This taxon rivals, or perhaps equals, Wyoming big sagebrush in its geographic range of distribution. However, the extent of area covered is much less than that covered by Wyoming big sagebrush.

Classification

Artemisia tridentata ssp. *tridentata*/*Bouteloua gracilis* (Johnston 1987)

Artemisia tridentata ssp. *tridentata*/*Chrysothamnus nauseosus* (Johnston 1987)

Artemisia tridentata ssp. *tridentata*/*Elymus cinereus* (Baker and Kennedy 1985; Johnston [1987] listed six references for Colorado and Wyoming.)

Artemisia tridentata ssp. *tridentata*/*Elymus lanceolatus* (An apparent type unpublished, Ashley National Forest.)

Artemisia tridentata ssp. *tridentata*/*Elymus smithii* (Francis 1983)

Artemisia tridentata ssp. *tridentata*/*Elymus spicatus* (Hironaka and others 1983; Jensen 1989; Nelson and Jensen 1987)

Artemisia tridentata ssp. *tridentata*/*Festuca idahoensis* (Hironaka and others 1983; Nelson and Jensen 1987)

Artemisia tridentata ssp. *tridentata*/*Stipa comata* (Hironaka and others 1983)

Artemisia tridentata ssp. *tridentata*/*Purshia tridentata*/*Elymus lanceolatus* (Johnston 1987)

Artemisia tridentata ssp. *tridentata*/*Sarcobatus vermiculatus*/*Elymus smithii* (Francis 1983)

Habitat and Capabilities

Stands of this shrub are most highly developed on deep alluvial soils of canyon bottoms and drainage ways of valleys. Although of alluvial settings, basin big sagebrush is highly sensitive to flooding and high water tables, and it does better on well-drained areas, such as old terraces, than it does on current flood plains with wet-meadow vegetation. Soil texture is often sandy, gravelly, or loamy. Height of basin big sagebrush plants is commonly 1 to 3 m and occasional specimens exceed 3 m.

Jensen (1989) listed annual production in one basin big sagebrush type at 665 kg/ha (593 lbs/acre). Although this indicates lower production than for many mountain big sagebrush communities, potential production under irrigation is high. This tall sagebrush was used as an indicator of productive sites for agriculture during settlement of the West. Due to the deep alluvial, productive soils and valley locations, much of the original habitat of basin big sagebrush has been converted to agricultural land. Many populations are highly vulnerable to cheatgrass invasion and subsequent displacement by cheatgrass via high fire frequency.

Based on observations and studies on the Tavaputs Plateau of Utah, it appears that basin big sagebrush might take 4 or more decades to achieve 20 percent crown cover following fire where livestock grazing is limited to winter. In this respect it appears to function more like Wyoming big sagebrush than like Vasey big sagebrush. However, in other parts of its range, it might recover more rapidly, and especially under spring and summer use by livestock.

Tall stature indicates low value for strutting habitat. Although stature of this shrub meets the height needs for sage-grouse nesting, the crowns of the shrubs are often elevated above the ground as much as 60 to 100 cm or more. Sage-grouse are likely to avoid stands with this feature when selecting nest sites. Stands with succulent forbs might provide moderate value brood-rearing habitat.

Tall stature and valley bottom habitat indicate foliage of basin big sagebrush would be available to sage-grouse in most locations in most winters. However, in very tall stands, the leaves are difficult for sage-grouse to reach. Other features of some basin big sagebrush habitats appear to be of low preference by sage-grouse. This includes the bottoms of narrow stream canyons where the physical features of the canyon perhaps discourage sage-grouse. Stands in wide valleys are indicated to be of much higher value to sage-grouse than those confined to narrow canyons.

Artemisia tridentata ssp. *vaseyana* Vasey Big Sagebrush, Subalpine Big Sagebrush, Mountain Big Sagebrush

In addition to *Artemisia tridentata.* ssp. *vaseyana*, *A. t.* var. *pauciflora* has been recognized as part of the Vasey big sagebrush complex based on fewer flowers per head and on distribution and habitat (Goodrich and others 1985).

In general, populations of Vasey big sagebrush are more common from Washington to Montana and south to Oregon and Wyoming. Stands of mountain big sagebrush are more common and more highly developed in the Great Basin, Colorado Plateau, and central Rocky Mountains. In Wyoming, communities of Vasey big sagebrush are generally at higher elevation than those of mountain big sagebrush (Tart 1996). Even at high elevations in Utah, very few stands of sagebrush are clearly identifiable as typical Vasey big sagebrush. Critical review of numerous populations is needed to more fully understand the distribution and to clarify separation of these two taxa. Intermediate populations might be encountered throughout much of the range of these two taxa.

The Vasey/mountain big sagebrush complex is a landscape dominant in mountains of much of the West from British Columbia and western Montana south to California and Colorado. Within the big sagebrush group, the Vasey sagebrush complex is likely second only to Wyoming big sagebrush in extent of area covered.

Classification

Distinction between *Artemisia tridentata* ssp. *vaseyana* and *A. t.* var. *pauciflora* is rare in literature dealing with vegetation type classification. This is because publication of *A. t.* var. *pauciflora* (Goodrich and others 1985) followed much of the sagebrush classification work listed below, and likely because of reluctance to accept the distinction. Of the works listed below, only Tart (1996) recognized *A. t.* var. *pauciflora.* Since the distinction was not made in most classification works, *A. t.* var. *pauciflora* is not treated separately in the following list of vegetation types or in the discussion that follows. All references to the complex are lumped under *A. t.* ssp. *vaseyana* or Vasey big sagebrush.

