Wyoming Guidelines for Managing Sagebrush Communities with Emphasis on Fire Management

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FORWARD

Beginning with the wildfire season of 1988 in the western U.S., and continuing to the present, considerable attention has been paid to the issue of fire fuels accumulation in natural ecosystems, largely as a result of decades of aggressive wildfire suppression practices. In response to this issue, a trend has emerged among many land and natural resource management agencies to develop prescribed fire programs as a tool for controlling fuels accumulation, as well as an ecosystem management tool. In recognition of this trend and the potential effects major burning programs could have on the Wyoming landscape (particularly sagebrush ecosystems), and as partners in species and habitat management, the Director of the Wyoming Game and Fish Department and the State Director of the USDI - Bureau of Land Management in Wyoming decided in the spring of 1999 to cooperatively assemble an interdisciplinary team to examine the issue of prescribed burning in sagebrush ecosystems, and as appropriate, to describe some basic operating principles, or guidelines, for conducting prescribed fire operations in sagebrush habitats. The information presented in this paper is the product of that effort. Cooperating agencies and individuals representing them are as follows: Wyoming Game and Fish Department: Gary Butler, Steve Kilpatrick, Mark Fowden, Bill Gerhart; Bureau of Land Management: Dave Roberts, Ken Stinson, Vicki Herren, Tom Rinkes; U.S. Forest Service: Dave Sisk, Rod Dykehouse, Dave Scott, and Natural Resource Conservation Service: Dick Rintamaki. Reviews of this document have been provided by both agency personnel and other subject matter experts.

The team recognizes that chemical, mechanical and biological treatments can also be effective tools for the management of sagebrush communities. Brief discussions of these tools are provided; however, the emphasis of these guidelines is on fire management. All treatments have the potential to result in both positive and negative impacts, depending on site-specific characteristics and objectives.

This document focuses on the health and ecological processes of the basic vegetation resource as it functions in the role of cover and food for wildlife. The field of view presented here examines the vegetation resource holistically on the landscape level. Wyoming's wildlife species have different habitat requirements. These guidelines are not customized to fit the needs of any individual species that might be found in the sagebrush ecosystem. Instead the information presented herein should be the base, or foundation, tier of a multi-tiered evaluation process that may be used for the planning of any project proposal in the sagebrush ecosystem. **Additional evaluation tiers for specific species management (e.g., sage grouse, mule deer, pronghorn, etc.) should overlay these guidelines when evaluating any given project proposal.** These fire management guidelines cover several of the most prominently occurring species of sagebrush found in Wyoming.

Management of sagebrush ecosystems is controversial. There are at least two separate "schools of opinion" regarding management of sagebrush: 1) aggressive, pro-active management of sagebrush; and 2) a more conservative, "hands-off" approach to sagebrush community management. Supporters of any combination of these management approaches hold strong views and have supporting literature and other documentation. The approach presented in this document leans toward the "pro-active management" of sagebrush ecosystems, but primarily promotes the collaborative planning and execution of resource management based on circumstances present for each specific management site and landscape.

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ABSTRACT

It is estimated over 153 million acres of the western United States are dominated by various sagebrush species and approximately 58,000 square miles (37 million acres) of Wyoming are covered by thirteen different types of sagebrush. Such sagebrush communities evolved as dynamic landscapes with climatic and edaphic variation driving changes in fire frequencies, and in adaptive development of different sagebrush species. Investigations indicate the historic sagebrush-steppe ecosystem was a mosaic of successional (age) classes created and maintained by fire regimes ranging in frequency from 10-110 years, or more, as well as other factors depending on sagebrush species and specific geographic area. The diversity and juxtaposition of sagebrush community type, age class and associated vegetative community types provide habitat for approximately 87 species of mammals, 297 species of birds and 63 species of fish, reptiles and amphibians. Human-induced fire suppression and repetitive domestic livestock and wild ungulate herbivory have led to successionally advanced ecological stages across the landscape. Prescribed fire, wildland fire use, and herbivory management can be effective tools available to managers for maintaining and enhancing sagebrush types and associated communities. If sagebrush treatments are planned, prescriptions must be carefully designed and tailored to the sagebrush species, herbaceous understory, and associated wildlife species. This paper provides recommendations for landscape-scale management of nine species/subspecies/varieties of sagebrush found in Wyoming: Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis);* mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana* var. *pauciflora);* Vasey big sagebrush (*Artemisia tridentata* ssp. *vaseyana* var. *vaseyana);* basin big sagebrush *(Artemisia tridentata* ssp. *tridentata);* plains silver sagebrush *(Artemisia cana* ssp. *cana);* mountain silver sagebrush *(Artemisia cana* ssp. *viscidula);* Wyoming threetip sagebrush *(Artemisia tripartita* ssp. *rupicola);* tall threetip sagebrush *(Artemisia tripartita* ssp. *tripartita),* and black sagebrush *(Artemisia nova)*.

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INTRODUCTION

Purpose/Reason for the Guidelines

With the current emphasis on management of fire in natural ecosystems in the western United States, the need has been identified for some form of guiding parameters for these activities. These guidelines have been developed to assess and direct prescribed fire management to improve and maintain sagebrush (*Artemisia*) communities in Wyoming. They are intended to help managers determine if, what, when, where, why, and how to utilize fire as a biological resource management tool.

Limited research and statewide inventory information on sagebrush ecosystem management exists for Wyoming, therefore the guidelines were developed from existing references, localized inventories and professional experience. As additional research and inventory information becomes available these guidelines may be modified.

Background/Setting of the Sagebrush Ecosystem in Wyoming

The historical presence of sagebrush in the west has been well documented through numerous paleontological studies. Pollen records near Grays Lake, Idaho indicate dense sagebrush stands were preserved well over 35,000 years ago (Beiswenger 1987). It is estimated over 153 million acres of the western United States are dominated by various sagebrush species (Kuchler 1970, West and Young 2000). Beetle and Johnson (1982) estimated that 58,000 square miles (37 million acres) of Wyoming are covered by thirteen different types of sagebrush, nine of which are addressed in this document.

In Wyoming, a significant amount of sagebrush communities exist in late successional stages dominated by older age plants (>50 years old) that are often of relatively even age classes (sagebrush monocultures) with reduced plant species quantity and diversity. (Cundy 1989, Nelson et al. 1994, Mononi and Altermatt 1996, Cundy and Schoup 1997, Bennett 1999, Clause 1999, Wyoming Game and Fish Department 2000, 2001, 2002). These stands of sagebrush often have relatively sparse cover of grasses and forbs in the understory compared to more open stands with a lower percentage of canopy cover, which are more typical of mid-seral sagebrush communities. Maintaining stands in this static state does little to benefit sagebrush ecosystems and the flora and fauna species dependent on a mosaic of seral states of sagebrush and its associated communities.

Many researchers believe fire historically, as a primary disturbance factor, had an important role in some sagebrush ecosystems, increasing the dominance of many herbaceous species while reducing the abundance and cover of woody plants (Daubenmire 1968, Burkhardt and Tisdale 1976, Wright et al. 1979, Gruel 1985, Eddleman and Doescher 1999, Brown 2000, Miller and Eddleman 2000, Miller 2001). Others contend that the sagebrush-steppe is and has been in a constant state of successional change from a variety of causes including, but not limited to fire (Peterson 1995, Braun pers. comm. 2002). Factors such as insects, rodents and lagomorphs, drought, wet cycles, gradual changes in climate, fire suppression, shifts in the intensity, frequency, and occurrence of fire, invasive plant species, and heavy grazing are equally important (Wright and Bailey 1982, Champlin and Winward 1982 , Hironaka et al. 1983, Winward 1985, Crane and Fisher 1986, Kauffman 1990, Young 1990, Tart 1996, Miller and Eddleman 2000, Payson et al. 2000, Ryan 2000). Fire was important in some types, primarily silver sagebrush (*A. cana*), mountain big sagebrush (*A. tridentata vaseyana)*, and threetip sagebrush (*A. tripartita*) and markedly less so in Wyoming big sagebrush (*A. tridentata wyomingensis*) and black sagebrush (*A. nova*) types (Braun pers. comm. 2002).

Importance/Value of Sagebrush Ecosystems to Wildlife Species

Active management of dynamic sagebrush and associated vegetative communities, **if performed appropriately for those species and habitats of concern**, may be needed for the long-term maintenance of an array of terrestrial and aquatic fauna species due to these systems having been altered. Appropriate sagebrush ecosystem management may require acceptance of some short-term reductions in habitat productivity for some wildlife species to overcome the cumulative effect of decades of inappropriate management. This is a trade-off that may have to occur to reverse the accumulated effect of decades of fire suppression, inappropriate grazing, and other human related ecosystem impacts.

Sagebrush ecosystems provide important food and cover, especially winter habitat, for big game and other species. Many plant communities (e.g., aspen, mountain shrubs, salt desert shrubs, open conifer) occur in association with sagebrush communities (e.g. intra- and inter-community associations). Such mixed stands are important to a myriad of aquatic and terrestrial wildlife species. Recent investigations in Wyoming indicate these habitats are also in advanced successional stages (Bennett 1999). These are also dynamic versus static, and perturbations (e.g., fire) may be an important component of their long-term maintenance. A mix of shrubs and herbaceous plants in sagebrush and associated communities provide a diverse habitat for approximately 87 species of mammals, 297 species of birds (Braun et al. 1976) and 63 species of fish, reptiles and amphibians (Wyoming Game and Fish Department Vertebrate Species List 1992).

Fishes and Other Aquatic Species

The supply of water available to aquatic species is controlled by precipitation and regulated by interactions among geology, soils, and vegetation. Optimal management to restore seeps, springs, riparian stability, bank storage, and base stream flow entails maintaining or increasing the total volume of water captured, stored, and released in a watershed. A landscape of dense sagebrush canopies can limit efforts to retain or restore optimal watershed dynamics, and, in turn, native trout, other aquatic-species, and recreational fishing opportunities.

Many remaining populations of native trout, e.g., Colorado River (*Oncorhynchus clarki pleuriticus*), Bonneville (*O. c. utah*), and Yellowstone (*O.c. bouvieri*) cutthroat trout subspecies are dependent on the water resources derived from sagebrush-associated landscapes. In Wyoming, each of these trout subspecies has been petitioned for listing as threatened or endangered species. Most genetically pure strains of these subspecies have been displaced to, or isolated as small populations in smaller order, headwaters streams draining landscapes with some proportion of sagebrush types. Prescribed fire and other management tools can be used to maintain and/or enhance base stream flows for these species.

See the statewide conservation plans for proposed activities in Bonneville and Colorado River cutthroat trout streams or watersheds (Lentsch et al. 2000, Colorado River Cutthroat Trout Task Force 2001). The State of Montana has also completed a draft cooperative conservation agreement for Yellowstone cutthroat trout containing information pertinent to Wyoming (Montana Fish, Wildlife and Parks 2000).

Greater Sage-Grouse

In Wyoming, the greater sage-grouse (*Centrocercus urophasianus*) populations in the Lander, Green River, and Pinedale regions, as well as some surrounding areas, are generally healthy, but have been declining for the past twenty years. In these same areas, sagebrush communities occur commonly in tracts occupying hundreds or thousands of acres, and many of these sagebrush communities are covered by dense, old-age, moderately to heavily hedged, monotypic stands lacking a diverse, productive grass/forb understory (Cundy 1989, Nelson et al. 1994, Mononi and Altermatt 1996, Cundy and Schoup 1997, Bennett 1999, Clause 1999, Wyoming Game and Fish Department 2000, 2001, 2002). Radio tracking data of 318 radio-years for female sage-grouse throughout Wyoming indicate nesting and early brooding-rearing sage-grouse select against interiors of extensive stands of monotypic, mature sagebrush, preferentially selecting edges of those habitats (Heath pers. comm. 2002, Lyon pers. comm. 2002, Holloran pers. comm. 2002). This suggests mosaics of sagebrush habitats with different composition, structure, shrub age class, and canopy coverage can be beneficial for sage-grouse during this time period. Wintering sage-grouse require sagebrush heights and cover classes which allow birds access to plants for food and cover regardless of snow depth.

See the Draft Wyoming Greater Sage-Grouse Conservation Plan (Wyoming Greater Sage Grouse Working Group 2002) and the Guidelines to Manage Sage Grouse Populations and Their Habitats (Connelly et al. 2000) for proposed activities in occupied sage-grouse habitats.

Other Birds of the Sagebrush Ecosystem

Many birds such as the sage thrasher (*Oreoscoptes montanus*), Brewer's sparrow (*Spizella breweri),* sage sparrow (*Amphispiza belli*), and several other birds are sagebrush obligates. The birds in these shrublands not only add to the West's wildlife diversity, but they are also important to the sagebrush ecosystem itself by providing such crucial services as dispersing seeds and preying on insects and rodents (Ritter and Paige 2000). Nationally, grassland and shrubland birds have shown the most consistent population declines over the last thirty years of any group of birds. The list of possible causes of these declines is lengthy. In the Intermountain West, population declines of more than 50% of grassland- and shrubland-associated bird species have been recorded. Sagebrush and the native perennial grasses and forbs associated with it are important sources of food and cover for many wildlife species, as well as providing essential nesting sites for many shrub-nesting birds (Paige and Ritter 1999). See the Wyoming Bird

Conservation Plan for typical activities and management guidelines for birds occurring in sagebrush ecosystems in Wyoming (Cerovski et al. 2001).

Pronghorn

The pronghorn (*Antilocapra americana*) symbolizes the vast, open plains and prairies of western North America, and they abound in Wyoming and elsewhere in suitable habitat. Although Wyoming still has some large expanses of big sagebrush habitat and the largest pronghorn population in North America populations are declining. The vast majority of pronghorn populations depend on the large, woody sagebrush species as a preferred food. In northern climates, deep snows frequently preclude the use of less nutritious dried forb and grass forage in winter, and it is here the available, highly nutritious sagebrush species permit the continued survival of the pronghorn and provide for its maximum productivity (Sundstrom et al. 1973). The vegetative structure of sagebrush often provides crucially needed cover for fawns in the spring and early summer (O'Gara and Yoakum 1992).

