Ecological site group R023XY915NV
Clayey Plateaus 10-12 PZ Sagebrush with Rhizomatous Grass

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Key Characteristics

- Site does not pond or flood
- Landform other than dunes
- Soil surface is clayey
- MAP > 10"
- Soils warmer than frigid.
- Soils extremely reactive and may have visible concentrations of $CaCO_3$.

Provisional. A provisional ecological site description has undergone quality control and quality assurance review. It contains a working state and transition model and enough information to identify the ecological site.

Physiography

This group occurs on plateaus at elevations from 4500' to 6000' with slopes from 0% to 20% with 6% slope being representative.

Climate

The climate is classified as Cold Semi-Arid in the Koppen classification system.

The area receives between 10" and 12" of annual precipitation as snow in the winter and rain in spring and fall. Summers are generally dry.

There are between 70 and 100 frost free days per year, and the mean annual air temperature is between 45° and 50° F.

Soil features

The soils in this group are clayey and shallow. The soils in this site are typically moderately deep to deep clay textured soils underlain by basalt bedrock. The thin surface layers are underlain by heavy clay subsoils having strong to massive structure. The fine textured soils swell on wetting then shrink and crack upon drying. When dry, the soils have wide cracks into which the granulated surface layers tend to slough. Upon wetting the cracks close. This continual, active, soil movement damages the root system of many plants. Infiltration of water is restricted once the surface soils are saturated and the site is subject to loss of water by runoff and evaporation. These soils normally have a high percentage of gravels and cobbles on the surface which occupy plant growing space yet provide a stabilizing effect on surface erosion conditions. Wind erosion potential is slight.

Taxonomically they are vertisols.

The most common soils are Horsecamp, Brubeck, and Gerlach

Vegetation dynamics

Ecological Dynamics and Disturbance Response:

An ecological site is the product of all the environmental factors responsible for its development and it has a set of key characteristics that influence a site's resilience to disturbance and resistance to invasives. Key characteristics include 1) climate (precipitation, temperature), 2) topography (aspect, slope, elevation, and landform), 3) hydrology (infiltration, runoff), 4) soils (depth, texture, structure, organic matter), 5) plant communities (functional groups, productivity), and 6) natural disturbance regime (fire, herbivory, etc.) (Caudle et al. 2013). Biotic factors that that influence resilience include site productivity, species composition and structure, and population regulation and regeneration (Chambers et al. 2013).

The ecological sites in this group are dominated by deep-rooted cool season, perennial grasses and long- lived shrubs (50+ years) with high root to shoot ratios. The dominant shrubs usually root to the full depth of the winter-spring soil moisture recharge, which ranges from 1.0 to over 3.0 m (Dobrowolski et al. 1990). Root length of mature sagebrush plants was measured to a depth of 2 meters in alluvial soils in Utah (Richards and Caldwell 1987). However, community types with low sagebrush as the dominant shrub were found to have soil depths and thus available rooting depths of 71 to 81 cm in a study in northeast Nevada (Jensen 1990). These shrubs have a flexible generalized root system with development of both deep taproots and laterals near the surface (Comstock and Ehleringer 1992).

In the Great Basin, the majority of annual precipitation is received during the winter and early spring. This continental semiarid climate regime favors growth and development of deep-rooted shrubs and herbaceous cool season plants using the C3 photosynthetic pathway (Comstock and Ehleringer 1992). Winter precipitation and slow melting of snow results in deeper percolation of moisture into the soil profile. Herbaceous plants, more shallow-rooted than shrubs, grow earlier in the growing season and thrive on spring rains, while the deeper rooted shrubs lag in phenological development because they draw from deeply infiltrating moisture from snowmelt the previous winter. Periodic drought regularly influences sagebrush ecosystems and drought duration and severity has increased throughout the 20th century in much of the Intermountain West. Major shifts away from historical precipitation patterns have the greatest potential to alter ecosystem function and productivity. Species composition and productivity can be altered by the timing of precipitation and water availability within the soil profile (Bates et al. 2006).

The Great Basin sagebrush communities have high spatial and temporal variability in precipitation both among years and within growing seasons (MacMahon 1980). Nutrient availability is typically low but increases with elevation and closely follows moisture availability. The invasibility of plant communities is often linked to resource availability. Disturbance can decrease resource uptake due to damage or mortality of the native species and depressed competition or can increase resource pools by the decomposition of dead plant material following disturbance (Whisenant 1999, Miller et al. 2013). The invasion of sagebrush communities by cheatgrass (*Bromus tectorum*) has been linked to disturbances (fire, abusive grazing) that have resulted in fluctuations in resources (Beckstead and Augspurger 2004, Chambers et al. 2007, Johnson et al. 2011).

Wyoming big sagebrush is the most drought tolerant of the big sagebrush's, and generally occurs in warmer and drier sites on shallower, sometimes saline soils. Lahontan sagebrush, a subspecies of low sagebrush (*A. arbuscula*), found primarily in northwestern Nevada and adjacent California and Oregon, prefers soils with low available water-holding capacities and a shallow depth to an argillic horizon and/or bedrock (Winward and McArthur 1995). All of these subspecies of sagebrush are long-lived; therefore it is not necessary for new individuals to recruit every year for perpetuation of the stand (Tisdale and Hironaka 1981). Infrequent large recruitment events and simultaneous low, continuous recruitment is the foundation of population maintenance (Noy-Meir 1973). Survival of the seedlings is, however, dependent on adequate moisture conditions.

Native insect outbreaks are also important drivers of ecosystem dynamics in sagebrush communities. Climate is generally believed to influence the timing of insect outbreaks especially a sagebrush defoliator, Aroga moth (Aroga websteri). Aroga moth infestations have occurred in the Great Basin in the 1960s, early 1970s, and have been ongoing in Nevada since 2004 (Bentz et al. 2008). Thousands of acres of big sagebrush have been impacted, with partial to complete die-off observed. Aroga moth can partially or entirely kill individual plants or entire stands of big sagebrush (Furniss and Barr 1975).

