# Management Considerations for Sagebrush (*Artemisia*) in the Western United States: a selective summary of current information about the ecology and biology of woody North American sagebrush taxa

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## PURPOSE

These management considerations for sagebrush were prepared in response to concerns regarding the long-term loss, degradation, and fragmentation of sagebrush vegetation (Connelly et al. 2000, Wisdom et al. 2000, West and Young 2000) throughout the West and attendant declines in populations of plant and animal species that depend on sagebrush habitats for part or all of their respective life cycles.

This document is intended to be a supplemental reference to assist BLM field office staff and managers when authorizing activities that may affect sagebrush communities, and during the revision of land use and activity plans relevant to sagebrush community management. It is not issued as either management direction or agency policy. Instead, it presents a selective summary of current information about the ecology and biology of woody North American sagebrush (*Artemisia*) taxa and describes how sagebrush plant communities and certain species and sub-species respond to management treatments and disturbances, including fire, livestock grazing and mechanized and chemical restoration practices. The management considerations themselves are recommendations that are more analogous to "best management practices."

While it is essential to understand the biological and ecological effects of management actions upon individual sagebrush species and their associated plant and animal communities, it is equally and perhaps even more important to understand the overall management context within which actions will be considered. Issues of scale in land management have become increasingly significant due to declines in the populations of widely distributed species such as sage-grouse. Accordingly, a discussion of Spatial and Temporal Considerations Related to Cumulative Effects Analysis is included in the management considerations.

Selected sagebrush species and subspecies information summaries are presented in Appendix A. As new information about sagebrush and the management of sagebrush ecosystems and habitats becomes available, these management considerations will be revised to incorporate new findings.

## INTRODUCTION

Kuchler (1970) and West and Young (2000) describe sagebrush ecosystems as occupying about1 153 million acres of the western United States, dominating substantial portions of the entire western landscape. Collectively, they comprise the sagebrush biome. A large percentage of the sagebrush biome is on public land managed by both the USDI Bureau of Land Management (BLM) and USDA Forest Service (USFS).

Within this document, the terms sagebrush plant communities and sagebrush communities are used interchangeably to refer to the various assemblages of different sagebrush species and associated other shrubs, forbs and grasses. In describing the number and types of sagebrushes, McArthur and his colleagues recognize 11 species and 14 subspecies (McArthur et al. 1998, McArthur and Sanderson 1999, McArthur 1999) .

Since settlement of the West began, there has been a substantial reduction in both the quantity and quality of sagebrush ecosystems. Westwide, sagebrush ecosystems and plant communities have been degraded or completely eliminated due to agricultural conversion, livestock grazing, invasions by exotic plants, oil and gas development, mining activities, fire management activities and policies, urban and suburban sprawl, water diversions, stream entrenchment, pinyon pine and juniper encroachment, off-highway vehicle activities, utility lines and corridors, arson, and altered wildfire cycles and fire behavior.

Many remaining sagebrush plant communities are at high risk of loss from wildfire as the result of weed infestations and unnatural fuels accumulations. As of 2000, within the Great Basin alone, three million acres of public land had become monocultures of cheatgrass (*Bromus tectorum*), an exotic annual that outcompetes most native plants and creates a high wildfire risk. Another 14 million acres are infested with cheatgrass to the extent that conversion to a cheatgrass monoculture is likely inevitable. Fragmentation of sagebrush communities is an additional problem, even for those of higher quality (Hann et al. 1997, Wisdom et al. 2000). West (1999) estimates that about 25percent of the total sagebrush steppe has made the transition to annual grasslands.

As devastating as the conversion to cheatgrass monocultures has been, these monocultures are not necessarily the end product facing land managers. Other exotic plants are invading cheatgrass-dominated communities and potentially degrading rangeland health even further (Hann et al. 1997), thus making the eventual restoration of sagebrush communities even more problematic.

## SAGEBRUSH BIOME CHARACTERISTICS AND COMPONENTS

The following is a condensed, generalized description of sagebrush biome characteristics and components. More complete descriptions are contained in West and Young (2000) and Miller and Eddleman (2000).

- **Climate**

  Sagebrush occurs throughout the West, a region of wide climactic variation. Within this variation, the sagebrush zone is typified by long cool to cold winters, hot, dry summers, and persistent winds. Precipitation, much of which falls in the form of snow at higher elevations, is generally sparse (6 - 16 inches annually) and occurs primarily in fall, winter and spring,

- **Vegetation**

  As noted earlier, the sagebrush biome encompasses approximately 153 million acres of the western United States. The BLM manages about 70 million acres. Within this biome, there are two major ecosystem types; sagebrush steppe and Great Basin sagebrush (Kuchler 1985). The sagebrush steppe ecosystem is about 44.8 million hectares (110.7 million acres) in size, and is characterized by more mesic, cooler climatic regimes than the Great Basin sagebrush ecosystem, which is about 17.9 million acres (44.2 million acres) (West and Young 2000). Geographic subdivisions of the sagebrush steppe ecosystem are the Columbia Basin, northern Great Basin, Snake River Plain and Wyoming Basin (Miller and Eddelman 2000). Sagebrush in this region is co-dominant with perennial bunchgrasses. Geographic subdivisions of Great Basin sagebrush are the southern Great Basin and Colorado Plateau (Miller and Eddelman 2000). Sagebrush in this region is dominant, with grasses being few and sparse.

- **Soils**

Most soils of the sagebrush-steppe are Mollisols which are commonly very dark colored, mineral soils with pH ranges from neutral to moderately alkaline. Most Mollisols within the range of the sagebrush-steppe are in a xeric (summer dry, winter wet) moisture regime and are classified as Xerolls. With descending elevation and/or latitude, the Xerolls become marginal with Aridisols until Aridisols are the dominant soil Order. Aridisols are soils in which water is not available to plants for long periods. They are typically light colored mineral soils with pH ranges from neutral to strongly alkaline. Aridisols typify the Great Basin sagebrush ecosystem. In many valley bottoms of the Great Basin that are lower in elevation than the Great Basin sagebrush zone, Aridisols contain high accumulations of salts and alkali, giving rise to the salt desert shrub zone.

Soil moisture regimes within sagebrush ecosystems are most commonly either Aridic (soils are dry for more than half the growing season and they are not moist for as long as 90 consecutive days during the growing season), or Xeric (soils in which large water deficits occur in the summer). Soils with a Udic soil mositure regime (not dry for as long as 90 cumulative days) do occur but are very localized.

Three soil temperature regimes predominate in the range of the sagebrush ecosystem: Cryic (very cold soils of the Rocky Mountains, Sierra and Cascade ranges, northern Great Plains, and high elevations of the inter-mountain West), Frigid (cold soils at high elevations of the mid- and northern Rocky Mountains, Sierra and Cascade ranges, and the inter-mountain West) and Mesic (soils with moderate temperatures in mid-elevations of the inter-mountain West, Midwest, Great Plains and western ranges.

- **Biological Soil Crusts**

Biological soil crusts consist of lichens, bryophytes, algae, microfungi, cyanobacteria, and bacteria growing on or just below the soil surface (Eldridge and Greene 1994). The ecological roles of biological soil crusts can vary widely in importance depending on crust composition and biomass and ecosystem characteristics (Belnap et al. 2001). Biological soil crusts contribute significantly to soil stabilization by reducing wind and water erosion of soil surfaces (Belnap and Gillette 1997, 1998; McKenna-Neumann et al. 1996). Biological soil crusts can be important sources of fixed carbon on sparsely vegetated areas (Beymer and Klopatek 1991) and fixed nitrogen for plants and soils in desert ecosystems (Evans and Ehleringer 1993; Belnap 1994). Through increasing soil temperatures, they may contribute to ecosystem processes such as microbial activity, plant nutrient uptake, soil water evaporation, seed germination time, and seedling growth rates (Belnap et al. 2001).

In addition to holding soil in place and restricting the amount of erosion, biological soil crusts also influence the type of material eroded from the soil. Laboratory studies showed that water erosion resulted in the erosion of mainly fine soil particles (silt and clay) from a sparsely-covered crust surface, while the extensively covered surface lost only coarse sand (Eldridge and Tozer 1997). Since most soil nutrients are bound onto the silts and clays, the loss of these fine particles represents a reduction in soil fertility and hence productivity. Wind erosion would be expected to have similar effects.

The relationship of biological crusts and the health of *Artemisia* stands is being studied in several different locations.

**Other Factors**

A few other factors that affect the health of *Artemisia* populations are presented below, however their ecological role(s) or significance is not well understood. As research provides additional information about them, management strategies will be amended to incorporate the new information.

- **Soil Mycorrhizae**

  Sagebrush are mycorrhizal obligates, particularly big sagebrush taxa, and the recovery of *Artemisia* on a given site is dependent on the recovery of the mycorrhizae, as well as the other factors discussed above. Research investigating the effects of fire, invasion by exotic plant species, or site occupancy by other non-mycorrhizal species on the recovery of mycorrhizae is in progress. Such information is essential for the successful management and restoration *of Artemisia* landscapes.

- **Insects**

  The sagebrush defoliator (*Aroga websteri*), also called the Aroga moth, can cause severe defoliation (Gates 1964), primarily of sagebrush taxa in the Tridentatae subgenus: *A. arbuscula*, *A. bigelovii*, *A. cana* spp. *cana*, *A. nova*, *A. pygmaea*, *A. tridentata* spp. *tridentata*, *A. t.* spp. *wyomingensis* and *A. tripartita* (Hsiao 1986). *Artemisia spinescens*, although not in Tridentatae, is also defoliated. Infestations can kill sagebrush or significantly reduce the vigor of sagebrush plants. High temperatures and low precipitation cause *Aroga* populations to decline drastically. The most promising strategy for avoiding defoliation where it may be a serious problem is to develop new plant materials that are unacceptable to the defoliator. The moth's high degree of host specificity suggests that this would be a feasible approach (Hsiao 1986). The extent and significance of *Aroga* defoliation in sagebrush ecosystems has not been evaluated.

  The leaf-feading beetles *Trirhabda pilosa* and *T. attenuata* may cause significant damage to *A. tridentata* in certain situations (Pringle 1960, Fisser and Lavigne 1961). The extent and significance of leaf-feeding beetle damage in sagebrush ecosystems have not been evaluated.

- **Parasites, Fungus and Diseases**

  A snowmold fungus can reduce the canopy cover and kill *A. t.* spp. *vaseyana*, *A. t.* spp. *tridentata* and *A. nova* in areas of deep snow accumulation (Sturges and Nelson 1986). At least 16" of snow are required to maintain temperatures conducive to fungal growth. The extent and significance of this fungus in sagebrush ecosystems has not been evaluated.

- **Voles**

  When vole (*Microtus* sp.) population cycles coincide with suitable weather conditions, voles can cause extensive sagebrush kills by girdling plants (Mueggler 1967, Frischknecht and Baker 1972). The extent and significance of vole girdling in sagebrush ecosystems has not been evaluated.

## TAXONOMY OF ARTEMISIA

Taxanomic keys, range maps, photos, or illustrations are not included in this document because there is no single comprehensive publication on *Artemisia* containing this information. The references cited provide some of this information, and there may be additional references that contain more details relative to local situations. Each field office should obtain the most current and complete information available for its respective area.

- **Taxonomy and Variation**

  A prerequisite for successful management of *Artemisia* is knowing which species, subspecies, forms, and ecotypes of *Artemisia* occur on the landscape under consideration, because the ecology and response to disturbances is highly variable among the species and subspecies (Appendix A). The *Artemisia* group contains a high level of variation, intergrades, and local adaptations that contribute to a complex taxonomy (Hall and Clements 1923, Winward and Tisdale 1977, Daubenmire 1978, 1982, McArthur and Plummer 1978, Winward 1980, Hironaka et al. 1983, Miles and Leonard 1984, Schultz 1986, McArthur 1983, McArthur and Goodrich 1986, Mozingo 1986, Walton et al. 1986).

  Variation within *Artemisia* occurs not only within species, subspecies, forms, or populations, but among individual plants as well. The size, productivity, morphology, and vigor of individuals depend on the composition, depth, texture, chemical, and physical characteristics of the soil. It is well established that the palatability of individual *Artemisia* taxa also varies (Stevens and McArthur 1974, Sheehy and Winward 1981, Hironaka et al. 1983, Wambolt et al. 1987, Welch et al. 1991).

  It is essential that land managers use the latest published information and available expertise to determine the local taxa and learn about management options. The information used should include both taxonomic keys and ecological site information (Winward 1983, Miles and Leonard 1984, West and Young 2000). Selected sagebrush species and sub-species information summaries are presented in Appendix A.

- **Federal Geographic Data Standards**

  The Federal Geographic Data Standards (Anderson et al. 1998, Grossman et al. 1998, http://www.nbs.gov/fgdc.veg/) list the following two formations that pertain to sagebrush: Microphyllus Evergreen Shrubland (generally big sagebrushes) and Dwarf Shrubland (generally low sagebrushes). As of December 2001, these standards had not yet been applied to create a uniform map across the sagebrush biome.

## MANAGEMENT CONSIDERATIONS

- **Ecological Sites**

  Soils and site capability are the foundations for ecological response. The characteristics of various ecological sites and their distribution within a given management area should be thoroughly understood prior to vegetation manipulation or other management actions. Site characteristics vary according to the potential natural community, plant species composition, annual production, soils, effective precipitation, erosion potential and other factors (National Research Council 1994). When ecological sites are properly classified, managers can have a reasonable expectation as to what type of ecological response can be expected following various types of disturbance (USDA 1991). This prerequisite knowledge applies to *Artemisia* as well as other taxa.

  It is particularly important to identify and understand that on certain ecological sites, exotic annuals such as cheatgrass have drastically altered succession and created new stable vegetation states (Hann et al. 1997) (West and Young 2000). Management actions such as prescribed burns can accelerate the transition of vegetation state(s) on these ecological sites from those that support *Artemisia* to those that will support exotic annual grasses and/or forbs, with intensive vegetation restoration then required to reverse the transition.