Artemisia tridentata ssp. *vaseyana/Bouteloua gracilis* (Tew 1988)

Artemisia tridentata ssp. *vaseyana/Bromus carinatus* (Hironaka and others 1983; Tew 1988)

Artemisia tridentata ssp. *vaseyana/Carex geyeri* (Hironaka and others 1983)

Artemisia tridentata ssp. *vaseyana/Elymus cinereus* (Jensen 1989; Nelson and Jensen 1987)

Artemisia tridentata ssp. *vaseyana/Elymus cinereus/Bromus carinatus* (Mooney 1985; Tew 1988)

Artemisia tridentata ssp. *vaseyana/Elymus lanceolatus* (An apparent type unpublished, Ashley National Forest.)

Artemisia tridentata ssp. *vaseyana/Elymus smithii* (Tew 1988)

Artemisia tridentata ssp. *vaseyana/Elymus spicatus* (Baker and Kennedy 1985; Bramble-Brodahl 1978; Hironaka and others 1983; Jensen 1989; Mooney 1985; Mueggler and Stewart 1980; Nelson and Jensen 1987)

Artemisia tridentata ssp. *vaseyana/Elymus spicatus/Poa fendleriana* (Mooney 1985)

Artemisia tridentata ssp. *vaseyana/Elymus trachycaulus* (Tart 1996)

Artemisia tridentata ssp. *vaseyana/Festuca idahoensis* (Bramble-Brodahl 1978; Francis 1983; Hironaka and others 1983; Jensen 1989; Mooney 1985; Mueggler and Stewart 1980; Nelson and Jensen 1987)

Artemisia tridentata ssp. *vaseyana/Festuca idahoensis/E. spicatus* (Tart 1996)

Artemisia tridentata ssp. *vaseyana/Festuca thurberi* (Francis 1983; Johnston[1987] listed nine references for Colorado.)

Artemisia tridentata ssp. *vaseyana*/*Festuca scabrella* (Mueggler and Stewart 1980)

Artemisia tridentata ssp. *vaseyana*/*Leucopoa kingii* (Johnston [1987] listed two references for Colorado; this is also found in Utah.)

Artemisia tridentata ssp. *vaseyana*/*Leucopoa kingii* / *Koeleria macrantha* (Mooney 1985)

Artemisia tridentata ssp. *vaseyana*/*Stipa comata* (Bramble-Brodahl 1978; Hironaka and others 1983)

Artemisia tridentata ssp. *vaseyana*/*Stipa richardsonii* (Tart 1996)

Artemisia tridentata ssp. *vaseyana*/*Trisetum spicatum* (Tart 1996)

Artemisia tridentata ssp. *vaseyana*/*Purshia tridentata* (Tart 1996)

Artemisia tridentata ssp. *vaseyana*/*Purshia tridentata* / *E. smithii* (Johnston [1987] listed three references for this association in Colorado.)

Artemisia tridentata ssp. *vaseyana*/*Purshia tridentata* / *F. idahoensis* (Francis 1983)

Artemisia tridentata ssp. *vaseyana*/*Symphoricarpos oreophilus* (Tart 1996)

Artemisia tridentata ssp. *vaseyana*/*Symphoricarpos oreophilus* / *Bromus carinatus* (Jensen 1989; Nelson and Jensen 1987)

Artemisia tridentata ssp. *vaseyana*/*Symphoricarpos oreophilus* / *E. spicatus* (Bramble-Brodahl 1978; Hironaka and others 1983; Jensen 1989; Nelson and Jensen 1987; Tew 1988; Tueller and Eckert 1987)

Artemisia tridentata ssp. *vaseyana*/*Symphoricarpos oreophilus* / *E. trachycaulus* (Tew 1988; Tueller and Eckert 1987)

Artemisia tridentata ssp. *vaseyana*/*Symphoricarpos oreophilus* / *F. idahoensis* (Bramble-Brodahl 1978; Hironaka and others 1983; Tueller and Eckert 1987)

Artemisia tridentata ssp. *vaseyana*/*Symphoricarpos oreophilus* / *Carex geyeri* (Hironaka and others 1983)

Habitat and Capabilities

The lengthy list of vegetation types listed above for the Vasey big sagebrush complex is a reflection of the high diversity of habitats occupied by this complex. It also reflects the favorable climate for plant growth within these habitats. Paralleling the diversity of vegetation types is the number of associated species, as discussed below and shown in table 3.

Stands of this complex are most highly developed in areas with about 35 to 75 cm of annual precipitation. Stands on sites receiving more than 75 cm annual precipitation are mostly confined to southerly exposures within the aspen and coniferous forest belts. Within the coniferous belt, stands are found on sites receiving as much as 149 cm annual precipitation. On drier sites receiving less than 35 cm of annual precipitation, they often grade into Wyoming big sagebrush communities.

Florescence tests in Utah show a rather broad hybrid or mixing zone between Wyoming big sagebrush and Vasey big sagebrush in the 30 to 36 cm precipitation belt, which in Utah corresponds rather well with the pinyon-juniper belt (Goodrich and others 1999a). Where stands of Vasey big sagebrush occur within the distribution of pinyon-juniper, they are often found in and mostly above the pinyon-juniper thermal belt (Goodrich 1981; Goodrich and others 1999a; Hodgkinson 1989). Within the mixing zone, bitterbrush is sometimes an associate. Below the pinyon-juniper belt and within well-marked Wyoming big sagebrush communities, bitterbrush is rare or lacking.

Table 3—Comparison of features of Wyoming big sagebrush communities (ARTRW) from pediments associated with the Green River and mountain big sagebrush communities (ARTRP) on the Bishop Conglomerate Formation (from Goodrich and Huber 2001).

Community feature	ARTRW	ARTRP
	n = 9	*n* = 6[a]
Crown cover of sagebrush (percent)	0–22	0–38
Total number of vascular plant taxa	51	93
Total number of shrub taxa	7	7
Total number of graminoid taxa	13	20
Total number of forb taxa	26	66
Average number taxa/site (alpha diversity)	18	47
Average number of taxa/quadrat (beta diversity)	2.92	11.35
Average number of shrub taxa/site	4	4
Average number of graminoid taxa/site	6	12
Average number of forb taxa/site	7	31
Shrubs with 100 percent consistency	1	3
Shrubs with >49 percent consistency	1	4
Graminoids with 100 percent consistency	1	7
Graminoids with >49 percent consistency	7	12
Forbs with 100 percent site consistency	0	8
Forbs with >49 percent site consistency	4	31
Average ground cover (percent)	58	92

[a] n = 6 except for crown cover of sagebrush for which n = 42.