Rhizomatous grasses, primarily western wheatgrass, thickspike wheatgrass, and creeping wildrye dominate this group. The dominant bunchgrass is bottlebrush squirreltail. The heavy clay soils with shrink swell characteristics are largely responsible for the type of grasses growing on these sites. Rhizomatous grasses are well adapted to disturbed soils and the shrink swell properties within the rooting zone promote establishment through rhizome breakage and expansion of plants.

Bottlebrush squirreltail is a short-lived (5-7 years) bunchgrass. The plant produces large quantities of viable seed that is windblown. This life history strategy has proven successful at maintaining stands of bottlebrush squirreltail and in reseeding depleted range (Tisdale and Hironaka 1981). It is adapted to a wide range of ecological and topographical conditions. This species can be found from 2,000 to 11,500 feet in elevation, in areas receiving as little as 5 inches of rain annually, and in various soil types (Monsen et al. 2004). Populations from different locations in the western U.S. exhibit wide ranges in germination and maturation times. Experimental field plantings have documented leaf growth starting in mid- to late March and seed ripening occurring between late June and the first week of July (Hironaka and Tisdale 1973). Seed is produced in abundant quantities, and germination occurs rapidly at high rates under a wide temperature range (Young and Evans 1977). Germination typically occurs in the fall when moisture conditions are favorable, and seedlings overwinter starting growth again in March (Davison 2004). This life history strategy, plus the ability of the root system to continue growth at low temperatures during winter enables bottlebrush squirreltail to compete with cheatgrass and medusahead (Tisdale and Hironaka 1981). Early growth, high seed production and high germination rates along with wind dispersed seed heads make it a successful species for increasing on heavily grazed, depleted rangelands. There is evidence that squirreltail plants growing in the presence of cheatgrass have adapted traits to more successfully compete with this annual grass (Ferguson et al. 2015). Seeds collected from these wild-grown plants are less negatively affected by cheatgrass competition because they are able to grow larger root systems (Ferguson et al. 2015, Atwater et al. 2015). In a restoration experiment, plants that were small in stature and earlier flowering period had greater success in establishment (Kulpa and Leger 2013). Bottlebrush squirreltail shows increasing promise as a restoration plant.

The ecological sites in this group have low to moderate resilience to disturbance and resistance to invasion. Resilience increases with elevation, aspect, increased precipitation and increased nutrient availability. Five possible states have been identified for this group.

Annual Invasive Grasses:

The species most likely to invade these sites are cheatgrass and medusahead. Both species are cool- season annual grasses that maintain an advantage over native plants in part because they are prolific seed producers, able to germinate in the autumn or spring, tolerant of grazing and increasers with frequent fire (Klemmedson and Smith 1964, Miller et al. 1999). Medusahead and cheatgrass originated from Eurasia and both were first reported in North America in the late 1800s (Mack and Pyke 1983; Furbush 1953). Pellant and Hall (1994) found 3.3 million acres of public lands dominated by cheatgrass and suggested that another 76 million acres were susceptible to invasion by winter annuals including cheatgrass and medusahead. By 2003, medusahead occupied approximately 2.3 million acres in 17 western states (Rice 2005). In the Intermountain West, the exponential increase in dominance by medusahead has largely been at the expense of cheatgrass (Harris 1967, Hironaka 1994). Medusahead matures 2-3 weeks later than cheatgrass (Harris 1967) and recently, James et al. (2008) measured leaf biomass over the growing season and found that medusahead maintained vegetative growth later in the growing season than cheatgrass. Mangla et al. (2011) also found medusahead had a longer period of growth and more total biomass than cheatgrass and hypothesized this difference in relative growth rate may be due to the ability of medusahead to maintain water uptake as upper soils dry compared to co- occurring species, especially cheatgrass. Medusahead litter has a slow decomposition rate, because of high silica content, allowing it to accumulate over time and suppress competing vegetation (Bovey et al. 1961, Davies and Johnson 2008). Harris (1967) reported medusahead roots have thicker cell walls compared to those of cheatgrass, allowing it to more effectively conduct water, even in very dry conditions.

Recent modeling and empirical work by Bradford and Lauenroth (2006) suggests that seasonal patterns of precipitation input and temperature are also key factors determining regional variation in the growth, seed production, and spread of invasive annual grasses. Collectively, the body of research suggests that the continued invasion and dominance of medusahead onto native grasslands and cheatgrass infested grasslands will continue to increase in severity because conditions that favor native bunchgrasses or cheatgrass over medusahead are rare (Mangla et al. 2011). Medusahead replaces native vegetation and cheatgrass directly by competition and suppression and native vegetation indirectly by increasing fire frequency.

Methods to control medusahead and cheatgrass include herbicide, fire, grazing, and seeding of primarily non-native wheatgrasses. Mapping potential or current invasion vectors is a management method designed to increase the cost effectiveness of control methods. A study by Davies et al. (2013), found an increase in medusahead cover

near roads. Cover was higher near animal trails than random transects but the difference was less evident. This implies that vehicles and animals aid the spread of the weed; however, vehicles are the major vector of movement. Spraying with herbicide (Imazapic or Imazapic + glyphosate) and seeding with crested wheatgrass and Sandberg bluegrass has been found to be more successful at combating medusahead and cheatgrass than spraying alone (Sheley et al. 2012). Where native bunchgrasses are missing from the site, revegetation of medusahead or cheatgrass invaded rangelands has been shown to have a higher likelihood of success when using introduced perennial bunchgrasses such as crested wheatgrass (Davies et al. 2015). Butler et al. (2011) tested four herbicides (Imazapic, Imazapic + glyphosate, rimsulfuron and sulfometuron + Chlorsulfuron) only treatments for suppression of cheatgrass, medusahead and ventenata (North Africa grass, *Ventenata dubia*) within residual stands of native bunchgrass. Additionally, they tested the same four herbicides followed by seeding of six bunchgrasses (native and non-native) with varying success (Butler et al. 2011). Herbicide only treatments appeared to remove competition for established bluebunch wheatgrass by providing 100% control of ventenata and medusahead and greater than 95% control of cheatgrass (Butler et al.
2011), however caution in using these results is advised, as only one year of data was reported. Prescribed fire has also been utilized in combination with the application of pre-emergent herbicide to control medusahead and cheatgrass (Vollmer and Vollmer 2008). Mature medusahead or cheatgrass is very flammable and fire can be used to remove the thatch layer, consume standing vegetation, and even reduce seed levels. Furbush (1953) reported that timing a burn while the seeds were in the milk stage effectively reduced medusahead the following year. He further reported that adjacent unburned areas became a seed source for reinvasion the following year.