- **Historical Range of Variation**

  Science teams participating in the Interior Columbia Basin Ecosystem Management Project (ICBEMP, http://www.icbemp.gov) utilized the concept of historical range of variation when conducting analyses or making recommendations at a broad-scale (Hann et al. 1997, Wisdom et al., 2000). The HRV provides an unbiased, value-neutral "baseline" for comparing the effects of proposed actions. A value-neutral baseline is important in avoiding management prescriptions that favor vegetation communities and habitat of certain species over those of others.

  The HRV incorporates the relationships between the energy of a system and the processes of disturbance, such as herbivory and fire. HRV can serve as a tool for understanding the causes and consequences of change in ecosystem characteristics over time. Not only can HRV be used to help describe native systems, but it can also serve as a benchmark for understanding the effects of human-induced changes on the landscape. This includes aiding in the comparison of alternative management scenarios for the future.

  The components of HRV are many. Establishing HRV for a given geographic region, to the level of detail produced for the ICBEMP (Hann et al. 1997), may be prohibitive in the short-term, yet some of the basic data that concern *Artemisia* dynamics typically are readily available. Key among these are soil type, historical precipitation patterns, temperature patterns, fire return intervals and the nature and degree of herbivory. The idea is to understand the historical ranges within which factors such as canopy cover of sagebrush on a given site varied over time and how it was spatially distributed across the landscape. These temporal and spatial patterns are not only an integral part of the ecosystem itself, but they have shaped the evolution and adaptations of many other organisms in that ecosystem. Mimicking the HRV in all likelihood will lead to the healthiest and most resilient ecosystem for the future.

Although managers can attempt to maintain or achieve landscape conditions within HRV, such achievement may well be obtainable only within those systems that have not been substantially altered. Livestock grazing, exotic invasives, urban development, roads, fire frequency and other familiar factors complicate the ability to manage within HRV. In addition, climate changes over the past 150 years may have changed successional trajectories on any given ecological site to make a return to the HRV of the mid-1800s unachievable (Tausch et al. 1993, Miller and Wigand 1994). Even so, the HRV remains a useful conceptual standard that should help land managers understand the tradeoffs of different management strategies.

- **Density and Extent of *Artemisia* (Limiting Factors and Management Objectives)**

Historically, *Artemisia* communities have existed in a variety of conditions, ranging from nearly pure grasslands in *Artemisia-Agropyron* sites following fire, to nearly pure sagebrush on black sagebrush *(A. nova)* sites or Wyoming big sagebrush sites following a century or more without fire. While it may seem at least theoretically possible, in the absence of major aberrations in successional processes such as the presence of cheatgrass, to produce a landscape with any configuration and density of *Artemisia*, this is not the case. Biological, physical, and past and ongoing disturbance regimes constrain the possibilities (Hann et al. 1997). It is within these constraints that the real possibilities of land management objectives exist. Attainable objectives for patch size, canopy cover and landscape connectivity should recognize these limitations.

Managers should determine, within the biological and physical constraints on a given area, actions that can reasonably be implemented to meet management objectives. The historical sagebrush landscape existed as a dynamic mosaic of vegetation with individual species adapted either to the mosaic, or to portions of it. Noxious weeds, both those that are here now and those that are yet to come, pose significant threats to even the most pristine sites.

Considering the tremendous lost sagebrush over the past century, it might seem wise in the short term to protect all remaining sagebrush. While total protection might be the correct stop-gap strategy in certain areas, it cannot be the cornerstone of a long-term design for land health. Determining how much sagebrush to protect and how to manage at any given time is crucial in determining the long and short-term survival of the species that rely on sagebrush habitats.

- **Reestablishment of *Artemisia* Populations**

Although a single sagebrush plant may produce 500,000 seeds in a typical year (Welch et al. 1990), yields are normally much lower (Monsen 1999). Seed production is directly related to precipitation, and there is vast annual variation in the amount of seed produced on a given site (Young and Evans 1975, Monsen and Shaw 1986, Walton et al. 1986). *Artemisia* seeds rarely survive for more than a year in the soil (Young and Evans 1975, McDonough and Harniss 1974, Caldwell 1978), and very few *Artemisia* seeds germinate and survive beyond the first year

(Walton et al. 1986). Either during or following years of poor precipitation, sagebrush recovery on project sites may be much slower, and a conservative approach in manipulating cover through management actions is warranted.

Big sagebrush seeds (all *A. tridentata* subspecies) are small and exceedingly light, with about 4.5 million seeds per kilogram (2 million per pound) (Monsen, 1999). They are dispersed to some degree by the wind, despite having no particular adaptations for wind dispersal. Nonetheless, maximum dispersal distances are only around 30 m from the parent plant and 85-90% of all seeds fall within 1 m of the edge of the sagebrush canopy (Young and Evans 1989, Wagstaff and Welch 1990). It is very important to maintain live sagebrush plants, at least in small patches, across any landscape to provide seed sources for reestablishment. Long-distance dispersal by wind is ineffective in recolonizing large burns, seedings or other disturbances (Meyer 1994).

During fire suppression actions, consistent with ensuring human safety and the protection of property, pockets of unburned *Artemisia* within fire perimeters should be maintained as much as possible to maintain natural seed sources. The practice of "burning out" sagebrush stands and "blacklining" along roads, canals and other wide barriers should be avoided. Any other activities that would further reduce sagebrush on the landscape should be evaluated to determine if safe, feasible alternatives can be used.

- **Wildfire**

Sagebrush is readily killed by fire (Blaisdell 1953, Harniss and Murray 1973). Most species, subspecies and ecotypes do not resprout, and therefore must regenerate from seed. This suggests that, in general, sagebrush is not well-adapted to fire. Only *A. tripartita, A. cana* and *Artemisia tridentata vaseyana (*form *spiciformis*) can resprout from root crowns or lower stem bases after being top-killed by fire (Winward 1985). (ed. note: form *spiciformis* is herein spp. *spiciformis*)

The ability of most *Artemisia* species to maintain themselves over time, where the natural fire-regime has not been altered due to invasion by cheatgrass or other weeds in spite of periodic burning, however, suggests that *Artemisia* might be considered fire-tolerant (Winward 1985).

Historically, fire return intervals were 12-15 years for mountain big sagebrush (*A. t. vaseyana)* (Miller and Rose 1999) and 60-110 years or longer for other taxa, such as Wyoming big sagebrush *(A. t. wyomingensis)* on the driest sites (Whisenant 1990, Peters and Bunting 1994). Some low sagebrush (*A. arbuscula* ssp. *arbuscula*) sites probably never burned because they never had enough fuel to carry a fire under any conditions. The invasion of fire-adapted exotic species such as cheatgrass has altered the vegetation composition and succession on sites, as well as fire return intervals and burning characteristics. It has made them much more likely to burn, and to burn repeatedly. Return intervals in cheatgrass-dominated landscapes are under five (5) years (Whisenant 1990). On these sites, sagebrush can quickly be eliminated, especially if a second fire occurs before new plants can produce seed (4-6 years). After sagebrush is eliminated, seeding will be necessary to restore sagebrush within a time-frame meaningful to contemporary human society.

While the speed, intensity and temperature of fires are relatively unimportant to individual sagebrush plants (Britton and Clark 1985), those factors obviously have a great impact on the burn pattern and its ultimate effect on the landscape

One study suggests that all wildfires in sage-grouse breeding and nesting habitat should be vigorously suppressed (Connelly 2001). However, another study concludes that the negative, or positive, effects of fire to native understory species are dependent on a site's moisture regime and plant community conditions (Miller and Eddleman 2001).

Detrimental or beneficial fire effects on sage grouse habitat are dependent on 1) site potential, 2) site condition, 3) functional plant group(s) is limiting, and 4) pattern and size of the burn (Miller and Eddleman 2000). Thus, the management response to wildfire (and potential uses of prescribed fire) will vary considerably; appropriate management responses to fire for specific sites can be described in a Fire Management Plan, although the response must still be adjusted by fire behavior and fire occurrence patterns.

- **Prescribed Fire**

In any situation involving sagebrush, the use of prescribed fire should be approached very conservatively. A even higher degree of caution must be used when considering applying prescribed fire to sagebrush vegetation communities on soils in mesic temperature/xeric or aridic moisture regimes, because of the heightened risk of invasion by exotic annuals. With respect to sage grouse habitat, although prescribed fire can have a role as a tool for recovering habitats with deteriorated herbaceous components, there is conflicting scientific evidence supporting its routine use in sagebrush management (Connelly 2001, Miller and Eddleman 2000). The least controversial use of prescribed fire to alter sagebrush communities appears to be on ecological sites dominated by mountain big sagebrush *(A. t. vaseyana).*

Discussing sage grouse breeding habitat management, Connelly et al. (2001) state:
"Generally, fire should not be used in breeding habitats dominated by Wyoming big sagebrush if these areas support sage grouse. Fire can be difficult to control and tends to burn the best remaining nesting and early brood-rearing habitats (i.e., those areas with the best remaining understory), while leaving areas with poor understory. Further, we recommend against using fire in habitats dominated by xeric mountain big sagebrush (*A. tridentata xericensis*) because annual grasses commonly invade these habitats and much of the original habitat has been altered by fire (Bunting et al. 1987)." Activity in leks declined for at least 2 to 5 years following treatment (Connelly, et al. 2000). In a study in mountain big sagebrush, nesting habitat declined for some 20 years following treatment, until canopy cover has increased (Nelle, et al.2000).

Winward, Connelly and Bohne (pers. comm. 2001) recommend that the spatial extent of burned areas created as a result of prescribed fire range from being a few hundred square feet in size to approximately two acres, and only occasionally range up to five acres in size, in small randomly distributed spots. They strongly discourage the creation of large burned areas within sagebrush stands. However, optimal patch sizes and spatial and temporal distributions of treatments in the various *Artemesia* species and the habitat use(s) by sage grouse must yet be defined.

- **Mechanical Treatment**

Mechanical treatment clearly has an advantage over fire in that the treatment area can be more precisely controlled. However, mechanical treatments vary greatly in their effects on sagebrush. The tops of plants can be reduced or removed with methods such as shredding, roller chopping and hand slashing. In most cases, this produces a temporary reduction in canopy cover and many taxa regrow vigorously (USDI BLM 1991).

Entire plants can be removed with hand grubbing, bulldozing, beating, chaining, root plowing and disk plowing (Pechanec et al. 1965, USDI BLM 1991). Bulldozing, beating and chaining are capable of killing 90% of the old plants whose rigid stems tend to break while killing less (20-30%) of the younger, more flexible individuals (Pechanec et al. 1965). Large amounts of litter may be generated by mechanical treatment, which may contribute to larger and hotter fires if and when burning does occur. However this same litter may provide protective cover for post-treatment plant seedlings.

Root and disk plowing completely remove sagebrush and can damage most other species as well (Monsen and Shaw 1986, USDI BLM 1991). Reestablishment of sagebrush seedlings can be poor because seeds can become buried too deeply. This impairment of seedling establishment can persist for years because the original seeds on the site largely perish after one year (see Natural Reestablishment of *Artemisia* Populations, above). Vigor of mature plants also may decline following this type of treatment. Basal and root sprouting may not occur and plants can be killed if the main stem is uprooted or severed.

A drawback to soil disturbing mechanical actions is that biological crusts may be damaged or destroyed as a result of direct disturbance and the accumulation of litter on the soil surface. Desirable microsites for the germination and establishment of *Artemisia* seedlings may also be eliminated. Winter season soil disturbance is less likely to damage biological crusts than disturbance during other seasons. The potential to damage biological crusts, however, must be weighed against the potential consequences of a failure to act. Irreversible dominance by annual species such as cheatgrass can prevent the return of even well-developed biological crusts (Kaltenecker 1997, Kaltenecker et al. 1999).

- **Herbicides**

The effects of herbicide applications are very complex because the combination of varied site conditions, the chemicals themselves, application rates and application conditions can lead to a wide variety of outcomes (USDI BLM 1991). Though herbicides can result in a complete elimination of sagebrush cover, the control over their application offers certain advantages (Pechanec et al.1965, Tisdale and Hironaka 1981, Monsen and Shaw 1986, Whisenant 1986).

The use of herbicides may be preferable to prescribed fire in some situations. Where factors such as fuel loading or post-fire plant composition are not within the management objectives for the site, herbicides may be a tool to consider. Damage to non-target species is perhaps the most serious complication of herbicide use (USDI BLM 1991). As for any treatment, there must be a clear potential for sites to recover to a healthy condition and the capability to fully manage them following treatment.

- **Livestock Grazing and Browsing**

Excessive, or poorly managed livestock grazing, such as too high a stocking rate over the grazing period, or uncontrolled or poorly timed grazing, causes degradation of sagebrush ecosystems. Improper livestock grazing practices change the proportion of shrubs, grasses, and forbs, increase the opportunity for invasion and dominance by exotic annual grasses and forbs, shorten the growing season, and can cause an overall decline in site potential through loss of topsoil. This decline in site potential often decreases the ability of soils to capture, store, and release water, causing sagebrush ecosystems to become more arid, which in turn provides less green plant material for shorter periods of time (Miller and Eddleman 2000).

It is well established that excessive livestock grazing increases the cover of *Artemisia* in many systems by reducing the competition from other plants (Whisenant 1990, Daddy 1988). Very often it is these other plants, especially native bunchgrasses and forbs, that are far below healthy levels in the ecosystem and that are the first to be eliminated under excessive livestock grazing (Watts and Wambolt 1996, West and Young 2000). While sagebrush densities could be increased in this way, it would likely be incompatible with attainment of BLM's Standards for Healthy Rangelands.

