11260
Inter-Mountain Basins Montane Sagebrush Steppe

BpS Model/Description Version: Aug. 2020

Modelers		Reviewers	
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Reviewer: Diane Abendroth, Alan Sands

Vegetation Type
Steppe/Savanna

Map Zone
21

Geographic Range
Scattered throughout map zone (MZ) 21.

Biophysical Site Description
In MZ21, this type ranges from 6,000-8,500ft (Bridger-Teton National Forest) in the southern portion of the zone. In southwest Montana, it could occur up to 9,600ft (Lesica et al. 2005).

It is scattered in forest openings and benches along mountain foothills throughout the zone, and adjacent to lower forested areas. Low sagebrush (*Artemisia arbuscula ssp. arbuscula*) is found in areas where clay layers cause a perched water table with saturated soils during parts of the year alternating with very dry soils.

This vegetation type is found on all aspects, although it rarely occurs on northerly slopes. Pure stands are found in areas with deeper soils and less topographic relief, but it is also common on slopes with a gradual shift to a mixed mountain shrub community on steeper slopes and in drainages. Precipitation ranges from 12-20in/yr. Soils are deep, well drained. Soil moistures are udic (not dry for as long as 90 cumulative days) and soil temperatures cryic (very cold soils of the Rocky Mountain Region).

In the high valleys of southwestern Montana, sagebrush was probably the historical dominant on sites having either coarse or clayey soils (Morris et al. 1976 in Arno and Gruell 1983). Grasses are poorly adapted to these soils, which have droughty surface conditions, whereas deep-rooting big sagebrush is well adapted (Arno and Gruell 1983). On the widely distributed loamy soils, prior to 1900, sagebrush might have been restricted to small patches or widely spaced plants. The fine-textured soils have good potential to support dense stands of grass (Arno and Gruell 1983).

Vegetation Description
Mountain sagebrush steppe dominated by mountain big sagebrush, with a frequent presence of mountain snowberry, and with a continuous grass and forb understory is believed to be a major

pre-settlement vegetation type within this MZ, although the exact composition of the community before settlement is unknown.

Dominant shrubs include mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana*), antelope bitterbrush (*Purshia tridentata*, in MZ10), and mountain snowberry (*Symphoricarpos* spp.). Artemisia tripartita can be present and resprouts rapidly after fire. Other common shrubs include serviceberry (*Amelanchier alnifolia*), chokecherry (PRVI), rose, currant, and rabbitbrush (CHRYS9 and CHVI8). Other shrubs may be locally common.

Herbaceous cover is moderate to abundant, ranging from 40-85%. Common grasses include: *Festuca idahoensis*, *Agropyron spicata* (now *Pseudoroegneria spicata*), *Elymus elymoides*, *Elymus trachycaulus*, *Hesperostipa comata*, *Koeleria cristata*, and *Poa secunda*. Common forbs include *Eriogonum umbellatum*, *Antennaria microphyla*, *Balsamorhiza sagittata*, *Lupinus* spp., *Delphinium* spp., *Castilleja* spp., *Geranium viscosissimum*, and *Astragalus purshii*.

This vegetation type may occur as inclusions within forested types.

BpS Dominant and Indicator Species

Symbol	Scientific Name	Common Name
ARTRV	*Artemisia tridentata ssp. vaseyana*	Mountain big sagebrush
PSSP6	*Pseudoroegneria spicata*	Bluebunch wheatgrass
FEID	*Festuca idahoensis*	Idaho fescue
POSE	*Poa secunda*	Sandberg bluegrass
SYOR2	*Symphoricarpos oreophilus*	mountain snowberry
BASA	*Baccharis salicina*	Great plains false willow

Species names are from the NRCS PLANTS database. Check species codes at http://plants.usda.gov.

Disturbance Description

Non-fire disturbances, including drought stress, insects and native grazing, were present under presettlement conditions in this type. Most of these disturbances were mixed-severity, resulting in thinning of sagebrush. Deer and elk, at high density, can use sagebrush on winter ranges. Gophers tunnel underground and browse on sagebrush roots possibly giving an advantage to forb species.