In considering the combination of pre-emergent herbicide and prescribed fire for invasive annual grass control, it is important to assess the tolerance of desirable brush species to the herbicide being applied. Vollmer and Vollmer (2008) tested the tolerance of mountain mahogany (*Cercocarpus montanus*), antelope bitterbrush, and multiple sagebrush species to three rates of Imazapic and the same rates with methylated seed oil as a surfactant. They found a cheatgrass control program in an antelope bitterbrush community should not exceed Imazapic at 8 oz/ac with or without surfactant. Sagebrush, regardless of species or rate of application, was not affected. However, many environmental variables were not reported in this study and managers should follow label directions and in sensitive habitat areas potentially install test plots before broad scale herbicide application is initiated.

Fire Ecology:

This group is dominated by Wyoming and basin big sagebrush, often occurring in equal proportions on the landscape. Changes if fire frequency have occurred because of fire supporession, livestock grazing, OHV use, and invasive annual grass invasions. Wyoming big sagebrush communities historically had low fuel loads, and patchy fires that burned in a mosaic pattern were common at 10-70 year return intervals (Young et al. 1979, West and Hassan 1985, Bunting et al. 1987). Davies et al. (2006) suggest fire return intervals in Wyoming big sagebrush communities were around 50-100 years. Wyoming and basin big sagebrush are killed by fire and only regenerate from seed. Because of the time needed to produce seed, frequent fires can eliminate sagebrush from a landscape (Bunting et al. 1987). Basin big sagebrush reinvades a site primarily by off-site seed or seed from plants that survive in unburned patches. Approximately 90% of big sagebrush seed is dispersed within 30 feet (9 m) of the parent shrub (Goodrich et al. 1985) with maximum seed dispersal at approximately 108 feet (33 m) from the parent shrub (Shumar and Anderson 1986). Therefore, regeneration of big sagebrush after stand replacing fires is difficult and dependent upon proximity of residual mature plants and favorable moisture conditions (Johnson and Payne 1968, Humphrey 1984). Big sagebrush may require 50-120 or more years to recover after fire (Baker 2006). The introduction and expansion of cheatgrass has dramatically altered the fire regime (Balch et al. 2013) and restoration potential of Wyoming big sagebrush communities.

The effect of fire on bunchgrasses relates to culm density, culm-leaf morphology, and the size of the plant. The initial condition of bunchgrasses within the site along with seasonality and intensity of the fire all factor into the individual species response. For most forbs and grasses the growing points are located at or below the soil surface providing relative protection from disturbances which decrease above ground biomass, such as grazing or fire. Thus, fire mortality is more correlated to duration and intensity of heat which is related to culm density, culm-leaf morphology, size of plant and abundance of old growth (Wright 1971, Young 1983). Rhizomatous grasses, such as western wheatgrass, also respond to timing and intensity of the fire. White and Currie (1983) found that dormant season fire increased western wheatgrass cover whereas growing season burning had no impact on basal cover. In Nevada, western wheatgrass increased in frequency after fire and above ground biomass increased more than seven times pre-burn levels during the first season following fire (Bushey 1987).

Bottlebrush squirreltail is considered one of the most fire resistant bunchgrasses due to its small size, coarse stems, and sparse leafy material (Britton et al. 1990, Wright 1971, Wright and Klemmedson 1965). Post-fire regeneration occurs from surviving root crowns and from on- and off-site seed sources (Bradley et al. 1992). Bottlebrush squirreltail has the ability to produce large numbers of highly germinable seeds, with relatively rapid germination (Young and Evans 1977) when exposed to the correct environmental cues. It exhibits the ability to germinate in the late fall and very early spring at a wide range of temperatures making it a strong competitor with cheatgrass (Arredondo et al. 1998). Early spring growth and ability to grow at low temperatures contribute to the persistence of bottlebrush squirreltail among cheatgrass dominated ranges (Hironaka and Tisdale 1973).

The grasses likely to invade this site are cheatgrass and medusahead. These invasive grasses displace desirable perennial grasses, reduce livestock forage, and accumulate large fuel loads that foster frequent fires (Davies and Svejcar 2008). Invasion by annual grasses can alter the fire cycle by increasing fire size, fire season length, rate of spread, numbers of individual fires, and likelihood of fires spreading into native or managed ecosystems (D'Antonio and Vitousek 1992, Brooks et al. 2004). While historical fire return intervals are estimated at 15 to 100 years, areas dominated with cheatgrass are estimated to have a fire return interval of 3-5 years (Whisenant 1990). The mechanisms by which invasive annual grasses alter fire regimes likely interact with climate. For example, cheatgrass cover and biomass vary with climate (Chambers et al. 2007) and are promoted by wet and warm conditions during the fall and spring. Invasive annual species have been shown able to take advantage of high N availability following fire through higher growth rates and increased seedling established relative to native perennial grasses (Monaco et al. 2003).

Livestock/Wildlife Grazing Interpretations:

Generally, Wyoming big sagebrush is the least palatable of the big sagebrush taxa (Bray et al. 1991, Sheehy and Winward 1981) however it may receive light or moderate use depending upon the amount of understory herbaceous cover (Tweit and Houston 1980). Personius et al. (1987) found Wyoming big sagebrush and basin big sagebrush to be intermediately palatable to mule deer when compared to mountain big sagebrush (most palatable) and black sagebrush (least palatable). Lahontan sagebrush, on the other hand, is considered preferred browse by mule deer (Clements and Young 1997) and is noted as often having a hedged appearance indicating high palatability by many species (McArthur 2005).