Grayson (1993) states that "The native grasses of the floristic Great Basin are not adapted to *heavy* [emphasis added] grazing by large mammals,"and the sagebrush biome is a large portion of the floristic Great Basin. Hann et al. (1997) and Holechek et al. (1999) summarize many studies and provide recommendations for livestock grazing for the vegetation communities in the Great Basin. In general, Platou and Tueller (1985, in Hann et al. 1997), propose that livestock grazing, and livestock grazing systems that emulate native grazing regimes of the vegetation communities in the late Holocene (pre-Euro-American settlement) would be more compatible with the evolutionary history of vegetation in the sagebrush biome. However, pre-Euro-American settlement conditions no longer exist in the sagebrush biome, because of agricultural and urban development, livestock grazing, the introduction of exotic plants, and changes in disturbance regimes.

Increasingly, because of the magnitude of such changes and projected trends for even more, a major issue being raised with respect to livestock grazing is whether livestock can be managed in a manner that is compatible with maintaining healthy native plant communities. The following summarizes the literature that attempts to answer this question.

Archer and Smeins (1991, in Hann et al. 1997) proposed that some traditional livestock grazing management practices are not compatible with native plant communities. They identified several examples of poor compatibility that are applicable to the sagebrush biome: (1) Traditionally, livestock are concentrated at artificially high levels. In contrast, densities of native herbivores varied seasonally and annually; (2) Fences prevent livestock from moving to new areas when the abundance of desired forages decreases. Consequently, traditional grazing practices result in higher frequencies and intensities of defoliation than would have occurred with pre-Euro-American settlement grazing regimes; (3) Mortality of native herbivores was a feedback loop that reduced grazing pressure, permitting recovery of native vegetation after periods of forage overuse. Supplemental feeding precludes mortality of livestock and thus maintains grazing over a greater portion of the year and over a higher frequency of years, compared with grazing that was exerted by native herbivores; and (4) Prolonged grazing in the sagebrush biome has decreased the capacity of grasses to competitively exclude woody plants, such as sagebrush. Therefore, sagebrush density and canopy cover increases at a faster rate compared with no grazing. In addition, fire frequency and intensity are concurrently reduced because the prolonged grazing prevents the accumulation of fine fuels.

Grazing systems have been promoted to mitigate or prevent the detrimental effects to native plant communities in the sagebrush biome. Rest-rotation grazing has been suggested as a grazing method that approximates the manner in which native ungulates grazed the Great Basin shrublands and shrub-grasslands (Platou and Tueller 1985, in Hann et al. 1997). Seasonal grazing (Vallentine 1990, in Hann et al. 1997), characterized by livestock moving to higher elevation with increasing temperatures and changes in plant phenology, might also approximate past grazing by native ungulates if constraints of land ownership, tenure, or administration do not prove to be problematic.

Under specific circumstances, rest-rotation, deferred, deferred rotational, and seasonal grazing methods have all been demonstrated to sustain rangeland plant communities within the sagebrush biome (Vallentine 1990, in Hann et al. 1997). However, none of these grazing methods have been conclusively more effective than light to moderate stocking rates under continuous seasonal grazing (Hart and Norton 1988, Heady 1975, Stoddart et al. 1975, Vallentine 1990, in Hann et al. 1997). Despite the array of grazing methods conceived and promoted since 1950 in the United States, there has been, and continues to be, considerable debate over compatibility with native plant communities. In addition, all of the livestock grazing recommendations for the sagebrush biome summarized in this section are based upon either short-term studies or short to long-term observations, rather than long-term studies. According to Holechek et al. (1999) ". . . although the sagebrush grassland is one of the largest range types, there have been no long term, replicated stocking rate studies with cattle in this type."

Grazing methods, and no grazing, are unlikely to elevate many plant communities that are in a low successional steady state to a higher successional state (Archer and Smeins 1991, in Hann et al. 1997). Sustainable grazing management relies on knowledge of critical thresholds and manipulation of livestock so these critical thresholds are not exceeded. Continued stocking at near-normal levels during periods of moderate to severe drought is probably the greatest cause of rangeland deterioration (Vallentine 1990, in Hann et al. 1997). Reduced stocking rates during drought, and for some time after drought, are necessary to minimize damage and hasten recovery of perennial vegetation (Vallentine 1990, in Hann et al. 1997; Holechek et al. 1999).

Holechek et al. (1999) report that improvement in rangeland vegetation can be achieved through changes in livestock grazing methods, and through changes in livestock stocking rates. They present two science findings that are very important to the sagebrush biome: (1) rotation livestock grazing methods in semi-arid and desert areas, which includes the sagebrush biome, show no advantage compared with continuous or season-long grazing methods; and (2) research shows that stocking rate reductions, from heavy down to conservative (35% or less forage use) have much greater probability of improvement in rangeland vegetation, compared with rotation livestock grazing methods. The greatest benefit accruing to light or conservative stocking (35% or less forage use on palatable forage species) in terms of forage production occurred in dry years.

Where invasive exotic annual plants, such as cheatgrass and mustards, have produced an unnaturally high density of fine fuels that make sites much more susceptible to fire, grazing can reduce these fuels and lessen the likelihood of wildfire (Vallentine and Stevens 1994). However the timing of the livestock grazing is critical. It has to be judiciously applied within a very short window of time in early spring, before remnant native perennial species are growing, or else the livestock will consume the remnant native species along with the exotics.

Late autumn browsing by sheep can reduce sagebrush cover. When suitable alternative forage is lacking, animals are essentially forced to browse sagebrush because herbaceous growth is dried, reduced and less palatable (Laycock 1967). Very heavy browsing by cattle also can reduce cover of *A. t. wyomingensis* purely through mechanical damage (Watts and Wambolt 1996). If these extreme stocking levels are repeated through time, rather than during a one-time event, the understory grasses and forbs can be extirpated from the site.

In Oregon, domestic sheep showed highest preference for low sagebrush (*A. arbuscula* spp. *arbuscula*) and medium preference for black sagebrush (*A. nova*). Sheep utilized, but did not prefer, Bolander silver sagebrush (*A. cana* spp. *bolanderi*) and mountain and foothill big sagebrush. They showed least preference for Wyoming and basin big sagebrush (Sheehy and Winward 1981).

- **Native Ungulate Browsing**

It is important to understand how native ungulates, primarily deer, elk and pronghorn antelope, may affect the potential for progress in achieving desired habitat conditions. The effects of big game use on sagebrush cover can range from negligible to substantial, depending on a variety of factors; population levels, the amount of sagebrush habitat available, sagebrush species and palatability, and seasonal or other climatic conditions, such as snow depth or drought.

In comparing shrub parameters of Northern Yellowstone Winter Range sagebrush habitat types that were either continually browsed or protected for 32 to 37 years, Wambolt and Sherwood (1999) determined that canopy cover and winter forage production of *A. tridentata* was significantly reduced by elk browsing. Their evaluation of 19 sites in this study showed that the average big sagebrush cover inside exclosures was three times that outside the exclosures. This relationship held for both Wyoming big sagebrush and mountain big sagebrush sites, and for all aspects, topographies and precipitation levels.

Both pronghorn and mule deer also often forage heavily on big sagebrush taxa (Welch and McArthur 1979). Wambolt (1996) and Personius et al. (1987) reported mule deer and elk preferences for four sagebrush taxa as being, from most preferred to least preferred, mountain big sagebrush, Wyoming big sagebrush, basin big sagebrush, and black sagebrush. In Oregon, mule deer showed highest preference among seven sagebrush taxa for low sagebrush, mountain big sagebrush, foothill big sagebrush (a relatively low elevational variant of mountain big sagebrush) and Bolander silver sagebrush (*A. cana bolanderi*), intermediate preference for basin big sagebrush and Wyoming big sagebrush, and least preference for black sagebrush, with genetic variation between kinds of sagebrush taxa appearing to be more influential in animal preference than environmental variation within a taxon (Sheehy and Winward 1981).

- **Biological Soil Crusts**

Soil surface disturbing activities, including livestock grazing, off-highway vehicle use, and recreational hiking, can reduce the maximum potential development of biological soil crusts. Fire can also deplete biological soil crusts at least temporarily. A high density of exotic annual plants, such as cheatgrass and medusahead, and the resultant litter accumulation, poses a long-term threat to biological soil crust development and maintenance. Airborne pollutants and urbanization can also negatively affect the abundance and composition of biological soil crusts. Except where habitat is completely displaced, for example urban areas, or altered by dominance by exotic annuals, initial recovery of biological soil crusts is fairly rapid (ranging from a few years to 100 years) after the disturbances abate. Cyanobacteria and algae are the first stage of recovery, with later successional stages of recovery characterized by bryophytes and lichens (Belnap and Gardner 1993, Rosentreter 1986).

Biological soil crusts, which are particularly important in basin big sagebrush (*A. t.* spp. *tridentata*) and Wyoming big sagebrush (*A. t.*spp. *wyomingensis*) sites (Kaltenecker and Wicklow-Howard 1994, Kaltenecker 1997), were speculated to have been widely destroyed by trampling during the excessive livestock grazing of the late 1800s and early 1900s (Poulton 1955, Daubenmire 1970, Mack and Thompson 1982, MacCracken et al. 1983, St. Clair et al. 1993). Eldridge and Tozer (1997) state that in Australia, crusts in dry landscapes have not co-evolved with hard-footed domestic animals such as sheep, goats and cattle so they are easily destroyed by excessive trampling by these animals.

Continuous season-long livestock grazing is deleterious to biological soil crusts, as shown by Jeffries and Klopatec (1987) and Brotherson et al. (1983). Likewise, short-duration livestock grazing strategies characterized by intense physical impact to the soil surface are deleterious to biological soil crusts, particularly on rangeland characterized by wet winter and dry summer climates in the Great Basin (Johansen 1986) and the Columbia Basin.

Livestock grazing impacts on biological soil crusts, and the thresholds (characterized by timing and intensity of livestock grazing pressure) at which those impacts become limiting to on-site sustainability and productivity of biological soil crusts, is a topic worthy of considerably more research (Kaltenecker and Wicklow-Howard 1994). Livestock grazing/biological soil crust studies conducted by Anderson et al. (1982) and Marble and Harper (1988) in the eastern Great Basin are particularly noteworthy because their long-duration grazing controls allow comparison of treatment effects. Heavy (probably connotes high levels of livestock grazing pressure), early winter livestock grazing when soils are wet or frozen is not deleterious to biological soil crust cover. Heavy livestock grazing that persists into late winter and early spring, however, becomes deleterious (Marble and Harper 1988) because it limits the time available for regrowth of biological soil crust organisms. Growth of biological soil crust organisms can continue from late winter through early spring because of optimal soil water conditions, but this growth is disrupted if livestock grazing persists. After early to late spring, soil water conditions are no longer optimal for biological soil crust development. We believe that the results from these studies apply particularly to the salt desert shrub and adjacent dry sagebrush (particularly the low sagebrush, basin big sagebrush, and Wyoming big sagebrush) potential vegetation types.

In discussing biological soil crusts, soil environment and vascular plants, Belnap et al. (2001) describe characteristic differences in seed entrapment and seed germination associated with biological soil crusts in hot and cold deserts. In noting the differences, though, they point out that introduced annual grasses that lack burial mechanisms have shown inhibited germination on all intact biological soil crust types in both hot and cold deserts. Citing Larsen (1995), Belnap et al. (2001) point out that, " ... in contrast to native annuals, the density of the exotic annual grass *Bromus tectorum* was lower on intact crusts. *Bromus* density was greater on crusts that were broken, but left in place."

Native annual seeds germinate in the light on the soil or upon the biological soil crust surface. In contrast, cheatgrass seeds germinate best when buried in the soil or covered by litter. This suggests that cheatgrass is excluded by biological soil crusts (Larsen 1995). A decrease in cheatgrass density allows space for *Artemisia* seedlings to become established. Biological soil crusts exclude cheatgrass by physically blocking the seeds from penetrating the soil surface.

The maintenance of the sagebrush steppe is, in part, dependent on the structure that develops with the existence of biological soil crusts. These crusts encourage a clumped vascular plant structure which may reduce the risk of fire by creating a discontinuous fuel that is less prone to carry fire.

Some *Artemisia* ecological sites lack biological soil crusts while other sites have crusts as a major functional component. Table 1 indicates which species and subspecies of *Artemisia* may be found in association with high or low microbiotic crust cover.

High potential for biological crust development exists within the salt desert shrub type, drier portions of the big sagebrush cover type (such as Wyoming big sagebrush), and the low sage cover type. However a site-specific evaluation of potential biological crust development should be performed because the degree of biological crust development within these and other cover types depends on factors such as spoil texture, amount of vascular plant cover, precipitation, and other factors.

Table 1. Relative cover of biological soil crusts in sagebrush (*Artemisia*) vegetation types (adapted from Belnap et al. 2001).

| HIGH biological crust cover | LOW biological crust cover |
|---|---|
| **Tall Sagebrush** | |
| Wyoming big sagebrush<br>*A. tridentata* ssp. *wyomingensis* | subalpine big sagebrush<br>*A. tridentata* ssp. *spiciformis* |
| basin big sagebrush<br>*A. tridentata* ssp. *tridentata* | xeric big sagebrush<br>*A. tridentata* ssp. *xericensis* |
| mountain big sagebrush<br>*A. tridentata* ssp. *vaseyana*<br>(biological crust cover high or low depending on site characteristics) | mountain big sagebrush<br>*A. tridentata* ssp. *vaseyana*<br>(biological crust cover high or low depending on site characteristics) |
| | silver sagebrush<br>*A. cana* |
| | three-tip sagebrush<br>*A. tripartita* |
| **Short Sagebrush** | |
| low sagebrush<br>*A. arbuscula* | alkali sagebrush<br>*A. longiloba* |
| black sagebrush<br>*A. nova* | fuzzy sagebrush<br>*A. papposa* |
| stiff sagebrush<br>*A. rigida* | |
| Bigelow sagebrush<br>*A. bigelovii* | |
| fringed sage<br>*A. frigida* | |

To assist with evaluating the potential for microbiotic crust development based on biological and physical features and the potential effects of management actions, an analysis matrix is provided in Appendix B. The matrix is taken from Appendix 13a: Biological Crust Evaluation, of the Interior Columbia Basin Ecosystem Supplemental Draft Environmental Impact Statement, Volume 2 (USDA Forest Service/USDI Bureau of Land Management 2000a). It is a tool that may be used at site-specific scales to pinpoint where there is high potential for biological crust development, and under what conditions biological crust development is affected by land uses such as livestock grazing and recreation (USDA Forest Service/USDI Bureau of Land

Management 2000b). This information can also help in analyzing the effects of livestock grazing on biological crust in environmental assessments or environmental impact statements. An example of a completed matrix is included as part of Appendix B.

