What We Know About Mountain Big Sagebrush Fire Ecology, Postfire Recovery Rate, and Fire Regimes

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INTRODUCTION

The area occupied by mountain big sagebrush (*Artemisia tridentata* subsp. *vaseyana*) communities has been greatly reduced since European-American settlement and is likely to be further reduced due to ongoing threats including land use and development, woodland expansion, nonnative plant invasions, altered fire regimes, and climate change. These threats and the recent federal listing review of greater sage-grouse (*Centrocercus urophasianus*) make conservation and proper management of sagebrush communities key priorities.

New publications in the Fire Effects Information System (FEIS, www.feis-crs.org/feis/) include a Species Review of mountain big sagebrush fire ecology (Innes 2017) and a Fire Regime Synthesis of the frequency, severity, pattern, and size of fires in mountain big sagebrush communities before and after European-American settlement (Innes 2018). These publications summarize hundreds of publications by researchers and managers and compliment the recent FEIS Species Review on sage-grouse (*Centrocercus* spp.) (Innes 2016), which are obligate species that require sagebrush communities for food and cover. This obligate relationship may suggest the need to protect remaining sagebrush ecosystems from disturbances such as fire, but sage-grouse habitat requirements vary seasonally. Thus, the species may be best served by a mosaic of sagebrush successional stages that provide diverse, productive forage near security and thermal cover. Such mosaics are beneficial to many wildlife species. Fire was an important driver in creating and maintaining these mosaics historically, so understanding fire ecology, postfire recovery dynamics, and fire history of mountain big sagebrush and other sagebrush taxa is critical for making sound management decisions and avoiding long-term negative impacts to sagebrush communities and associated wildlife. In this extended abstract, we summarize the information on mountain big sagebrush fire ecology and fire regimes reported in these two FEIS publications, which includes the results of our analyses on postfire recovery from over 300 sites. Primary citations used in FEIS publications are not included in this abstract. See the FEIS publications for detailed information and citations.

FIRE ECOLOGY

Regeneration Processes

Mountain big sagebrush plants are easily killed by fire and do not sprout, although hybrids of mountain big sagebrush × silver sagebrush (*Artemisia cana*) may sprout after fire. Postfire establishment is exclusively from seeds, which may be present in the soil seed bank or come from unburned plants in and adjacent to burns. The rate of recovery (i.e., the length of time necessary for canopy cover to reach unburned (or prefire) levels) is driven by timing and abundance of postfire seedling establishment.

Keywords: conifer expansion, fire ecology, fire regimes, mountain big sagebrush, nonnative annual grasses, postfire recovery, regeneration processes, prescribed fire, succession

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Seedling establishment during the first few postfire years is highly variable because it is influenced by many interacting factors including the abundance of viable seeds in the soil seed bank, location of and seed production by unburned plants, postfire moisture availability and weather, and postfire herbivory. Fire timing, severity, size, and pattern affect soil-stored seeds and the amount and distribution of unburned, seed-producing plants. Establishment from soil seed banks may be limited because seeds are vulnerable to lethal temperatures during fire. Unburned mountain big sagebrush plants in and adjacent to burns are important seed sources for postfire establishment; however, seed production is highly variable and depends on weather, site, and plant characteristics (e.g., size, age, and genetics). Most mountain big sagebrush seeds disperse within 3 m of parent plants, so the distance from parent plants to the burn affects the rate and distribution of postfire seedling establishment. Seeds from unburned plants ripen and disperse during fall and winter, typically after wildfire season.

Postfire Succession

Most mountain big sagebrush seedling establishment occurs within the first 4 postfire years, although postfire seedling establishment may be absent or limited on some sites for many years, especially when available moisture is low. Mountain big sagebrush seedling establishment typically slows after the first few postfire years because soil seed banks are depleted and seedlings must compete with other vegetation for resources. Secondary peaks in establishment occur when mountain big sagebrush individuals that established soon after fire mature and produce seeds (anywhere from 2 to >13 years old). Thereafter, establishment may be episodic.