Bottlebrush squirreltail generally increases in abundance when moderately grazed or protected (Hutchings and Stewart 1953). It is considered to be fair to good forage for cattle, horses and sheep in the spring prior to seed development, and in the late fall after seed shatter. In addition, moderate trampling by livestock in big sagebrush rangelands of central Nevada enhanced bottlebrush squirreltail seedling emergence compared to untrampled conditions. Heavy trampling however was found to significantly reduce germination sites (Eckert et al. 1987). Squirreltail is more tolerant of grazing than Indian ricegrass but all bunchgrasses are sensitive to over utilization within the growing season.

Reduced bunchgrass vigor or density provides an opportunity for Sandberg bluegrass or bottlebrush squirreltail expansion and/or cheatgrass and other invasive species such as halogeton (*Halogeton glomeratus*), bur buttercup (*Ceratocephala testiculata*) and annual mustards to occupy interspaces. Sandberg bluegrass and/or bottlebrush squirreltail increases under grazing pressure (Tisdale and Hironaka 1981) and is capable of co-existing with cheatgrass. Excessive sheep grazing favors Sandberg bluegrass; however, where cattle are the dominant grazers, cheatgrass often dominates (Daubenmire 1970). Thus, depending on the season of use, the grazer and site conditions, either Sandberg bluegrass, bottlebrush squirreltail or annual invasive grasses may become the dominant understory with inappropriate grazing management.

Inappropriate grazing practices can be tied to the success of medusahead, however, eliminating grazing will not eradicate medusahead if it is already present (Wagner et al. 2001). Sheley and Svejcar (2009) reported that even moderate defoliation of bluebunch wheatgrass resulted in increased medusahead density. They suggested that disturbances such as plant defoliation limit soil resource capture, which creates an opportunity for exploitation by medusahead. Avoidance of medusahead by grazing animals allows medusahead populations to expand. This creates seed reserves that can infest adjoining areas and cause changes to the fire regime. Medusahead replaces native vegetation and cheatgrass directly by competition and suppression and native vegetation indirectly by an increase in fire frequency.

Medusahead litter has a slow decomposition rate, because of high silica content, allowing it to accumulate over time and suppress competing vegetation (Bovey et al. 1961, Davies and Johnson 2008).

References:

Atwater, D. Z., J. J. James, and E. A. Leger. 2015. Seedling root traits strongly influence field survival and performance of a common bunchgrass. Basic and Applied Ecology 16(2):128-140.

Arredondo, J., T. Jones, and D. Johnson. 1998. Seedling growth of Intermountain perennial and weedy annual grasses. Journal of Range Management 51(5):584-589.

Baker, W. L. 2006. Fire and restoration of sagebrush ecosystems. Wildlife Society Bulletin 34(1):177-185.

Balch, J. K., B. A. Bradley, C. M. D'Antonio, and J. Gómez-Dans. 2013. Introduced annual grass increases regional fire activity across the arid western USA (1980–2009). Global Change Biology 19(1):173-183.

Bates, J. D., T. Svejcar, R. F. Miller, and R. A. Angell. 2006. The effects of precipitation timing on sagebrush steppe vegetation. Journal of Arid Environments 64(4):670-697.

Beckstead, J., and Augspurger, C. K. 2004. An experimental test of resistance to cheatgrass invasion: limiting resources at different life stages. Biological Invasions 6(4):417-432.

Bentz, B., D. Alston, and T. Evans. 2008. Great Basin Insect Outbreaks. In: J. Chambers, N. Devoe, A. Evenden (eds.). Collaborative Management and Research in the Great Basin -- Examining the issues and developing a framework for action Gen. Tech. Rep. RMRS-GTR-204. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO. Pages 45-48.

Bovey, W. R., D. Le Tourneau, and C. L. Erickson. 1961. The chemical composition of medusahead and downy brome. Weeds 9(2):307-311.

Bradford, J. B., and W. K. Lauenroth. 2006. Controls over invasion of *Bromus tectorum*: The importance of climate, soil, disturbance and seed availability. Journal of Vegetation Science 17(6):693-704.

Bradley, A. F., Noste, N. V., and Fischer, W. C. 1992. Fire ecology of forests and woodlands in Utah. Gen. Tech. Rep. INT-287. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 128 p.

Bray, R. O., C. L. Wambolt, R. G. Kelsey, 1991. Influence of sagebrush terpenoids on mule deer preference. Journal of Chemical Ecology. 17(11):2053-2062.

Britton, C. M., G. R. McPherson, and F. A. Sneva. 1990. Effects of burning and clipping on five bunchgrasses in eastern Oregon. Western North American Naturalist 50:115-120.

Brooks, M. L., C. M. D'Antonio, D. M. Richardson, J. B. Grace, J. E. Keeley, J. M. Ditomaso, R. J. Hobbs, M. Pellant, and D. Pyke. 2004. Effects of Invasive Alien Plants on Fire Regimes. BioScience 54(7):677-688.

Bunting, S. C., B. M. Kilgore, and C. L. Bushey. 1987. Guidelines for prescribed burning sagebrush-grass rangelands in the northern Great Basin. Gen. Tech. Rep. INT-231. US Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT. 33 p.

Bushey, C. L. 1987. Short-term vegetative resonse to prescibed burning in the sagebrush/grass ecosystem of the northern Great Basin. Final Report. Cooperative Agreement 22-C-4-INT-33. Missoula, MT. Systems for Environmental Management. 77 p.

Butler, M., R. Simmons, and F. Brummer. 2011. Restoring Central Oregon Rangeland from Ventenata and Medusahead to a Sustainable Bunchgrass Environment – Warm Springs and Ashwood. Central Oregon Agriculture Research and Extension Center. COARC 2010. Pages 77-82.

Caudle, D., J. DiBenedetto, M. Karl, H. Sanchez, and C. Talbot. 2013. Interagency ecological site handbook for rangelands. Available at: http://jornada.nmsu.edu/sites/jornada.nmsu.edu/files/InteragencyEcolSiteHandbook.pdf. Accessed 4 October 2013.

Chambers, J. C., B. A. Roundy, R. R. Blank, S. E. Meyer, and A. Whittaker. 2007. What makes great basin sagebrush ecosystems invasible by *Bromus tectorum*? Ecological Monographs 77(1):117-145.