FIRE OVERVIEW

Fire is a major disturbance factor for mountain big sagebrush (Blaisdell et al 1982, Johnson 2000), but the fire return interval in sagebrush is poorly understood and can only be estimated using either the duration of the succession process post fire or fire scars found on adjacent trees (e.g. ponderosa pine, pinyon, and juniper). The latter is problematic because trees tend to burn during the mid summer before sagebrush is sufficiently cured to carry a fire, so using the scars could be an over-estimation of the frequency of fire in the surrounding sagebrush. The use of prescribed fire is controversial in sagebrush due to habitat concerns associated with sagebrush obligates and the lack of understanding of the fire regime. It is likely that different sagebrush communities have highly variable fire history. The fire return intervals (FRI) reported in the literature for this type vary from 10-70yrs (Hironaka et al. 1983, Miller and Rose 1999, Wright and Bailey 1982; Houston 1973; Arno and Gruell 1983) and up to 200yrs (Baker 2006). Fire

effects monitoring data form Grand Teton National Park shows that some sites have very low sagebrush cover 20 years post burn, while others are roughly 50% of pre-burn cover after 20 years (pers comm Diane Abendroth).

Since there is no means to accurately measure historic fire frequency in sagebrush communities (Kitchen, personal correspondence), there are conflicting opinions about the approaches taken to determine MFRI for these systems. It is unclear how fire might have behaved across the fuel threshold at the forest/shrubland ecotone. Therefore, we do not know how accurately proxy fire chronologies derived from fire-scarred trees predict fire regimes in nearby shrublands (Kitchen, personal correspondence). The remainder of this section summarizes the debate about the fire regime that occurred when this model was developed during LANDFIRE National.

The model for MZ21 was based on the model for MZs 10 and 19; however, major quantitative changes were made. The model for MZs 10 and 19 employed an overall FRI of 26yrs (100yrs for replacement fire; 35yrs for mixed fire). The model for MZ21 was originally modeled with an FRI of 175yrs in A, 130yrs in B, and 130yrs in C, for an overall FRI of 135yrs. Initial reviewers suggested an overall 50-70yr interval. After much debate, as described below, the Regional Lead chose an interval of 50yrs, which was accepted by Tart and Kitchen. An anonymous contributor disagreed and presented evidence to the contrary. The Regional Lead, therefore, chose an interval of 80yrs, which was then met with disapproval by Tart, Kitchen, and others. This led to the request that these issues be elevated to LANDFIRE leadership. Kitchen recommended an interval of 60yrs in order to reach a compromise.

20-50YR INTERVAL
Tart (personal correspondence) states that the studies most relevant to MZ21 are Houston (1973) and Arno and Gruell (1983). Neither reported the composite fire interval (CFI) over a large area. Houston (1973) reported single tree fire interval from 36-108yrs for the life of the tree up to 1970; the average for the subunits of the study area ranged from 53-96yrs on trees (adjacent to shrubland); they adjusted to account for fire frequencies prior to modern man to get a mean fire interval (MFI), resulting in 32-62yrs on representative unprotected sites for the period through 1890 (pre-suppression), with a mean of 49yrs. Also, to evaluate single-tree values, Houston used 6 groups of 2-3 cross-dated trees to account for missing scars. Trees within a group were 5-25m apart. The MFI resultant values ranged from 17-26yrs with a mean of 22yrs on representative unprotected sites.

Arno and Gruel (1983) reported intervals between 22-60yrs, with a mean of 43yrs for the Douglas-fir/shrub/grass ecotone, based on tree fire scars adjacent to shrubland. They both report MFI values for either single trees or small areas (Tart, personal correspondence).

However, an anonymous contributor (personal correspondence) states that Houston's (1973) value of 53-96yrs (and 32-62yrs in pre-European settlement) is CFI estimate from 34 trees in a set of 7 units within which trees were composited (Houston, Table 1). The individual tree values are only given in the text as "36-108yrs" across the sample (p. 1112). Houston's "intrastand" estimates of 20-25yrs are CFI estimates. Note that these trees also are not scattered within the steppe as in the first sample but are from along the forest ecotone (p. 1113). Thus, Houston's estimate of 20-25yrs requires correction for adjacency and for unburned area.

An anonymous contributor (personal correspondence) also states that Arno and Gruell also used an extreme form of targeting and a very insufficient sample size (n = 1) at 8 sites and did, in fact, make a composite at the other 4 sites. Houston (1973) and Arno and Gruel (1983) do need correction for unburned area and adjacency in both cases, as both were collected along the forest-grassland ecotone (an anonymous contributor, personal correspondence; Baker 2006), and neither used cross-dated scars.

An anonymous contributor also states that Houston (1973) and Arno and Gruell (1983) are about grasslands, not mountain big sagebrush stands in the pre-European landscape (see below regarding adjacency issues). He also states that neither study cross-dated scars, so it cannot be determined whether fires did or did not burn among trees scattered across landscapes in the Houston study area or whether separate fire years are valid in the Arno and Gruell study.