Big sagebrush of this complex is often indicative of Mollisols or mollic intergrades with mollic epipedons. In Oregon, Swanson and Buckhouse (1984) found it on Mollisols and Wyoming big sagebrush on Aridisols. Jensen (1989, 1990) listed five community types for Vasey big sagebrush in northeastern Nevada, all of which were found principally on Cryoboralls (Mollisols with cold temperature regime). Tart (1996) found communities of Vasey big sagebrush common on Cryoboralls on the west flank of the Wind River Mountains, Wyoming.

Plants of the Vasey big sagebrush complex frequently grow where depth and duration of snow pack is considerably greater than what is typical for Wyoming big sagebrush (Meyer and Monsen 1992). Sturges and Nelson (1986) found Vasey big sagebrush grew where snow depth was greater than 38 cm, and Wyoming big sagebrush was more common where snow depth was less than 40 cm.

Compared to those of Wyoming big sagebrush, the ecological settings of Vasey big sagebrush are more productive. Higher production is indicated as inherent over at least the past few hundred to thousands of years by the dominance of Mollisols instead of Aridisols in Vasey big sagebrush communities. Higher production of Vasey big sagebrush compared to Wyoming big sagebrush at present is verified by comparison of annual growth per unit area. It is also indicated by greater ground cover potential, higher diversity of understory species, and the potential for greater crown cover of sagebrush.

A range of annual production of 418 to 2,354 kg/ha (373 to 2,100 lbs/acre) is indicated for Vasey big sagebrush communities (Goodrich and Huber 2001; Harniss and Murray 1973; Jensen 1989; Tart 1996; Tew 1988). The low end of the range (418 kg/ha) was reported from near Dubois, Idaho, where sample sites were likely near the ecotone with Wyoming big sagebrush. Sites where bluebunch wheatgrass and blue gramma (*Bouteloua gracilis*) were indicators generally had lower production than sites with snowberry (*Symphoricarpos* spp.) and slender wheatgrass (*Agropyron trachycaulum*) as indicator species.

Ground cover is rarely less than 65 percent, and it is commonly above 85 percent even under moderate livestock grazing. At sites in the Uinta Mountains with a history of about 100 years of livestock grazing, ground cover has been found at 87 to 95 percent with an average of 92 percent (Goodrich and Huber 2001). For the Fishlake National Forest, Tew (1988) considered Vasey big sagebrush communities at potential to have between 7 and 22 percent bare soil. This indicates ground cover potential of between 78 and 93 percent for that National Forest. Tart (1996) listed percent bare soil at 6 to 15 percent for 8 plant associations at late seral condition on the West Flank of the Wind River Mountains. This indicates potential for ground cover of about 85 to 94 percent.

Potential for recovery of ground cover following fire is high. Ground cover was found at potential (90 percent or higher) within 5 to 7 years postfire on the Ashley National Forest. This recovery was concurrent with light to moderate livestock grazing. At a site without livestock (ASNF 5-29), ground cover increased from 55 to 97 percent at 2 and 6 years postfire, respectively. However, it is apparent that not all Vasey big sagebrush sites have potential for ground cover of over 90 percent. At two adjacent sites on Bare Top Mountain, Uinta Mountains (ASNF 5-13), ground cover was found at 62 and 85 percent in an area closed to livestock grazing for over 20 years. The site with 62 percent ground cover supported moderate frequency of rock goldenrod (*Petradoria pumila*) and low pussytoes (*Antennaria dimorpha*). These plants were lacking on the site with 85 percent ground cover. These and other plants might be used as indicators of lower potential for ground cover in Vasey big sagebrush communities.

On the west flank of the Wind River Mountains, Wyoming, Tart (1996) generally found 10 to 44 vascular plant taxa per 375 m^2 plot in associations of the Vasey big sagebrush complex. He also indicated potential for ground cover was greater than 80 percent in these associations.

Fisser (1962) found average percent basal area was 12.4 for graminoids and 6.4 for forbs. Although he found 43 forbs in his study area, only silver lupine (*Lupinus argenteus*) and 11 other forbs had greater than trace amounts of cover, and the lupine accounted for 70.1 percent of the forb cover.

Diversity of vascular plants is relatively high in Vasey big sagebrush communities compared to Wyoming big sagebrush communities. Table 3 compares Vasey big sagebrush communities on plateau lands of the Bishop Conglomerate Formation in the eastern Uinta Mountains with Wyoming big sagebrush communities on gravel pediments at the base of the Uinta Mountains. This comparison includes a contrast of an average of 47 and 18 vascular plant taxa per site for Vasey big sagebrush and Wyoming big sagebrush communities, respectively (Goodrich and Huber 2001).

Average crown cover of Wyoming big sagebrush rarely exceeds 25 percent in areas of over 0.5 ha, while values of greater than 25 percent are common in Vasey big sagebrush communities. Without fire or other crown-reducing disturbance for greater than 30 years, crown cover values between 25 and 40 percent are common for Vasey big sagebrush communities in the Uinta Mountains. On the west flank of the Wind River Mountains, Tart (1996) found that canopy cover of all shrubs in mid and late seral communities of Vasey big sagebrush was between 23 to 40 percent. Crown cover of Vasey big sagebrush of nearly 50 percent was recorded in recent studies in Strawberry Valley and West Tavaputs Plateau, Utah, where values of between 35 and 45 percent are not uncommon (Goodrich and Huber 2004, unpublished data).