Chambers, J., B. Bradley, C. Brown, C. D'Antonio, M. Germino, J. Grace, S. Hardegree, R. Miller, and D. Pyke. 2013. Resilience to Stress and Disturbance, and Resistance to *Bromus tectorum* L. Invasion in Cold Desert Shrublands of Western North America. Ecosystems 17(2):360-375.

Clements, C. D. and J. A. Young. 1997. A Viewpoint: Rangeland Health and Mule Deer Habitat. Journal of Range Management 50(2):129-138.

Comstock, J. P. and J. R. Ehleringer. 1992. Plant adaptation in the Great Basin and Colorado plateau. The Great Basin Naturalist 52(3):195-215.

D'Antonio, C. M., and P. M. Vitousek. 1992. Biological invasions by exotic grasses, the grass/fire cycle, and global change. Annual Review of Ecology and Systematics 23:63-87.

Daubenmire, R. 1970. Steppe vegetation of Washington. Technical Bulletin 62. Washington Agriculture Experiment Station. 131 p.

Davies, K. W., and D. D. Johnson. 2008. Managing medusahead in the intermountain west is at a critical threshold. Rangelands 30(4):13-15.

Davies, K. W., and T. J. Svejcar. 2008. Comparison of medusahead-invaded and noninvaded Wyoming big sagebrush steppe in southeastern Oregon. Rangeland Ecology and Management 61(6):623-629.

Davies, K. W., J. D. Bates, and R. F. Miller. 2006. Vegetation characteristics across part of the Wyoming Big Sagebrush Alliance. Rangeland Ecology & Management 59(6):567-575.

Davies, K. W., A. M. Nafus, and M. D. Madsen. 2013. Medusahead invasion along unimproved roads, animal trails, and random transects. Western North American Naturalist 73(1):54-59.

Davies, K. W., C. S. Boyd, D. D. Johnson, A. M. Nafus, and M. D. Madsen. 2015. Success of seeding native compared with introduced perennial vegetation for revegetating medusahead-invaded sagebrush rangeland. Rangeland Ecology & Management 68(3):224-230.

Davison, J. 2004. A Field Guide for Collecting Native Seeds in Nevada. EB-03-03. University of Nevada Cooperative Extension. Reno, NV. 135 p.

Dobrowolski, J. P., M. M. Caldwell, and J. H. Richards. 1990. Basin hydrology and plant root systems. Pages 243-292 in C. B. Osmond, L. F. Pitelka, and G. M. Hidy (eds.). Plant biology of the basin and range. Springer-Verlag, New York.

Eckert, R. E., Jr., F. F. Peterson, and F. L. Emmerich. 1987. A study of factors influencing secondary succession in the sagebrush [Artemisia spp. L.] type. In: G. W. Frazier, R.A. Evans [eds.] Proceedings: Seed and seedbed ecology of rangeland plants. U. S. Department of Agriculture, Agricultural Research Service, Tucson, AZ. Pages 149-168.

Ferguson, S. D., E. A. Leger, J. Li, and R. S. Nowak. 2015. Natural selection favors root investment in native grasses during restoration of invaded fields. Journal of Arid Environments 116:11-17.

Furbush, P. 1953. Control of Medusa-Head on California Ranges. Journal of Forestry 51(2):118-121.

Furniss, M. M. and W. F. Barr. 1975. Insects affecting important native shrubs of the northwestern United States Gen. Tech. Rep. INT-19. Intermountain Forest and Range Experiment Station, U.S. Department of Agriculture, Forest Service. Ogden, UT. 68 p.

Goodrich, S., E. D. McArthur, and A. H. Winward. 1985. A new combination and a new variety in *Artemisia tridentata*. The Great Basin Naturalist 45(1):99-104.

Harris, G. A. 1967. Some Competitive Relationships between Agropyron spicatum and *Bromus tectorum*. Ecological Monographs 37(2):89-111.

Hironaka, M. 1994. Medusahead: Natural Successor to the Cheatgrass Type in the Northern Great Basin. In: Proceedings of Ecology and Management of Annual Rangelands. USDA Forest Service, Intermountain Research Station. Gen. Tech. Rep. INT-GTR-313. Pages 89-91.

Hironaka, M., and E. W. Tisdale. 1973. Growth and development of Sitanion hystrix and Poa sandbergii. Research Memorandum RM 73-16. U.S. International Biological Program, Desert Biome. Logan, UT.

Humphrey, L. D. 1984. Patterns and mechanisms of plant succession after fire on Artemisia-grass sites in southeastern Idaho. Vegetatio 57(2/3):91-101.

Hutchings, S. S. and Stewart, G. 1953. Increasing forage yields and sheep production on intermountain winter ranges. Circular No. 925. U.S. Department of Agriculture, Washington, D.C.

James, J., K. Davies, R. Sheley, and Z. Aanderud. 2008. Linking nitrogen partitioning and species abundance to invasion resistance in the Great Basin. Oecologia 156(3):637-648.

Jensen, M. E. 1990. Interpretation of environmental gradients which influence sagebrush community distribution in northeastern Nevada. Journal of Range Management 43(2):161-166.

Johnson, B. G.; Johnson, D. W.; Chambers, J. C.; Blank, B. R. 2011. Fire effects on the mobilization and uptake of nitrogen by cheatgrass (*Bromus tectorum* L.). Plant and Soil 341(1-2):437-445.

Johnson, J. R., and G. F. Payne. 1968. Sagebrush reinvasion as affected by some environmental influences Journal of Range Management 21(4):209-213.

Klemmedson, J. O., and J. G. Smith. 1964. Cheatgrass (Bromus Tectorum L.). The Botanical Review 30(2):226-262.

Kulpa, S. M., and E. A. Leger. 2013. Strong natural selection during plant restoration favors an unexpected suite of plant traits. Evolutionary Applications 6(3):510-523.

Mack, R. N., and D. Pyke. 1983. The Demography of Bromus Tectorum: Variation in Time and Space. Journal of Ecology 71(1):69-93.