35-40YR INTERVAL

Heyerdahl et al. (2006) document 4 large fires in Douglas-fir/mountain big sagebrush sites during their reporting period of 1700-1860 (Figure 3b) and possibly 2 more between 1650-1700 (Figure 2). Using these values gives MFIs of between 35-40yrs -- or 37yrs on average. The range of variation in fire occurrence under this regime was 2-84yrs. In other words, between the years 1700-1860, on some portions of the landscape, fire had a point or plot interval of ~37yrs with intervals as short as 2yrs and as long as 84yrs. This frequency is also comparable to the frequency estimated by modeling studies to exclude Douglas-fir (~30yrs, Keane et al. 1990) and to that reconstructed from tree rings in Douglas-fir/mountain big sagebrush elsewhere in southwestern Montana (20-40yr mean fire return intervals, Houston 1973; Arno and Gruell 1983; Littell 2002), where frequent past fires are also thought to have prevented the establishment of Douglas-fir. They believe that fires likely burned the area between plots with evidence of fire in the same year, including across historical sagebrush-grass plots (Heyerdahl et al. 2006).

Heyerdahl et al. (2006) also state that after fire, mountain big sagebrush at sites in southwestern Montana required up to 30yrs to return to >20% cover (Wambolt et al. 2001 in Heyerdahl et al. 2006).

As per Tart (personal correspondence), another approach to estimating MFI in the shrub/grass areas beyond the forest ecotone is to consider only large fires documented from both sides or scattered across the shrub/grass area (Baker 2006; Kitchen, personal communication). This method can be used with the data of Houston (1973) (see Table 3) and Miller and Rose (1999) (see Figure 4). Applying this approach to both data sets to calculate MFI for large fires for the period 1650-1890, the results are: Miller and Rose (1999) between 27-34yrs MFI; Houston (1973) between 30-40yrs MFI. Using the more restrictive definitions of large fire for the period 1700-1890 gave an MFI of 32yrs for both study areas.

50YR INTERVAL

According to Miller and Rose (1999) and Wright and Bailey (1982), there is a 50yr MFI. However, those studies did not take into account the limitations of fire history data or the recovery rate.

Based on what has been shown through different approaches and field experience of those who know the system, the estimate of total MFI for mountain big sagebrush steppe is between 40-80yrs (Kitchen, personal correspondence).

50+ YR INTERVAL

Welch and Criddle (2003) report greater than 50yr interval. They also report the following:

> 10 biological and ecological characteristics of mountain big sagebrush do not support the idea that mountain big sagebrush evolved in an environment of frequent fires of 20-30yrs: (1) a life expectancy of 70yrs+; (2) highly flammable bark (this stringy bark makes excellent fire starting material); (3) production of highly flammable essential oils; (4) a low growth form that is susceptible to crown fires; (5) nonsprouting; (6) seed dispersal occurs in late fall or early winter long after the fire season has ended; (7) lack of a strong seed bank in the soil; (8) seed lack anatomical fire resistance structures or adaptations -- that is, a thick seed coat; (9) seeds must lie on the soil surface, which exposed them to higher temperatures than seeds that occur deeper in the soil; (10) seeds lack any adaptations for long distance dispersal, hence, mountain big sagebrush lack the ability for rapid reestablishment. Thus, it appears that an estimated fire interval of 20-30yrs for mountain big sagebrush is too low and that the natural or normal fire interval is much longer, perhaps 50yrs or more.

70-200YR INTERVAL and RECOVERY

Recovery rates should also be taken into account (Baker 2006). Mountain big sagebrush has the fastest recovery rate of the 3 subspecies of big sagebrush (Johnson 2000; local data). Rates of recovery under the natural disturbance regime most likely were longer than we see in small burns today (anonymous contributor, personal correspondence). It is not necessarily preferred to use a fixed percent cover as a standard for recovery, as the percent cover of ARTRV varies widely with environment.

An anonymous contributor (personal correspondence) suggested a 70-200yr MFI. Recent data from long-term vegetation transects collected over a 20yr period in Wyoming suggest that the recovery of mountain sagebrush steppe communities following fire requires at least 25yrs in northwestern Wyoming and at least 40yrs in southern Wyoming to reach a late seral state with >30% sagebrush cover (Grand Teton National Park/Bridger Teton National Forest Fire Effects Monitoring Data, Southern Wyoming Fire Zone BLM Fire Effects Monitoring Data). If recovery rates are correlated with composite FRIs, FRIs may lie somewhere between 40-60yrs. However, recent data show that FRIs may be twice or more as long as recovery periods, indicating a FRI of 70-200yrs (Baker 2006). If FRI is twice as long as recovery, it might be that the FRI in this system is at least between 50yrs to at least 80yrs. However, the reason the range goes up to 200yrs is because Bruce Welch at USFS Provo Shrub Lab has observed that, in large fires, ARTRV reseeds very slowly, creeping in from the edge at rates that suggest it will require perhaps 100yrs to fully recover. There is wide variation in recovery rate (Lesica et al. 2005). In recent work and new data (Lesica et al. 2005), it seems that most ARTRV will not recover in 25-40yrs, but some will. So the lower end of recovery would be 25-40yrs, and the upper end of the recovery curve may be quite long -- 100yrs. Thus, the 100yr figure gets multiplied by 2 to