Higher productivity, including greater crown closure of Vasey big sagebrush communities, supports a higher fire frequency than for Wyoming big sagebrush communities. Although Houston (1973) did not specify subspecies of sagebrush for his study area, the location and associated species indicate Vasey big sagebrush where he suggested a mean fire frequency of 20 to 25 years.

Miller and Rose (1999) found mean fire intervals of 12 to 15 years for a sagebrush steppe basin in Oregon. Citing four papers, Miller and others (1999) indicated fire return intervals usually ranged between 10 and 25 years. This is well within the range of 10 to 40 years suggested by Winward (1991).

Shorter recovery time for Vasey big sagebrush, compared to Wyoming big sagebrush, following fire is also indicative of an ecological history of higher fire frequency. Recovery from a burn to 20 percent canopy cover can range from 12 years in the Vasey big sagebrush type to over 40 years in the drier Wyoming big sagebrush type (Winward 1991). Annual herbage production of sagebrush has returned to preburn levels within 30 years or less following fire (Harniss and Murray 1973). Review of data from over 40 sites on the Ashley National Forest shows Vasey big sagebrush returning to over 20 percent crown cover within 20 years of burning (Goodrich and others 2004, unpublished data). History of some of these sites included previous burns or herbicide applications from which sagebrush recovered prior to the most recent fire.

Although some species are reduced in density and production for a few years, essentially all plant species of Vasey big sagebrush ecosystems return to burned areas by seedbanks, sprouting, or mobile seeds. Big sagebrush is among the least responsive species to fire, but it generally returns to burned areas.

The general adaptation of plant species to fire within Vasey big sagebrush ecosystems is additional evidence of an ecological history of fire. Also indicative of a high fire frequency for Vasey big sagebrush communities is the ease with which these communities are burned under prescribed conditions. On the Ashley National Forest, fire has spread though these communities when most other communities will not carry fire.

In general, Vasey big sagebrush communities demonstrate greater capacity to recover from fire and to resist cheatgrass dominance or turn into cheatgrass-driven communities than do Wyoming big sagebrush communities. In the Uinta Mountains, cheatgrass has made little entry into Vasey big sagebrush communities of plateau lands above 2,450 m elevation. It has made conspicuous advances into

these communities on southerly facing aspects of these mountains, and particularly on gradients exceeding 40 percent. However, even on southerly aspects, native plants have demonstrated high capacity to recover in the presence of cheatgrass following fire.

Height and crown cover of Vasey big sagebrush in mid- and late-seral communities provide high-value nesting habitat for sage-grouse. Distance between the ground and lower level of the dense, spreading crowns of Vasey big sagebrush is often highly favorable for concealment of sage-grouse nests. The high capacity of these communities to produce an abundance of understory herbage is highly conducive to nest concealment and for brood-rearing habitat. Abundance and diversity of forbs and graminoids and succulence of herbaceous plants in summer indicate higher value for sage-grouse brooding habitat than for many Wyoming big sagebrush communities.

Deeper snow accumulations than in Wyoming big sagebrush communities indicate lower value for winter habitat. However, in the presence of tall shrubs or on windswept sites, high-value winter habitat is provided within some stands of Vasey big sagebrush. In some cases sage-grouse are known to summer in Vasey big sagebrush areas (Strawberry Valley, Utah), and migrate to Wyoming big sagebrush areas for winter (Current Creek near Fruitland, Utah) (Bambrough 2002).

The differences between communities of Wyoming big sagebrush and those of Vasey big sagebrush are major. These differences have implications for restoration projects and habitat values for sage-grouse and other wildlife. Where expectations exceed the capability of the land, restoration projects and other management activities are marked for disappointment.

Artemisia tridentata ssp. *wyomingensis* Wyoming Big Sagebrush

Wyoming big sagebrush is a landscape dominant of plains and basins from eastern Washington to western North Dakota and south to California and northern Arizona and New Mexico (McArthur and Sanderson 1999a). This range includes the Snake River Plain of Idaho, basins of the Great Basin, and the Intermountain basins and high plains of Wyoming that grade into the mixed grass prairie.

Classification

Artemisia tridentata ssp. *wyomingensis* / *Atriplex confertifolia* / *Grayia spinosa* / *Stipa comata* (Baker and Kennedy 1985)

Artemisia tridentata ssp. *wyomingensis*/*Elymus elymoides* (Hironaka and others 1983; Nelson and Jensen 1987)

Artemisia tridentata ssp. *wyomingensis*/*Elymus spicatus* (Baker and Kennedy 1985; Francis 1983; Hironaka and others 1983; Mueggler and Stewart 1980)

Artemisia tridentata ssp. *wyomingensis* / *Poa secunda* (Hironaka and others 1983)

Artemisia tridentata ssp. *wyomingensis*/*Elymus lanceolatus* (An apparent type unpublished, Ashley National Forest.)

Artemisia tridentata ssp. *wyomingensis* / *Elymus smithii* (Baker and Kennedy 1985; Johnston [1987] listed nine references from Colorado, Idaho, Montana, North Dakota, and Wyoming for this association. Although both *A. t. vaseyana* and *A. t. wyomingensis* were listed by Johnston [1987] for this association, elevation and soils strongly indicate *A. t. wyomingensis* is the sagebrush of this association in most areas.)

Artemisia tridentata ssp. *wyomingensis* / *Stipa comata* (Hironaka and others 1983)

Artemisia tridentata ssp. *wyomingensis*/*Stipa hymenoides* (Johnston [1987] listed three references for Colorado.)

Artemisia tridentata ssp. *wyomingensis* / *Stipa thurberiana* (Hironaka and others 1983)

Hilaria jamesii / *Artemisia tridentata* ssp. *wyomingensis* (Everett and others 1980)

Habitat and Capabilities

The list of vegetation types for Wyoming big sagebrush is only about one-third as long as that for the Vasey big sagebrush complex. This shorter list is an apparent reflection of the lower diversity of habitats occupied by Wyoming big sagebrush. It also reflects the more restrictive climate for plant growth within the habitat of this shrub. Parallel to the reduced diversity of vegetation types is the reduced number of associated species, as discussed below and as shown in table 3.