- **Spatial and Temporal Considerations Related to Cumulative Effects Analysis**

Historically many National Environmental Policy Act (NEPA) analyses for natural resource impacts on federal public lands have not adequately considered the cumulative effects of management actions, particularly for impacts to the total habitat required through time by wide-ranging wildlife species such as sage grouse, migratory songbirds, Canada lynx and some large ungulate populations. Impact analysis, particularly at the project level, has frequently been limited to using environmental assessments (EAs) to describe impacts that would occur within an immediate project area or within local field office or ranger district boundaries. Little to no ecological consideration was given to the ways in which local actions affecting natural resources within any given administrative unit were complementing, or conflicting with, the impacts to those same resources as a result of decisions and actions taking place in another part of their range.

In some of the environmental impact statements (EIS) prepared for BLM land use plans developed in the 1970s and 1980s, one consequence of failing to adequately consider both the true geographic extent of resources affected by local actions, and the length of time during which those impacts would have effect, has been more optimistic conclusions about the impacts of proposed actions than was warranted. When preparing new impact analyses, it is instructive to review the conclusions of prior EISs prepared in that time period. In addition to reviewing prior EIS's prepared for a given planning unit, a review of conclusions contained in EISs prepared for adjacent planning units can provide further insights into the need for analyses to be scaled to, for example, the complete range of a wildlife population that spends only part of the year within one planning unit.

The Council on Environmental Quality (CEQ), responsible for administering the NEPA, has prepared a handbook that addresses the complex issue of cumulative effects, outlines general principles, presents useful steps, and provides information on methods of cumulative effects analysis and data sources. The handbook, Considering Cumulative Effects Under the National Environmental Policy Act, addresses both spatial and temporal considerations. Though not issued as formal CEQ guidance, readers are strongly encouraged to become familiar with it. As of Janaury 2002, it was posted on the internet at http://ceq.eh.doe.gov/nepa/ccenepa/ccenepa.htm. The handbook's eight principles of cumulative effects analysis, Chapter 1, Table 1-2, are reproduced in Appendix C.

1) **Spatial Component**. The geographic area(s) to be considered for impact analysis should be delineated based on the resource(s) under consideration. Depending on the resource(s) affected and the nature of the action(s), the area(s) may be fairly small in size or, in the case of wide-ranging species, unique circumstances, or multiple offices conducting similar activities over a broad geographic range, they may be very large, such as sub-basins. For a land use plan in the sagebrush biome, the sub-basin level is recommended for conducting cumulative effects analyses. Scoping can help refine appropriate cumulative effects analysis areas.

Once the analysis areas are determined, all pertinent information pertaining to impacts should be analyzed in conformance with NEPA procedures. Most critically, for sagebrush, the type, canopy cover, vigor and ecological condition of *Artemisia spp.* vegetation should be described. Past burns, seedings and other vegetation changes should be noted. Roads, urban development, private lands and other obvious factors that cause fragmentation and loss of connectivity within the area(s) should be described for analysis. Any management plans, or planned management activities that affect the health of sagebrush communities must also be considered. This approach provides appropriate spatial perspective(s) and allows for improved cumulative effects analysis across the landscape.

2) **Temporal Component**. The time periods considered in cumulative effects analyses commonly address either the expected effective life of projects or, in the case of land use plans and land and resource management plans, the expected life of such plans, with projections. For vegetation manipulation projects, impacts have often been analyzed over an expected interval that would pass until the vegetation either achieved a desired plant community (after which time management would seek to keep it in that specified condition), or until it would return to the condition it was in before the action and retreatment might be needed. It is particularly important to define the correct time period for assessment of prescribed burns, because fire return intervals may be well in excess of 100 years in some sagebrush vegetation types (Whisenant 1990, Peters and Bunting 1994). Irrespective of project type, as a minimum, the analyses should address the entire time period of vegetation recovery on project areas both on-site, and within the context of overall plant community condition across the entire spatially defined area for the resource(s) under consideration (e.g., a two-stage migratory sage grouse population whose range encompasses two or more administering offices and other lands).

As NEPA analysis becomes more sophisticated with improvements in technology, natural resource science and modeling,, cumulative effects analyses that are more reflective of the true spatial and temporal frames will become easier, more accurate, and have greater utility in management planning.

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**Appendix A. Summary of Artemisia species and subspecies characteristics, site preferences, and management responses.**

The summaries that follow are presented in three groups, associated primarily with soil temperature gradient. These groups are derived from the ordination of major sagebrush taxa against gradients of soil temperature and soil moisture presented by West and Young (2000), but do not necessarily reflect the soil moisture gradient component of the ordination. Also, the West and Young ordination depicts silver sagebrush, which they assign to the Dwarf Sagebrushes of Cooler Sites, only to the species level. Based on known and probable soil temperature relations, all three subspecies of silver sagebrush in these summaries are placed in that group. The first common name shown for species is that used by McArthur (1999). Additional common names in the summaries are from other sources.

**Dwarf Sagebrushes of Warmer Sites**

| | |
|---|---|
| Bigelow sagebrush | *Artemisia bigloveii* |
| Black sagebrush | *A. nova* |
| Pygmy sagebrush | *A. pygmaea* |
| Low sagebrush | *A. arbuscula* spp. *arbuscula* |
| Stiff sagebrush | *A.rigida* |
| Tall threetip sagebrush | *A. tripartita* spp. *tripartita* |

**Large Sagebrushes**

| | |
|---|---|
| Sand sage | *A. filifolia* |
| Xeric big sagebrush | *A. xericensis* |
| Wyoming big sagebrush | *A. tridentata* spp. *wyomingensis* |
| Basin big sagebrush | *A. tridentata* spp. *tridentata* |
| Rothrock sagebrush | *A. rothrockii* |
| Mountain big sagebrush | *A. tridentata* spp. *vaseyana* |
| Snowbank big sagebrush | *A. tridentata* spp. *spiciformis* |

**Dwarf Sagebrushes of Cooler Sites**

| | |
|---|---|
| Wyoming threetip sagebrush | *A. tripartita* spp. *rupicola* |
| Alkali sagebrush | *A. longiloba* |
| Cleftleaf sagebrush | *A. arbuscula* spp. *thermopola* |
| Coaltown sagebrush | *A. argilosa* |
| Silver sagebrush | *A. cana* spp. *viscidula* |
| Bolander silver sagebrush | *A. cana* ssp. *bolanderi* |
| Plains silver sagebrush | *A. cana* ssp. *cana* |

Information in the summaries pertaining to states of occurrence, leaf persistence, elevation, flowering periods, habit, vegetation spreading, seed/pound, moisture regime, and soil are from Borland (1998) unless otherwise indicated. Other information is from literature as cited in the text.

Two highly recommended internet sources of sagebrush information are the PLANTS database of the Natural Resource Conservation Service, http://plants.usda.gov/plants, and the Fire Effects Information System (FEIS) database, http://www.fs.fed.us/database/feis. As of January 2002, the FEIS contained 21 *Artemisia* species and subspecies. The following summaries address most of the species included in the FEIS, and additional species and subspecies that are not in the FEIS database.

# Dwarf Sagebrushes of Warmer Sites

| | |
|---|---|
| **Species:** | *Artemisia biglovii* |
| **Common Names:** | Bigelow sagebrush, flat sagebrush, slender gray sagebrush |
| **States of Occurrence:** | Texas (west), Colorado (south), New Mexico, Arizona, Utah, Nevada, California |
| **Deciduous or Evergreen:** | Deciduous above, late deciduous below |
| **Elevation:** | 3,200-8,000' |
| **Flowers:** | August to October |
| **Habit:** | Low, spreading, 8-16" tall |
| **Vegetative Spreading:** | Stem layers rarely |
| **Seed/lb:** | 2,710,000 |
| **Moisture Regime:** | Dry to very dry |
| **Soil:** | Rocky, sandy |
| **Soil Moisture:** | Aridic |
| **Soil Temperature:** | Mesic |
| **Fire Tolerance:** | Intolerant This species is in the FEIS database. |

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**Response to Fire:** Bigelow sagebrush is severely damaged or killed by fire (McArthur 1981) and burned areas are reoccupied through on-site or wind-borne seed (Wright et al.1979). Bigelow sagebrush does not sprout after fire or other disturbance (Wright et al. 1979, Walton et al.1986). Little is documented concerning the germination requirements or seedling establishment of Bigelow sagebrush. The timing of burn may influence recovery rates of many shrubs in sagebrush-grassland communities (Wright et al. 1979).

**Response to Browsing:** No information

**Response to Mechanical Treatment:** No information

**Response to Herbicides:** All varieties of *Artemisia* are readily killed by herbicides (Pechanec *et al.*1965, Tisdale and Hironaka 1981, Western States Sage Grouse Committee 1982, Monsen and Shaw 1986, Whisenant 1986).

# Dwarf Sagebrushes of Warmer Sites

| | |
|---|---|
| **Species:** | *Artemisia nova* |
| **Common Names:** | Black sagebrush, little black sagebrush, small sagebrush |
| **States of Occurrence:** | Great Basin |
| **Deciduous or Evergreen:** | Evergreen |
| **Elevation:** | 4,500-9,500' |
| **Flowers:** | August to October |
| **Habit:** | Erect from spreading base, 6-18" tall |
| **Vegetative Spreading:** | None |
| **Seeds/lb:** | 907,000 |
| **Moisture Regime:** | Dry |
| **Soil:** | Calcareous with rocky pavement, stony, well-drained, thin pH 6.5-7.5 |
| **Soil Moisture:** | Aridic |
| **Soil Temperature:** | Mesic |
| **Fire Tolerance:** | Intolerant This species is in the FEIS database. |

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**Response to Fire:** Black sagebrush is highly susceptible to fire. Plants are readily killed by all fire intensities and do not sprout (Wright et al. 1979). Its intricate branches, low stature and non-sprouting habit make it very vulnerable (Volland and Dell 1981) where fires can carry through this community. Following burning, reestablishment occurs through off-site seed sources (Tisdale and Hironaka 1981, Wright et al.1979, Young 1983). Information concerning reestablishment after burning is lacking. Effective soil moisture and patterns of burning have an influence upon the rate of site recovery.

Historically fire has had little or no influence in communities dominated by black sagebrush (Winward 1985). Typically the sparse vegetation of most black sagebrush stands precludes the occurrence of fire (Clary 1986). In fact, dwarf sagebrush species are commonly recognized as potential natural fire breaks. Beardall and Sylvester (1976) found that low sagebrush communities in Nevada did not burn on a hot day in mid-August despite wind speeds of up to 25 miles per hour (40.3 km per hour). Use of prescribed burning is not usually feasible where black sagebrush forms dense stands.

**Species:** *Artemisia nova*

Since black sagebrush stands do not readily burn, existing response data involves information obtained from study sites where this species is not a dominant vegetation component. In Utah, West and Hassan (1985) found no evidence of black sagebrush reestablishment up to 2 years following a late July fire. Most black sagebrush seeds are dispersed close to the parent plant. Fire in this type is not recommended.

**Response to Browsing:** Black sagebrush was consistently reduced in cover by both cattle and sheep winter grazing (Clary 1986). On some sites, reduction were severe. Low-elevation stands experienced the greatest reductions. Moderate use during mid-winter appears to be compatible with maintaining black sagebrush cover (Clary 1986).

Black sagebrush sites also often have well developed biological crusts due to the calcareous nature of many of the site soils. These crusts also sometimes have a high proportion of nitrogen-fixing species. Mechanical trampling damage can be very detrimental to the health of these sites, particularly through damage to conditions for seedling establishment.

**Response to Mechanical Treatment:** No information

**Response to Herbicides:** All varieties of *Artemisia* are readily killed by herbicides (Pechanec *et al.*1965, Tisdale and Hironaka 1981, Western States Sage Grouse Committee 1982, Monsen and Shaw 1986, Whisenant 1986).

# Dwarf Sagebrushes of Warmer Sites

| | |
|---|---|
| **Species:** | *Artemisia pygmaea* |
| **Common Names:** | Pygmy sagebrush |
| **States of Occurrence:** | Within the Great Basin of Nevada, Utah to northern Arizona, Uinta Basin of Utah and Colorado |
| **Deciduous or Evergreen:** | Evergreen |
| **Elevation:** | 5,200-7,500' |
| **Flowers:** | August to September |
| **Habit:** | Cushion-like, 8-10" tall |
| **Vegetative Spreading:** | None |
| **Seeds/lb:** | 440,000 |
| **Moisture Regime:** | Very dry |
| **Soil:** | Calcareous, clay, gravels, gypseous, shale |
| **Soil Moisture:** | Aridic |
| **Soil Temperature:** | Mesic-frigid |
| **Fire Tolerance:** | Intolerant This species is in the FEIS database. |

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**Response to Fire:** Pygmy sagebrush is killed by fire but readily reoccupies a site through seed (Beetle 1960, McArthur et al. 1979). It does not resprout following fire or other disturbance (Beetle 1960, Walton et. al. 1986).