The Wyoming Game and Fish Department (WGFD) has prepared a set of standard recommendations for wildlife habitat management activities related to grazing (Wyoming Game and Fish Department 1999). Most of these recommendations are directed at management of rangeland ecosystems, including sagebrush.

SAGEBRUSH ECOSYSTEM MANAGEMENT GOALS

The sagebrush steppe ecosystem can be characterized by an overstory of sagebrush and an understory of perennial grasses and forbs (Beetle and Johnson 1982, West 1983, 1988). It has a natural variability of sparse, open sagebrush dominated by grasses and forbs to dense stands of sagebrush cover with very little herbaceous cover. These communities generally contain three to four vegetation layers: (1) a shrub layer 12 to over 40 inches tall, (2) forbs and caespitose grasses 8 to 24 inches, (3) low growing grasses and forbs less than 4 to 8 inches, and (4) the cryptogamic soil crust (Miller and Eddleman 2000). Sagebrush ecosystem management goals will be primarily based on the concept of the health of the system. For the purposes of this document the definition of rangeland health is adopted from the National Research Council (1994) as: "---the degree to which the integrity of the soil and ecological processes of rangeland ecosystems are maintained," and the Task Group on Unity in Concepts and Terminology (1995) definition which states: "The degree to which the integrity of the soil, vegetation, water, and air, as well as the ecological processes of the rangeland ecosystem are balanced and sustained."

The role of fire in sagebrush ecosystems can be placed in two contexts. The first context includes those situations where other vegetation types, often dominated by conifers, are encroaching and will eventually replace sagebrush communities. In Wyoming these include ponderosa pine (*Pinus ponderosa*), limber pine (*P. flexilis*), and juniper (*Juniperus* spp.). This encroachment could either be simply due to a successional response to the change in the fire regime or a change of conifer distribution resulting from climatic changes. In either case fire or some other disturbance to periodically limit the encroaching species is required to maintain sagebrush communities. The other context is where sagebrush stands are the potential natural community. Disturbance in this second context may be desired for the development of early seral vegetation within late seral sagebrush communities, such as herbaceous communities or communities dominated by younger populations of sagebrush (Bunting pers. comm. 2002).

This document concentrates on the use of prescribed fire as a landscape management tool. Landscape is defined here as "a heterogeneous land area composed of a cluster of interacting ecosystems that is repeated in similar form throughout" (Forman and Godron 1986). Urban et al. (1987) characterized a landscape as "a mosaic of heterogeneous land forms, vegetation types, and land uses". Landscapes may also be thought of as a land pattern of repeating habitat components that occur in various shapes, sizes, and spatial relationships (Noss and Cooperrider 1994). While a landscape has no definitive size, for most practical applications a landscape is considered to be large in scale, similar to a fifth level hydrologic unit (HU). See Appendix A for a map of fifth level hydrologic units of Wyoming (U.S. Geological Survey/U.S. Environmental Protection Agency 2000).

Landscape level goals for the management of sagebrush ecosystems are to:

1. Promote a healthy, productive mosaic of shrub age classes and canopy covers with a diversity of plant species in sustainable sagebrush communities.

2. Encourage activities directed at maintaining or restoring the sagebrush acreage in Wyoming.

3. Evaluate the need for rehabilitation or restoration work following disturbances focusing on immediate reestablishment of native vegetation species suited to local range sites.

4. Encourage mitigation of sagebrush ecosystem loss, fragmentation, or degradation.

5. Promote communication between, and the cooperation of, all entities involved in the management of sagebrush ecosystems in Wyoming.

Regional and/or local sagebrush management needs and objectives may vary, and will require continual evaluation.

SAGEBRUSH ECOSYSTEM MANAGEMENT CONCERNS

Sagebrush Loss/ Sagebrush Fragmentation (Partitioning/Barriers)

Agricultural Conversions

Conversion of sagebrush vegetation to agricultural crops and irrigated pastures has been identified as a cause of decline in sagebrush ecosystems in portions of Wyoming. Significant acreages of private lands in the Bighorn Basin, Wind River Basin, Powder River Basin, and lower Platte River drainage have been converted to agricultural lands. Many conversions were the result of federally funded programs such as irrigation projects, desert land entry and homesteading. While agricultural conversions have and continue to occur on private lands, their effect often extends into the surrounding, intact ecosystems, including public lands.

Housing Developments

Urban development results in direct loss of sagebrush ecosystem acreage, and the human disturbance associated with these developments makes even more acreage non-functional. Selection of town sites resulted from a variety of factors including easy access, presence of water, presence of building materials, a relative high degree of security and safety, etc. Some residences and subdivisions (i.e., ranch/farmsteads and ranchettes) are far removed from actual incorporated towns, but have the same type of impact on the ecosystem though on a smaller scale. This trend in habitat loss is continuing at an ever-expanding rate as the human population grows. Some investigators have estimated that as much as 3-5% of this ecosystem may have already been negatively impacted by town and urban development (Braun 1998).

Mineral Development

Impacts to the sagebrush ecosystem, and thereby wildlife, can include direct habitat loss from mine and oil and gas well construction and associated facilities. While the amount of sagebrush habitat acreage lost at any individual site may be small, the accumulated acreage over entire fields, and the state as a whole, can be significant.

Industrial Developments

Mineral development has occurred widely throughout sagebrush habitats in the state of Wyoming. These activities involve the extraction of coal, uranium, trona, bentonite, oil, and gas. Very few studies have been conducted to determine the quantifiable impacts of mining, oil, and gas developments on most wildlife species in sagebrush habitats. Impacts to the sagebrush ecosystem, and wildlife, can include increased human activity and associated effects (e.g., noise) causing avoidance of habitat, displacement of populations, or disruption of life cycle activities. Indirect impacts can result from the partitioning, or fragmentation, of large blocks of habitat. These activities result in the destruction of the integrity of the habitats, at least from a wildlife use standpoint. The cumulative impacts of industrial developments, though often difficult to adequately describe, can sometimes have a very subtle and insidious effect on the wildlife populations of an area.

Facilities

Power lines, fences, and roads, have all had some level of adverse impact on intact sagebrush ecosystems. Impacts to wildlife can include direct habitat loss from road, pipeline, and transmission line construction. Increased human activity and the associated noise and road development makes habitat ineffective and increases mortality. Power lines and fences often provide perches for birds of prey, and fences may actually cause direct mortality when birds fly into them (Connelly pers. comm. 1999) or game animals become entangled in them. Furthermore, migratory patterns of big game animals may be significantly modified by fencing.

Sagebrush Degradation (Including Simplification)

Soil and Water Depletion (Drought)

Many sagebrush-dominated rangelands in Wyoming have low average annual precipitation. By definition, a desert is an area with less than 10 inches of precipitation per year (Odum 1959). Evaporation:transpiration ratios are generally high, except in northern latitudes, and effective moisture for plant growth is usually extremely variable. Drought commonly occurs, either seasonally or for periods of several years, and is normal within the distribution of sagebrush ecosystems. If average moisture conditions are considered, generally one-half of each 10- or 20-year period will have less than average moisture (Palmer 1965). Thus habitat management for average herbaceous production could result in inappropriate use in 50% of the years. Drought naturally causes a decreased production of herbaceous cover and forb availability, which in turn, may affect the abundance of many forms of wildlife (Braun 1998). While often overlooked or discounted, drought conditions could have one of the most significant impacts on the use of sagebrush ecosystems by wildlife species. The difference between sagebrush production in drought versus non-drought years can be as much as 900% (Winward pers. comm. 2000).

Drought can lead to increased competition between livestock and wildlife for food and cover in the sagebrush ecosystem. Drought will exacerbate the adverse effects of heavy livestock grazing on vegetation and soils (Vallentine 1990). In some instances, the failure to make timely adjustments in livestock use during drought has resulted in limited plant regrowth, overuse in wet meadows and riparian areas, and has negated gains in rangeland conditions made during higher-precipitation years (Thurow and Taylor 1999). Bennett (1992) found domestic livestock stocking rates were often not adjusted in Wyoming during recurring drought cycles. In fact, during the notorious drought of the 1930's, livestock numbers actually increased overall. An overabundance of big game populations during prolonged droughts can have a detrimental effect on shrubs. Wildlife managers need to monitor and adjust big game population trends to prevent/reduce habitat deterioration. The combined impact of inappropriate grazing and drought conditions are thought to have had an exponential impact on sagebrush community composition, diversity, and structure.

Herbivory (Domestic and Wild)

Grazing and browsing have strongly influenced existing sagebrush ecosystem conditions. Crawford et al. (1992) states domestic livestock grazing potentially has the greatest impact on sagebrush habitats because it remains the most common and widespread use of rangelands, and is the principal land management practice that affects herbaceous composition, cover and height. Livestock grazing also affects sagebrush density, canopy cover, and reinvasion rates (Goodrich et al. 1999, Bennett 1992). Beck and Mitchell (2000) conclude that grazing may reduce fine fuels to such an extent that natural fire intervals are no longer maintained, even further exacerbating the condition and health of the area, and thereby degrading the natural ecosystem processes. Miller and Rose (1999) concluded that a significant reductions in fire occurrence occurred within a few years after livestock were introduced in the early 1870s resulting in a change in mean fire return intervals within mountain big sagebrush communities.

Livestock management practices such as spring developments, water pipelines, and fencing have distributed livestock and wildlife use over areas that were formerly only sporadically or lightly used altering sagebrush habitats over the last century. Grazing and browsing have contributed to long-term changes in plant communities and reduced certain habitat components that contribute to the health of sagebrush-steppe habitat (Mack and Thompson 1982, Quigley and Arbelbide 1997, Wisdom et al. 2000). Heavy grazing too soon after disturbances such as fire may lead to permanent reductions in herbaceous forage and nesting cover for a number of wildlife species.

Supplemental feeding of both domestic livestock and wildlife can result in excessive grazing on vegetation and trampling of soils at the site of feeding and the surrounding area. Physical trampling of the vegetation can result in reduction or loss of sagebrush and residual herbaceous cover and contributes to the establishment of non-native plants.

Grazing by wild horses has altered sagebrush ecosystems over the last century in much the same fashion as livestock. In many areas, grazing contributed to long-term changes in plant communities and reduced certain habitat components that contribute to the health of sagebrush-steppe habitat (Mack and Thompson 1982, Quigley and Arbelbide 1997, Wisdom et al. 2000). Wild horses are managed in 10 Herd Management Areas (HMAs) in Wyoming that involve 3.7 million acres of public lands located primarily in the southwestern part of the state. The cumulative Appropriate Management Level (AML) for horse numbers in these areas is 2,490 to 3,725 animals. Many herds in the state have been two to three times over AML for significant periods of time. This season-long use contributes to the degradation of the sagebrush communities.

Rangeland Manipulations

Herbicide Use:

When applied properly, herbicides can be an effective habitat management tool. However, prior to the 1980s, herbicide treatment (primarily 2,4-D) of large tracts of rangeland was a common method of reducing sagebrush (Braun 1987). In many cases, broad herbicide treatment may have contributed to declines in wildlife populations (Enyeart 1956, Higby 1969, Peterson 1970, Wallestad 1975). A Utah study suggests this adverse impact was compounded if the area was subsequently re-seeded to crested wheatgrass (*Agropyron cristatum*) (Enyeart 1956). Herbicide treatments have generally occurred in the eastern portion of Wyoming, but seeding of crested wheatgrass has occurred as a part of watershed improvement projects and along rights-of-way in the western portion of the state also.

Mechanical Treatments:

As with many other rangeland manipulation tools, mechanical treatments can play a very useful role in rangeland management when used appropriately. Mechanical treatments (i.e., mowing, plowing, chaining, etc.) of sagebrush have generally been more localized in nature, but these, too, have been known to adversely impact wildlife if done on a broad scale (Swenson et al. 1987).

Wild/Prescribed Fires:

Miller and Tausch (2000) summarized work done in the West related to fire and fire regimes. Investigations indicate the historic sagebrush-steppe ecosystem was a mosaic of successional (age) classes created and maintained by fire regimes ranging in frequency from 10-110 years or more, depending on sagebrush species and specific geographic area (Whisenant 1990, Peters and Bunting 1994). Presettlement mean fire return interval in Vasey big sagebrush(*A. t. vaseyana* var. *vaseyana*)/Idaho fescue (*Festuca idahoensis*)was 10-20 years (Miller and Rose 1999). After investigating fire episodes in the Interior Columbia Basin Ecosystem from 1540 to 1940, Barrett et al. (1997) concluded that 4% (4 million acres) of the Columbia Basin sagebrush types burned annually. In some areas mosaics of different seral stages have changed to rather homogenous stands of dense sagebrush with corresponding reductions in herbaceous understory species as a result of fire suppression and livestock influence (Winward 1985; Kauffman 1990; Young 1990; Crawford et al.1992; Wright and Bailey 1982; Champlin and Winward 1982; Hironaka et al. 1983; Crane and Fisher 1986; Tart 1996; Goodrich 1999). Moreover, active fire suppression and, in some cases, improper livestock grazing in Wyoming have contributed to denser, more monotypic stands of sagebrush, reduction of herbaceous understories, and simplification of community diversity (Bennett 1999). Sagebrush has both a lateral and tap root system which makes it very efficient at water/nutrient uptake. Thus, as stands become more dense or during times of stress, sagebrush easily dominates over herbaceous species.