produce the high-end estimate of 200yrs (Baker 2006). The midpoint would probably lie in the 100yrs+ range (anonymous contributor, personal correspondence).

This methodology has been debated by some researchers. Some do not advocate the use of the 2 multiplier of the recovery rate to arrive at the fire interval.

CORRECTION FACTORS – 60YRS VERSUS 240YRS

An anonymous contributor (personal correspondence) advocates use of correction factors (Baker 2006) for most of the studies above. If applying correction factors to the Heyerdahl et al. (2006) study, a fire rotation of between 240yrs (anonymous contributor, personal correspondence) is reached. Fire rotation is: (period of estimate)/fraction of area burned. He estimated the fires to be 10, 160, 70, 35, 100, 210, 30, 40, and 210ha for a total of 865ha, but each fire has unburned area. Using the 21% correction for sagebrush fires gives an estimated total of 683ha burned in a study area of 1030ha (66.3% of the area or a fraction of 0.663) over the period from 1700-1860 (160yrs). Thus, the fire rotation is estimated as: 160yrs/0.663 = 241yrs. The fire rotation/population MFI is thus about 6-7.5 times the composite fire intervals, consistent with what has been seen in other empirical comparisons.

Kitchen (personal correspondence) counters that by stating that to calculate an accurate estimate of fire rotation using the anonymous contributor's approach, a basal area considerably smaller than the 1030ha (study area) would have to be used. Just as one cannot assume a fire interval for the non-recording portions of the landscape, one also cannot assume a fire-free period for the whole test period. Either assumption introduces bias. Therefore, all of the unsampled but fire-scarred portions of the landscape would have to be subtracted from the base study area before calculation. In other words, the Heyerdahl et al. (2006) fire sizes are at most conservative estimates of actual areas burned and probably miss fires that went unrecorded. Kitchen therefore used a modified approach to arrive at a fire rotation interval. He visually added up total burn area from Figure 2 as the anonymous contributor did and got 1340ha in 11 fires. An unburned area correction factor should not be used. If it is assumed that the sampled area (portion of study area with fire record) was half the total study area (ballpark guess looking at the map) or 515ha, then a fire rotation of 61.5yrs is reached.

Kitchen (personal correspondence) also counters the anonymous contributor's estimate by stating that in the Heyerdahl et al. (2006) study, fire was largely lost from the system after 1860 (Figure 2). Concurrent with that loss just 146yrs ago, the range and density of Douglas-fir and lodgepole pine trees has increased dramatically throughout the study area. The beginning of heavy use by livestock coincides with the late 1800s shift. If that much has changed in 146yrs, it is not possible that a fire rotation of 241yrs would have been sufficient to maintain the pre-1860 woodland/shrubland mosaic documented by this study.

ADJACENCY

Tart (personal correspondence) states that this BpS in this MZ was occupied by a mosaic of grassland and varying densities of big sagebrush. The FRI of sagebrush BpS sites historically maintained as grasslands is generally reported to be 10-40yrs (Winward 1991; Arno and Gruel 1983; Houston 1973). The longer intervals reported by Baker (2006) and Welch and Criddle (2003) would imply that there was little grassland (Tart, personal correspondence).

There is some disagreement as to whether the sites studied by Arno and Gruell and by Houston apply to BpS of mountain big sagebrush or sites invaded by sagebrush. The anonymous contributor states that in western Montana (Sindelar 1981), grasslands invaded by ARTRV are not fire-maintained, and instead livestock grazing removes the grass competition, leading to ARTRV invasion.

For those areas that might be maintained as grassland along ponderosa pine or Douglas-fir ecotones, FRI -- reported as CFI -- has been indicated between 10-40yrs (Winward 1984; Winward 1991; Johnson 2000; Miller and Tausch 2001; Tart 1996) and >50yrs (Welch and Criddle 2003) and between 35-100yrs (Baker 2006). Again, interpretation of the estimates and corrections used varies.