**Response to Browsing:** No information

**Response to Mechanical Treatment:** No information

**Response to Herbicides:** All varieties of *Artemisia* are readily killed by herbicides (Pechanec *et al.*1965, Tisdale and Hironaka 1981, Western States Sage Grouse Committee 1982, Monsen and Shaw 1986, Whisenant 1986).

# Dwarf Sagebrushes of Warmer Sites

| | |
|---|---|
| **Species:** | *Artemisia arbuscula* ssp. *arbuscula* |
| **Common Names:** | Low sagebrush, gray low sagebrush, scabland sagebrush, dark sagebrush, little sagebrush, dwarf sagebrush |
| **States of Occurrence:** | Southern Colorado to western Montana, through Utah, Idaho to northern California, Oregon, and Washington |
| **Deciduous or Evergreen:** | Evergreen |
| **Elevation:** | 3,000-12,200' |
| **Flowers:** | August to September |
| **Habit:** | Dwarf, irregular shape 15-20", 15-30" wide |
| **Vegetative spreading:** | Seldom layers |
| **Seeds/lb:** | 980,000 |
| **Moisture Regime:** | dry |
| **Soil:** | Harsh, infertile, alkaline, rocky, shallow, hardpan, gravelly, calcic |
| **Soil Moisture:** | Aridic |
| **Soil Temperature:** | Mesic |
| **Fire Tolerance:** | Intolerant This subspecies is in the FEIS database. |

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**Response to Fire:** Gray low sagebrush is a nonsprouter which is readily killed by fire (Britton and Ralphs 1979, Beetle and Johnson 1982). It reestablishes on burned sites through small, light, wind-dispersed seed but this may require 10 years or more (Young 1983). Many gray low sagebrush communities are characterized by a depauperate understory with significant amounts of exposed soil and rock, and stands often lack enough fuels to carry a fire (Beardall and Sylvester1976, Blaisdell et al. 1982, Bunting et al. 1987). Consequently, fires in gray low sagebrush communities are comparatively rare. In fact, these sites can even be used as fuel breaks (Young and Evans 1971, Young 1983).

The possibility of fire is increased during years of above-average precipitation which can result in increased herbaceous growth. This is especially true on sites that have been invaded by weedy species such as medusahead (*Taeniatherum caput-medusae*) or cheatgrass (*Bromus tectorum*) (Bunting et al. 1987, Young and Evans 1971). Recovery time of gray low sagebrush following fire is variable and is described as "slow to rapid." Recovery may occur within 2 to 5 years under favorable conditions but may require more than 10 years on harsh sites.

**Species:** *Artemisia arbuscula* ssp. *arbuscula*

Even when conditions allow fire spread, prescribed burning in low sagebrush sites often produces few benefits (Blaisdell et al. 1982., Young 1983); many experts recommend against widespread burning in low sagebrush types (Bunting et al.1987). Erosion may also be a problem on many harsh sites where revegetation proceeds very slowly. Reliable prescriptions have not yet been developed for use in low sagebrush habitat types (Blaisdell et al.1982).

**Response to Browsing:** *A. arbuscula* sites are greatly preferred by mule deer and domestic sheep (Sheehy and Winward 1981). Trampling damage can occur on sites supporting this taxa because soils are often saturated in early spring (Hironaka et al. 1983). Livestock should be kept off low sagebrush sites until soils have dried out. These sites also have the potential for well developed biological crusts where the soil surface is covered by rock. Mechanical trampling damage can be particularly detrimental to the establishment of *A. arbuscula* seedlings on these sites.

**Response to Mechanical Treatment:** No information

**Response to Herbicides:** This taxa is readily killed by herbicides (Tisdale and Hironaka 1981).

## Dwarf Sagebrushes of Warmer Sites

| | |
|---|---|
| **Species:** | *Artemisia rigida* |
| **Common Names:** | Stiff sagebrush, scabland sagebrush |
| **States of Occurrence:** | Columbia River Basin of eastern Washington, Oregon, and western Idaho |
| **Deciduous or Evergreen:** | Deciduous |
| **Elevation:** | 3,000-7,000' |
| **Flowers:** | September to October |
| **Habit:** | Low, spreading, with thick, brittle branches, to 16" tall |
| **Vegetative Spreading:** | Possible root sprouts |
| **Seeds/lb:** | 550,000 |
| **Moisture Regime:** | Dry |
| **Soil:** | Rocky, shallow |
| **Soil Moisture:** | Xeric |
| **Soil Temperature:** | Mesic |
| **Fire Tolerance:** | Intolerant This species is in the FEIS database. |

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**Response to Fire:** Preliminary tests suggest that stiff sagebrush does not sprout after clipping to a height of 1 to 1.5 inches (3-4 cm) (Tisdale and Hironaka 1981). Establishment following fire depends on off-site seed. Because stiff sagebrush does not sprout, it is likely that it would be killed by most fires. The sparse herbaceous understory of stiff sagebrush stands make them practically immune to fire (Tisdale and Hironaka 1981); consequently they can be used for fire control lines (Clifton 1981).

**Response to Browsing:** This taxa is heavily browsed by big game animals in winter but the effects of this are not known (Hironaka et al. 1983). The shallow, rocky soils where stiff sagebrush often grows are good sites for the development of biological crusts. Mechanical trampling damage may occur, thus degrading the site's capability for new seedling establishment.

**Response to Mechanical Treatment:** No information

**Response to Herbicides:** All varieties of *Artemisia* are readily killed by herbicides (Pechanec *et al.*1965, Tisdale and Hironaka 1981, Western States Sage Grouse Committee 1982, Monsen and Shaw 1986, Whisenant 1986).

## Dwarf Sagebrushes of Warmer Sites

| | |
|---|---|
| **Species:** | *Artemisia tripartita* spp. *tripartita* |
| **Common Names:** | Tall threetip sagebrush, Idaho threetip sagebrush |
| **States of Occurrence:** | British Columbia south through Washington to Nevada, east to northern Utah and western Montana |
| **Deciduous or Evergreen:** | Evergreen to early deciduous |
| **Elevation:** | 3,000-9,000' |
| **Flowers:** | August to September |
| **Habit:** | Erect, freely branching, 6' tall |
| **Vegetative Spreading:** | Root sprouts, stem layers, stump sprouts |
| **Seed/lb:** | 2,490,000 estimated |
| **Moisture Regime:** | Semi-dry |
| **Soil:** | Moderate to deep, well-drained, loamy, sandy |
| **Soil Moisture:** | Aridic - xeric |
| **Soil Temperature:** | Mesic |
| **Fire Tolerance:** | Varies from tolerant to intolerant. See Response to Fire discussion. This species is in the FEIS database, but not to the subspecies level. |

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**Response to Fire:** Tall threetip sagebrush can sprout or layer following fire (Beetle and Johnson 1982, Hironaka et al. 1983, Winward 1985). In some areas, fire may cause a large number of plants to sprout. However, Hironaka et al. (1983) caution that there may be significant ecotypal variation in this taxa and that populations in different areas may respond differently to the same burn conditions.

Fires can spread in threetip sagebrush stands (Britton 1979) and kill aerial plant parts. The shrub can reestablish through stump-sprouting and layering (Mueggler and Stewart 1980). Beetle (1960) notes that tall threetip sagebrush sprouts vigorously from the stump following fire; layering may also occur. Volland and Dell (1981) list the shrub as a weak sprouter in Oregon and Washington.

**Response to Browsing:** No information

**Response to Mechanical Treatment:** No information

**Species:** *Artemisia tripartita* spp. *tripartita*

**Response to Herbicides:** All varieties of *Artemisia* are readily killed by herbicides (Pechanec *et al.*1965, Tisdale and Hironaka 1981, Western States Sage Grouse Committee 1982, Monsen and Shaw 1986, Whisenant 1986).

# Large Sagebrushes

| | |
|---|---|
| **Species:** | *Artemisia filifolia* |
| **Common Names:** | Sand sagebrush, threadleaf sagebrush, oldman sagebrush |
| **States of Occurrence:** | South Dakota to Wyoming, Colorado, Nebraska, Kansas, Texas, Utah, Nevada, New Mexico, Oklahoma, south to Chihuahua, Mexico |
| **Deciduous or Evergreen:** | Semi-deciduous |
| **Elevation:** | 2,700-7,500' |
| **Flowers:** | August to September |
| **Habit:** | Freely branched, rounded, 2-4' tall |
| **Vegetative Spreading:** | None |
| **Seed/lb:** | 3,135,000 |
| **Moisture Regime:** | Dry |
| **Soil:** | Sandy, deep |
| **Soil Moisture:** | Xeric |
| **Soil Temperature:** | Mesic |
| **Fire Tolerance:** | See Response to Fire discussion. This species is in the FEIS database. |

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**Response to Fire:** Specific fire adaptations of sand sagebrush are not well documented. In the northern Texas panhandle, sand sagebrush is considered a "nonsprouter' (Wright et al. 1972) and is often severely damaged or even killed by fire (U. S. Department of the Interior, Bureau of Land Management. [no date], Wright et al. 1972). Conversely, it is described as a fire-tolerant species capable of resprouting after fire in the southern Great Plains (Wright and Bailey1980, 1982).

Ecotypic differences in sprouting capabilities obviously exist. Similarly, differences in season of burn, soil characteristics, fire intensity and severity, and climatic factors may also influence the sprouting ability of sand sagebrush. Many sand sagebrush stands are characterized by an abundance of exposed sand and sparse understory vegetation. Fires are probably infrequent on such sites. Fires, however, have been historically important in many grassland or shrubland communities of the Great Plains and Southwest which support the growth of sand sagebrush (Jackson 1965). Fires presumably carry well in sand sagebrush stands with a dried herbaceous understory of forbs and grasses.

**Species:** *Artemisia filifolia*

Sand sagebrush quickly reoccupies burned sites with an abundance of seedlings (Jackson 1965). It is not known if sand sagebrush typically resprouts, or if reestablishment is through seed. Sand sagebrush produces an abundance of light, wind-dispersed seed, and relatively rapid reestablishment through off-site sources is frequently possible. Grazing may slow recovery of sand sagebrush following fire.
Areas dominated by sand sagebrush, shinnery oak, and skunkbush sumac (*Rhus trilobata*) in Texas and eastern New Mexico have been burned to promote forbs and to encourage new shrub. Such fires can enhance the value of these areas to mule deer and other wildlife species. Recommended procedure is to burn small patches of 5 acres or less in years with greater than normal fall and winter precipitation. The patches should be left unburned for 10 to 12 years and scattered more than 0.25 miles apart to encourage mule deer utilization of these areas (Bryant and Morrison 1985). Burning small patches or swaths minimizes adverse impacts on many wildlife species including small birds (Davis et al. 1974, Holechek 1981). Lesser prairie chickens are more mobile than many other species and can reportedly tolerate brush control on blocks of 370 to 740 acres (150-300 hectares) (Holechek 1981).

**Response to Browsing:** No information

**Response to Mechanical Treatment:** No information

**Response to Herbicides:** All varieties of *Artemisia* are readily killed by herbicides (Pechanec *et al.*1965, Tisdale and Hironaka 1981, Western States Sage Grouse Committee 1982, Monsen and Shaw 1986, Whisenant 1986).

# Large Sagebrushes

| | |
|---|---|
| **Species:** | *Artemisia tridentata* spp. *xericensis* |
| **Common Names:** | Xeric big sagebrush, Scabland big sagebrush |
| **States of Occurrence:** | West central Idaho |
| **Deciduous or Evergreen:** | Evergreen |
| **Elevation:** | 2,500-4,500' |
| **Flowers:** | Early August |
| **Habit:** | More branched paniculate inflorescence than mountain big sagebrush |
| **Vegetative Spreading:** | Radiate with uneven-top (compared to mountain big sagebrush) |
| **Seed/lb:** | 2,500,000 (Best estimate) |
| **Moisture Regime:** | Semi-dry |
| **Soil:** | Basaltic and granitic soils |
| **Soil Moisture:** | Xeric |
| **Soil Temperature:** | Mesic |
| **Fire Tolerance:** | Intolerant This subspecies is not in the FEIS database. |

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**Response to Fire:** Fires in this habitat burn very hot, killing associated perennial species such as *Agropyron spicatum*. Natural replacement after fire is by exotic medusahead (*Teaniatherum caput-medusae*) and cheatgrass (*Bromus tectorum*)with successional trends towards squirreltail (*Sitanion hystrix*) and later, bluebunch wheatgrass (*Pseudoroegneria spicata*) (Rosentreter and Kelsey 1991).

**Response to Browsing:** This species tends to increase in density if the understory is grazed. The deep soils encourage the shrubs to develop deep root systems, allowing annual grasses to occupy much of the upper soil profile beneath and adjacent to the shrub canopy (Rosentreter and Kelsey 1991).

**Response to Mechanical Treatment:** No information

**Response to Herbicides:** All varieties of *Artemisia* are readily killed by herbicides (Pechanec *et al.*1965, Tisdale and Hironaka 1981, Western States Sage Grouse Committee 1982, Monsen and Shaw 1986, Whisenant 1986).

# Large Sagebrushes

| | |
|---|---|
| **Species:** | *Artemisia tridentata* spp. *wyomingensis* |
| **Common Names:** | Wyoming big sagebrush |
| **States of Occurrence:** | Wyoming Basin east to Montana, Wyoming, Colorado, Idaho, North Dakota |
| **Deciduous or Evergreen:** | Evergreen |
| **Elevation:** | 5,000-7,000' |
| **Flowers:** | Late July to September |
| **Habit:** | Basally branched, rounded, uneven topped, 4-38" tall |
| **Vegetative Spreading:** | None |
| **Seed/lb:** | 1,215,000-3,000,000 |
| **Moisture Regime:** | Dry |
| **Soil:** | Dry, shallow, well-drained, gravelly, fine-textured silt-loams |
| **Soil Moisture:** | Aridic-Xeric |
| **Soil Temperature:** | Mesic-frigid |
| **Fire Tolerance:** | Intolerant       This subspecies is in the FEIS database. |

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**Response to Fire:** Wyoming big sagebrush is readily killed by fire. If the foliage is exposed to a minimum temperature of 194ºF for a period of at least 30 seconds, the plant will die. In essence, any fire passing through a plant will cause mortality (Britton and Clark 1985). Some plants in Montana were reported to have survived the burning of lower branches.