MacMahon, J. A. 1980. Ecosystems over time: succession and other types of change. In: Waring, R., ed. Proceedings—Forests: fresh perspectives from ecosystem analyses. Biological Colloquium. Corvallis, OR: Oregon State University. Pages 27-58.

Mangla, S., R. Sheley, and J. J. James. 2011. Field growth comparisons of invasive alien annual and native perennial grasses in monocultures. Journal of Arid Environments 75(2):206-210.

McArthur, E. D. 2005. View Points: Sagebrush, Common and Uncommon, Palatable and Unpalatable. Rangelands 27(4):47-51.

Miller, H. C., Clausnitzer, D., and Borman, M. M. 1999. Medusahead. In: R. L. Sheley and J. K. Petroff (eds.). Biology and Management of Noxious Rangeland Weeds. Corvallis, OR: Oregon State University Press. Pages 272-281.

Miller, R. F., Chambers, J. C., Pyke, D. A., Pierson, F. B. and Williams, C. J., 2013. A review of fire effects on vegetation and soils in the Great Basin Region: response and ecological site characteristics. Gen. Tech. Rep.

RMRS-GTR-308. Fort Collins, CO: US Department of Agriculture, Forest Service, Rocky Mountain Research Station. 126 p.

Monaco, T. A., C. T. Mackown, D. A. Johnson, T. A. Jones, J. M. Norton, J. B. Norton, and M. G. Redinbaugh. 2003. Nitrogen effects on seed germination and seedling growth. Journal of Range Management 56(6):646-653.

Monsen, S. B., R. Stevens, N. L. Shaw, (comps.). 2004. Restoring western ranges and wildlands. Gen. Tech. Rep. RMRS-GTR-136-vol-2. Volume 2. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. Pages 295-698 plus index.

Noy-Meir, I. 1973. Desert Ecosystems: Environment and Producers. Annual Review of Ecology and Systematics 4(1973):25-51.

Pellant, M., and C. Hall. 1994. Distribution of two exotic grasses in intermountain rangelands: status in 1992. USDA Forest Service Gen. Tech. Rep. INT-GTR-313S. Pages 109-112.

Personius, T. L., C. L. Wambolt, J. R. Stephens and R. G. Kelsey. 1987. Crude terpenoid influence on mule deer preference for sagebrush. Journal of Range Management 40(1):84-88.

Rice, P. M. 2005. Medusahead (*Taeniatherum caput-medusae* (L.) Nevski). In: C. L. Duncan and J. K. Clark (eds.). Invasive plants of range and wildlands and their environmental, economic, and societal impacts. Weed Science Society of America, Lawrence, KS.

Richards, J. H. and M. M. Caldwell. 1987. Hydraulic lift: Substantial nocturnal water transport between soil layers by *Artemisia tridentata* roots. Oecologia 73(4):486-489.

Sapsis, D. B., and J. B. Kauffman. 1991. Fuel consumption and fire behavior associated with prescribed fires in sagebrush ecosystems. Northwest Science 65(4):173-179.

Sheehy, D. P. and A. H. Winward. 1981. Relative Palatability of Seven Artemisia Taxa to Mule Deer and Sheep. Journal of Range Management 34(5):397-399.

Sheley, R. L., and Svejcar T. J. 2009. Response of bluebunch wheatgrass and medusahead to defoliation. Rangeland Ecology & Management 62(3):278-283.

Sheley, R. L., E. A. Vasquez, A. Chamberlain, and B. S. Smith. 2012. Landscape-scale rehabilitation of medusahead (*Taeniatherum caput-medusae*)-dominated sagebrush steppe. Invasive Plant Science and Management 5(4):436-442.

Shumar, M. L., and J. E. Anderson. 1986. Gradient analysis of vegetation dominated by two subspecies of big sagebrush. Journal of Range Management 39(2):156-160.

Tisdale, E. W. and M. Hironaka. 1981. The sagebrush-grass region: A review of the ecological literature. Bulletin 33. University of Idaho, Forest, Wildlife and Range Experiment Station. Moscow, ID. 31p.

Tweit, S. J., and Houston, K. E. 1980. Grassland and shrubland habitat types of the Shoshone National Forest. Cody, WY: U.S. Department of Agriculture, Forest Service, Shoshone National Forest. 143p.

Vollmer, J. L., and J. G. Vollmer. 2008. Controlling cheatgrass in winter range to restore habitat and endemic fire. United States Department of Agriculture, Forest Service. RMRS-P-52. Pages 57-60.

Wagner, J. A., R. E. Delmas, and J. A. Young. 2001. 30 years of medusahead: return to fly blown-flat. Rangelands 23(3):6-9.

West, N. E. and M. A. Hassan. 1985. Recovery of sagebrush-grass vegetation following wildfire. Journal of Range Management 38(2):131-134.

Whisenant, S. G. 1990. Changing fire frequencies on Idaho's Snake River Plains: ecological and management implications. In: Proceedings - Symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management. 1989 April 5-7, Las Vegas, NV. Gen. Tech. Rep. INT-GTR-276. USDA Forest Service, Intermountain Research Station, Ogden, UT. Pages 4-10.

Whisenant, S., 1999. Repairing Damaged Wildlands: a process-orientated, landscape-scale approach (Vol. 1). Cambridge, UK: Cambridge University Press. 312 p.

White, R. S. and P. O. Currie. 1983. Prescribed burining in the Northern Great Plains: Yield and Cover Responses of 3 Forage Species in the Mixed Grass Prairie. J. of Range Management 36(2):179-183.

Winward, A. H., and E. D. McArthur. 1995. Lahontan sagebrush (*Artemisia arbuscula* ssp. longicaulis): A new taxon. Great Basin Naturalist 55(2):151-157.

Wright, H. A. 1971. Why Squirreltail Is More Tolerant to Burning than Needle-and-Thread. Journal of Range Management 24(4):277-284.

Wright, H. A., and Klemmedson, J. O. 1965. Effect of fire on bunchgrasses of the sagebrush-grass region in southern Idaho. Ecology 46:680-688.

Young, J. A., and R. A. Evans. 1977. Squirreltail Seed Germination. Journal of Range Management 30(1):33-36.