Mountain big sage is also adjacent to Douglas-fir and lodgepole pine, and intervals for those could be used, which could range from 30-130yrs. This is a vegetation type for which we do not have much confidence in the intervals or interpretation of intervals in the literature (Romme, personal correspondence).

SEVERITY

The severity of fire is also debated in this system. While the majority of fires were likely stand-replacing, some mixed-severity fire may have occurred, though there are few data documenting mixed-severity fires (Sapsis and Kaufmann 1991). Mixed-severity fires were likely small in area, but ignitions may have occurred as frequently as 5-20yrs. There were probably also portions of this system that never carried fire because of sparse fuel (Bushey 1987). Historic fires likely occurred during the summer months and were wind-driven events. Lightning ignitions are variable and affect fire frequency on regional landscapes in the Northern Rockies. Fire may spread from adjacent forested communities.

Reviewer Diane Abendroth stated that she has observed resprouting in ARTRV2 post fire. This seems to occur in some percentage of the plants, but perhaps not on all sites. I have dug into the roots to see well developed caudex even the spring following a complete burn that removes the entire overstory. This has greatly accelerated sage recovery in sites where it has occurred.

ERRORS, VARIABILITY, AND SUMMARY

Just as there exists a potential for error from estimating a shorter than real FRI when compositing, there is also an opposing risk of estimating a longer than real FRI by using an incomplete record of fire (temporally due to missed fires or spatially due to underestimation of fire size, or both). Both sources of error should receive further attention (Kitchen, personal correspondence). If we base estimates of the extent of historical fires on the evidence recovered, much will be lost, as evidence tends to be lost due to decay, erosion, subsequent fires, etc. There is therefore a good probability fire size and frequency will consistently be underestimated. Missed fires result in longer than real estimates of fire rotation (Kitchen, personal correspondence).

There is much variability in the fire intervals in this system. In the late 1800s the interval was shorter than the early 1800s (Romme, personal correspondence). There was a big shift in the late

1800s with fire intervals, whereas it could have been longer in the early 1800s, more akin to present day, due to climate (Tausch, personal correspondence). Fire regimes also vary considerably across the biogeographic range of mountain big sagebrush, based on factors like elevation, soil depth, slope, aspect, adjacent vegetation, frequency of lightning, and climate. The climate, slope, aspect, soil, and elevation can vary widely, and thus the fire interval for this system can be as low as 30yrs to several hundred years, depending on what is surrounding the system. Although an average value could be chosen and although it perhaps lies in the 50yr range, most fire intervals would probably not be at the average value (Tausch, personal correspondence).

There is no means to accurately measure historic fire frequency in sagebrush communities (Kitchen, personal correspondence), and there are conflicting opinions as to the approaches taken to determine MFI for these systems. It is not known how fire might have behaved across the fuel threshold at the forest/shrubland ecotone. Therefore, it is not known how accurately proxy fire chronologies derived from fire-scarred trees predict fire regimes in nearby shrublands (Kitchen, personal correspondence).

When inputting differing fire probability values in VDDT, the following class percentages were output (early 0-13; mid 14-40; late 41-):
30yr interval: 35/45/20
50yr interval: 25/45/30
80yr interval: 15/45/40
100yr interval: 10/45/45

When the longer fire interval parameters were used in VDDT, the proportion of the landscape in the earlier classes declined. Tart and other experts felt that those percentages of the landscape successional classes were not indicative of what would have been found historically. Succession Class A needed to incorporate grass/forbs, and it should have been more prevalent on the landscape. However, the anonymous contributor and others contended that there is no knowledge of what percentage of the successional classes could be found on the landscape historically.

After these issues were elevated to LANDFIRE leadership/guidance, the 50yr interval was decided upon. This interval is still considered on the longer side of the range by some (Winward, personal communication).

Other disturbances, including drought stress, insects, and native grazing, were present under pre-settlement conditions in this type. Most of these disturbances were mixed-severity, resulting in thinning of sagebrush. In MZ21, deer and elk, at high density, can use sagebrush on winter ranges.

Fire Frequency

Severity	Avg FI	Percent of All Fires	Min FI	Max FI
Replacement	49	100	30	200
Moderate (Mixed)				
Low (Surface)				
All Fires	49	100		

Fire interval is expressed in years for each fire severity class and for all types of fire combined (All Fires). Average FI is the central tendency modeled. Percent of all fires is the percent of all fires modeled in that severity class. Minimum and Maximum FIs show the relative range of fire intervals as estimated by model contributors, if known.

Scale Description

Fires burn in patchy mosaics in this type, and scales ranged from small (10s of acres) to very large (possibly 100s of 1,000s of acres) contingent on sufficient understory fuel continuity.