In the absence of fire or other disturbances (e.g., heavy browsing, freeze-kill, snow mold, and drought), mountain big sagebrush can dominate shrub steppe communities indefinitely. However, when the interval between fires is long enough for junipers (*Juniperus* spp.), pinyons (*Pinus* spp.), and other conifers to establish and mature, woodlands may expand into adjacent mountain big sagebrush communities. The rate of woodland expansion varies with conifer species and site characteristics. Woodland expansion is most common on sites with frigid to mesic soil temperature regimes and xeric soil moisture regimes. Cover of mountain big sagebrush and native grasses and forbs declines as cover of trees increases during succession. Succession of mountain big sagebrush communities to late-successional woodlands causes changes in wildlife habitat, fuel characteristics, and fire behavior.

POSTFIRE RECOVERY RATE

Due to concerns regarding habitat requirements for sagebrush obligates, postfire recovery rate has been the focus of numerous studies. We obtained data from 306 burned sites examined in 20 studies to synthesize information on mountain big sagebrush recovery. To assess changes in postfire recovery across all sites over time, we averaged these data within 5-year, time-since-fire bins and plotted recovery versus time-since-fire (fig. 1), and we used a binary logistic regression model to estimate the overall probability of recovery over time (fig. 2). Sites were classified as "recovered" when mean canopy cover equaled or exceeded unburned (or prefire) canopy cover and "not recovered" when mean canopy cover was less than unburned (or prefire) cover. We then explored whether changes in recovery over time differed geographically by plotting postfire recovery by time-since-fire for each of eight ecoregions.

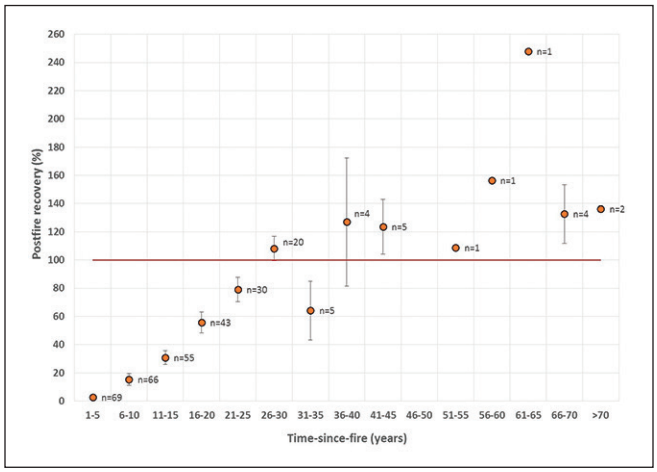

Figure 1—Percent mean ratio (±SE) of burned to unburned (or prefire) canopy cover (i.e., "postfire recovery") of mountain big sagebrush averaged within 5-year, time-since-fire bins. The red line indicates recovery to unburned (or prefire) canopy cover.

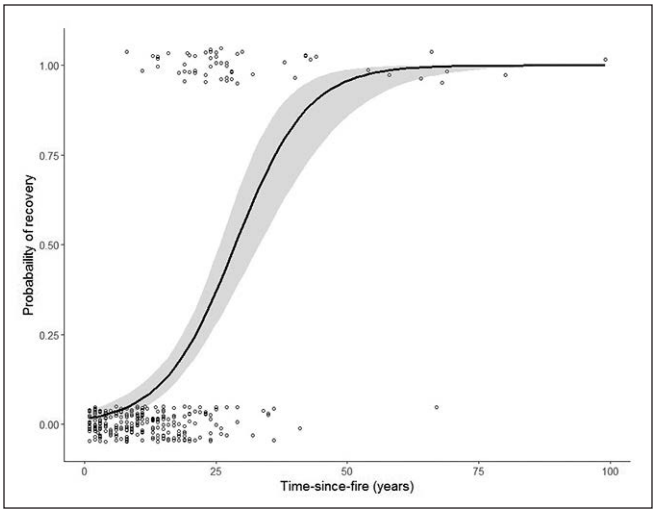

Figure 2—Binary logistic regression analysis of mountain big sagebrush postfire recovery as a function of time-since-fire (n = 306 burned sites). Circles around the "1" line on the y-axis indicate recovered sites, and circles around the "0" line indicate sites that had not recovered to unburned canopy cover. The solid line represents the probability function derived from the prediction equation and the gray area shows the 95% confidence interval.