Site productivity affects the ease with which big sagebrush will burn. Highly productive sites have greater plant density and more biomass which provide more fuel to carry a fire. Within the three major subspecies of big sagebrush, mountain big sagebrush (ssp. *vaseyana*) is most flammable, basin big sagebrush (ssp. *tridentata*) is intermediate, and Wyoming big sagebrush is least flammable (Britton and Clark 1985).

**Species:** *Artemisia tridentata* spp. *wyomingensis*

Prolific seed production and high rates of germination enables big sagebrush to reestablish rapidly after fire. Wind-, water-, and animal-carried seed contribute to regeneration on a site (Goodwin 1956, Tisdale and Hironaka 1981). Soil-stored seed is thought to be important in the reestablishment of mountain big sagebrush (ssp. *vaseyana*) (Mueggler 1956). On-site seed storage permits rapid reestablishment even where most shrubs in an area are eliminated.

Postfire reestablishment of Wyoming big sagebrush has not been widely documented. On xeric Wyoming big sagebrush sites, several years may be required for seedling establishment to occur (Clifton 1981, Wambolt and Payne 1986, West and Hassan 1985, Young and Evans 1978). During years of low precipitation, few sagebrush plants may become established, and it may take many years before recolonization takes place. In the Great Basin, these sites are at very high risk for permanent degradation as a result of invasion by exotic plants. Even under favorable conditions, site recovery may take 60-100 years.

**Response to Browsing:** In a central Wyoming study, grazing was shown to have a pronounced effect on the longevity of a Wyoming big sagebrush control effort. On plots which had been sprayed but not grazed, sagebrush remained in a reduced state for 14 to 17 years. Fourteen years after spraying, the number of young plants was about 30 percent less than on the untreated plots. The number of mature plants was about 50 percent below that measured on the control. After 17 years, the number of young plants on sprayed and grazed plots was much greater than that for unsprayed and grazed, or sprayed and ungrazed areas. The increase in sagebrush cover and concomitant decrease in forage began 5 years after treatment. Part of the measured decrease in forage production may be due to the tendency of livestock to utilize the treated areas more heavily, reducing the vigor of understory plants (Johnson 1969).

**Response to Mechanical Treatment:** Mechanical or chemical treatments are generally most suitable for *wyomingensis* sites because there often is insufficient fine fuels to allow for controlled burns (Hironaka et al. 1983).

**Response to Herbicides:** All varieties of *Artemisia* are readily killed by herbicides (Pechanec *et al.*1965, Tisdale and Hironaka 1981, Western States Sage Grouse Committee 1982, Monsen and Shaw 1986, Whisenant 1986). In a central Wyoming study, plots which had been sprayed but not grazed, has sagebrush in a reduced state for 14 to 17 years. Fourteen years after spraying, the number of young plants was about 30 percent less than on the untreated plots. The number of mature plants was about 50 percent below that measured on the control. After 17 years, the number of young plants on sprayed and grazed plots was much greater than that for unsprayed and grazed, or sprayed and ungrazed areas. The increase in sagebrush cover and concomitant decrease in forage began 5 years after treatment. Part of the measured decrease in forage production may be due to the tendency of livestock to utilize the treated areas more heavily, reducing the vigor of understory plants (Johnson 1969).

# Large Sagebrushes

| | |
|---|---|
| **Species:** | *Artemisia tridentata* spp. *tridentata* |
| **Common Names:** | Basin big sagebrush, big sagebrush |
| **States of Occurrence:** | Montana south to New Mexico and all western states, extreme southwest North Dakota |
| **Deciduous or Evergreen:** | Evergreen |
| **Elevation:** | 1,500-10,600' |
| **Flowers:** | August to October |
| **Habit:** | Erect, spreading, heavily branched, uneven topped, 3-6 (15)' tall, 5-8' wide |
| **Vegetative Spreading:** | None |
| **Seed/lb:** | 2,500,000 |
| **Moisture Regime:** | Semi-dry |
| **Soil:** | Deep, well-drained, fertile, coarse to fine |
| **Soil Moisture:** | Aridic-xeric |
| **Soil Temperature:** | Frigid-mesic |
| **Fire Tolerance:** | Intolerant This subspecies is in the FEIS database. |

**Response to Fire:** Adult big sagebrush plants are killed by most fires. If sagebrush foliage is exposed to temperatures above 195 degrees Fahrenheit (90 deg C) for longer than 30 seconds, the plant dies (Britton and Clark 1985). Prolific seed production from nearby unburned plants coupled with high germination rates enable seedlings to establish rapidly following fire. Wind-, water-, and animal-carried seed contribute to regeneration on a site (Goodwin 1956, Johnson and Payne 1968, Tisdale and Hironaka 1981).

Site productivity affects the ease with which big sagebrush will burn. Highly productive sites have greater plant density and more biomass, providing more fuel to carry a fire. Of the three major subspecies of big sagebrush, basin big sagebrush is considered intermediate in flammability. Mountain big sagebrush is most flammable, and Wyoming big sagebrush is least flammable (Britton and Clark 1985).

The rate of stand recovery depends on the season of burn as, season affects the availability of seed, postfire precipitation patterns, and the amount of interference offered by other regenerating plant species, particularly exotic annual grasses (Britton and Clark 1985, Daubenmire 1975, Zschaechner 1985).

**Species:** *Artemisia tridentata* spp. *tridentata*

Where sagebrush stands are dense, rangeland fire may stimulate the growth of forage plants and increase their accessibility. Grazing must be closely monitored in the postfire stand. If the vigor of understory plants is low or their cover is reduced too greatly, newly bared soil may become a seedbed for sagebrush rather than the desired grasses and forbs. Where big sagebrush has been removed by chemical means, it has regained its pretreatment cover in 17 years on stands where grazing was not controlled (Johnson 1969).

**Response to Browsing:** Browsing impact generally is not an issue because this taxa has low palatability for both wildlife and domestic livestock (Hironaka et al. 1983). However mechanical trampling damage to soil crusts does occur when these sites are grazed during the hot, dry season. The result is soil erosion and a much less suitable substrate for the establishment of new *A. t. tridentata* seedlings.

**Response to Mechanical Treatment:** No information

**Response to Herbicides:** All varieties of *Artemisia* are readily killed by herbicides (Pechanec *et al.*1965, Tisdale and Hironaka 1981, Western States Sage Grouse Committee 1982, Monsen and Shaw 1986, Whisenant 1986).

# Large Sagebrushes

| | |
|---|---|
| **Species:** | *Artemisia rothrockii* |
| **Common Names:** | Rothrock sagebrush, timberline sagebrush |
| **States of Occurrence:** | Southern California (Uncertain about Wyoming, Colorado, Nevada, or Utah) |
| **Deciduous or Evergreen:** | Evergreen |
| **Elevation:** | 8,500-11,000' |
| **Flowers:** | August to September |
| **Habit:** | Wide, low, 4-32" tall, 1-2' wide |
| **Vegetative Spreading:** | Stem layers and root sprouts |
| **Seed/lb:** | No information |
| **Moisture Regime:** | Dry |
| **Soil:** | Deep, fine to coarse, well-drained |
| **Soil Moisture:** | Xeric |
| **Soil Temperature:** | Frigid-cryic |
| **Fire Tolerance:** | Tolerant — This species is <u>not</u> in the FEIS database. |

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**Response to Fire:** No information

**Response to Browsing:** No information

**Response to Mechanical Treatment:** No information

**Response to Herbicides:** All varieties of *Artemisia* are readily killed by herbicides (Pechanec *et al.*1965, Tisdale and Hironaka 1981, Western States Sage Grouse Committee 1982, Monsen and Shaw 1986, Whisenant 1986).

# Large Sagebrushes

| | |
|---|---|
| **Species:** | *Artemisia tridentata* spp. *vaseyana* |
| **Common Names:** | Mountain big sagebrush, Vasey sagebrush |
| **States of Occurrence:** | Throughout the Rocky Mountains |
| **Deciduous or Evergreen:** | Evergreen |
| **Elevation:** | 4,600-10,000' |
| **Flowers:** | July to September |
| **Habit:** | Spreading, even-topped, 2-4 (6)' tall |
| **Vegetative Spreading:** | Stem layers rarely |
| **Seed/lb:** | 1,760,000-2,500,000 |
| **Moisture Regime:** | Semi-dry |
| **Soil:** | Deep, well drained, pH +-7.0 |
| **Soil Moisture:** | Udic |
| **Soil Temperature:** | Cryic |
| **Fire Tolerance:** | Intolerant This subspecies is in the FEIS database. |

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**Response to Fire:** Fire return intervals in mountain big sagebrush communities historically were 12-15 years (Miller and Rose 1999). Plants are easily killed by fire in all seasons by even light intensity fires (Blaisdell et al. 1982). Mountain big sagebrush will not resprout, but this taxa can rapidly reestablish itself from seed under the typically more mesic conditions of *vaseyana* sites (Harniss and Murray 1973). Seedlings on burned-over areas arise both from seed introduced into the area from an adjacent unburned seed source and from seed stored in the soil that remains viable after burning. Seed present in the upper soil layers can be stimulated during low to moderate severity fires (Hironaka et al. 1983, Mueggler 1956). Reproductive maturity may occur in 3 to 5 years. Preburn density and cover may be achieved in 15 to 20 years under favorable conditions (Hironaka et al. 1983).

Mesic site conditions and fuel discontinuities may result in unharmed mountain big sagebrush plants or groups of plants within light and moderately severe burns. Whereas the normally mesic site conditions often preclude severe burns, severe wildfires are more likely to occur on steep, south slopes during hot, dry summers. Such severe fires leave few unburned plants and consume most of the seed stored in the litter and upper soil. These sites also are highly susceptible to invasion by exotic plants.

**Species:** *Artemisia tridentata* spp. *vaseyana*

Rapid reestablishment and growth of sagebrush is aided by: 1) reduction in bunchgrasses, 2) suitable soil surface moisture conditions for seedling establishment, and 3) the tendency of soil stored seed to be stimulated by fire. Natural establishment of seedlings may be slow where severe burns occur on steep slopes because of unstable soil surface conditions, intense surface temperatures, and poor moisture conditions. It may take 30 years or more before preburn densities and coverages of mountain big sagebrush are regained on severe burns. Rapid reestablishment is more likely on sandy or gravelly soils which are well suited for supporting sagebrush but have poor potential for herbaceous plants. Sagebrush returns slowly on fine-textured soils with good potential for production of herbaceous species (Blaisdell et al. 1982, Hironaka et al. 1983).

**Response to Browsing:** This taxa is relatively palatable and provides an important source of browse for wintering big game (Hironaka et al. 1983). Effects of browsing are not known.

**Response to Mechanical Treatment:** No information

**Response to Herbicides:** All varieties of *Artemisia* are readily killed by herbicides (Pechanec *et al.*1965, Tisdale and Hironaka 1981, Western States Sage Grouse Committee 1982, Monsen and Shaw 1986, Whisenant 1986). Up to 90% canopy reduction can be obtained with 2,4-D, dicamba, picloram or clopyralid. The latter compound is preferred where this sagebrush occurs with bitterbrush (*Purshia tridentata*) or serviceberry (*Amelanchier* sp.). Clopyralid has relatively minor effects on members of the Rosaceae (Whisenant 1986).

# Large Sagebrushes

| | |
|---|---|
| **Species:** | *Artemisia tridentata* spp. *spiciformis*, also described as *A. t. vaseyana* form *spiciformis* |
| **Common Names:** | Subalpine big sagebrush |
| **States of Occurrence:** | Colorado, northcentral Wyoming, southeastern Idaho, central Utah (see McArthur and Plummer 1978, Schultz 1986, McArthur and Goodrich 1986) |
| **Deciduous or Evergreen:** | Evergreen |
| **Elevation:** | 8,800-10,000' |
| **Flowers:** | July to September |
| **Habit:** | 2-4' tall |
| **Vegetative Spreading:** | Stem layers |
| **Seed/lb:** | No information |
| **Moisture Regime:** | Semi-dry |
| **Soil:** | Basic, deep |
| **Soil Moisture:** | Udic |
| **Soil Temperature:** | Cryic |
| **Fire Tolerance:** | Tolerant This subspecies is not in the FEIS database. |

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**Response to Fire:** Winward (1985) reports that this form will resprout following fire, which is especially significant as it is the only member of the big sagebrush group with this capacity. No other information on this taxa is available.

**Response to Browsing:** No information

**Response to Mechanical Treatment:** No information

**Response to Herbicides:** All varieties of *Artemisia* are readily killed by herbicides (Pechanec *et al.*1965, Tisdale and Hironaka 1981, Western States Sage Grouse Committee 1982, Monsen and Shaw 1986, Whisenant 1986).