Young, J. A., R. E. Eckert, Jr., and R. A. Evans. 1979. Historical perspectives regarding the sagebrush ecosystem. (eds.). The Sagebrush Ecosystem: A Symposium. 1978, April. College of Natural Resources, Utah State University, Logan, UT. Pages 1-13.

Young, R. P. 1983. Fire as a vegetation management tool in rangelands of the Intermountain region. In: Monsen, S. B. and N. Shaw (eds). Managing Intermountain rangelands—improvement of range and wildlife habitats: Proceedings. 1981, September 15-17; Twin Falls, ID; 1982, June 22-24; Elko, NV. Gen. Tech. Rep. INT-157. Ogden, UT. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. Pages 18-31.

Major Land Resource Area

MLRA 023X
Malheur High Plateau

Subclasses

- R023XF084CA–CLAY UPLAND 9-16"
- R023XY033NV–CLAYEY 10-14 P.Z.

Correlated Map Unit Components

21659154, 21659435, 21659157, 21659723, 21659780, 21660108, 21660412, 21659289, 21659549, 21660101, 21660104, 21660112, 21659319, 21500612, 21500649, 21605120, 21604953

Stage

Provisional

Contributors

T Stringham (UNR under contract with BLM)
DMP

State and transition model

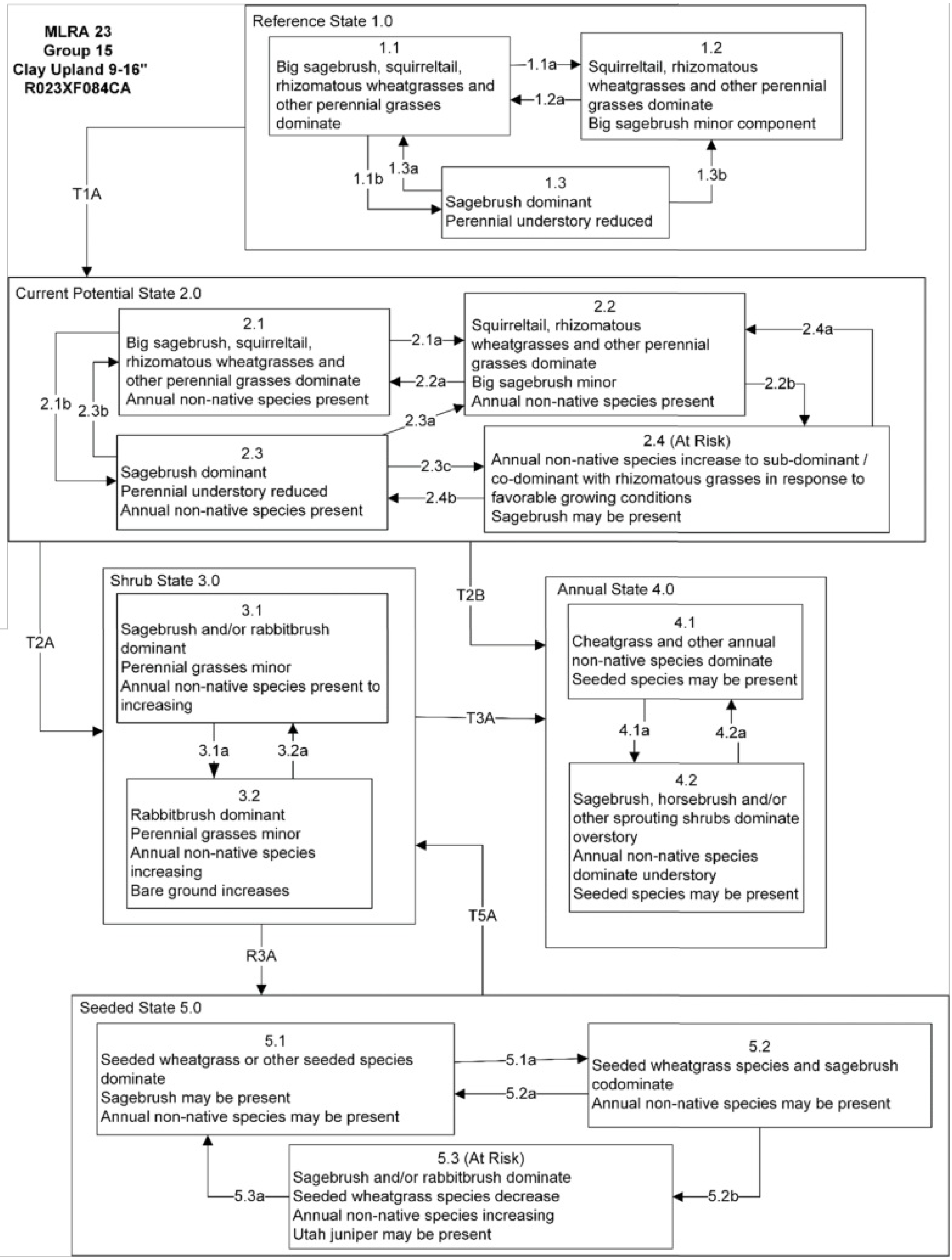
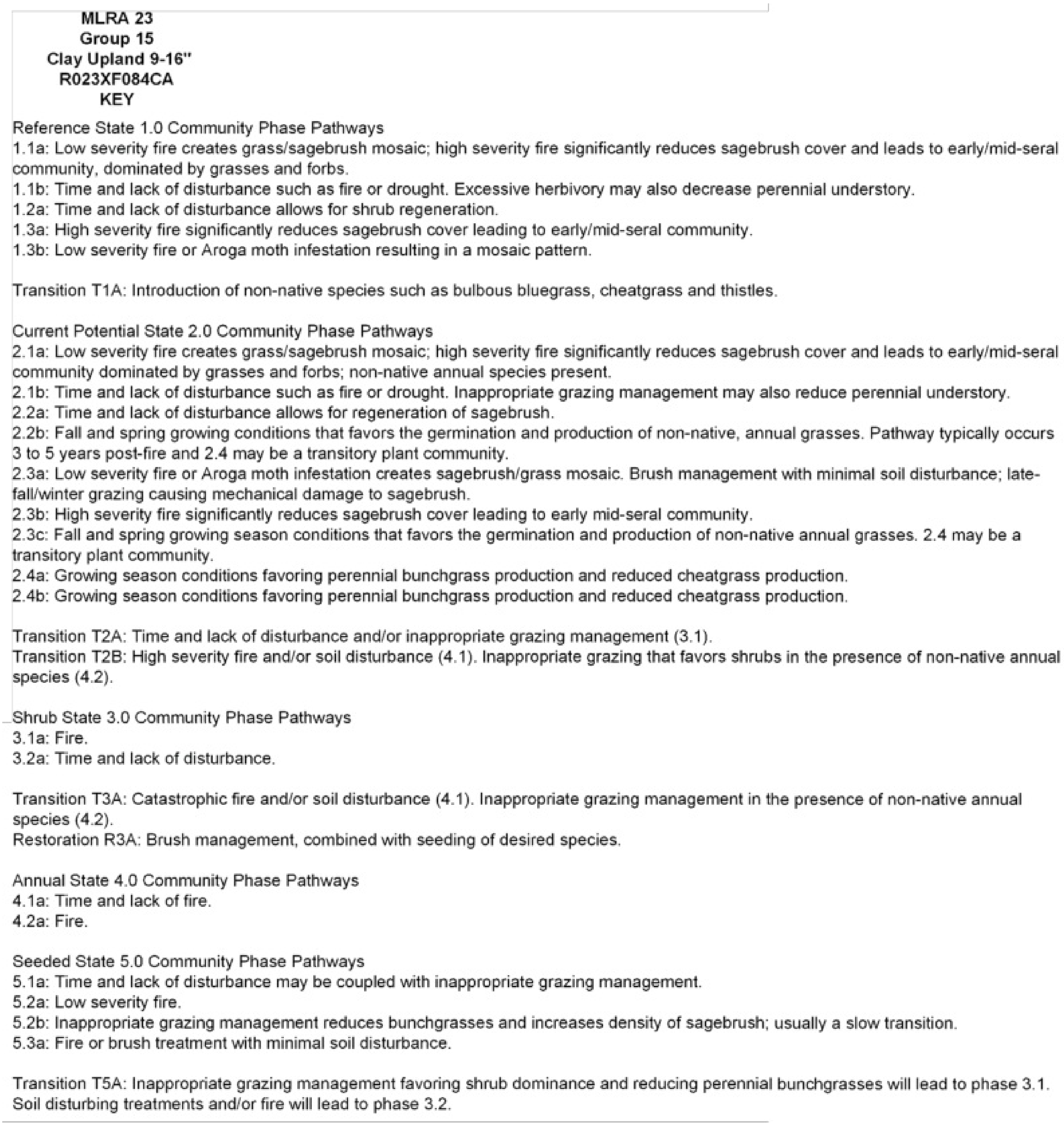