Our analyses showed that mountain big sagebrush canopy cover and postfire recovery increased fairly consistently during the first 30 postfire years. On average, mountain big sagebrush sites began reaching full recovery around 26 to 30 years after fire (fig. 1), when mountain big sagebrush canopy cover averaged 28 percent, although variability among sites is high. On average, a given site has little chance of recovery (12%) within 15 years, a 50 percent chance of recovery in 29 years, and a high chance of recovery (95%) in 49 years ($P < 0.0001$) (fig. 2); however, the certainty around these probabilities varies. Based upon 95% confidence intervals (shown by the gray area in fig. 2), uncertainty of recovery is greatest for sites about 25 to 50 years after fire, due to a similar number of recovered and unrecovered sites in that age range.

Mountain big sagebrush postfire recovery may be faster on some sites and in some ecoregions than in others; however, differences in unburned cover values (i.e., the recovery threshold) among study sites and in the number of study sites among ecoregions complicate comparisons of postfire recovery within and among ecoregions. Overall, sites in the Middle Rockies appeared slowest to recover, in part due to heavy postfire browsing; however, exceptions occurred and a site with sprouting mountain big sagebrush hybrids recovered relatively fast, reaching 20 percent canopy cover 15 years after fire. These results emphasize the importance of postfire land use and prefire plant community composition in estimating postfire recovery rates.

FIRE REGIMES

Presettlement fires in the sagebrush biome were both lightning- and human-caused. Peak fire season occurred between April and October and varied geographically. Wildfires were high-severity, stand-replacement fires. Fire frequency was influenced by site characteristics, and frequency estimates range from decades to centuries, depending on the applicable scale, methods used, and metrics calculated. Because mountain big sagebrush steppe communities occur over a productivity gradient driven by soil moisture and temperature regimes, fire regimes likely varied across the gradient, with more frequent fire on more productive sites that supported more continuous fine fuels. Sites with mountain big sagebrush burned more frequently than sites with Wyoming big sagebrush (*A. t.* subsp. *wyomingensis*) because the former tend to be more productive. Mountain big sagebrush communities adjacent to fire-prone forest types (e.g., ponderosa pine (*Pinus ponderosa*)) may have had more frequent fires than sites adjacent to less fire-prone types (e.g., pinyon-juniper) and those far from forests and woodlands. Most fires were likely small (less than ~500 ha), and large fires were infrequent. Large fires were most likely after one or more cool, wet years that allowed fine fuels to accumulate and become more continuous.

Since European-American settlement, fuel and fire regime characteristics in many big sagebrush (*A. tridentata*) steppe communities have shifted outside the range of historical variation. Settlement generally began in the mid-1800s and caused changes in ignition patterns and fuel characteristics, although the timing and magnitude of these changes varied among locations. Since then, fuels and fire regimes in many sagebrush ecosystems have changed due to a combination of interrelated factors, including land development for agriculture and energy, urbanization and infrastructure development, proliferation of nonnative invasive plants, woodland expansion, overgrazing by livestock, fire exclusion, and climate

changes. Since 1980, the number of fires each year and total annual area burned have increased in the sagebrush biome. However, in most mountain big sagebrush communities, available data suggest that fire frequency has either not changed or has been reduced, with the exception of an area in the Colorado Plateaus ecoregion where fire frequency may have increased due to frequent prescribed burning.

MANAGING MOUNTAIN BIG SAGEBRUSH COMMUNITIES

Creating and maintaining sufficient habitat and forage for wildlife, especially sagebrush obligates, are primary objectives of managing mountain big sagebrush communities. This involves increasing resilience to stress and disturbance and enhancing resistance to establishment and spread of nonnative species. Resilience and resistance differ among big sagebrush communities, and generally increase with increasing soil moisture availability and decrease with increasing soil temperature; thus, researchers emphasize the importance of site-specific management. Fire management considerations are covered in the following sections.