## Dwarf Sagebrushes of Cooler Sites

| | | |
|---|---|---|
| **Species:** | *Artemisia tripartita* spp. *rupicola* | |
| **Common Names:** | Wyoming three-tip sagebrush | |
| **States of Occurrence:** | Central and southeast Wyoming | |
| **Deciduous or Evergreen:** | Evergreen to early deciduous | |
| **Elevation:** | 7,000-9,000' | |
| **Flowers:** | August to September | |
| **Habit:** | Decumbent, 6" tall, 12-20" wide | |
| **Vegetative Spreading:** | Root sprouts, stem layers, and stump sprouts | |
| **Seed/lb:** | 2,490,000 (Estimate) | |
| **Moisture Regime:** | Semi-dry | |
| **Soil:** | Rocky, gravelly, shallow to deep | |
| **Soil Moisture:** | Xeric | |
| **Soil Temperature:** | Frigid-cryic | |
| **Fire Tolerance:** | Tolerant | This species is in the FEIS database, but not to the subspecies level. |

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**Response to Fire:** Wyoming threetip sagebrush can sprout from its root crown following fire (Beetle 1960, 1977; Winward 1985). It may also layer (Beetle 1960). Fire on some sites occupied by its sister taxa, *A. tripartita tripartita,* may cause a large number of plants to sprout. However, Hironaka et al. (1983) caution that there may be significant ecotypal variation in this taxa and that populations in different areas may respond differently to the same burn conditions.

Wyoming threetip sagebrush can stump-sprout or sprout from its rootcrown following fire (Beetle 1960, Beetle 1977). However, sprouting ability varies considerably regionally, indicating that several ecotypes may exist (Barrington *et al.*1988, Bunting et al. 1987).

**Response to Browsing:** No information

**Response to Mechanical Treatment:** No information

**Response to Herbicides:** All varieties of *Artemisia* are readily killed by herbicides (Pechanec *et al.*1965, Tisdale and Hironaka 1981, Western States Sage Grouse Committee 1982, Monsen and Shaw 1986, Whisenant 1986).

# Dwarf Sagebrushes of Cooler Sites

| | |
|---|---|
| **Species:** | *Artemisia longiloba* |
| **Common Names:** | alkali sagebrush, early sagebrush, longleaf sagebrush |
| **States of Occurrence:** | Foothills on both sides of the Continental Divide, west to southwest Montana, Utah, Idaho, Nevada, Oregon |
| **Deciduous or Evergreen:** | Not persistent |
| **Elevation:** | 5,500-8,000' |
| **Flowers:** | June |
| **Habit:** | Spreading, 6-9 (18)" tall |
| **Vegetative Spreading:** | Stem layers |
| **Seed/lb:** | 2,655,000 |
| **Moisture Regime:** | Semi-dry |
| **Soil:** | Alkaline shales, light to tight clays, shallow, claypan |
| **Soil Moisture:** | Xeric |
| **Soil Temperature:** | Frigid-cryic |
| **Fire Tolerance:** | Intolerant This species is in the FEIS database. |

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**Response to Fire:** Prescribed burning on early sagebrush sites has rarely been attempted because the understory is normally not sufficient to carry fire (Monsen and Shaw 1986). The two publications on this species are in conflict as to its fire tolerance. A mid-June burn in an early sagebrush/Idaho fescue stand resulted in spotty kills, leaving enough seed to ripen on unburned shrubs to provide a good seed source. A large number of the burned shrubs recovered via regrowth from remaining branches. However, Dealy et al. (1981) report that early sagebrush does not sprout from the root or stump and reestablishes following fire via seed.

One year after a mid-June burn there was a 26 percent reduction of early sagebrush. Burning can be used to reduce shrub density and is a good tool if retention of some shrubs is desired. Shrub seedlings could increase rapidly if a sufficient understory is not present to control early sagebrush through competition (Monsen and Shaw 1986).

**Response to Browsing:** Trampling damage can occur on sites supporting this taxa because soils are often saturated in early spring (Hironaka et al. 1983).

**Species:** *Artemisia longiloba*

**Response to Mechanical Treatment:** Discing resulted in a 65% reduction in total shrub population one year later while chaining resulted in a 33% reduction. Seedling establishment was poor as seeds may have been buried too deeply by these treatments. This impairment of seedling establishment persisted for five years following treatment. Further, the vigor of mature plants declined more rapidly on the treated sites as compare to the controls suggesting that mechanical damage continued to take a toll. Basal and root sprouting did not occur and plants were killed if the main stem was uprooted or cut off. Generally, discing is a more severe treatment than chaining (Monsen and Shaw 1986).

**Response to Herbicides:** Spraying with 2, 4-D resulted in a complete eradication of sagebrush cover (Monsen and Shaw 1986) and the reductions persisted longer than on the disced and chained sites. Spraying must be completed early in the season (by 20 May in southern Idaho) to be effective.

# Dwarf Sagebrushes of Cooler Sites

| | |
|---|---|
| **Species:** | *Artemisia arbuscula* spp. *thermopola* |
| **Common Names:** | cleftleaf sagebrush, hotsprings sagebrush, thermopola sagebrush, low sagebrush |
| **States of Occurrence:** | Southern Colorado to western Montana, through Utah, Idaho to northern California, Oregon, and Washington |
| **Deciduous or Evergreen:** | Evergreen |
| **Elevation:** | 5,000-9,000' |
| **Flowers:** | August to September |
| **Habit:** | Spreading, 6-9 (12)” tall, 12-16" wide |
| **Vegetative Spreading:** | None |
| **Seed/lb:** | 980,000 |
| **Moisture Regime:** | Semi-dry |
| **Soil:** | Sterile, often volcanic, shallow, claypan, non-calcic |
| **Soil Moisture:** | Possibly xeric |
| **Soil Temperature:** | Frigid-cryic |
| **Fire Tolerance:** | Intolerant This subspecies is in the FEIS database. |

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**Response to Fire:** Evidence suggests that cleftleaf sagebrush is readily killed by fire. It is not known to sprout, but reestablishes through light, off-site, wind-dispersed seed from surviving plants adjacent to the burn, as is the case for most *Artemisia* taxa. Gray low sagebrush can recover within 2 to 5 years with favorable conditions, but more than 10 years may be required under less favorable circumstances (Hopkins and Kovalchik 1983). However, recovery time is not well documented.

Low sagebrush communities are characterized by much exposed soil and surface rock along with a lower species richness and density of forbs and grasses than that found in many other *Artemisia* types. Many stands lack sufficient fuels to carry a fire even on hot days with winds up to 40 km/hr (25 mph) (Beardall and Sylvester 1976, Bernard and Brown 1977, Blackburn et al. 1969). Consequently, fires in cleftleaf sagebrush communities are probably rare. The probability of fire increases as herbaceous growth increases as a result of above-average precipitation or increased protection from grazing (Blackburn et al. 1969). Weedy species such as medusahead and cheatgrass will increase flammability of low sagebrush stands (Blackburn et al. 1969, Hopkins 1979). Gray low sagebrush has been successfully used as a fuelbreak when adjacent big sagebrush communities have been burned (Hitchcock and Cronquist 1973, Hopkins and Kovalchik 1983).

**Species:** *Artemisia arbuscula* spp. *thermopola*

Prescribed fires may not be possible or desirable in cleftleaf sagebrush stands. Fires in most low sagebrush communities produce relatively few benefits (Beardall and Sylvester1976, Blackburn et al. 1969, Hopkins and Kovalchik 1983).

**Response to Browsing:** *A. arbuscula* sites are greatly preferred by mule deer and domestic sheep (Sheehy and Winward 1981). Trampling damage can occur on sites supporting this taxa because soils are often saturated in early spring (Hironaka et al. 1983). Livestock should be kept off low sagebrush sites until soils have dried out.

**Response to Mechanical Treatment:** No information

**Response to Herbicides:** All varieties of *Artemisia* are readily killed by herbicides (Pechanec *et al.*1965, Tisdale and Hironaka 1981, Western States Sage Grouse Committee 1982, Monsen and Shaw 1986, Whisenant 1986).

# Dwarf Sagebrushes of Cooler Sites

| | |
|---|---|
| **Species:** | *Artemisia argilosa* |
| **Common Names:** | Coaltown sagebrush |
| **States of Occurrence:** | Jackson County, Colorado |
| **Deciduous or Evergreen:** | Deciduous |
| **Elevation:** | 8,000' |
| **Flowers:** | July to August |
| **Habit:** | Erect, 20-32" tall |
| **Vegetative Spreading:** | None |
| **Seed/lb:** | No information |
| **Moisture Regime:** | No information |
| **Soil:** | Strongly alkaline, poor drainage, shaley |
| **Soil Moisture:** | Udic |
| **Soil Temperature:** | Cryic |
| **Fire Tolerance:** | Tolerant          This species is not in the FEIS database. |

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**Response to Fire:** No information

**Response to Browsing:** No information

**Response to Mechanical Treatment:** No Information

**Response to Herbicides:** All varieties of *Artemisia* are readily killed by herbicides (Pechanec *et al.*1965, Tisdale and Hironaka 1981, Western States Sage Grouse Committee 1982, Monsen and Shaw 1986, Whisenant 1986).

## Dwarf Sagebrushes of Cooler Sites

| | |
|---|---|
| **Species:** | *Artemisia cana* spp. *viscidula* |
| **Common Names:** | Mountain silver sagebrush, silver sagebrush, coaltown sagebrush |
| **States of Occurrence:** | Southwest Montana to New Mexico, west to Arizona, Nevada, Utah, and Idaho |
| **Deciduous or Evergreen:** | Not persistent |
| **Elevation:** | 5,500-10,000' |
| **Flowers:** | August to September |
| **Habit:** | Erect, thickly branched, 3.3' tall |
| **Vegetative Spreading:** | Stem layers and root sprouts |
| **Seed/lb:** | 2,200,000 |
| **Moisture Regime:** | Semi-dry |
| **Soil:** | Deep, rich loams |
| **Soil Moisture:** | Udic |
| **Soil Temperature:** | Cyric |
| **Fire Tolerance:** | Tolerant This subspecies is in the FEIS database. |

**Response to Fire:** Fire effects information on mountain silver sagebrush has not been widely documented. Studies on the morphologically similar plains silver sagebrush indicate that the extent to which plants survive burning is directly related to fire intensity and severity. Totally consumed plants sustain higher mortalities than those less thoroughly burned. This trend is further accentuated by season of burning; more plants survive spring burns than fall burns (White and Currie 1983). Apparently soil moisture and phenological stage at the time of burning have a significant influence on plant survival (White and Currie 1984) as well.

Information from related species indicates that silver sagebrush resprouts vigorously via root sprouts and rhizomes following fire (Beetle 1960, Winward 1985). Apparently, however, resprouting abilities differ between the mountain (ssp. *viscidula*) and high desert (ssp. *bolanderi*) subspecies (Young 1983). Postburn regeneration also involves the germination of off-site, wind-dispersed seed (Wright et al. 1979). Preburn coverages are rapidly regained in most cases. Studies on plains silver sagebrush indicate that as burn intensity and severity increase, plant mortality also increases and regrowth decreases (White and Currie 1983).

**Species:** *Artemisia cana* spp. *viscidula*

Herbaceous production is potentially quite high on mesic sites characterized by mountain silver sagebrush (Winward 1980), and dense stands are candidates for control measures. Although burning appears to be an effective means of managing plant densities in the plains subspecies, the degree to which these data apply to mountain silver sagebrush is unknown. The mesic nature of most areas dominated by this subspecies suggests that burns must be well-timed, especially where shrub control is an objective.

**Response to Browsing:** No information

**Response to Mechanical Treatment:** No information

**Response to Herbicides:** All varieties of *Artemisia* are readily killed by herbicides (Pechanec et al. 1965, Tisdale and Hironaka 1981, Western States Sage Grouse Committee 1982, Monsen and Shaw 1986, Whisenant 1986).

# Dwarf Sagebrushes of Cooler Sites

| | |
|---|---|
| **Species:** | *Artemisia cana* spp. *bolanderi* |
| **Common Names:** | Bolander silver sagebrush, white sagebrush, silver sagebrush |
| **States of Occurrence:** | Central Oregon, western Nevada, eastern California |
| **Deciduous or Evergreen:** | Evergreen to deciduous |
| **Elevation:** | Up to 5,000' |
| **Flowers:** | August to September |
| **Habit:** | Erect, spreading, much branched, 8-24" tall |
| **Vegetative Spreading:** | Stem layers and root sprouts |
| **Seed/lb:** | 846,000-2,200,000 |
| **Moisture Regime:** | Moist |
| **Soil:** | Extremely clayey, alkaline, granitic |
| **Soil Moisture:** | Possibly Udic |
| **Soil Temperature:** | Frigid-cyric |
| **Fire Tolerance:** | Tolerant This subspecies is in the FEIS database. |

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**Response to Fire:** Bolander silver sagebrush resprouts vigorously from the root crown (Beetle 1960, Dealy et al. 1981) and rhizomes following most fires, suggesting that this taxon is adapted to higher fire return frequencies. Postfire regeneration also involves the germination of wind-dispersed seed (Volland and Dell 1981, Wright et al. 1979, Hironaka et al.1983). In most cases, recovery is relatively rapid. Fire response information on the silver sagebrush complex as a whole indicates that densities are rapidly regained and even enhanced following burning.

The ability of Bolander silver sagebrush stands to carry fire is low because of seasonally high water tables and sparse understories. Plant manipulation via prescribed burning in communities dominated by this subspecies appears questionable because few species are adapted to the moisture regimes and alkaline soils characterized by these sites (Dealy *et al.*1981, White and Currie 1983).

**Response to Browsing:** No Information

**Response to Mechanical Treatment:** Silver sagebrush can regenerate from root sprouts following disturbance (Harvey 1981, Walton et al. 1986) and can recover quickly following mechanical disturbance (Urness 1966).

**Species:** *Artemisia cana* spp. *bolanderi*

**Response to Herbicides:** All varieties of *Artemisia* are readily killed by herbicides (Tisdale and Hironaka 1981, Western States Sage Grouse Committee 1982, Monsen and Shaw 1986, Whisenant 1986).