In MZ21, occurrences are on the scale of 10s-100s of acres, as opposed to other MZs where landscape-scale assessments could be in the order of 10,000ac for mountain sagebrush steppe communities because of the mosaic nature of vegetation communities, the moderate-to-long mean fire return intervals and the extent of the vegetation community.

On the widely distributed loamy soils, prior to 1900, sagebrush might have been restricted to small patches or widely spaced plants (Arno and Gruell 1983).

Adjacency or Identification Concerns

Differentiation of mountain big sagebrush steppe from Wyoming big sagebrush may be difficult at the ecotone due to physical similarities and hybridization zones (i.e., species concepts become blurred).

Identification of the succession classes via remote sensing is complicated when canopy cover is used as a surrogate for succession class because canopy cover is also a reflection of site factors. Sparse but very old stands of sagebrush could be mapped as mid-succession. Young but dense stands could be erroneously considered Class C.

Adjacent plant associations on shallow clay soils are dominated by Wyoming big sagebrush. Shallow clay soil inclusions also support *Artemisia arbuscula*. Above about 8,500 feet this BpS transitions to a more forb-dominated vegetation type, “Tall Forb,” and above about 10,000 feet to a tundra type.

In MZ21, there is most commonly Douglas-fir and sometimes lodgepole pine encroachment. Douglas-fir trees have encroached into sagebrush-grasslands from historically stable tree islands, and tree density has increased on the tree islands (Heyerdahl et al. 2006). Mountain big sagebrush cover decreases rapidly as juniper dominance increases today (Miller et al. 2000 in Heyerdahl et al. 2006).

Nearly all sagebrush communities today have been grazed, and there are no refugia to use as reference conditions.

Some grassland systems are invaded by sagebrush today in larger quantities. These grassland systems might today have mountain big sage and, in pre-European settlement, might have had a bit of mountain sage. Pre-European settlement. they would have been grassland systems, whereas today they might be confused for mountain big sagebrush systems. It might therefore be difficult to distinguish the early seral stages of this class from the grassland BpS 1139 system. It should be distinguished by elevational component.

Historically, this BpS in MZ21 was likely dominated by grassland such as that in succession Class A along the forest ecotone (Houston 1973; Arno and Gruel 1983). Since this type is largely interspersed with forest or occupies a narrow band adjacent to lower timberline, Class A is likely to have dominated the landscape. A reviewer disagreed stating that at higher elevations the understory is dominated by forbs and that these areas stay green late into fire season and don't carry fire as frequently as the adjacent forest.

Mountain big sagebrush was probably not as abundant in pre-settlement conditions (Arno and Gruell 1983), since the original vegetation of sagebrush-grass consisted of a dense cover of perennial grasses among which were scattered moderate-sized shrubs. Sagebrush might be more dense now in these communities due to fire exclusion, overgrazing by livestock, and/or climate change.

Fire exclusion is a major effect of livestock grazing in dynamic sagebrush/grassland systems (Miller et al. 1994; Miller and Rose 1999; Gruell 1999; Miller et al. 2000; Miller and Eddleman 2000; Crawford et al. 2004).

In MZ21, there are non-native species such as *Phleum pratense*, *Cynoglossum officinale*, and many others. Species such as Bromus inermis, Poa pratensis, Poa compressa make sagebrush more likely to burn because they create a continuous fuel bed (rhizomatous growth form).

Currently, there is probably a higher proportion of the landscape in the late development Class (C) than would have been expected under the reference condition, but this may not be captured well in mapping. Class C does not always have to have the most dense cover; it has older and larger sagebrush plants, that may look like class B when mapped with remote sensing. Therefore, class B may be over-represented on the mapped landscape.

Issues or Problems

There is a limited amount of information available on fire regimes and reference conditions in sagebrush due to modern overgrazing (the herbaceous component is severely impacted and current information cannot exclude the effects of cattle). Nearly all sagebrush communities today have been grazed -- there are few known refugia to use as reference conditions. There is much controversy surrounding FRIs within this system and how to define this system adjacent to grassland systems.

Native Uncharacteristic Conditions

Shrub cover >45% cover or taller than 1m may be uncharacteristic, but there is some debate about this. A reviewer commented that she had measure up to 65% sagebrush cover using line intercept transects, but the highest cover was measure in places with moderate to heavy cattle grazing and/or previous hay production so it is unclear if this much cover is possible under the reference condition. Greater than 10% canopy cover by conifers can be considered uncharacteristic. Potential causes of encroachment include grazing and lack of fire, as well as climatic episodes favorable to tree regeneration.