Soils under Wyoming big sagebrush communities are typically Aridisols (Barker and McKell 1986; Swanson and Buckhouse 1984) with restrictive horizons at about 30 to 56 cm (Goodrich 1981; Winward 1983). However, communities of this plant are also found on soils with alluvial features in which deposition exceeds horizon development where the restrictive horizon, if present, is much deeper than indicated above.

Stands of Wyoming big sagebrush are most highly developed in areas with about 22 to 30 cm of annual precipitation. They do develop with only 17 to 22 cm of annual precipitation, but in this case they are often confined to drainageways and other local conditions where they grade into cold desert shrub communities. With about 30 to 36 cm of annual precipitation they often grade into stands of the Vasey big sagebrush complex.

Florescence tests in Utah show a rather broad hybrid or mixing zone between Wyoming big sagebrush and Vasey big sagebrush within the 30 to 36 cm precipitation belt, which in Utah corresponds rather well with the pinyon-juniper belt (Goodrich and others 1999a). Where Wyoming big sagebrush is found within the distribution of pinyon-juniper, it is often found in and below the pinyon-juniper thermal belt (Goodrich 1981; Goodrich and others 1999a; Hodgkinson 1989).

Lower annual precipitation indicates less annual production for Wyoming big sagebrush communities than for the Vasey big sagebrush complex. Lower production potential is reflected in a lower potential for ground cover. Winward (1983) noted as much as 25 percent bare ground for Wyoming big sagebrush communities even under undisturbed conditions. Kindschy (1994) reported 38 percent bare soil and 21 percent rock for a pristine site with 5 to 7.5 percent crown cover of Wyoming big sagebrush in the Jordan Crater Kipukas of southeastern Oregon. In Daggett County, Utah, a mean of 55 percent ground cover and 45 percent bare soil was found for six sites that had been rested from livestock use for

greater than 10 years (Goodrich and others 1999b). Rowlands and Brian (2001) indicated as high as 70 percent bare ground was found in a relic site in northern Arizona in what appeared to be a Wyoming big sagebrush community.

Lower potential for production compared to Vasey big sagebrush communities is also reflected in the lower potential for crown cover of Wyoming big sagebrush. Average crown cover of Wyoming big sagebrush rarely exceeds 25 percent in areas of over 0.5 ha, while values of greater than 25 percent are common in Vasey big sagebrush communities.

Fisser (1962) found average percent crown cover of big sagebrush ranged from 17.8 to 27 with an overall average of 22.4 on arid, low-elevation sites on the Owl Creek Range in Wyoming. In contrast, he found average percent crown cover of big sagebrush ranged from 13 to 60 with an overall average of 35.6 on high-elevation, moist sites. The work of Fisser (1962) preceded the published taxonomic distinction of Wyoming big sagebrush by Beetle and Young (1965); however, his description of sites and community features leaves little doubt that he was distinguishing between Wyoming big sagebrush and the Vasey big sagebrush complex.

On low-elevation, semiarid sites, average crown cover of big sagebrush of up to 23 percent has been reported by Anderson and Holte (1981), Goodrich and others (1999b), Rowlands and Brian (2001), Tuller and Blackburn (1974), and Winward (1991). Average values of higher than 23 percent were not found in the literature reviewed for this paper. The high of 27 percent reported by Fisser (1962) appears to represent the high end for Wyoming big sagebrush. Higher values might be found under some conditions including alluvial soils without restrictive horizons and where some moisture is funneled; however, these appear to be exceptions limited to localized areas.

Winward (1991) suggested Wyoming big sagebrush sites with the least disturbance had sagebrush crown cover values of between 8 and 11 percent while those with highest grazing impacts had sagebrush crown cover that exceeded 20 percent.

Sturges and Nelson (1986) found Wyoming big sagebrush grew in locations where the snow pack was less than 40 cm deep and Vasey big sagebrush grew where snow pack was greater than 38 cm. In this respect, Wyoming big sagebrush communities are indicted to provide a larger base of winter habitat for sage-grouse than communities of Vasey big sagebrush.

In addition to sagebrush-grass communities, Wyoming big sagebrush forms communities with sparse understory at lower elevations and especially at the lower end of its precipitation range. Such communities are particularly common in some geomorphic settings. They are common on the Green River Formation in Sweetwater County, Wyoming, where annual precipitation is about 18 to 20 cm, and where they intergrade into cold desert shrub communities as they do in other parts of the West. Striking contrasts in understory composition and abundance are common at the interface of materials of the Green River Formation and areas where this formation is covered with pediment materials deposited by the Green River. The pediment materials support grass-rich communities, and the Green River Formation is grass-poor. Wyoming big sagebrush dominates the overstory on both substrates.

Volland (1976) provided another example of low-producing sagebrush communities of specific geomorphic settings for the Central Oregon Pumice Zone. Rhyolite was recognized as a major abiotic feature of this community. Although he did not specify subspecies of big sagebrush, Volland (1976) recognized a big sagebrush/needlegrass plant community for which, under good condition, herbage production was approximately168 kg/ha (150 lbs/acre) and bare ground and pavement ranged from 60 to 85 percent. Sagebrush crown cover was limited to 10 to 20 percent.

Sparse understory is indicated for some areas of the Wyoming big sagebrush belt by early explorers of the West. One of the examples cited by Peters and Bunting (1994) is from John C. Fremont and illustrates this point. The report, made in 1843, includes a note made near the mouth of Goose Creek on the Snake River Plain in which Fremont reported "the country has a barren appearance, sandy, and densely covered with the artemisias from the banks of the river to the foot of the mountains." Several days later, near the present site of Twin Falls, Fremont added "there was no grass here, the soil among the sage being entirely naked."