Prescribed fire can be an appropriate wildlife habitat management tool. If prescribed fires are designed with the habitat needs of the endemic wildlife species in mind, they can improve and enhance landscape diversity. Mosaics of habitat can be created to increase the amount of habitat edge within sagebrush communities and between other community types. This edge is favored by some wildlife species (edge effect). It has been found that the more edge per unit area the greater the overall species diversity and abundance of wildlife (a principle referred to as the Law of Interspersion) (Shaw 1985). This principle suggests more edge benefits species with limited mobility and varied habitat requirements. Conversely, some species need large expanses of sagebrush habitat for many of their life requirements (e.g. sage-grouse and Brewer's sparrow). There is some optimum, or compromise, between the amount of edge and the size of the homogenous blocks or units of the various habitat types in the landscape (*vis-a-vis*, the common comparison of holstein vs. dalmation [size and pattern] landscape blocks). Within limits, species diversity tends to increase with edge, and prescribed fire can be a tool for creating this edge and diversity. Vertical structure (height of the sagebrush) is a very important component of wildlife habitat regardless of the seral stage. Generally, taller sagebrush is found in mid to late seral stage sagebrush communities.

Over the past 22 years (January 1980 – July 2002), Bureau of Land Management (BLM) reported almost 330,000 acres of wildfires in non-forested lands in Wyoming (U.S. Department of Interior [USDI] - BLM 2002). Most of these fires occurred in sagebrush communities, although this number includes other shrub communities. Many of these fires have burned large solid blocks, which may have been detrimental to maintaining healthy reproducing sagebrush communities.

The lack of sagebrush seed source in these sites results in long periods without sagebrush recovery, especially in the drier Wyoming sagebrush sites. Wyoming BLM fuels management projects, which are primarily prescribed fires, have treated almost 184,000 acres in non-forested areas between 1985 and July 2002, averaging 10, 819 acres/year (USDI - BLM 2002). Again, the total number of acres includes other shrub communities.

The increase in size and intensity of wildfires has been caused by a variety of reasons. Many of the low precipitation zones with infestations of cheatgrass (*Bromus tectorum*) and Japanese brome (*B. japonicus*) in the sagebrush stand provide continuous fine fuels for fire spread and burn intensity. During the past several decades, there has also been a concerted effort in some areas of the state to improve the herbaceous bunchgrass understory within sagebrush communities with a grazing system. This improvement has increased fine fuels. Changes in the season of livestock use from spring and early summer to fall and winter grazing in low elevation sagebrush zones has in some places increased biomass of herbaceous understory species. This has resulted in more fuel available during the summer lightning period. This increases the potential for large intense wildfires that can negatively affect sagebrush systems, especially during extended drought periods.

Invasive Species (Native and Non-Native)

Juniper / Conifer Encroachment:

Relict juniper woodlands are primarily confined to rocky slopes or ridges with sparse understory vegetation (West 1984). However, expansion has occurred on the more productive sagebrush sites with deep well drained soils (Wright and Bailey 1982). Young (1984) documented Western juniper (*J. occidentalis*) density doubling every three years in the early stages of development on a susceptible Wyoming big sagebrush site. Barney and Frischknect (1974) reported that the majority of shrubs were dead in dense Utah juniper (J. *osteosperma*) woodland. There is a significant negative relationship of juniper and shrub canopy, sagebrush being the most sensitive (Miller et al. 2000).

Since the 1880s, juniper has increased in density and distribution in many areas of Wyoming. Juniper (*Juniperus* spp.) and other conifer species have expanded into Wyoming big sagebrush, mountain big sagebrush, low sagebrush (*A. arbuscula*), quaking aspen (*Populus tremuloides*), and riparian communities reducing the diversity of grasses and forbs in these habitats. Increased livestock grazing in the late 1800s and early 1900s contributed to a reduction in fuels that could carry fire, thereby reducing fire frequency (Eddleman 1986). Fire suppression policies have generally lengthened fire-return intervals in juniper-dominated areas. Juniper and pinyon pine (*P. edulis*) woodlands have been dynamic over the past 10,000 years but increases in the past 120 years are unprecedented (Miller and Wigand 1994).

Non-Native Species Invasion:

Noxious weeds are not a new problem, but they are a rapidly growing problem. It has been estimated non-native invasive plants (weeds) are overtaking many wildland areas at the rate of about 4,600 acres a day, on BLM-administered Public Lands alone (USDI-BLM 2000a and 2000b). While cheatgrass proliferation has been widespread, increases in other exotic species such as Japanese brome and knapweed (*Centaurea* spp.) are also adversely impacting sagebrush-steppe habitat (Quigley and Arbelbide 1997). The increased fire frequency in areas with cheatgrass affects the ability of sagebrush to reestablish between fire events. The rapid rate of expansion is partly attributable to the life history of exotic plants. Exotic plants are often opportunists, and many are pioneer, colonizing species. If present, they quickly increase to establish and colonize areas that have experienced soil-surface disturbance or areas that lack plant cover. Their establishment and spread are aided by disturbance to the soil surface (Bazzaz 1986). Spotted knapweed (*C. maculosa*) and leafy spurge (*Euphorbia esula*) have exhibited the ability to invade relatively undisturbed sites, including wilderness areas (Tyser and Key 1988).

Construction activities from mines, wells, roads and other surface disturbance activities provide avenues for the establishment of non-native plants that degrade sagebrush ecosystems. Again, reclamation practices that do not include native species can be detrimental to sagebrush ecosystem integrity and functionality (Monsen 2001).

Cumulative Effects

Evidence is increasing that the most devastating environmental effects may result not from the direct effects of a particular action, but from the combination of individually relatively minor effects of multiple actions over time (Council on Environmental Quality 1997). Human environments continue to change in unintended and unwanted ways that are largely attributable to incremental (e.g., cumulative) impacts in spite of new and improved decision-making processes. An example in Wyoming is the increasing number of access routes to private homes and developments that is not always desirable from a natural resource management standpoint. Sometimes these roads start as 2-track trails that become expanded by increased traffic. Some forms of development (e.g., oil and gas) inherently have multiple roads and other disturbances.

Cumulative impacts can also occur with multiple vegetation treatments and disturbances. This makes it imperative that resource managers track the accumulation and the juxtaposition of multiple treatments and disturbances over time.

MANAGEMENT PROCESSES

Collaborative Planning and Implementation

The information herein focuses on the vegetation resource as it relates to watershed functions and wildlife habitat needs. This document addresses the vegetation resource holistically on the landscape level. The information presented here is the foundation of a multi-tiered process to plan projects in sagebrush ecosystems.

Each wildlife species has different ecological requirements, and there has been no attempt to customize these guidelines to fit the needs of any individual species found in the sagebrush ecosystem. Additional evaluation tiers for specific species of concern (e.g., sage-grouse, mule deer (*Odocoileus hemionus*), pronghorn, etc.) may have to overlay these guidelines when evaluating any given project proposal.

Decisions about whether to treat an area of sagebrush or not and with what method (Appendix B) should begin with an assessment. Then, treatment prescriptions must be carefully designed and tailored to the species, subspecies and varieties of sagebrush targeted. Factors such as climate and post treatment management will determine rate and degree of recovery. Decision elements include:

- evaluate the juxtaposition, extent, importance and value of this sagebrush patch in the landscape (is this the only patch of sagebrush in the landscape?),
- identify the sagebrush species/subspecies/variety,
- understand the sagebrush species ecology and fire effects,
- determine the associated vegetation composition and condition (e.g. composition of desirable and non-desirable species and their response to fire) and their effects on wildlife habitat,
- site potential and resilience of the site to recover,
- assess the existence of other potential site influences (e.g., current grazing use, presence of noxious/exotic plant infestations, cumulative impacts, etc.),
- evaluate past management history of the site,
- establish post-treatment vegetation management objectives tiered to the future management plan, and
- create a baseline for short-term/long-term post-treatment monitoring of the site.

In conducting project analyses, managers should routinely address the direct and (to a lesser extent) indirect effects of a proposed action on the environment. Analyzing cumulative effects is more challenging, primarily because of the difficulty of defining the geographic (spatial) and time (temporal) boundaries. For example, if the boundaries are defined too broadly, the analysis becomes unwieldy; if they are defined too narrowly, significant issues may be missed, and decision-makers will be incompletely informed about the consequences of their actions. Considering cumulative effects is also essential to developing appropriate mitigation and monitoring its effectiveness. A process and considerations of cumulative impact analysis can be found in the Council on Environmental Quality guidelines (1997).

This site evaluation should be done with input and planning from managers and biologists with sagebrush ecosystem management expertise, as well as those making future use of the area. This coordination is absolutely essential at the local level if future problems are to be avoided.

Sagebrush Ecosystem Restoration/Maintenance

Seeding

For a sagebrush community to reproduce and thrive there must be viable seeds present and a bare soil substrate. Sagebrush seed viability starts to decrease after the first year. In large complete burns in mountain big sagebrush where seed source is from soil seed pools, establishment primarily occurs in the first two years, dropping off in year three, to near zero in year four, until young plants begin producing seeds. Good establishment occurs in wet to slightly below average years. However, when years are very dry following a fire, little establishment occurs (Miller pers. comm. 2002). Most shrubby sagebrush germinate and grow a month earlier than most herbaceous species in a cool, wet climate. There must be good winter/spring moisture with a heavy seed crop produced the previous fall to establish the seedlings. Therefore, most sagebrush stands tend to be even aged due to the lack of favorable growth conditions in many seasons. In drier sites, sagebrush only thrive where snowfall accumulates on loamy or sandy-loam soils. Therefore, it is a challenge to restore lower precipitation Wyoming big sagebrush communities after extensive wildfires or other treatments that do not leave adequate seed sources. These Wyoming sagebrush sites may be grass/forb dominated for long periods (30 to 60 years) afterwards. Maximum seed dispersal distances are only 30 meters from the parent plant and 85-90% of all seeds fall within 1 meter of the edge of the sagebrush canopy (Young and Evans 1989, Wagstaff and Welch 1990). If the area lacks a nearby sagebrush seed source, it is critical that sagebrush seeds be applied back on the sites the first fall or winter after the disturbance, and to take advantage of winter/spring moisture to germinate. If sagebrush does not become established within the timeframe of the plan objectives, site restoration may require tublings or seedings of sagebrush, or additional soil disturbance. Some severe situations may require chemical treatment with follow-up reseeding to reestablish a native plant community. However, intentional seeding can also delay full site recovery, so care must be taken with seeding programs.

Some soil microbiologists believe loss of mycorrhizae fungi affects reestablishment of some species. This loss generally occurs on high severity burned forested sites. Little is known about the ecology of mycorrhizae in rangeland sites.

Grazing

Livestock grazing is the most widespread human-mediated influence on grassland vegetation in the American West (Fleischner 1994). Crawford et al. (1992) found that domestic livestock grazing potentially has the greatest impact on sage-grouse habitat because it remains the most common and widespread use of rangelands and is the principal land management practice that affects herbaceous composition, cover, and height. Livestock grazing also affects sagebrush density, canopy cover, and reinvasion rates (Goodrich et al. 1999, Bennett 1992).

"Prescribed fire should not be a substitute for good range management. A problem rooted in inappropriate range management practices may not be corrected by vegetation treatment. In these instances management should be altered prior to application of fire. If livestock have premature access to the burn area, the full benefits of the prescribed fires may not be realized and negative impacts may occur unless management of the livestock is included in the plan" (Bunting et al. 1987). The amount of nonuse necessary after a fire varies considerably with the vegetal composition, site conditions, and objectives of the burn (Bunting et al. 1987).

The initial concern following burning is the restoration of plant vigor and seed production. Generally, at least two growing seasons rest is recommended (Pase and Granfelt 1977, Wright et al. 1979, Blaisdell et al. 1982). Grazing in the early growing season immediately following burning may accelerate sagebrush reestablishment. This is particularly true when areas with dense sagebrush and low production of grasses are burned (Laycock 1979, Smith et al. 1985). "It has become increasingly apparent that former utilization standards are often several times more than can be tolerated continuously, and that reduction in livestock numbers is often necessary to correct unsatisfactory conditions" (Blaisdell et al.1982). Holechek (1988) researched and published utilization guides that recommend average degree of use of the key species to vary from 20 to 50% with the upper levels only on good condition ranges or for dormant season grazing. Heavy grazing without adequate growing season recovery invariably leads to gradual loss in forage productivity and vigor.

Post-treatment management of livestock and wild ungulate grazing, both short and long-term, is essential for long-term maintenance of desired sagebrush canopy cover and herbaceous understory. There is no point in expending resources on prescribed fire projects without a commitment to long-term livestock and wild ungulate grazing management. In regard to animal use in prescribed burn areas, determination of the desired plant community (DPC) objectives is necessary before the grazing strategy can be decided. Some sagebrush sites targeted for treatment are in poor ecological condition with heavy shrub canopy and a poor understory of perennial grasses and forbs. These sites usually require a long time period post-treatment to progress through successional changes to meet land use objectives. Many of the lower precipitation Wyoming big sagebrush sites have non-native, invasive species in the shrub understory. These invaders include species such as cheatgrass, Japanese brome, and other noxious weeds, which can create many ecological impacts. These plants can be released and spread with burning treatment or improper grazing. It is essential these sites are allowed full opportunity to recover before and after fire or other treatments. Deferment for two growing season is generally necessary before desirable plants species can sustain much utilization. BLM emergency fire rehabilitation guideline calls for a minimum of two growing seasons of rest following prescribed fire (USDI - BLM 1999).

The follow-up grazing strategy must be designed to maintain a healthy, perennial plant cover. The challenge to maintain a healthy diverse sagebrush community lies in the proper balance of grazing pressure between grasses, forbs, and shrub vegetation components by season, and the ability to allow adequate recovery periods. Continual heavy fall/winter use by browsers will push the site towards a grass/forb community and heavy spring/summer use by herbivores will usually move the site toward a shrub/tree dominated community. The continual heavy spring grazing can also increase the dominance of annuals, or noxious weeds. Light utilization levels are critical in maintaining upland meadows and riparian communities within the sagebrush system. Heavy to severe use will cause these sites to dry out, and promote sagebrush invasion. For a detailed discussion, see the Fire Effects Guide (National Wildfire Coordinating Group 1994).

