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Information and tools to conserve and restore Great Basin ecosystems

Management of Aspen in a Changing Environment

Purpose: To provide land managers with information that can help them identify different aspen types, assess the condition of aspen stands, and prioritize stands for restoration using appropriate treatments.

In Brief:

- Aspen communities are biologically rich and ecologically valuable, yet they face myriad threats, including changing climate, altered fire regimes, and excessive browsing by domestic and wild ungulates.
- Recognizing the different types of aspen communities that occur in the Great Basin, and being able to distinguish between seral and stable aspen stands, can help managers better identify restoration needs and objectives.
- Identifying key threats to aspen regeneration and persistence in a given stand or landscape is important to designing restoration plans, and to selecting appropriate treatment types.
- Although some aspen stands will need intensive treatment (e.g., use of fire) to persist or remain healthy, other stands may only require the modification of current management practices (e.g., reducing livestock browsing) or may not require any action at all (e.g., self-replacing stable aspen communities).

Background and Ecology

Quaking aspen (*Populus tremuloides*) is an economically and ecologically valuable tree species that is considered to be in decline across much of the western United States due to fire suppression, severe drought, herbivory, conifer competition, and mortality from disease and insects (Campbell and Bartos 2001). Both gradual aspen decline and sudden aspen dieback (SAD) events have been recorded throughout the western U.S. in recent decades. Aspen communities are often biological hotspots in the Great Basin, because they provide critical habitat for many plant, mammal, bird, and insect species. Thus, continued aspen decline could result in cascading losses of animal and plant species.

The potential for aspen habitat loss may be particularly pronounced in the Great Basin. Aspen is the only broad-leaved, deciduous tree species of significant areal extent here, but it occupies only about one percent of this generally arid ecoregion. Aspen communities are found in higher-elevation mountain ranges in much of the northern and central portions of the Great Basin, but become less common in the southern part of the region. Aspen are typically found in montane and subalpine zones, where soil moisture is adequate during the growing season. These are typically areas with winter snowfall that subsidizes soil moisture content during drier summer months. Riparian aspen communities occur along streams and other water features, and may extend into lower elevations with generally drier conditions.

Although aspen is often considered an early successional species, aspen forms both seral (transitional) and stable (persistent or "pure") communities. In seral communities, especially those in landscapes with longer-lived conifer species, disturbance plays an important role in the persistence of aspen. Fire, in particular, is critical for aspen renewal in many seral stands, and it can create mosaics of aspen- and conifer-dominated communities that are dynamic across landscapes and over time. After fire, aspen typically resprouts prolifically and can dominate in post-fire landscapes for decades. Without a return of fire, conifer species gradually increase and form late successional communities, potentially eliminating aspen over time (Strand et al. 2009a). However, in pure aspen, or even in mixed stands with an absence of strong conifer competitors, fire may not be necessary for aspen persistence. Stable aspen communities persist via steady rates of tree recruitment, or with episodic regeneration stimulated by overstory mortality events caused by drought, pathogens, or age (Shinneman et al. 2013). In the Great Basin, both pure aspen and mixed aspen-conifer stands occur, with some mountain ranges (e.g., Ruby Mountains, Santa Rosa Range, Steens Mountain) dominated by pure aspen communities in montane and subalpine zones.

Aspen communities in the western U.S. are often dominated by long-lived clones of genetically identical individuals (ramets) that can comprise entire stands of trees and that persist through asexual reproduction (suckering). However, recent research has shown that sexual reproduction (through seed production and seedling establishment) in aspen of the Mountain West is more important than previously understood. Sexual reproduction is most common after disturbance, can provide greater genetic diversity at both stand and landscape scales, and may allow better adaptation to changing environmental and climate conditions (Long and Mock 2012).

Prioritizing stands for restoration treatments

It can be difficult to identify and then prioritize aspen stands most in need of restoration, let alone determine effective treatments. However, a key consideration is to recognize that aspen communities in the Great Basin are influenced by diverse biophysical settings, disturbance regimes, and climate conditions that have shaped the successional, compositional, and structural characteristics of the stands. Determining the stand type can help managers evaluate how current stand conditions compare to historical ranges of variability and develop appropriate management strategies. What follows are four classifications of aspen stand types that have been developed based on relationships among stand conditions, disturbance regimes, and environmental settings.