# Dwarf Sagebrushes of Cooler Sites

| | |
|---|---|
| **Species:** | *Artemisia cana* spp. *cana* |
| **Common Names:** | Plains silver sagebrush, silver sagebrush, hoary sagebrush |
| **States of Occurrence:** | Southern Alberta, Saskatchewan south through Montana, western and central North Dakota, South Dakota, Wyoming, northwest Nebraska, and northern Colorado |
| **Deciduous or Evergreen:** | Evergreen to deciduous |
| **Elevation:** | 5,000-10,000' |
| **Flowers:** | August to September |
| **Habit:** | Erect, rounded, freely branched, 3-5' tall |
| **Vegetative Spreading:** | Root spouts, rhizomes, and stem layers |
| **Seed/lb:** | 846,000-2,200,000 |
| **Moisture Regime:** | Moist |
| **Soil:** | Coarse, well-drained, deep, loam to sandy pH 6.5-8.5 |
| **Soil Moisture:** | Udic |
| **Soil Temperature:** | Cyric |
| **Fire Tolerance:** | Tolerant This species is in the FEIS database. |

**Response to Fire:** Like *A. c. bolanderi*, the ability of this taxon to sprout suggests a history of higher fire return intervals and an adaptation to burning. Plants that are not killed by fire resprout vigorously, both through basal and root sprouts, and may return to pre-burn canopy coverage in three years. Plants that are burned annually up to three consecutive years, and not killed, will continue to sprout, although vigor declines substantially.

Burning causes complete top-kill of plains silver sagebrush regardless of the degree to which aerial plant parts are consumed. The extent to which plants survive burning, however, is directly related to fire intensity. Totally consumed plants sustain higher mortalities than those less thoroughly burned. This trend is further accentuated by season of burning as it relates to fire severity and plant phenology. More plants survive spring burns than fall burns (White and Currie 1983, 1984).

This range in plant response suggests that fire can be an effective method of managing plant densities, at least over periods of a few years. On winter ranges where this subspecies is a palatable forage, spring burning can be used to enhance plant coverages and rejuvenate stands. Where plant control is deemed necessary, fall burning can drastically reduce coverages. Silver sagebrush apparently experiences moisture stress as the season progresses, which is compounded in thick stands (White and Currie 1984).

**Species:** *Artemisia cana* spp. *cana*

**Response to Browsing:** Big game browse on silver sagebrush but are not known to cause obvious reductions in extent. Livestock do not use this taxa.

**Response to Mechanical Treatment:** No information

**Response to Herbicides:** All varieties of *Artemisia* are readily killed by herbicides (Pechanec et al. 1965, Tisdale and Hironaka 1981, Western States Sage Grouse Committee 1982, Monsen and Shaw 1986, Whisenant 1986).

## Appendix B. Microbiotic crust evaluation form and example.

### INSTRUCTIONS FOR USING THE MATRIX

The matrix is split into two main parts: 1) The potential for microbiotic crust development based on biological and physical factors and 2) The potential for management actions to negatively impact microbiotic crusts.

### 1. Potential for microbiotic crust development based on biological and physical factors.

The first step in use of the matrix is to determine whether or not the site has the potential to support a well-developed microbiotic crust. **Knowledge of local ecological sites (particularly soil characteristics and vegetation potential) is essential for use of the matrix.** The factors listed are closely related and are components of the ecological site description, however variation in any one factor can influence microbiotic crust cover and its relative importance to the ecological stability of the site.

In general, ecological sites dominated by shrubs listed in the first column will consistently have a well-developed microbiotic crust. The main characteristic that will modify crust cover is soil surface texture. For example, low sagebrush communities often have a well-developed microbiotic crust. Low sagebrush communities occurring on calcareous, gravelly loams and silt loams (such as alluvial deposits from the Lemhi Range) have well developed lichen crusts that occupy fine-textured, mineral soil within the gravel matrix (and, in fact, are protected by the gravel). In constrast, low sagebrush communities occurring on rocky, well-drained, rhyolitic soils in the Owyhee Mountains have little potential for crust development due to high cover of rock fragments and coarser, rhyolite-derived soils.

A second important cut is the potential herbaceous plant density. Note that mountain big sagebrush is listed in the "moderate", "low", and "very low" columns. Communities at the drier end of the mountain big sagebrush zone will have greater cover of biological crust due to lower density of herbaceous plants, limited by effective precipitation. More productive sites will have mosses and lichens occuring beneath a dense herbaceous layer. However the vascular plant component has higher cover and is more important in these communities for soil protection relative to the microbiotic crust.

Status of existing vegetation on the site is determined using the "Current ecological condition" or categories under "Artificial seedings". Sites where vegetation structure has been modified due to introduction of invasive weeds or rhizomatous grasses seeded into areas that naturally supported bunchgrass vegetation will have reduced potential for microbiotic crust. Sites that have become dominated by annual species such as cheatgrass or medusahead wildrye have lowered potential for microbiotic crust development due to high plant density, litter accumulation, and frequent fire. Microbiotic crusts will recover on burned sites seeded with bunchgrasses, forbs and shrubs, if the resulting community structure is similar to that of the potential natural community and contains open interspaces.

### 2. Potential for management actions to negatively impact microbiotic crusts.

After determination of the potential for microbiotic crust development, livestock impacts can be evaluated using two criteria: season of use and utilization levels (from monitoring data). Microbiotic crusts require moisture for growth and reproduction, however moisture requirements are minute compared to vascular plants. Growth is promoted by cool season, as opposed to summer, moisture. Microbiotic crusts are fragile when dry (dormant), but quite pliable when moist. The least impact occurs when the crust is moist or frozen. Regrowth potential is greatest during periods when cool season moisture is consistent for several weeks. For example, late fall use has low impacts because: 1) the microbiotic crust is likely to be moist and pliable due to dew, frost, and periodic rain; 2) there is a considerable length of time between the period of use and the dry, hot season. Late spring use may also occur under conditions listed in #1 above, however, the dry, hot season is imminent and the crust may not have time to recover from trampling impacts via reattachment and regrowth. Once the crust is fragmented, the soil surface is vulnerable to erosion by wind and water. In addition, the crust fragments can be removed from the site along with surface soil, reducing the potential for future recovery.

Vegetation utilization is representative of stocking rates or length of grazing period. Hoof action impacts the crust (the crust is not grazed). Severe to high utilization is indicative of localized concentration of animals and heavy trampling. Again, trampling impacts will be somewhat dependent on season of use and soil texture.

## Microbiotic Crust Evaluation

Impacts of livestock grazing on microbiotic crust are judged to be **significant, present but not significant or not present.** This judgment is based upon **data (incorporate data here) and/or completion of the following matrix.**

| **Potential for microbiotic crust development based on physical and biological factors (based on site potential):** | **High** | **Moderate** | **Low** | **Very Low** |
|---|---|---|---|---|
| **Dominant shrub or tree** | salt desert shrub<br>Wyoming big sage-brush, basin big sagebrush, low sagebrush, black sagebrush, stiff sagebrush, Bigelow sagebrush | Wyoming big sagebrush<br>basin big sagebrush<br>mountain big sagebrush<br>low sagebrush<br>black sagebrush<br>stiff sagebrush | mountain big sagebrush<br>xeric big sagebrush<br>subalpine big sagebrush<br>threetip sagebrush, silver sagebrush, alkali sage-brush, fuzzy sagebrush, juniper, pinyon pine | mountain big sagebrush<br>mountain shrub |
| **Herbaceous plant density** | low | low-moderate | moderate-high | high |
| **Dominant herbaceous life form** | bunchgrass | bunchgrass | rhizomatous | rhizomatous |
| **Annual precipitation** | < 12'' | 12-14" | >14-16" | >16" |
| **Soil surface texture** | silts<br>silt loams<br>clays (excluding shrink/swell clays) | loamy | sandy | coarse sand<br>gravel or broken rock<br>(>80% rock fragment) |
| **Historical fire return interval** | >50 years | 25-50 years | 10-25 years | <10 years |
| **Current ecological condition** | mid- to late-seral or potential natural community | early- to mid-seral | disturbed to early-seral | disturbed with/without high weed cover |
| **Artificial Seedings:** | | | | |
| **Date since seeding** | >20 years | 10-20 years | 5-10 years | <5 years |
| **Primary seeded life-forms** | bunchgrasses | bunchgrasses | rhizomatous grasses | rhizomatous grasses |
| **Potential for management actions to impact microbiotic crusts:** | **High** | **Moderate** | **Low** | **Very Low** |
| **Livestock season of use** | summer | late spring<br>early fall | early spring<br>late fall | winter |
| **Vegetation utilization** | severe to high | moderate | light | slight |

**Microbiotic Crust Evaluation - Completed Example**

| 1. Potential for microbiotic crust development based on biological and physical factors (based on site potential): High------------------------>Moderate--------------------->Low----------------->Very Low | | | | |
|---|---|---|---|---|
| **Dominant shrub or tree** | salt desert shrub√<br>Wyoming big sagebrush<br>basin big sagebrush<br>low sagebrush<br>black sagebrush<br>stiff sagebrush | Wyoming big sagebrush<br>basin big sagebrush<br>mountain big sagebrush<br>low sagebrush<br>black sagebrush<br>stiff sagebrush | mountain big sagebrush<br>xeric big sagebrush<br>subalpine big sagebrush<br>threetip sagebrush, silver sagebrush, alkali sage-brush, fuzzy sagebrush, juniper, pinyon pine | mountain big sagebrush<br>mountain shrub |
| **Herbaceous plant density** | low√ | low-moderate | moderate-high | high |
| **Dominant herbaceous life form** | bunchgrass√ | bunchgrass | rhizomatous | rhizomatous |
| **Annual precipitation** | < 12"√ | 12-14" | >14-16" | >16" |
| **Soil surface texture** | silts √<br>silt loams<br>clays (excluding shrink/swell clays) | loamy | sandy | coarse sand<br>gravel or broken rock<br>(>80% rock fragment) |
| **Historical fire return interval** | >50 years √ | 25-50 years | 10-25 years | <10 years |
| **Current ecological condition** | mid- to late-seral or potential natural community | early- to mid-seral | disturbed to early-seral √ | high weed cover |
| **Artificial Seedings:** | | | | |
| **Date since seeding** | >20 years | 10-20 years | 5-10 years | <5 years |
| **Primary seeded life-forms** | bunchgrasses | bunchgrasses | rhizomatous grasses | rhizomatous grasses |
| **2. Potential for management actions to negatively impact microbiotic crusts: High------------------------>Moderate--------------------->Low----------------->Very Low** | | | | |
| **Livestock season of use** | summer | late spring<br>early fall | early spring<br>late fall √ | winter |
| **Vegetation utilization** | severe to high √ | moderate | light | slight |

The top of the matrix indicates the potential for microbiotic crust cover is high and season of use by livestock should result in low impact to the crust. However, level of use when livestock are present is high (e.g. >80% utilization). This indicates that impacts of livestock on microbiotic crust are probably significant due to vegetation use levels and the associated trampling impacts. Field observations support this analysis as microbiotic crust is present but highly fragmented (clumps <1" inch diameter) and primarily restricted to protected areas under shrubs. Reducing livestock numbers would probably result in improved cover and distribution of microbiotic crust.

## Appendix C. Principles of Cumulative Effects Analysis

The following principles of cumulative effects analysis are reproduced from Considering Cumulative Effects Under the National Environmental Policy Act, Chapter 1: Introduction to Cumulative Effects Analysis, prepared by the Council on Environmental Quality.

**1. Cumulative effects are caused by the aggregate of past, present, and reasonably foreseeable future actions.**

The effects of a proposed action on a given resource, ecosystem, and human community include the present and future effects added to the effects that have taken place in the past. Such cumulative effects must also be added to effects (past, present, and future) caused by all other actions that affect the same resource.

**2. Cumulative effects are the total effect, including both direct and indirect effects, on a given resource, ecosystem, and human community of all actions taken, no matter who (federal, nonfederal, or private) has taken the actions.**

Individual effects from disparate activities may add up or interact to cause additional effects not apparent when looking at the individual effects one at a time. The additional effects contributed by actions unrelated to the proposed action must be included in the analysis of cumulative effects.

**3. Cumulative effects need to be analyzed in terms of the specific resource, ecosystem, and human community being affected.**

Environmental effects are often evaluated from the perspective of the proposed action. Analyzing cumulative effects requires focusing on the resource, ecosystem, and human community that may be affected and developing an adequate understanding of how the resources are susceptible to effects.

**4. It is not practical to analyze the cumulative effects of an action on the universe; the list of environmental effects must focus on those that are truly meaningful.**

For cumulative effects analysis to help the decision-maker and inform interested parties, it must be limited through scoping to effects that can be evaluated meaningfully. The boundaries for evaluating cumulative effects should be expanded to the point at which the resource is no longer affected significantly or the effects are no longer of interest to affected parties,.

**5. Cumulative effects on a given resource, ecosystem, and human community are rarely aligned with political or administrative boundaries.**

Resources typically are demarcated according to agency responsibilities, county lines, grazing allotments, or other administrative boundaries. Because natural and sociocultural resources are not usually so aligned, each political entity actually manages only a piece of the affected resource or ecosystem. Cumulative effects analysis on natural systems must use natural ecological boundaries and analysis of human communities must use actual sociocultural boundaries to ensure including all effects.

**6. Cumulative effects may result from the accumulation of similar effects or the synergistic interaction of different effects.**

Repeated actions may cause effects to build up through simple addition (more and more of the same type of effect), and the same or different actions may produce effects that interact to produce cumulative effects greater than the sum of the effects.

**7. Cumulative effects may last for many years beyond the life of the action that caused the effects.** Some actions cause damage lasting far longer than the life of the action itself (e.g., acid mine drainage, radioactive waste contamination, species extinctions). Cumulative effects analysis needs to apply the best science and forecasting techniques to assess potential catastrophic consequences in the future.

**8. Each affected resource, ecosystem, and human community must be analyzed in terms of he capacity to accommodate additional effects, based on its own time and space parameters.** Analysts tend to think in terms of how the resource, ecosystem, and human community will be modified given the action's development needs. The most effective cumulative effects analysis focuses on what is needed to ensure long-term productivity or sustainability of the resource.