Current relic sites also indicate low potential for diversity and production. In a study of a relic site that included big sagebrush communities on Fishtail Mesa in northern Arizona, Rowlands and Brian (2001) found crown cover of big sagebrush and muttongrass averaged 19.2 and 2.6 percent, respectively. All other species including forbs contributed less than 1 percent cover each, and comparison of relative cover with absolute cover in the Rowlands and Brian (2001) data indicates total absolute cover of all other species was only 2.4 percent. They listed only 14 forbs for their sagebrush sites. Eight of the 14 forbs were found in only 12 percent of their sample sites. Number of forbs/sample site varied from 1 to 6 with an average of 3.75 forbs/site. The sample size in this study was a line intercept 121.9 m long. Although they did not specify subspecies of big sagebrush, their site seems to fit within the climatic zone for Wyoming big sagebrush for northern Arizona. That their site was considered a relic without livestock grazing strongly suggests low inherent capability to produce forbs.

The Arizona location is toward the margin of the range of Wyoming big sagebrush, and this could be a factor in the sparse understory found in the relic site of Rowlands and Brian (2001). However, Marquiss and Lang (1959) reported similar conditions for two relic sites in Sweetwater County, Wyoming. On the two relic sites, they found only five forbs with greater than 2 percent frequency. Common forbs included Hoods phlox, cushion buckwheat (*Eriogonum ovalifolium*), and Hooker sandwort (*Arenaria hooker*). Hooker sandwort had 74 percent frequency for the two sites. This cushion plant is an indicator of harsh sites with inherently high percent bare soil and exposed gravel. Marquiss and Lang (1959) also noted forbs were more abundant in adjacent areas grazed by livestock than in the relic sites.

Winward (1983) noted relatively few perennial forbs for Wyoming big sagebrush communities even in undisturbed conditions. Bunting (1985) reported that Wyoming big sagebrush habitat types have low perennial forb components in any successional stage. Although Fisser (1962) found 38 forbs in a study area, the total combined average percent basal area was 2.6, and only Hoods phlox (*Phlox hoodii*) and six other forbs were found with greater than trace amounts. Hoods phlox alone accounted for 69.5 percent of forb cover. A contrast of Wyoming big sagebrush and Vasey big sage-

brush communities in the Uinta Mountains indicated 7 and 31 forbs per site, respectively, for these communities (Goodrich and Huber 2001). This and other comparisons are made in table 3.

In a relic site in Oregon, two forbs were found at 5.9 percent and 1.7 percent crown cover. However, Wyoming big sagebrush crown cover was only 5.2 percent at this site (Kindschy 1994). Tueller and Blackburn (1974) defined an overstory/understory inverse relationship in which needle-and-thread grass decreased from 7.5 percent to 1.4 percent basal area as big sagebrush increased from 1.3 percent to 13.5 percent crown cover. Similar overstory/understory relationships have been discussed by a number of workers (Fisser 1986; Rittenhouse and Sneva 1976; Sturges 1983, 1986; Tanaka and Workman 1988; Wambolt and Payne 1986; West and Hassan 1985; Winward 1983). Some Wyoming big sagebrush sites might not have the capability to provide high percent crown cover of herbaceous plants concurrent with high percent crown cover of sagebrush.

A low perennial forb component is often characteristic for salt-desert shrub communities (Goodrich 1986). Proximity of many Wyoming big sagebrush communities to salt-desert shrub communities is also an indicator that a low forb component is inherent to Wyoming big sagebrush communities. As Wyoming big sagebrush communities intergrade into desert shrub communities, it is reasonable to expected fewer forbs, decreasing percent ground cover, and lower production. As they grade toward Vasey big sagebrush communities, it seems reasonable to expect more forbs, higher percent ground cover, and greater production.

The preceding discussion of overstory/understory relationships could be misleading if it is read to imply that a vigorous understory, including forbs, is necessary for Wyoming big sagebrush communities to function as sage-grouse habitat. Sage-grouse populations have been sustained in forb-poor Wyoming big sagebrush and mountain big sagebrush stands in Sweetwater County, Wyoming, Parker Mountain, Utah, and other locations. These populations strongly indicated that the structure and forage provided by big sagebrush is far more important than any other habitat component. Features of Wyoming big sagebrush, including spreading, dense crowns in close proximity to the ground, appear to be major compensating factors for low presence of herbaceous plants. This is not to imply that succulent forbs are not beneficial. However, an abundance of herbaceous plants will not compensate for lack of sagebrush structure and sagebrush forage.

The discussion of overstory/understory relationships is directed to the need for management to be based on inherent capabilities of the land. If expectations exceed the inherent capabilities of Wyoming big sagebrush communities, management decisions will be poorly founded, and habitat improvement or restoration projects will fail to achieve desired results.

Wyoming big sagebrush is commonly 40 to 70 cm tall and sometimes taller. The crowns are often dense and spreading with the lower part of the crown in close proximity to the ground, but not so close as to obstruct sage-grouse nesting. These features indicate high values for nesting and other habitat needs of sage-grouse. Potential for crown cover of many Wyoming big sagebrush communities is within the range indicated by Connelly and others (2000) to meet the needs of sage-grouse. Crown cover of stands of Wyoming big sagebrush often ranges from about 5 to 25 percent. However, the low percent crown cover (5.2 percent) of sagebrush found in a relic site by Kindschy (1994) indicates potential for sagebrush cover can be well below the range recommended by Connelly and others (2000). Other reports of inherently low potential for cover are listed above. Also there are many areas where browsing by wild ungulates, including pronghorn antelope (*Antilocapra americana*), keeps crown cover of Wyoming big sagebrush well below the levels most preferred by sage-grouse.