Comments

In 2017 Diane Abendroth and Alan Sands reviewed this model and noted that they agreed with the circa 50 year FRI. Sands also suggested that the model should include a tree class to account for conifer invasion potential (see more on this below).

During the BpS Review in 2017, this model was part of a "macro-review" where all models representing this BpS were reviewed and evaluated relative to one another. One goal of the review was to check for logical consistency between the models. Outstanding questions from this review that should be evaluated in the future include:
-Should all models for this BpS include a tree succession class? The current model set includes models that have tree succession classes and those that do not. The models representing MZ06 et al. and MZ13 note that the Ecological Systems classification does not distinguish between mid- to high-elevation mountain big sagebrush communities that can be invaded by conifers and those at elevations too high for tree encroachment. The MZ06 et al. description also notes that where tree encroachment is impossible, a three-box model (i.e., this model without tree classes D and E) should be used. Sands, during the 2017 BpS Review, suggested that all models for this BpS include a tree succession class.
-Does the low sagebrush versus mountain big sagebrush split applied in the model representing MZs 16, 23, and 24 apply elsewhere? This split was implemented by modelers to allow low sagebrush communities to have a much lower fire frequency than mountain big sagebrush communities. MZ06 et al. notes that mountain low sagebrush communities should be classified as Columbia Plateau Low Sagebrush Steppe **(**BpS 1124). MZ13 notes that extensive areas of low/black sagebrush should be considered Great Basin Xeric Mixed Sagebrush Shrubland (BpS 1079).
-What is an appropriate fire frequency and severity for this BpS? Estimates for these fire regime parameters vary widely (see Innes 2017), and during LANDFIRE National, there was considerable debate about these values in some areas as documented in this description.

Original modelers for MZ21 were Tim Klukas (tim_klukas@nps.gov), Reggie Clark (rmclark@fs.fed.us), John Simons (john_simons@blm.gov), and one anonymous contributor. Additional reviewers for MZ21 were Steve Kilpatrick, Klara Varga, Stan Kitchen (skitchen@fs.fed.us), Dave Tart, and Brenda Fiddick. Because there were significant differences of opinion between the original modelers and the reviewers, no compromise could be reached. After an extensive model review process, LANDFIRE leadership/guidance determined that the original modelers used an interpretation of the fire information available on sagebrush systems that did not represent the majority expert opinion/interpretation of the fire literature. Therefore, the original MZ21 model was altered to reflect majority opinion/interpretation of literature regarding the fire regime of this sagebrush system.

Succession Classes

Mapping Rules

Upper Layer Lifeform	Height (m)	Canopy Cover (%)									
		0-10	11-20	21-30	31-40	41 - 50	51-60	61-70	71-80	81-90	91-100
Herb	0-0.5	A	A	A	A	A	A	A	A	UN	UN
Herb	0.5-1.0	A	A	A	A	A	A	A	A	UN	UN
Herb	>1.0	A	A	A	A	A	A	A	A	UN	UN
Shrub	0-0.5	B	B	B	C	C	UN	UN	UN	UN	UN
Shrub	0.5-1.0	B	B	B	C	C	UN	UN	UN	UN	UN

Shrub	1.0-3.0	UN	UN	UN	UN	UN	UN	UN	UN	UN	UN
Shrub	>3.0	UN	UN	UN	UN	UN	UN	UN	UN	UN	UN
Tree	0-5	C	UN	UN	UN	UN	UN	UN	UN	UN	UN
Tree	5-10	C	UN	UN	UN	UN	UN	UN	UN	UN	UN
Tree	10-25	UN	UN	UN	UN	UN	UN	UN	UN	UN	UN
Tree	25-50	UN	UN	UN	UN	UN	UN	UN	UN	UN	UN
Tree	>50	UN	UN	UN	UN	UN	UN	UN	UN	UN	UN

Succession class letters A-E are described in the Succession Class Description section. Some classes use a leafform distinction where a qualifier is added to the class letter: Brdl (broadleaf), Con (conifer), or Mix (mixed conifer and broadleaf). UN refers to uncharacteristic native or a combination of height and cover that would not be expected under the reference condition. NP refers to not possible or a combination of height and cover which is not physiologically possible for the species in the BpS.