Vacant domestic livestock allotments, or those with significant non-use, should not be immediately restocked following prescribed burning. An analysis of watershed and range conditions, livestock management problems, and wildlife grazing conflicts and opportunities should be completed and incorporated into revised allotment management plans prior to restocking. Some vacant/non-use allotments should be maintained as relief, or rest pastures, during drought conditions for other active allotments. These allotments can serve as critical, short term alternative grazing allotments where livestock can be moved to accommodate habitat enhancements, including rest, in occupied allotments. Landscape scale habitat enhancements simply will not be possible without providing alternative grazing sites for permittees. Moreover, long-term, follow-up grazing management will be critical to meet and maintain sagebrush community vegetation objectives into the future.

Drought

Drought can delay full site recovery. Thus, low precipitation sites require longer recovery periods and lighter utilization than more favorable sites. The need exists to make appropriate grazing adjustments during drought conditions.

Wildfire

Following are some suggestions for wildfire management planning.

- Manage for areas of fine fuels using prescribed fire, chemical, biological or mechanical methods in sagebrush communities to reduce the potential of catastrophic wildfires.
- Develop detailed resource management guidelines to direct fire suppression efforts, especially size and control methods. (An example would be to leave jagged edges and leave unburned islands of sagebrush within the wildfire boundaries.)
- Reduce the dominance of invasive and noxious species (e.g. cheatgrass, Russian knapweed (*C. repens*), etc…) by improved livestock management, treatment with spring prescribed burns, chemical and biological control, and reseeding.
- Evaluate wildfires (greater than 100 acres) without islands of sagebrush for possible sagebrush seeding or planting to accelerate sagebrush recovery.

Juniper/Conifer Encroachment

While restoration of juniper dominated woodlands may be beneficial to some wildlife species, without fire or other control actions, juniper or other conifers may sometimes encroach and dominate sites with deep, well-drained, soils where productive stands of sagebrush occur. In these circumstances, the juniper out competes, and ultimately eliminates, sagebrush and desirable herbaceous species (Miller et al. 2000). It may be necessary to periodically prescribe burn some sites, or provide other vegetative treatments, and to follow these treatments with appropriate sagebrush seeding, and possibly grazing to hold down the herbaceous vegetation and provide a competitive advantage to sagebrush. However, care must be taken so post-treatment of these sites does not allow invasion by undesirable, annual grasses and other noxious weeds. If post-treatment management is not conducted properly, native plant recovery could be negatively impacted and re-establishment of juniper woodlands could occur on the site.

Weeds

Land managers must take into account the significant impact weeds can have on the landscape and the economy. Weed infestations can be very difficult and costly to control. Effective weed control generally takes years and multiple treatment applications. Impacts of weeds and control measures can significantly affect ecological processes within sagebrush ecosystems.

Following are some suggestions for addressing weeds in the context of managing fire:

- When developing a prescribed fire plan, consider and identify what, if any, existing noxious weed infestations that occur within the proposed prescription area. Weed awareness and identification training should be given to all personnel involved in fire.
- After identifying any existing weed situations, prepare a post-fire weed control plan. This is when weeds should be treated, when new infestations are still small.
- Equipment used at the fire site should avoid, wherever possible, driving or working through patches of noxious weeds. Following use on the fire, engines and other equipment should be washed to remove weed seeds before moving out to another area.
- After the fire is out, a map of the burned area should be developed quickly, so monitoring of new weed infestations can be initiated. Monitor the burn area for new weed infestations for a minimum of 2-3 years after the burn. If the burn is in a remote area, consider using aircraft to monitor the site.
- Particularly in the case of wildfire, rehabilitation can be a very critical step in the recovery process. Emphasis should be placed on the use of native species in the rehabilitation reseeding mixes.
- Carefully evaluate what biological, mechanical, or chemical weed control methods should be used if weed infestations arise.

Monitoring

Prescribed fire treatments need measurable objectives for post-treatment vegetative composition and condition. This requires a commitment for long-term monitoring to determine project success or failure and to fine-tune future treatments. Prescribed fire treatments without monitoring and follow-up management are recipes for failure. See Appendix E for an appropriate monitoring example.

Monitoring is necessary to evaluate treatment results relative to objectives. In many cases it is required for federal agencies through the National Environmental Policy Act. (NEPA) Documenting spatial and temporal aspects of treatments as well as site-specific effects is critical to understanding and implementing a multi-agency prescribed fire program in Wyoming. Moreover, consistency of monitoring protocol facilitates comparison and sharing of project files.

Burn plans should include a monitoring plan, which addresses project objectives and pertinent monitoring activities. If project objectives dictate that additional data collection is needed, the plan will address these also.

Minimum Monitoring Requirements are as follows:
1. Map(s) of burn unit showing and describing plant community or habitat types
2. Measurable and quantifiable monitoring objectives tiered from management objectives
3. Geographic Positioning System (GPS) locations and descriptions of monitoring plots and/or photopoints
4. Monitoring methods used, including a monitoring schedule

A monitoring plan template and example is included in Appendix E.

Setting Objectives

Measurable project objectives are crucial to project monitoring and are often used to evaluate project effectiveness. Table 1 illustrates measurable objectives.

Table 1. Components of a measurable monitoring objective.

Component	Example
1. Target population	Native bunch grasses
2. Time frame	Two years post burn
3. Direction and amount of change / trend *-or-* Target/threshold condition	Increase by 40-60% *-or-* At least 40% cover
4. Variable to be measured	% cover
5. Location	Pup Creek
6. Statistical confidence level	80%
Measurable Objective Example: "Increase the % cover of native bunch grasses in Pup Creek by 40-60% (or "to at least 40%") two years post burn with 80% confidence level."	

Objectives and monitoring plans need to be identified during the planning stages to allow for pre-treatment monitoring and the establishment of controls, where applicable. Statistical accuracy, which will affect monitoring effort, should be clearly defined. The choices of sampling methods will be guided by agency protocols and regional staff recommendations; however, customary, peer-reviewed and/or published methods are required. Consideration should also be given to available resources.

Data Storage and Access

An original project file will be maintained for each burn project at the responsible agency field office. Fire effects information will be stored with the NEPA documentation, funding proposals, etc. Additional copies will be filed with cooperating agencies. Appendix E provides an example of a basic monitoring plan.

PROMINENT SAGEBRUSH SPECIES AND MANAGEMENT GUIDELINES

Wyoming Big Sagebrush (*Artemisia tridentata* ssp. *wyomingensis*)

Wyoming big sagebrush community types occupy the more arid sites in the western United States and accounts for the largest area of the big sagebrush cover types (Tisdale 1994). In Wyoming it normally achieves heights of 1 to 3 feet and is common across the Wyoming Basin and east of the Continental Divide as far as the Black Hills on dry soils at elevations of 5,000 to 7,000 feet (Beetle and Johnson 1982). Wyoming big sagebrush is wide spread in Wyoming and commonly occurs from foothills to basins and valley bottoms (Dorn 1988). Soil parent material is highly variable in texture and pH (Tweit and Houston 1980; Johnston 1987). Wyoming big sagebrush tends to grow on shallower, well-drained, and xeric soils when compared to mountain and basin big sagebrush (Barker and McKell 1983). In Wyoming, a considerable amount of Wyoming big sagebrush occurs in the 5-9 inch and the 10-14 inch precipitation zones. Accumulation of snow enhances these communities in lower precipitation zones (Knight 1994). When Wyoming big sagebrush occurs with black, longleaf (*A. longiloba*), and threetip sagebrush communities, it often occupies the relatively deeper soils (Tweit and Houston 1980).

Wyoming big sagebrush is a long-lived species, exceeding 150 years in undisturbed settings (Ferguson 1964). Plants averaged 42 years (range 26-57) at an undisturbed site in southcentral Wyoming (Sturges 1977). Winward (2001) reported that Wyoming big sagebrush communities with a preponderance of sagebrush plants reaching about 60 years of age have outlived their prime and are in a declining condition.

Wyoming big sagebrush is a mid- to late-seral species requiring a decade or more for establishment after a stand-replacing fire (Sturges 1994). Grasses usually dominate the site prior to re-establishment. Site re-establishment is by seedbank, seed production from remnant plants, and seeds from adjacent (untreated) plants. Discontinuity of fuels in Wyoming big sagebrush usually results in mosaic burn patterns, leaving remnant plants for seed (Bushey 1987). Fire does not stimulate germination of soil-stored Wyoming big sagebrush seed, but neither does it inhibit its germination (Champlin and Winward 1982).

Fire intervals in Wyoming big sagebrush appear to have ranged from 10-110 years or more, and recovery to 20% canopy cover from a burn may take more than 40 years (Young and Evans 1981, Winward 1991). Bunting et al. (1987) found that the average recovery time following fire in Wyoming big sagebrush communities was 30 years. The maximum canopy cover that can be expected for Wyoming big sagebrush in the 8+-inch precipitation zone is normally 25-30%. Even in areas with little or no grazing or browsing use by large herbivores, researchers who have studied long-term grazing exclosures or relict areas report cover values between 10 and 15% sagebrush canopy cover in Wyoming big sagebrush communities (Blaisdell 1953, Pearson 1965, Tisdale et al. 1969, Harness and Murray 1973, Tueller 1973, Tueller and Blackburn 1974, Passey et al.1982, Holechek and Stephenson 1983, Sneva et al. 1984, Eckert and Spencer 1987, Rickard and Sauer 1988, Rose et al. 1994). At canopy coverage of 12-15%, competition begins to decrease the understory herbaceous component (Tueller and Blackburn 1974, Winward 1991, Goodrich et al. 1999). Goodrich (1999) estimates a 3.8% decrease in understory herbaceous production for every 1% increase in Wyoming big sagebrush canopy cover over 15%. Goodrich et al. (1999) and Rittenhouse and Sneva (1976) recommend the following desired conditions for ecological functions: 5-15% canopy cover, > 50% ground cover, 4-12 forb species present in a 100 ft. radius plot. These figures would probably represent a mid-point and would locally be variable due primarily to precipitation and soil type with potentially lower ground cover values and productivity on the drier end of the precipitation range. Examples of Wyoming big sagebrush canopy cover are depicted in Figure 1.

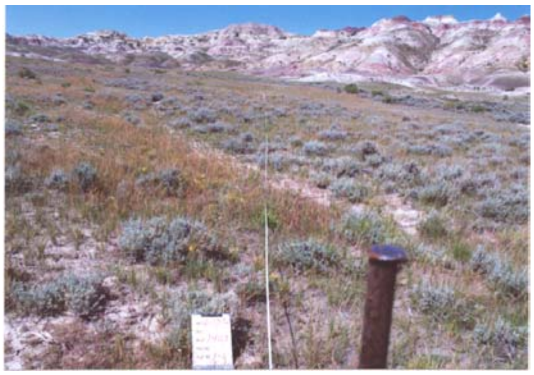

Figure 1a. Example of *Ar.tr.wy.* with 6% live sagebrush canopy cover.

Figure 1b. Example of *Ar.tr.wy.* with 19% live sagebrush canopy cover.

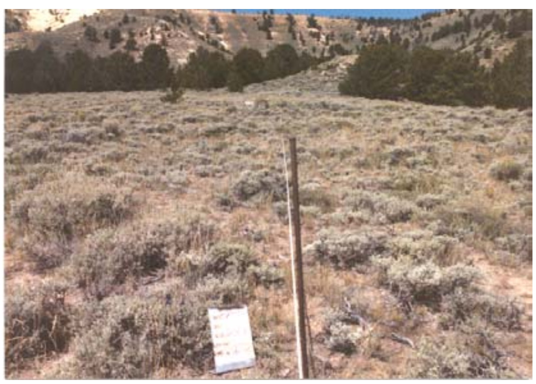

Figure 1c. Example of *Ar.tr.wy.* with 23% live sagebrush canopy cover.

Figure 1d. Example of *Ar.tr.wy.* with 37% live sagebrush canopy cover.

Figure 1. Examples of Wyoming big sagebrush canopy cover.

Heath et al. (1997) recommended maintaining average residual grass height between 10-15 cm for potential Wyoming big sagebrush sage-grouse nesting habitat in Wyoming. Forbs generally play a lesser role in community dynamics of Wyoming big sagebrush. These communities are often important as winter range for pronghorn, sage-grouse, and mule deer.

Treatment Recommendations for Wyoming Big Sagebrush:

From a landscape or burn unit perspective, a portion of the terrain historically did not carry fire well; and fire events were infrequent to rare. Examples are windswept ridge tops and sites having shallow soils where fine fuel production is limited. Such sites need to be identified during the pre-burn inventory and removed from the potentially treatable portion of the burn unit. These areas may total 10–40% (25% average) of the burn unit.

In Figure 2, less than 75% of the landscape has the potential for treatment. Approximately 10% of the treatable area should be maintained in an earlier seral stage with 0-5% sagebrush canopy cover. Twenty-five percent should be maintained in a mid-seral stage with 5- 15 % sagebrush canopy cover. Areas should not be retreated until sagebrush canopy is >15% or vascular plant species diversity objectives are not being met. The remaining 40% of the landscape should be maintained in a later seral stage with sagebrush canopy >15%.