Due to its growth form, height, widespread distribution, and expansive areas covered, Wyoming big sagebrush is perhaps the most important plant in the ecology of sage-grouse. Perhaps no other factor is more important to declining populations of sage-grouse than are the changes that have taken place in the Wyoming big sagebrush system. Substantial areas have been converted to agriculture. Others have fallen to urban expansion. However, more extensive loss of sagebrush cover is associated with the introduction of annual grasses. In the past few decades, millions of hectares of Wyoming big sagebrush have been converted to cheatgrass and other annuals (Billings 1994; Monsen 1994).

Monsen (1994) reported over 1.3 million ha burned between 1979 and 1993 in southern Idaho with much of this in an ecological setting where cheatgrass is highly competitive. A table of acres burned from 1979 to 1993 in southern Idaho (Monsen 1994) shows area burned varying widely from year to year without an upward trend. In 1999 and 2000, over 121,410 hectares (300,000 acres) burned on lands managed by the Bureau of Land Management in Idaho. This indicates large acreages of annual burning will continue. In 1999, about 68,800 hectares (1.7 million acres) burned in Nevada. Much of this burning was in sagebrush types that are highly vulnerable to cheatgrass dominance. The 1999 fire season in Nevada represents about one-half of the burned acreage reported by Monsen (1994) for a 14-year period in southern Idaho. Perhaps the 1999 season in Nevada will prove to be a rare exception. However, it could also be an indication of occasional to common fire seasons of the future. Many of the acres included in annual reports also burned in previous fires of recent years. The influence of fire is not only size, it is also frequency. High fire frequency sustains cheatgrass communities and prevents the return of sagebrush.

Cheatgrass with its associated fire regime becomes the driver of the system (Billings 1994; Peters and Bunting 1994). This has reduced diversity and eliminated structure and forage required by sage-grouse.

The displacement of Wyoming big sagebrush by cheatgrass and its associated fire system over millions of hectares is likely the most important factor in the future of sage-grouse in many parts of the West. Reclamation of lands under a system driven by cheatgrass and fire will be important to the future of sage-grouse and other sagebrush associated species.

Due to low precipitation inherent in much of the Wyoming big sagebrush system, reclamation will be difficult with limited plant materials likely to succeed in reclamation projects. Hull (1974) evaluated performance of 90 plant taxa, including many natives, in seedings on rangelands of southern Idaho. Where annual precipitation was less than 25 cm, only 17 of the 90 taxa rated over 1 on a relative scale of 1 to 10. Of these 17, only 6 were natives, and none of the

natives rated over 2.1. Many natives failed to show any establishment. Although the work of Hull (1974) is over 25 years old, it clearly indicates the difficulty in reclamation of Wyoming big sagebrush communities. The difficulty inherent to the low precipitation of many of these communities is compounded by the highly competitive capability of cheatgrass. Difficulty of reclamation with a diversity of native plants was acutely demonstrated by the work of Hull (1974). Later review of restoration of areas similar to those studied by Hull (1974) supports Hulls' work. Monsen (1994) indicated low potential for successful seedings in areas with less than 250 mm of annual rainfall. To be successful in breaking the high fire frequency associated with cheatgrass, plant materials used in restoration projects must be able to compete with and reduce cheatgrass, and they will be most useful if they have comparatively low propensity to carry fire (Monsen 1994).

"Hands-off" or passive management is sometimes recommended with an apparent concept that left alone, cheatgrass-dominated areas will revert to native sagebrush/grass steppe. However, this concept is not supported by studies in relic or natural areas. Kindschy (1994) reported the presence and increase of cheatgrass in southeastern Oregon's Jordan Crater Research Natural Area that has been protected from human activities including livestock grazing. In Red Canyon of the Green River, cheatgrass has been found as the most frequent species where livestock use and other disturbance have been minimal (Goodrich and Gale 1999). Young and Tipton (1990) cited two works from southeastern Washington that documented observations of cheatgrass successfully inserting itself into climax perennial grass/shrub communities that had been protected from fire and grazing for as long as 50 years. They proposed that the idea of cheatgrass spreading in a biological vacuum created by excessive grazing may be somewhat misleading or overstated.

Young and Allen (1997) have emphasized that site degradation is not necessary for cheatgrass invasion. In western Utah, Harper and others (1996) found cheatgrass able to establish in ungrazed areas in desert shrub communities where, although native perennials were able to greatly suppress the size of cheatgrass plants, cheatgrass was able to maintain a presence by which it could expand upon disturbance, including gopher mounds.

Austin and others (1986) found cheatgrass present in Red Butte Canyon of the Wasatch Mountains where livestock grazing was discontinued in 1905, likely before cheatgrass reached that area. They reported higher cover values for cheatgrass in 1983 than for 1935 in Red Butte Canyon. The Red Butte Canyon study demonstrates increase of cheatgrass in absence of livestock grazing.

Knight (1994) reported that the cheatgrass problem is not restricted to land managed for livestock, and he gave an example of an increase of cheatgrass following fire in Little Bighorn Battlefield National Monument in southern Montana. He suggested that managing vegetation of a National Monument to reflect presettlement conditions is a goal that may be impossible to attain once certain introduced species become established.

A hands-off approach does not seem to address the capability of cheatgrass. As suggested by Peters and Bunting (1994), the introduction of annuals, including cheatgrass, possibly has been the most important event in the natural history of the Snake River Plain of Idaho since the last glacial period. The system has changed. A hands-off approach that anticipates the return of presettlement ecosystems does not seem to include the reality of the change. Restoration of sagebrush-grass communities replaced or displaced by cheatgrass and other introduced plants is difficult. No satisfactory method for controlling weed competition on large-scale sagebrush restoration projects has been developed (Meyer 1994). Although current technology of dealing with cheatgrass probably has a long way to go, the future of much of the Wyoming big sagebrush system will likely be determined by development and application of restoration technology. This technology is a focus of these proceedings.

Restoration will include expectations of production, diversity, and potential cover of shrubs and other species. These expectations can be expected to be associated with costly disappointments and poorly based management decisions if inherent as well as induced features of specific sites are not considered.