Wildlife Considerations

Challenges of managing mountain big sagebrush communities for wildlife include maintaining sufficient mountain big sagebrush cover and native herb abundance while reducing opportunities for conifer and nonnative plant establishment and spread. Mountain big sagebrush provides important forage and cover for many wildlife species, particularly in winter, and fire reduces its abundance for many years. Conversely, prescribed burning may increase the abundance and productivity of native herbs for up to 10 postfire years, providing important forage for sage-grouse and wild ungulates. A landscape mosaic of successional stages provides wildlife habitats with diverse, productive forage near areas with security and thermal cover, but effects depend on the ratio of forage to cover over time.

Conifer Management

Prescribed fire is sometimes recommended to reduce conifer establishment in mountain big sagebrush communities because cover of mountain big sagebrush and native herbaceous species decline with increasing conifer cover, which is detrimental to sagebrush obligates. Because conifers are important habitat components for many facultative wildlife species, especially if tree density is low enough to allow a healthy understory of shrubs and grasses, researchers generally only advocate conifer removal in areas where trees were historically absent or where tree density has increased since European-American settlement. Several researchers recommend that priority for conifer removal be given to mountain big sagebrush sites in early to middle stages of woodland succession, before trees become dominant, because they are likely to have more native plants in the understory and more native seeds in the soil seed bank, making them more resilient than sites in later stages of woodland succession.

Nonnative Plants

Of the nonnative plants present in mountain big sagebrush ecosystems, annual grasses pose the biggest threat because they alter fuel characteristics in invaded communities and have the potential to increase the frequency, size, spread rate, and duration of wildfires. Among nonnative annual grasses of concern in big sagebrush communities, cheatgrass (*Bromus tectorum*) has been the most harmful. While mountain big sagebrush communities are among the least susceptible of big sagebrush communities to invasion by cheatgrass, cheatgrass can dominate mountain big sagebrush communities after fire, especially if pre- and postfire cover of native herbs is low and weather is favorable for cheatgrass establishment and growth. Areas with a history of overgrazing by livestock or a high density of conifers are likely to have low cover of native perennial grasses and therefore less resistance to the establishment and spread of cheatgrass after fire. In areas where native perennial plant cover is depleted, seeding after fire may help stabilize soils, increase recovery of native plants, and prevent establishment and spread of cheatgrass and other nonnative plants. Prescribed fire is recommended only in areas where postfire dominance by nonnative plants is unlikely and plans include postfire monitoring and invasive plant management.

Postfire Grazing

Livestock tend to concentrate on burned mountain big sagebrush communities. To protect regenerating plants, many authors recommend excluding livestock for at least 1 or 2 years after fire, or until perennial grasses have recovered and are producing viable seeds in numbers equal to that of unburned levels.

Prescribed Fire

In general, fire is considered an appropriate and effective tool only on sites where mountain big sagebrush is abundant, native perennial grasses and forbs are present, nonnative plants are absent or sparse, and plans include postfire monitoring and invasive plant management.

Authors recommend that fires in mountain big sagebrush communities be frequent enough to prevent tree establishment and succession to conifer woodland, but not more frequent than the amount of time required for mountain big sagebrush to recover (~26 to 30 years, on average, although use of site-specific estimates is critical). Postfire recovery of mountain big sagebrush communities is likely to be faster if fires are small or patchy, with unburned plants inside burn perimeters. Authors recommend burning when plants are dormant, either in the spring or fall, if the objective is to produce a patchy burn that reduces big sagebrush cover and increases herbaceous plant production.

CONCLUSIONS

The FEIS publications on mountain big sagebrush fire ecology and fire regimes help land and resource managers locate and apply the best available science to planning and management decisions because they synthesize information from hundreds of sources and describe management implications.

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