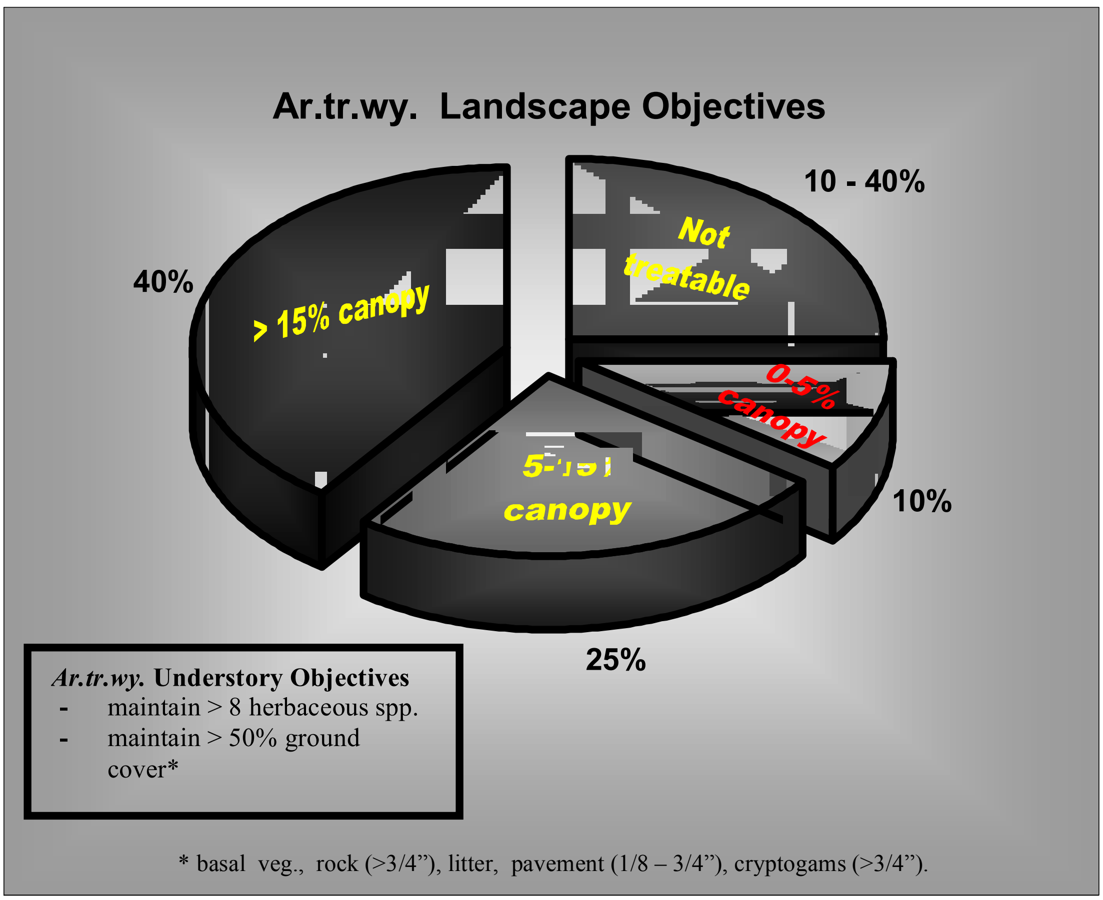

Figure 2. Landscape objectives for Wyoming big sagebrush.

The above mix of seral stages should be maintained in a temporal and spatial mosaic (not depicted in this example). Vertical structure of the sagebrush community, regardless of seral stage, should be considered for those wildlife species of importance in the project area. The size, design and positioning of treatments, as well as the analysis area itself, should be derived by consensus of local resource experts. Consideration should be given to species of special interest and management needs. For example, burns conducted within important sage-grouse nesting habitat should ideally be of a finer scale mosaic (mean width of <120 meters) and well dispersed so as to create a patchwork of burned and unburned areas.

The landscape objectives in Figure 2 represent mid-point recommendations based on ecosystem management principles for Wyoming from the information cited in the section above. As noted previously ecosystems are inherently variable and these figures may need to be adjusted for local conditions, especially on the differences in precipitation, soil types and current community health and condition. Use caution when treating dry sites of Wyoming big sagebrush since recovery can take much longer than in moist sites. Reestablishment of Wyoming big sagebrush will be more successful following a good seed production year (Bunting et al. 1987).

Vasey Big Sagebrush *(Artemisia tridentata* ssp. *vaseyana* var. *vaseyana)* and Mountain Big Sagebrush *(Artemisia tridentata* ssp. *vaseyana* var. *pauciflora)*

Mountain and Vasey big sagebrush generally occur on foothills, ridges, slopes and valleys in the upper elevational range of big sagebrush (Appendix C, Beetle and Johnson 1982). Vasey big sagebrush has been documented at elevations of 9,600 ft. in Wyoming (Tart 1996). Mountain big sagebrush has been reported as low as 2,600 ft. in Idaho. Moderately deep and well-drained soils are typical of occupied sites (Beetle 1961). Both varieties grow well in full sunlight but also tolerate shade and often occur in association with conifers and aspen. (Noste and Bushey 1987, Tart 1996). Because the two species are so similar, we are combining them into *Ar.tr.va* for the rest of this discussion.

Major species associated with *Ar.tr.va.* are bluebunch wheatgrass (*Elymus spicatus*), antelope bitterbrush (*Purshia tridentata*), Idaho fescue, arrowleaf balsamroot (*Balsamorhiza sagittata*), snowberry (*Symphoricarpos* spp.), Oregon-grape (*Mahonia repens*), slender wheatgrass (*Elymus trachycaulus),* shrubby cinquefoil (*Potentilla gracilis*), sticky geranium (*Geranium viscosissimum*), and spike trisetum (*Trisetum spicatum*) (Tart 1996).

In Wyoming, *Ar.tr.va.* often forms extensive stands at elevations of 7,000 to 9,500 feet occupying well watered swales and pockets of deeper soils at lower elevations (Beetle and Johnson 1982). Beetle and Johnson (1982) indicated mountain big sagebrush self-replaces post burn. Rapid growing seedlings reach reproductive maturity at 3 to 5 years (Bunting et al. 1987).

Ar.tr.va. had a natural fire frequency of 10-30 years and usually returns to preburn density and canopy cover in 15-20 years. (Bunting et al. 1987, Champlin and Winward 1982, Hironaka et al. 1983, Miller et al. 2000). In drier mountain big sagebrush sites, mean fire return interval was longer and varied depending on topography, frequency of ignition, fuels, flammability of neighboring communities, and climate (Miller pers. comm. 2002). Burkhardt and Tisdale (1976) indicated fire return intervals of three to five per century prior to 1910. *Ar.tr.va* is easily killed by fire and post-fire establishment is from seed.

Ar. tr .va. canopy cover ranges from 14-41% with most stands in western Wyoming falling in the 22-29%, and many in the 30-35% (Winward 1991, Tart 1996). The number of herbaceous species in the understory in western Wyoming ranged from 11-39, with a mean of 27 (Tart 1996). Density, cover and biomass of herbaceous species can be reduced when *Ar. tr .va.* cover exceeds 20% for a long period of time. Hironaka et al. (1983) suggested a 10-20 year cycle of sagebrush manipulation in Idaho if the objective is to maintain optimum amounts of forbs and grasses. Recovery rate on mountain big sagebrush burns are highly variable (15 –50 years) with recovery rate in patchy burns being more rapid (Miller pers. comm. 2002). Examples of Vasey and mountain big sagebrush canopy cover are depicted in Figure 3.

Figure 3a. Example of Vasey big sagebrush community with 3-5% sagebrush canopy cover and understory lacking herbaceous diversity and residual cover.


Figure 3b. Example of mountain big sagebrush community with 12% live sagebrush canopy cover.

Figure 3c. Example of Vasey big sagebrush with 21% sagebrush canopy cover and understory lacking herbaceous diversity and residual cover.


Figure 3d. Example of mixed mountain big sagebrush and *Purshia tridentata* community with 51% live shrub canopy cover.

Figure 3. Examples of Vasey and mountain big sagebrush canopy cover.

Treatment Recommendations for Vasey and Mountain Big Sagebrush:

Vasey big sagebrush and mountain big sagebrush are the types of sage most frequently targeted for treatment. Moreover, they are quite palatable and provide valuable habitat for large ungulates, sage-grouse and a myriad of other fauna species.

From a landscape or burn unit perspective, a portion of the terrain historically did not carry fire well. However, fires were more frequent in Vasey than in Wyoming big sagebrush. Examples of areas that didn't burn are windswept ridge tops and sites having shallow soils where fine fuel production is limited. Such sites need to be identified during the pre-burn inventory and removed from the potentially treatable portion of the burn unit. These areas may total 25% of the burn unit.

Figure 4 illustrates a landscape objective for Vasey big sagebrush. Seventy five percent of the landscape has the potential for treatment. Approximately 10% of the treatable area should be maintained in an earlier seral stage with 0-5% sagebrush canopy cover. Twenty-five percent should be maintained in a mid-seral stage with 5-20% sagebrush canopy cover. Areas should not be retreated until sagebrush canopy is >20% or vascular plant species diversity objectives are not being met. The remaining 40% of the landscape should be maintained in a later seral stage with sagebrush canopy >20%.

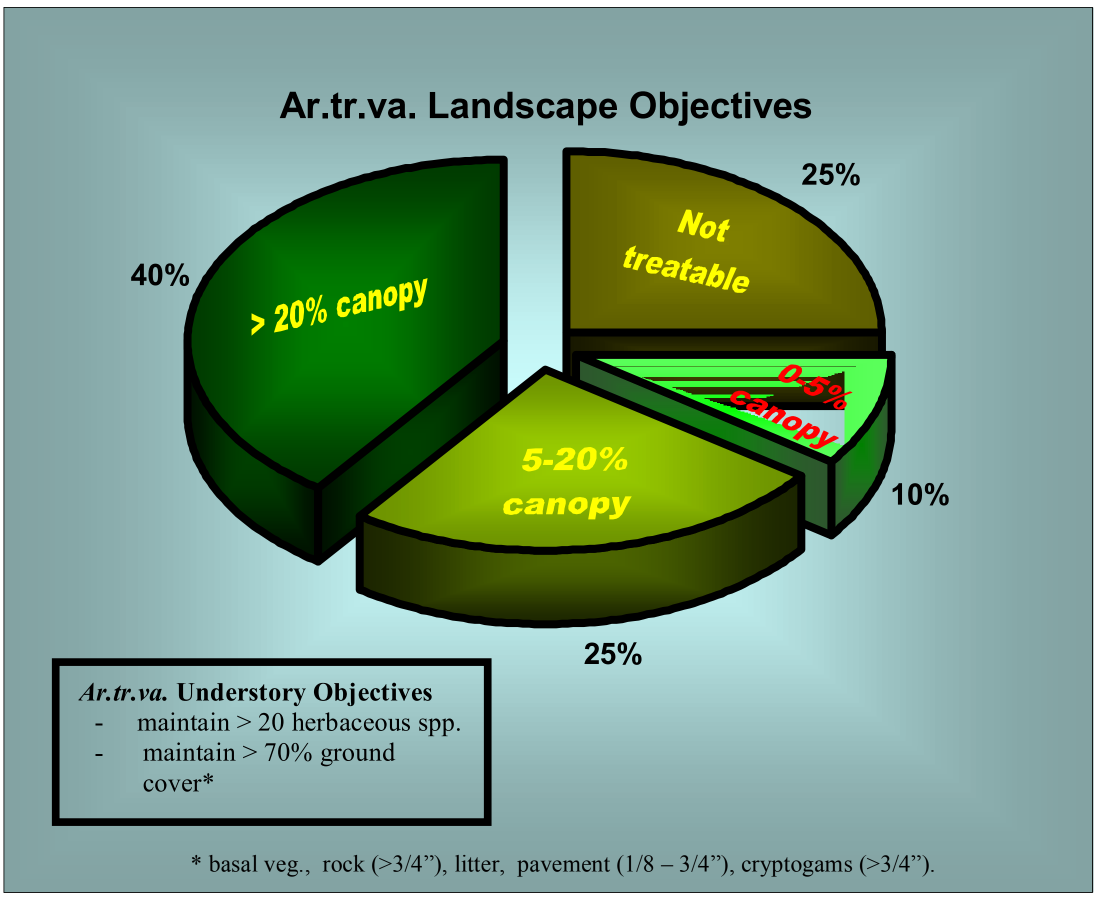

Figure 4. Landscape objectives for Vasey and mountain big sagebrush.

The above mix of seral conditions should be maintained in a temporal and spatial mosaic (not depicted in this example). Vertical structure of the sagebrush community, regardless of seral stage, should be considered for those wildlife species of importance in the project area. The size, design and positioning of treatments, as well as the analysis area itself, should be derived by consensus of local resource experts. Consideration should be given to species of special interest and management needs. For example, burns conducted within important sage-grouse nesting habitat should be of a finer scale mosaic (mean width of <120 meters) and well dispersed so as to create a patchwork of burned and unburned areas.

Basin Big Sagebrush *(Artemisia tridentata* ssp. *tridentata)*

Basin big sagebrush tends to grow in deep, fertile soils, and is an indicator of productive sites (Appendix C). Many sites once dominated by basin big sagebrush are now farmlands where it is restricted to field edges, swales, and along drainage ways (Collins 1984). Outside farmlands it is also associated with deep, seasonally dry, well-drained soils on plains, valleys, and foothills (Beardall and Sylvester 1976). Basin big sagebrush commonly grows in association with cheatgrass, bluebunch wheatgrass, Thurber needlegrass (*Achnatherum thurberianum*), needle-and-thread grass (*Hesperostipa comata*), Idaho fescue, and Sandberg bluegrass (*Poa secunda*) (Hodgkinson 1989).

A wide variation in fire frequency is expected with this subspecies. Sapsis (1990) suggests that fire return intervals in basin big sagebrush are intermediate between mountain big sagebrush and Wyoming big sagebrush (15–70 yrs). Repeat fires within short intervals have removed this species from extensive areas (Bunting 1990).