Artemisia tridentata ssp. *xericensis* Foothills Big Sagebrush, Xeric Big Sagebrush

Foothills big sagebrush is known from west central Idaho where it grows on mesic temperature and xeric moisture rated soils derived from Columbia River basalt at elevations between 752 and 1,524 m (Rosentreter and Kelsey 1991). Morphology and ecology of foothills big sagebrush suggest a hybrid origin involving basin big sagebrush and Vasey big sagebrush (Rosentreter and Kelsey 1991).

Classification

Artemisia tridentata ssp. *xericensis*/*Elymus spicatus* (Hironaka and others 1983)

Artemisia tridentata ssp. *xericensis*/*Festuca idahoensis* (Hironaka and others 1983)

Habitat and Capabilities

The habitat and growth form, as indicated above, are intermediate between basin big sagebrush and Vasey big sagebrush. Moderate to high values for sage-grouse for nesting, breeding, and wintering are indicated. Due to drying of herbaceous plants, values for brood rearing in mid and late summer are likely lower than in higher montane stands of Vasey big sagebrush. However, brood rearing is common in big sagebrush areas equally as dry or drier than found in the range of this taxon.

Artemisia tripartita ssp. *rupicola* Wyoming Threetip Sagebrush

This shrub is known from east of the Continental Divide in Wyoming on the Owl Creek Range, Wind River Range, and the Laramie Range where its elevational range of dominance is between 1,768 and 2,560 m (Fisser 1962) and south-central Montana (Wambolt and Frisina 2002).

Classification

Artemisia tripartita ssp. *rupicola*/*Festuca idahoensis* (Johnston [1987] listed references under *Artemisia tripartita* for the Medicine Bow National Forest, Roosevelt National Forest, and Shoshone National Forest. These National Forests are within the range of *A. t. rupicola*.)

Artemisia tripartita ssp. *rupicola*/*Poa secunda* (Johnston [1987] listed two references for this type for the Shoshone National Forest under *Artemisia tripartita*. This National Forest is within the range of *A. t. rupicola*.)

Artemisia tripartita ssp. *rupicola*/*Stipa comata* (Johnston [1987] listed two references for the Medicine Bow National Forest under *A. tripartita*. This National Forest is within the range of *A. t. rupicola.*)

Thatcher (1959) found slimstem muhly (*Muhlenbergia filiculmis*) associated with *A. tripartita ssp. rupicola,* but not with any other sagebrush taxa in his study area in Albany County, Wyoming.

Habitat and Capabilities

This shrub is found on windswept, shallow, gravelly soils of foothills and mountains and flats with estimated average annual precipitation of between 38 and 48 cm (Thatcher 1959). It is associated with a minimum of winter snow accumulation and is generally not present on sites where snow tends to drift (Fisser 1962). In addition to the associated grasses listed above under classification, this shrub is found with blue gramma and fringed sagebrush (Knight 1994).

Height of this somewhat sprawling shrub, excluding the flowering stems, is seldom as much as 15 cm (Dorn 1992) and not over 18 cm (Thatcher 1959). Percent crown cover is generally between 4 and 12, and other shrubs are commonly of minor cover (Fisser 1962). Fisser (1962) found Hood's phlox and three other forbs provided most of the forb cover in Wyoming threetip sagebrush communities.

Height and crown cover common to this plant indicate little value for sage-grouse at any time of the year except when stands of this shrub are adjacent to taller taxa of sagebrush. Shultz (1986) indicated this shrub is usually on barren knolls surrounded by well-developed grasslands. Proximity to big sagebrush is comparatively uncommon. However, Fisser (1962) found some stands adjacent to big sagebrush stands. Where adjacent to stands of big sagebrush, stands of Wyoming threetip sagebrush might be selected for strutting grounds, and the windswept habitat might indicate some forage value in winter. However, since the leaves are deciduous, winter value of this shrub is very low. The sprouting feature indicates high value for reclamation projects.

Artemisia tripartita ssp. *tripartita* Idaho Threetip Sagebrush, Tall Threetip Sagebrush

This deciduous, sprouting shrub ranges from Washington and adjacent British Columbia south to Elko County, Nevada, Box Elder and Cache Counties, Utah, and to Teton County, Wyoming, and the southwestern portion of Montana (Wambolt and Frisina 2002). Centers of distribution are in western Washington and east-central Idaho. Much of the area once covered by threetip sagebrush has been converted to agricultural land (Schultz 1986).

Classification

Artemisia tripartita ssp. *tripartita*/*Elymus spicatus* (Hironaka and others 1983)

Artemisia tripartita ssp. *tripartita*/*Festuca idahoensis* (Hironaka and others 1983; Mueggler and Stewart 1980; Johnston [1987] listed six other references that are from within the range of *A. t. tripartita.*)

Artemisia tripartita ssp. *tripartita*/*Stipa comata* (Hironaka and others 1983)

Habitat and Capabilities

Idaho threetip sagebrush occurs primarily on fertile volcanic soils (Shultz 1986) that class in a variety of Mollisols or intergrade with Mollisols (Hironaka and others 1983) on dry plains and hills at 1,100 to 2,300 m (Cronquist 1994).

Height of Idaho threetip sagebrush is 20 to 100 cm, and the plant has high capacity to form closed stands with high percent crown cover. The herbaceous understory can be fairly productive, but it is sometimes inversely related to crown cover of the shrubs (Hironaka and others 1983).

The features of Idaho threetip sagebrush communities indicate high-value habitat for sage-grouse nesting, breeding, and brood rearing. However, due to the deciduous feature of the shrub, it can be expected to provide little, if any, forage in winter.

Hironaka and others (1983) noted cheatgrass is generally not a problem in this type even though the vegetation may be severely disturbed. The sprouting feature of the shrub indicates high value for reclamation projects where ability to recover from fire is important.

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