Description

Class A 23 Early Development 1 - All Structures

Indicator Species

Symbol	Scientific Name	Common Name	Canopy Position
FEID	Festuca idahoensis	Idaho fescue	Lower
PSSP6	Pseudoroegneria spicata	Bluebunch wheatgrass	Lower
Forbs	<NOT FOUND IN NRCS>	<NOT FOUND IN NRCS>	Lower
ARTRV	Artemisia tridentata ssp. vaseyana	Mountain big sagebrush	Lower

Description

Herbaceous cover is dominant but cover is variable. Shrub cover is low and typically ranges from 0-10%; 5% shrub cover indicates good establishment of a post-fire cohort. Purshia tridentata may resprout rapidly after a fire with fairly low percent cover. In drought conditions the survival of these resprouts is low. Grazing is common but rarely severe enough to set back succession.

Historically, this BpS in MZ21 was likely dominated by grassland such as that in succession Class A along the forest ecotone (Houston 1973; Arno and Gruel 1983). Since this type is largely interspersed with forest or occupies a narrow band adjacent to lower timberline, Class A is likely to have dominated the landscape.

In this environment (and a number of the other grassland, shrub steppe types), forb density and cover are most responsive to climatic conditions. Hence, fire response will vary according to precipitation patterns before and immediately after the fire. Forbs are less conducive to fire spread, and they have a high proportion of the overall cover for a couple of years post-fire, especially at higher elevations.

Maximum Tree Size Class

None

Class B 47 Mid Development 1 - Open

Indicator Species

Symbol	Scientific Name	Common Name	Canopy Position
ARTRV	Artemisia tridentata ssp. vaseyana	Mountain big sagebrush	Upper
FEID	Festuca idahoensis	Idaho fescue	Lower
PSSP6	Pseudoroegneria spicata	Bluebunch wheatgrass	Lower
ARTR4	Artemisia tripartita	Threetip sagebrush	Upper

Description

Developing shrubs. Reaching 20% sagebrush cover following a stand-replacing fire takes between 10-33yrs (Tart, personal correspondence). There is a 40% herbaceous canopy cover across this class. *Purshia tridentata* may be present and takes at least 20-30 years to recover pre-burn percent cover. Presence of Purshia tridentata seems to depend on soil type. Native grazing on winter ranges by elk and deer typically decreases sagebrush cover.

Maximum Tree Size Class

None

Class C 30 Late Development 1 - Closed

Indicator Species

Symbol	Scientific Name	Common Name	Canopy Position
ARTRV	Artemisia tridentata ssp. vaseyana	Mountain big sagebrush	Upper
PSSP6	Pseudoroegneria spicata	Bluebunch wheatgrass	Lower
FEID	Festuca idahoensis	Idaho fescue	Lower
ARTR4	Artemisia tripartita	Threetip sagebrush	Upper

Description

Shrubs are dominant. Sagebrush cover rarely exceeds 40% cover. Mountain big sagebrush canopy cover is constrained by competition from herbaceous vegetation on all but the wettest sites (Tart 1996). Competition between herbs and sagebrush is less pronounced on cooler, wetter sites. High canopy cover of mountain big sagebrush only develops after removal of herbaceous vegetation. Some researchers believe that mountain big sagebrush can never exceed 25% cover (Pedersen et al. 2003), but reviewer Abendroth stated that she has measured over 60% cover. Understory vegetation has low cover in this class. *Purshia tridentata* may be present and may have over 20% cover. Insects and drought stress can thin sagebrush.

Maximum Tree Size Class

None

Model Parameters

Deterministic Transitions

From Class	Begins at (yr)	Succeeds to	After (years)

Early1:ALL	0	Mid1:OPN	13
Mid1:OPN	14	Late1:CLS	40
Late1:CLS	41	Late1:CLS	999

Probabilistic Transitions

Disturbance Type	Disturbance occurs In	Moves vegetation to	Disturbance Probability	Return Interval (yrs)	Reset Age to New Class Start Age After Disturbance?	Years Since Last Disturbance
Native Grazing	Early1:ALL	Early1:ALL	0.002	500	No	0
Replacement Fire	Early1:ALL	Early1:ALL	0.02	50	Yes	0
Native Grazing	Mid1:OPN	Mid1:OPN	0.002	500	No	0
Insects or Disease	Mid1:OPN	Mid1:OPN	0.005	200	No	0
Wind or Weather or Stress	Mid1:OPN	Mid1:OPN	0.01	100	No	0
Replacement Fire	Mid1:OPN	Early1:ALL	0.02	50	Yes	0
Native Grazing	Late1:CLS	Late1:CLS	0.002	500	No	0
Wind or Weather or Stress	Late1:CLS	Mid1:OPN	0.01	100	Yes	0
Insects or Disease	Late1:CLS	Mid1:OPN	0.013	77	Yes	0
Replacement Fire	Late1:CLS	Early1:ALL	0.02	50	Yes	0

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