Fires in basin big sagebrush communities, although variable in severity, are typically stand replacing with most plants killed, and resprouting does not occur (Sapsis and Kauffman 1991). Scattered unburned basin big sagebrush may survive, particularly where the soil is thin and rocky and where low herbaceous biomass limits the fire's spread (Bushey 1987). Basin big sagebrush reinvades a site primarily by off-site seed or seed from plants that survive in unburned patches.

Plants 2 to 3 years of age are capable of producing viable seed and approximately 90% of basin big sagebrush seed is dispersed within 30 feet of the parent plant (Goodrich et al. 1985). Seed production occurs from October to December with most seeds being shed throughout the fall and some seeds remaining on plants throughout the winter. Seeds germinate in the spring as early as April. Seed of basin big sagebrush is short-lived and lasts less than five years when stored in a warehouse (Mueggler 1956). Prolific seed production from nearby live plants and high germination rates enable seedlings to establish post fire (Johnson and Payne 1968). The vast majority of basin big sagebrush seed produced during fall does not persist. Seedling survival is greatest under mature sagebrush plants and is lower in unsheltered areas (Owens and Norton 1992).

The rate of stand recovery depends on the season of burn, which affects the availability of seed, postfire precipitation patterns, and the amount of interference offered by other regenerating plant species (Daubenmire 1975). Seedling establishment may begin immediately following a disturbance, but it usually takes a decade or more before basin big sagebrush dominates the site. In Wyoming, where basin big sagebrush has been removed by chemical means, it regained its pretreatment cover in 17 years on stands where grazing was not controlled (Johnson 1969).

Mycorrhizal associations may also affect stand recovery. The presence of *Glomus* spp. fungi may be required for the successful establishment of seedlings. Areas that lose their basin big sagebrush cover due to frequent fire and are dominated subsequently by nonmycorrhizal cheatgrass may no longer have the fungi in the soil. Basin big sagebrush reestablishment may be inhibited on these sites (Rosentreter and Jorgenson 1986).

Palatability is low for most ungulates (McArthur et al. 1977, Sheehy and Winward 1981). However, during severe winters it may function as an emergency food. Its greatest value appears to be that of providing structural diversity and cover for a variety of wildlife species.

In summary, basin big sagebrush acreage has been significantly reduced throughout the west due to its association with deep fertile soils that have been converted to farmland. A very low percentage of its historic acreage remains today. It does not resprout postburn, and stand recovery may take 10-20 years (Young and Evans 1981). Cheatgrass is more likely to invade after fire if the dominant native grass is not a fire-resistant species or if native grasses were in poor condition prior to fire (West and Hassan 1985).

Treatment Recommendations for Basin Big Sagebrush:

Basin big sagebrush should not generally be targeted as a high priority for treatment. The reduction in historic distribution and the potential for cheatgrass or other invasive species need to be considered prior to treatment.

Where it is not limited in extent and the understory appears to be limited in production or diversity, treatments can be warranted. If treatments are to be implemented a very low percentage (5-15%) of the existing community should be treated with the ultimate objective to restore a healthy basin big sagebrush community. Treatments within this type should generally follow the guidelines provided for *Ar.tr.wy.*

Silver Sagebrush *(Artemisia cana)*

Two subspecies of silver sagebrush are present in Wyoming: plains silver sagebrush *(Artemisia cana* ssp. *cana)* and mountain silver sagebrush *(Artemisia cana* ssp. *viscidula*). The silver sagebrush subspecies usually occur in mixed stands with other sagebrush species. Their general distributions within Wyoming are depicted in Appendix C. Proper identification is necessary for predicting treatment effects and establishing objectives.

Plains Silver Sagebrush *(Artemisia cana* ssp. *cana)*

Plains silver sagebrush typically grows in basins and along drainageways where it represents a potential natural community. Upland sites usually have a sandy soil component while coarse, alluvial deposits comprise bottomland sites. Many of the lowland sites are also subjected to periodic flooding, erosion, and deposition. Site preference includes locations influenced by high water tables, especially where roots can intersect the water table for at least part of the growing season (Johnson 1979). Plains silver sagebrush has high forage value and palatability for wintering wildlife (Beetle and Johnson 1982).

Plains silver sagebrush regenerates both sexually and vegetatively. Vegetative regeneration is the primary mode of reproduction with plants capable of spreading extensively through layering, rhizomes, and root sprouting (Harvey 1981). Layering occurs almost exclusively in habitats subjected to periodic flooding where vegetative branches become covered with silt.

Plains silver sagebrush reestablishes primarily through root sprouting and rhizomes following burning (Beetle 1960). Study results indicate that prescribed burning can create a wide range of plant responses and densities (White and Currie 1983). Preburn densities are quickly restored following most spring burning.

Mortality is directly related to fire intensity, fire severity, and season of burning. White and Currie (1983) conducted spring and fall burns under comparable site conditions on a mixed-grass prairie in eastern Montana. Fall burning produced 75% mortality of totally consumed plants while spring burning resulted in 33% mortality of totally burned plants. Fall fire severity was greater as a result of reduced soil moisture conditions.

Mountain Silver Sagebrush *(Artemisia cana* spp. *viscidula)*

Mountain silver sagebrush is generally restricted to areas along and west of the Continental Divide (Beetle and Johnson 1982) (Appendix C). Mountain silver sagebrush communities may be considered a potential natural community within non-forested habitats. Common sites include streamsides, meadow margins, seeps, depressions, and wet mountain slopes. Mountain silver sagebrush sites are characterized by seasonally high soil moisture conditions and are often associated with areas of heavy, lingering snowpacks with short-duration standing water. It occupies deep soils with variable textures (Hironaka et al. 1983).

Mountain silver sagebrush leaves are smaller, more narrow, and darker green than those of plains silver sagebrush and are often crowded in clusters. On sites where the two occur together, mountain silver sagebrush is always darker green than mountain big sagebrush (McArthur and Stevens 1986).

Native graminoids commonly associated with mountain silver sagebrush include slender wheatgrass, Sandberg bluegrass, bromes, fescues and a variety of rushes and sedges (*Carex spp*.). Nonnative grasses have become established on many areas; understories are sometimes composed entirely of Kentucky bluegrass *(Poa pratensis*), rushes and sedges. Extensive, meadow-like stands have been reported on gently sloping, alluvial benches, and toeslopes in portions of western Wyoming (Youngblood et al. 1985).

Mountain silver sagebrush plants regenerate primarily through vegetative means, rhizomes, root sprouting, and layering (Beetle 1960).

Information regarding the response of mountain silver sagebrush to fire is generally lacking. As a group, the silver sagebrush complex resprouts vigorously following fire, and it appears mountain silver sagebrush response is very similar to that of plains silver sagebrush (Wright et al. 1979). Postfire regeneration involves sprouting from rootcrowns and rhizomes; new individuals are also established from wind-dispersed seed.

Treatment Recommendations for Plains and Mountain Silver Sagebrush:

Since these subspecies sprout vigorously following disturbance, no action should be taken in areas where existing densities are acceptable (Beetle and Johnson 1982). Due to the infrequent occurrence of extensive stands, silver sagebrushes are not usually candidates for treatment.

Treatments may be desirable in dense stands where understory species have been depleted. Silver sagebrush density and canopy cover may be significantly influenced by altering fire severity (i.e.

spring vs. fall treatment). Post-burn densities are rapidly regained, especially following spring burns. Spring burns can be used to increase plant coverage, rejuvenate sagebrush plants and enhance understories. Fall burns with greater severity may reduce silver sagebrush density (White and Currie 1983) and shift the competitive advantage to herbaceous species.

Greater mortality can be achieved by increasing fire intensity through fuel manipulation; fuels can be supplemented by deferring grazing prior to burning.

Due to limited distribution of silver sagebrush, landscape objectives should follow those of the associated sagebrush species. Silver sagebrush will recover quickly, providing short-term structural and species diversity.

Threetip Sagebrush *(Artemisia tripartita)*

Two subspecies of threetip sagebrush are found in Wyoming: Wyoming threetip sagebrush *(Artemisia tripartita* ssp. *rupicola)* and tall threetip sagebrush *(Artemisia tripartita* ssp. *tripartita*) (Appendix C). Wyoming threetip sagebrush occurs mainly east of the Continental Divide in central and southeastern Wyoming (Fisser 1962). The Rocky Mountain Herbarium (1998) shows specimens collected from Park, Hot Springs, Johnson, Fremont, Natrona, Carbon, Albany, Laramie, Converse and Platte Counties. Tall threetip sagebrush primarily occurs only along the Snake River drainage in western Wyoming (Beetle 1960) although the Rocky Mountain Herbarium (1998) shows a collection site from Albany County. Although some use by wild ungulates and domestic sheep has been recorded it is generally considered relatively unpalatable.

Wyoming Threetip Sagebrush *(Artemisia tripartita* spp. *rupicola)*

Fisser (1962) found Wyoming threetip sagebrush most often on wind-swept gentle slopes and ridgetops on coarse-textured, well-drained shallow soils of low mountains and margins of high-elevation basins between 6,000 and 9,000 feet. Beetle (1960) reported the elevation range of Wyoming threetip sagebrush in Wyoming is 7,000 to 9,000 feet. Similar site characteristics were reported by Beetle and Johnson (1982).

Wyoming threetip sagebrush is most often characterized as a low, layered shrub seldom exceeding 12 inches in height (Fisser 1962). Hironaka et al. (1983) reported canopy cover typically varies between 10 and 20% with a moderate herbaceous understory cover dominated by graminoids.

Fire did not historically play a significant role in the ecology of this subspecies (Winward pers. comm.). Fuels are generally limited within occupied sites, preventing fire spread. Wyoming threetip sagebrush can sprout from the root crowns, stumps and by layering following fire (Beetle 1960,1977; Beetle and Johnson 1982; Hironaka et al. 1883; Winward 1985).). Moist soil conditions at the time of treatment enhance sprouting.

Treatment Recommendations for Wyoming Threetip Sagebrush*:*

There are few landscape objectives for this subspecies. Treatment guidelines for Wyoming threetip sagebrush should generally follow the recommendations for the dominant sagebrush species in adjacent or mixed stands and resource objectives desired for the area. In the Middle Fork of Powder River area on the slopes west of Kaycee, Jellison et al. (1997) found winter burning basically did not reduce Wyoming threetip sagebrush canopy cover. They did find a slight increase in grass cover and a moderate increase in forb cover following winter burns. Fall burns decreased shrub canopy coverage and increased grass and forb coverage as well as production following the burns (Jellison et al. 1997). Grazing management systems should be considered as it becomes more dominant on overgrazed ranges (Hironaka et al. 1983).

Tall Threetip Sagebrush *(Artemisia tripartita* spp *tripartita)*

Tall threetip sagebrush is generally found on flat to relatively steep, moderate to deep, well-drained, loamy to sandy loam soils and is especially common along river drainages in Wyoming up to 9,000 feet (Beetle and Johnson 1982; Rocky Mountain Herbarium 1998). It is also tolerant of dry soil conditions and found from 6,000 to 7,000 ft. in Wyoming (Beetle 1960). Stands of tall threetip sagebrush often occur adjacent to mountain big sagebrush stands, but usually on moister soils at higher elevations (Blaisdell et al. 1982). Tall threetip sagebrush typically occurs at elevations above Wyoming big sagebrush but below mountain big sagebrush; 6,000 to 7,000 ft. in Wyoming (Cronquist et al. 1994).

Tall threetip sagebrush is commonly associated with bluebunch wheatgrass, Idaho fescue, needle-and-thread grass, Sandberg bluegrass, and Thurber's needlegrass. Common shrub associates of tall threetip sagebrush include Vasey big sagebrush, broom snakeweed (*Gutierrezia sarothrae*), green rabbitbrush (*Chrysothamnus viscidiflorus)*, gray horsebrush (*Tetradymia canescens*), and curlleaf mountain-mahogany (*Cercocarpus ledifolius*). Tall threetip sagebrush typically averages 5-15% canopy cover and contributes at least 40% of the total shrub cover in the community (Hironaka et al. 1983). It can grow to a height of 6 feet with a moderate to moderately high (25-70%) herbaceous cover dominated by graminoids (Hironaka et al. 1983).

Tall threetip sagebrush can sprout from the root crowns, stumps as well as layering following fire (Beetle 1977; Beetle and Johnson 1982; Hironaka et al. 1983; Winward 1985) but exhibits variable sprouting abilities. The specific response may depend on ecotypic differences or on fire severity (Akinsoji 1988). Beetle (1960) observed that tall threetip sagebrush sometimes sprouts vigorously from the root crown following fire. In other instances he described sprouting as "weak". Sprouting is most likely to occur with moist soil conditions. It appears to be a highly competitive subspecies and can assume dominance on overgrazed ranges (Hironaka et al. 1983).

When occurring in mixed stands with Vasey big sagebrush, burning can result in nearly pure stands of tall threetip sagebrush (Passey and Hugie 1962). In southeastern Idaho, Barrington et al. (1988) reported that without periodic fire, threetip sagebrush gradually increases in density and cover. Recovery to preburn level ranges from 25–40 years. With time, the shading effects of Vasey and basin big sagebrush will reduce densities of tall threetip sagebrush (Winward pers. comm.).

Treatment Recommendations for Tall Threetip Sagebrush*:*

Care must be exercised when treating mixed stands of tall threetip and Vasey big sagebrush because it is capable of vigorous vegetative regeneration and dominating the site. Thus mixed stands can be converted entirely to tall threetip sagebrush, and reduced species diversity (Passey and Hugie 1962). This is of more concern if fire return intervals are shortened. However, quick recovery results in short-term establishment of ground cover as well as structure and species diversity in mixed stands.