Figure . State and Transition Model



MLRA 23
Group 15
Clay Upland 9-16"
R023XF084CA
KEY

Reference State 1.0 Community Phase Pathways
1.1a: Low severity fire creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush cover and leads to early/mid-seral community, dominated by grasses and forbs.
1.1b: Time and lack of disturbance such as fire or drought. Excessive herbivory may also decrease perennial understory.
1.2a: Time and lack of disturbance allows for shrub regeneration.
1.3a: High severity fire significantly reduces sagebrush cover leading to early/mid-seral community.
1.3b: Low severity fire or Aroga moth infestation resulting in a mosaic pattern.

Transition T1A: Introduction of non-native species such as bulbous bluegrass, cheatgrass and thistles.

Current Potential State 2.0 Community Phase Pathways
2.1a: Low severity fire creates grass/sagebrush mosaic; high severity fire significantly reduces sagebrush cover and leads to early/mid-seral community dominated by grasses and forbs; non-native annual species present.
2.1b: Time and lack of disturbance such as fire or drought. Inappropriate grazing management may also reduce perennial understory.
2.2a: Time and lack of disturbance allows for regeneration of sagebrush.
2.2b: Fall and spring growing conditions that favors the germination and production of non-native, annual grasses. Pathway typically occurs 3 to 5 years post-fire and 2.4 may be a transitory plant community.
2.3a: Low severity fire or Aroga moth infestation creates sagebrush/grass mosaic. Brush management with minimal soil disturbance; late-fall/winter grazing causing mechanical damage to sagebrush.
2.3b: High severity fire significantly reduces sagebrush cover leading to early mid-seral community.
2.3c: Fall and spring growing season conditions that favors the germination and production of non-native annual grasses. 2.4 may be a transitory plant community.
2.4a: Growing season conditions favoring perennial bunchgrass production and reduced cheatgrass production.
2.4b: Growing season conditions favoring perennial bunchgrass production and reduced cheatgrass production.

Transition T2A: Time and lack of disturbance and/or inappropriate grazing management (3.1).
Transition T2B: High severity fire and/or soil disturbance (4.1). Inappropriate grazing that favors shrubs in the presence of non-native annual species (4.2).

Shrub State 3.0 Community Phase Pathways
3.1a: Fire.
3.2a: Time and lack of disturbance.

Transition T3A: Catastrophic fire and/or soil disturbance (4.1). Inappropriate grazing management in the presence of non-native annual species (4.2).
Restoration R3A: Brush management, combined with seeding of desired species.

Annual State 4.0 Community Phase Pathways
4.1a: Time and lack of fire.
4.2a: Fire.

Seeded State 5.0 Community Phase Pathways
5.1a: Time and lack of disturbance may be coupled with inappropriate grazing management.
5.2a: Low severity fire.
5.2b: Inappropriate grazing management reduces bunchgrasses and increases density of sagebrush; usually a slow transition.
5.3a: Fire or brush treatment with minimal soil disturbance.

Transition T5A: Inappropriate grazing management favoring shrub dominance and reducing perennial bunchgrasses will lead to phase 3.1. Soil disturbing treatments and/or fire will lead to phase 3.2.

Figure 1. STM Narrative

Citations