There are few landscape management objectives for this subspecies, however, a hot fall fire can be used when tall threetip dominates the site to thin threetip and increase the herbaceous component. Grazing management systems should be considered as it becomes more dominant on overgrazed ranges (Hironaka et al. 1983).

Black Sagebrush *(Artemisia nova)*

Black sagebrush is usually associated with areas with little soil profile development on the lower slopes of the high desert foothills. Typical sites consist of the dry, shallow, gravelly, well-drained soils of alluvial fans, sills, mountain slopes, and wind-blown ridges. It occurs most abundantly at elevations between 4,900 to 7,000 ft. in Wyoming.

Black sagebrush communities located on impermeable layers (clay and/or bedrock) at approximately one-foot depth and within higher precipitation zones (12-14") are quite capable of producing adequate fuels for fire spread. Where fire does occur, plants are easily killed by fire and recovery is very slow (West and Hassan 1985).

The total acreage of black sagebrush is relatively small, and historically fire had little or no influence in communities dominated by black sagebrush (Winward 1985). Dwarf sagebrush species such as black sagebrush, are commonly recognized as potential natural fire breaks. The lack of fuels within most black sagebrush stands precludes the use of prescribed fire. In situations where plants are exposed to fire they are easily killed and do not sprout. Seed dispersal is close to the parent plant.

Treatment Recommendations for Black Sagebrush:

Because plants do not resprout, fire is not recommended on winter ranges where the species is an important forage plant. Where fire is used, small mosaic burning is necessary to enhance recovery (West and Hassan 1985).

Treatments should follow temporal and spatial guidelines similar to Wyoming big sagebrush.

SUMMARY

The guidelines described in this document are intended to help the natural resource managers evaluate and perform sagebrush ecosystem management functions and operations. While this document focuses on prescribed fire as a management tool for the vegetation of sagebrush dominated ecosystems, other tools such as chemical, biological and mechanical techniques are available. These guidelines should be viewed as a foundation tier of a multi-tiered evaluation and management process that could be used for the planning and implementation of any project in the sagebrush ecosystem.

The ecological and physiographical settings of sagebrush ecosystems in Wyoming are characterized, as well as the importance of these ecosystems to the wildlife resources dependent on them. The issues of management concern in sagebrush ecosystems are also detailed in the context of habitat loss (e.g., vegetation conversions, etc.), fragmentation (e.g., industrial and facility development, etc.), and degradation (e.g., drought, herbivory, invasive species, etc.). The importance of collaborative, intra- and interagency management processes for ecosystems is outlined. Specific landscape objectives and treatment recommendations are presented for the major sagebrush species found in Wyoming.

Distribution maps and an identification key for the major sagebrush species of the state, as well as an example of fire planning in a sagebrush ecosystem, are included as appendices.

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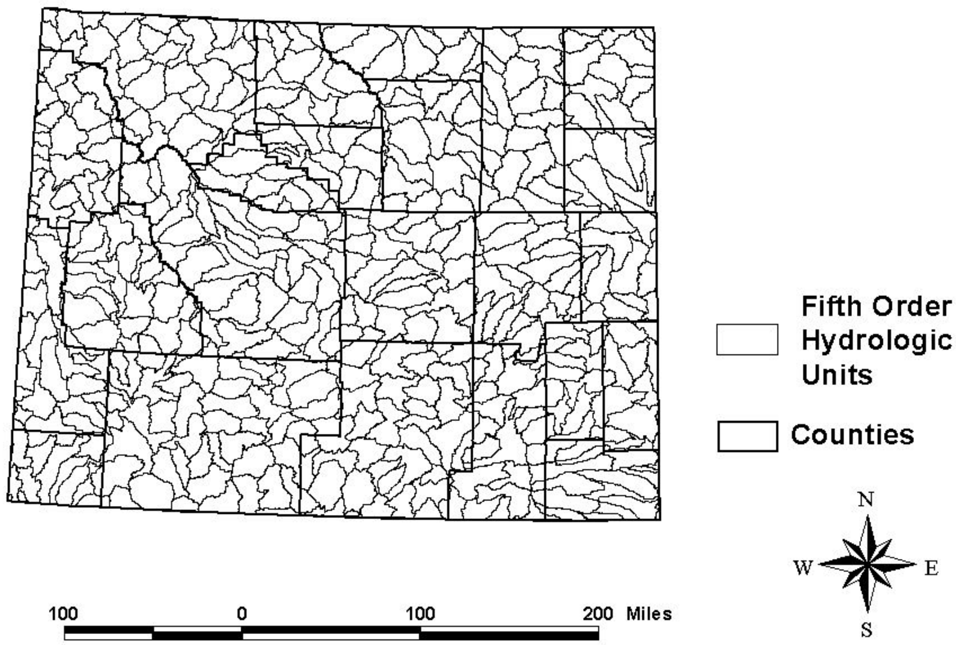
Appendix A
Fifth Order Hydrologic Units - Wyoming



- There are 425 fifth order hydrologic units in Wyoming.
- These units range in size from 15,380 to 344,298 acres.
- The average size is approximately 169,376 acres.
- Each fifth order hydrologic unit is composed of many vegetation communities.

Appendix B

<u>Comparison of Sagebrush Management Techniques</u>

I. Prescribed Fire

<u>Advantages</u>

- A "natural" process, therefore, generally fewer environmental side effects
- Can be used in a wide variety of circumstances under the proper environmental conditions
- Returns nutrients to the soil quickly

<u>Disadvantages</u>

- Implementation can be potentially hazardous with associated liability
- Generally, requires fine fuels present (rest) to be effective
- Can potentially negatively affect non-target species
- Short term aesthetic, smoke and erosion concerns

II. Chemical (Herbicides)

<u>Advantages</u>

- Can be quite selective
- Can be relatively inexpensive
- Can be regulated for partial or total treatment
- Can cover large areas quickly

<u>Disadvantages</u>

- Many chemicals are residual, and may inhibit plant regrowth
- Can have environmental / toxic side effects if not used carefully
- Application rates and timing can be limiting
- Leaching and drift into non-target areas
- Can affect non-target species within the treatment area

III. Mechanical (Mowing, Chaining, Plowing/Ripping/Scalping/Pitting, Brushrake, Brush Disc, Choppers, Mulchers, Drills, Pipe Harrows, etc)

<u>Advantages</u>

- Can be quite fast
- Easily controlled
- Can be very effective when used under the right conditions
- Soil disturbance can prepare seed bed

<u>Disadvantages</u>

- Topography (i.e., relief/slope, rocky soils) can be limiting for many techniques
- Costs (equipment and operators) can be expensive in some cases
- Benefits may be short-lived
- Short term aesthetic and erosion concerns
- Cultural concerns
- Litter management may be required

IV. Biological (Insects and Herbivory)

<u>Advantages</u>

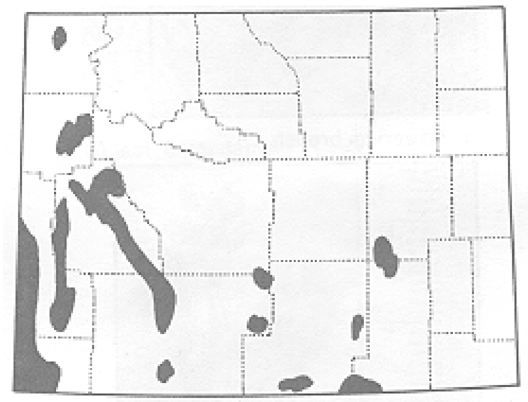
- Often target species (host) specific / selective
- Grazing treatments can be relatively inexpensive

<u>Disadvantages</u>

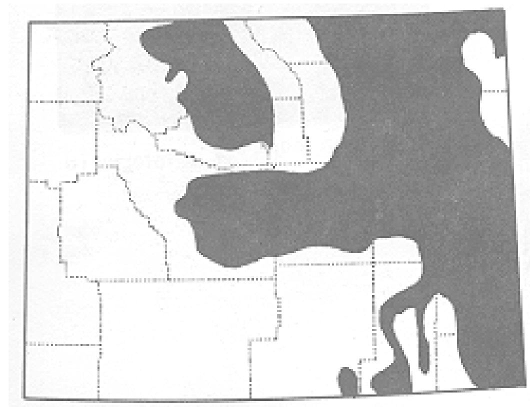
- Limited number of bioagents available
- Can take a long time (several years in some cases) to see wide-spread results
- Grazing methods can be counter-productive / abusive if not carefully monitored and managed

Appendix C

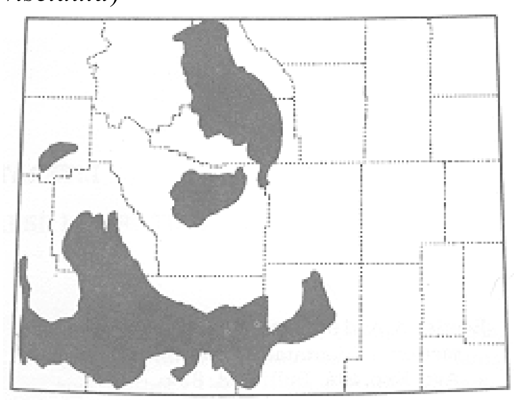
Sagebrush Distribution Maps
(Beetle and Johnson 1982)



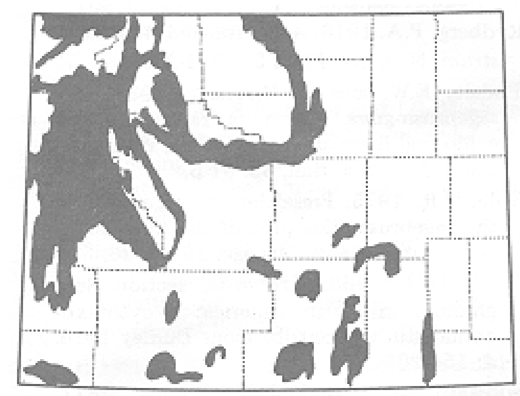
Mountain silver sagebrush (*Artemisia cana* ssp. *viscidula*)



Plains silver sagebrush (*Artemisia cana* ssp. *cana*)

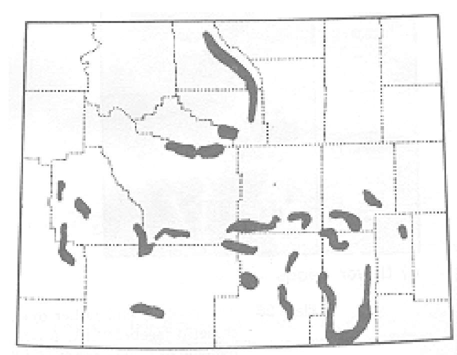


Basin big sagebrush (*Artemisia tridentata* ssp. *tridentata*)

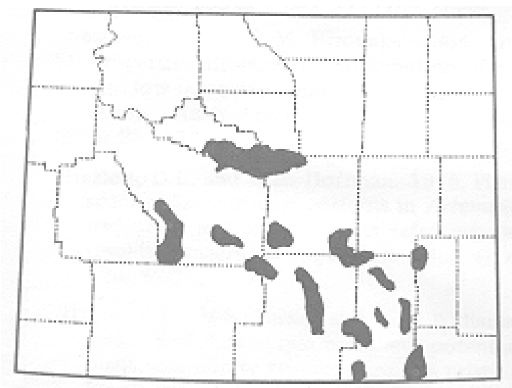


Mountain & Vasey big sagebrush (*Artemisia tridentata* spp. *vaseyana*) (includes vars. *vaseyana* & *pauciflora*)

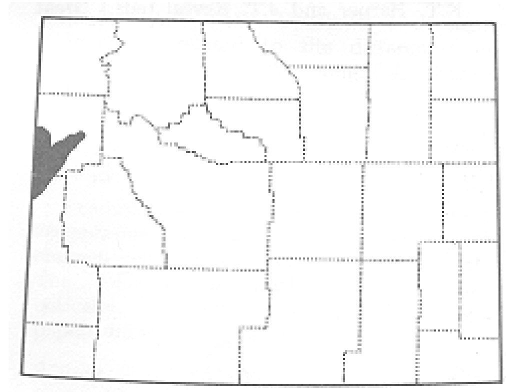
Wyo. big sagebrush (*Artemisia tridentata* spp. *wyomingensis*) Modified by Rinkes, 2002.



Black sagebrush (*Artemisia nova*)



Wyoming threetip sagebrush (*Artemisia tripartita* ssp. *rupicola*)



Tall threetip sagebrush (*Artemisia tripartita* ssp. *tripartita*)

The maps above illustrate general distribution of major sagebrush species discussed in this document.

Appendix D

Key to Sagebrushes (*Artemisia*) of Wyoming

David Tart and Alma Winward

August 1996 (Revised December 2001)

1a. Persistent leaves all or mostly entire, linear to narrowly lanceolate.

2a. Mature plants 3 to 5 feet tall. Leaves strongly silvery-green pubescent. Outer involucral bracts canescent . . . . ***A. cana* ssp. *cana***

1a

2b. Mature plants less than 40 inches tall. Leaves sparsely pubescent and gray-green. Outer involucral bracts sparsely pubescent . . . . ***A. cana* ssp. *viscidula***

1b. Persistent leaves 3-lobed or deeply 3-cleft.

1b

3a. Persistent leaves deeply cleft (lobes 3 times as long as wide or longer).

4a. Inflorescence a narrow to open panicle. Upper bracts of inflorescence much longer than the flower heads. The basal part of the leaf no wider than the lobes.

5a. Mature plants 1 to 3 feet tall. Leaves rarely over 2cm long. Panicle open to narrow. . . . . ***A. tripartita* ssp. *tripartita***

5a

5b. Mature plants less than 10 inches tall. Leaves often over 2cm long. Panicle narrow. . . . . ***A. tripartita* ssp. *rupicola***

4b. Inflorescence a sparse spike or raceme. Upper bracts of inflorescence shorter to only slightly longer than the flower heads. The basal part of the leaf wedge-shaped (widened below the teeth). . . . . ***A. arbuscula* ssp. *thermopola***

4b

3b. Persistent leaves shallowly lobed (lobes less than 3 times as long as wide).

3b

6a. Persistent leaves bell-shaped with middle lobe overlapping the two outer teeth.

6a

7a. Inflorescence a sparse spike or raceme, flowering by mid summer, mature plants less than 20 inches tall. . . . . ***A. longiloba***

7b. Inflorescence a raceme or narrow panicle, flowering in early fall, mature plants 18 to 36 inches tall. . . . . ***A. "g."*** (Bonneville sagebrush)

6b. Middle lobe of persistent leaves rarely overlaps the two outer lobes.


6b

8a. Mature plants less than 20 inches tall.

9a. Inflorescence with brown stalks that persist into the following year. Leaves dark green, shiny, and sticky. . . . . ***A. nova***

9b. Inflorescence with gray, weakly persistent stalks. Leaves grayish green, not shiny or sticky.

10a. Inflorescence a narrow panicles; the heads clustered. ***A. tridentata* spp. *wyomingensis***

10b. Inflorescence a sparse spike or raceme; the heads single or 2 to 3 together. . . . . ***A. arbuscula* ssp. *arbuscula***

8b. Mature plants over 20 inches tall.

11a. Uneven-topped shrubs with flowering and vegetative twigs intermingled.

12a. Mature plants mostly over 40 inches tall, often with a discernable main trunk. Persistent leaves 4 times as long as wide or longer with straight margins. . . . . ***A. tridentata* ssp. *tridentata***


12a

12b. Mature plants mostly less than 40 inches tall, often quite branched from near base with no discernable main trunk. Persistent leaves less than 4 times as long as wide with curved margins. ***A. tridentata* ssp. *wyomingensis***


12b

11b. Even-topped shrubs with flowering stalks well elevated above the vegetative twigs; the flowering stalks mostly over twice as long as the subtending vegetative twigs.

13a. Mature seed heads present; individual flowers discernable. . . . . FLORAL KEY (14)

13b. Seed heads immature; individual flowers not discernable. . . . . VEGETATIVE KEY (18)

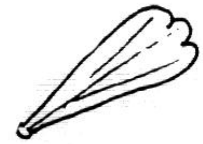
FLORAL KEY

14a. Heads with a maximum of 6 flowers or less.

15a. Mature persistent leaves mostly less than 12mm long, with margins curved outward (bell-shaped). . . . . . ***A. tridentata* ssp. *wyomingensis***


15a

15b. Mature persistent leaves mostly longer than 12mm with straight margins. . . . . ***A. tridentata var. pauciflora***

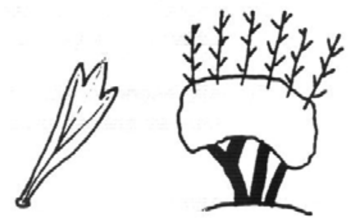


15b

14b. Heads with a maximum of 7 flowers or more.

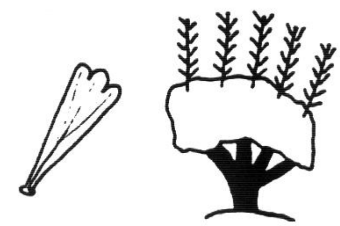
16a. Heads with a maximum of 12 flowers or more. . . . . ***A. tridentata*** **ssp.** ***spiciformis***

16b. Heads with a maximum of 11 flowers or less.



17a

17a. Lobes of persistent leaves variable in size, shape, and number; many lobes with pointed tips. Plants mostly multi-stemmed. . . . . . . ***A. tridentata*** **ssp.** ***spiciformis***



17b

17b. Persistent leaves mostly with 3 rounded lobes; each usually similar in size and shape. Plants mostly single-stemmed or two-stemmed. . . . . ***A. tridentata*** **var.** ***vaseyana***

VEGETATIVE KEY

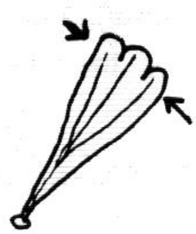
18a. Mature persistent leaves mostly less than 12mm long, with margins curved outward (bell-shaped). . . . . ***A. tridentata*** **ssp.** ***wyomingensis***

18b. Mature persistent leaves mostly longer than 12mm, with straight margins.

19a

19a. Lobes of persistent leaves variable in size, shape, and number; many lobes with pointed tips. Plants mostly multi-stemmed and tend to resprout after fire. . . . . ***A. tridentata*** **ssp.** ***spiciformis***

19b. Persistent leaves mostly with 3 rounded lobes, each usually similar in size and shape. Plants mostly single-stemmed or two-stemmed and do not resprout after fire.



20a

20a. Persistent leaves widest at base of lobes. Inflorescence a spike or raceme with relatively few heads. Plants occasionally layering. . . . . ***A. tridentata*** **var.** ***vaseyana***

20b

20b. Persistent leaves widest slightly below the base of the lobes. Inflorescence a panicle with numerous heads. Plants do not layer. . . . . ***A. tridentata*** **var.** ***pauciflora***

Appendix E
Example of a Planned Prescribed Burn

Recommendations for Planning a Prescribed Burn within Wyoming Big Sagebrush

✓ Analysis should be done on a 5th order Hydrologic Unit (HU) (See Appendix A)
This example illustrates a 5th order HU within Sublette Co., (#14044010203)
consisting of 181,405 acres.

✓ Map the Wyoming big sagebrush within the HU as follows:

1) Area not treatable
2) 0-5% canopy cover
3) 5-15% canopy cover
4) > 15% canopy cover

✓ Review landscape objectives for Wyoming big sagebrush (Figure 3). In the example approximately 48% of the HU is occupied by sagebrush with a canopy cover > 15%. The landscape objective recommends approximately 40% of the landscape should be occupied by Wyoming big sagebrush (*Ar. tr.wy.*) with a canopy cover > 15%.

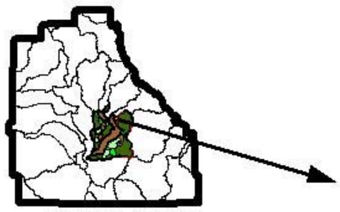
✓ Recommend treatments that address the landscape objectives. In the example, three (3) sites within one larger patches of sagebrush having canopy cover > 15% are selected for treatment. The proposed treatments range from 5-7,000 acres in size and are positioned to enhance patchiness.

✓ A mosaic pattern of burned and unburned (40-60%) within the treated areas should be a management objective (not illustrated in the example). Reentry to treat unburned sagebrush patches or islands within burned areas is not recommended.

✓ Other important/essential planning and management considerations are:

1) Apply all other applicable map "layers" (i.e. sage-grouse seasonal habitats, livestock grazing system, seasonal big game ranges, etc.).
2) Establish a plan for short and long-term grazing management that promotes a healthy sustainable sagebrush community.
3) Implement a monitoring program that addresses short and long-term objectives and goals.
4) Review the decision elements on page 12 of this document.

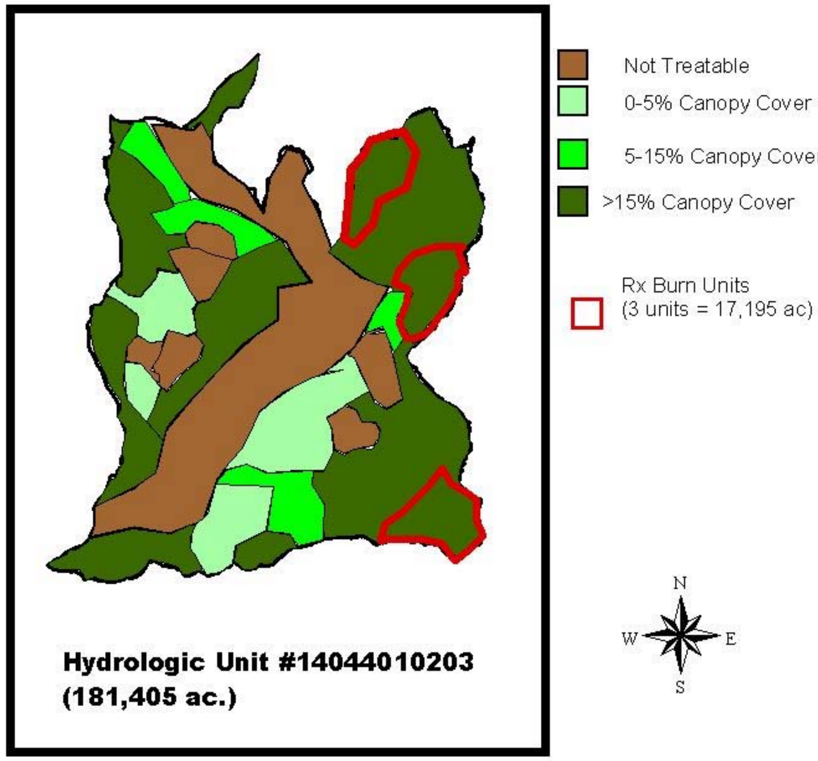
Wyoming Big Sagebrush Prescribed Burn Example



Sublette County
Fifth Order Hydrologic Units

Pre and Post Rx Burn Sagebrush Conditions
(% of HU by Canopy Class)

Artrwy (canopy class)	Pre	Post
Not Treatable	30%	30%
0-5%	7%	16%
5--15%	12%	12%
>15%	48%	39%



MONITORING PLAN	
Preparer(s): Stroud, Kilpatrick, Scott	Date: 10/22/02
Location: Pinedale BLM	Project Name: Prescribed Burn Example
Project Cooperators: WYGF, BLM, FS	Burn Unit: Prescribed Burn Example
Monitoring Contact: Stroud	Season of Burn: fall/spring

PHYSICAL DESCRIPTION OF BURN UNIT (ATTACH PROJECT MAP THAT INCLUDES PLANT COMMUNITIES AND/OR HABITAT TYPES)
The area is predominantly a Wyoming big sagebrush community with interspersed meadows, riparian communities, and barren ridges. Western wheatgrass (*Pascopyrum smithii*), needle-and –thread (*Stipa comata*), Idaho fescue (*Festuca idahoensis*), bluegrass (*Poa* spp.) , June grass (*Koleria cristata*), and spikefescue (*Leucopoa kingii*), Hood's phlox *(Phlox hoodii*), rose pussy-toes (*Antennaria rosea*), goldenweed (*Haplopappus acaulis*) and winterfat (*Eurotia lanata*) limited number of other forbs make up the understory. Fuels are generally discontinuous except in depressions and along ephemeral drainages where more mesic conditions enhance forage production and fuels. Sagebrush canopy cover is generally > 15% and the understory herbaceous component depauperate except for mat-forming species.

RESOURCE MANAGEMENT OBJECTIVES
SEE "RESOURCE MANAGEMENT OBJECTIVES" IN THE BURN PLAN

MONITORING OBJECTIVES TIERED FROM SECTION 4 "RANGE OF ACCEPTABLE RESULTS, EXPRESSED IN QUANTIFIABLE TERMS" IN THE BURN PLAN. IN SOME CASES, THE RANGE OF ACCEPTABLE RESULTS CAN BE USED FOR MONITORING, HOWEVER IF MORE SPECIFICITY IS DESIRED, MORE COMPLETE MONITORING OBJECTIVES CAN BE WRITTEN AND INSERTED BELOW.	
IMMEDIATE POST BURN	1. Treat 30-50% of the sagebrush having >15% canopy cover in a mosaic pattern within each of the three burn units. 2. Achieve >80% mortality of *Artrwy* plants in treated areas (80 % statistical reliability). 3. 4.
LONG-TERM	1. Increase herbaceous species diversity by 30% within ≤ 3 years post burn. 2. Reestablish pre-burn *Artrwy* densities within < 25 years post-burn (80% statistical reliability). 3. Achieve >50% ground cover within 10 years post-burn. 4. Achieve and maintain ≥8 vascular plant species within 3 years post-burn. 5. Increase frequency of forb occurrence by 35% within 3 years post-burn (80% statistical reliability).

PLOTS NECESSARY TO MONITOR FIRE OBJECTIVES		
Community Type	Number of Plots	Plot Type(s) Include all applicable plots
Artrwy	6 – 2 for ea. Unit	Nested Frequency, Belt Transect, Line Intercept, and Photo point [established paired plots (control & treatment) for each burn unit].

MONITORING PLOT LOCATION(S)

NOTE THE PLANT COMMUNITIES AND/OR HABITAT TYPES MONITORING PLOTS RESIDE

Plot #	Location (UTMs) East	North	Community/Hab. Type	Notes
1	456678	5432456	Artrwy	Unit A Control
2	456732	5432501	Artrwy	Unit A Treatment
3	457823	5433201	Artrwy	Unit B Control
4	458134	5436011	Artrwy	Unit B Treatment
5	456018	5437006	Artrwy	Unit C Control
6	456116	5437306	Artrwy	Unit C Treatment

MONITORING SCHEDULE

All plots were read from 07/10/02 to 07/18/02 with a full nested frequency for pre-burn treatment information. The next scheduled readings will be immediately post-burn. Belt transects will be read for sagebrush density/mortality, photo points will be retaken, and the burned/unburned areas mapped. The next scheduled readings will be three years post-burn at which time species diversity, frequency of occurence, and numbers of vascular plants will be monitored with nested frequency methodology. Photo points will also be retaken. A third post-burn reading will occur at year 10 to determine ground cover. Photo points will be retaken and full or partial nested frequency may also be conducted if managers wish to monitor other parameters (optional). A fourth post-burn reading (belt transect) will occur at year 25 to determine sagebrush density. A full or partial nested frequency may be done if managers feel it necessary to monitor other parameters (optional).

NOTES

Indicator species may be selected for conducting partial nested frequency monitoring.