- At the continental scale, aspen communities of North America have been classified into seven subtypes (e.g., montane aspen), each nested within seral or stable functional types (Rogers et al. 2014).
- At the regional scale of the Intermountain West, aspen communities have been classified into 56 types based primarily on plant composition and structural characteristics, and further characterized by seral versus stable stand dynamics (Mueggler 1988).
- Within the Intermountain West aspen have also been classified into five fire-regime types, delineated along gradients of fire frequency and severity, defined as fire-dependent (seral) or fire-independent (stable), and associated with specific environmental conditions (Shinneman et al. 2013).
- At a local scale, aspen in the Sierra Nevada were classified based on growing conditions and relative dependence on fire for persistence (Table 1; Shepperd et al. 2006).

In addition to stand type, other important considerations for prioritizing sites for treatment include land use history, landscape context, and ongoing or future threats (e.g., climate change). For instance, a stable aspen stand with an old and senescent overstory might not be a concern, especially if wild or domestic ungulate browsing has not limited recruitment and if multi-cohort aspen stands exist elsewhere on the landscape.

Table 1. Prioritization of treatment sites and methods in aspen communities is based on an understanding of different aspen functional/stand types. Several aspen classifications exist, including this one developed for the Sierra Nevada. By using stand types, resource managers can better assess management options to achieve desired outcomes, including restoring stand composition and age structures, promoting recruitment, and influencing successional trajectories beneficial to aspen (adapted from Sheppard et al. 2006).

Aspen Stand Type	Successional Type	Characteristics
Meadow Fringe	Seral	Aspen restricted to less saturated soils on meadow edges (fringe). They typically have diverse herbaceous understories and are often seral to conifers.
Riparian	Seral	Aspen occurring along water sources (streams, seeps) that may or may not contain a woody understory (e.g., alders or willows).
Upland Aspen/Conifer	Seral	Aspen co-occurring with conifers, located away from obvious surface water sources.
Lithic	lava, boulder, talus	Aspen occurring in association with lithic features, such as glacial moraines, talus, or lava flows. May serve as refugia from browsing, fire or other disturbance.
Snowpocket	Stable	Aspen occurring where topography causes greater snow accumulation.
Upland Pure	Stable	Aspen occurring outside riparian zones, but not typically containing conifers.
Krummholz	Stable	Aspen with a low shrub-like stature that is often associated with high-elevation, wind-swept topographic features (e.g., rocky ridgelines).

In contrast, a conifer-dominated mixed aspen stand might need restoration treatment, especially if natural fire regimes have been altered by suppression activities at landscape scales and/or browsing has impacted recruitment rates.

Once assessments of stand history and stand type have been made, additional site-specific criteria are needed to further prioritize stand treatment. Various ecosystem attributes can be used to evaluate aspen stand stability, conditions, and trends such as proportion of conifer in the overstory, aspen age, and density of regenerating aspen trees (Table 2). Also, various protocols have been developed to quantify risk factors and prioritize aspen stands for treatment, based on these ecosystem attributes (see review in Shepperd et al. 2006).

Restoration Strategies and Treatment Types

Once a stand has been assessed and restoration objectives established, various treatments can be implemented to achieve those objectives (Figure 1). Regardless of treatment type, chances for successful aspen asexual reproduction depend on the factors in the "Aspen Regeneration Triangle."

Table 2. Ecosystems attributes that can be evaluated to determine aspen stand stability, conditions, and trends. The attributes and the criteria used to determine the type of management action, if any, will vary depending on stand type, stand history, and restoration objectives. Other attributes that may be monitored include soil temperature, distance to water, and wildlife habitat structure. Assessment and monitoring protocols are available in Sheppard et al. 2006 and Strand et al. 2009b.

Category	Key Attributes to Evaluate and Monitor
Forest overstory	• Absolute tree cover, canopy closure • Proportion aspen vs. conifer species • Tree density • Stem diameter / basal area • Stand age / tree age class distribution • Tree height • Live / dead crown ratio
Understory plant community	• Total understory cover • % cover by functional type (native forbs, native grasses, shrubs, and suckers/saplings) • Plant species richness
Ground cover	• Cover of litter, basal vegetation, downed wood, moss, fungi, decomposing organic matter, bare ground
Regeneration	• Number of aspen suckers/seedlings/saplings per area • Recruitment rate (to height adequate to avoid excessive herbivory)
Non-native, noxious, or invasive species	• % cover (by invasive species type)
Fragmentation	• % of landscape fragmented by roads, trails, powerlines, structures, campsites, mines, ponds, or reservoirs
Disturbance agents	• Estimates of fire history (e.g., frequency) from maps, fire-scars, soil charcoal • Uncharacteristic plant type conversion (due to excessive or inadequate rates of disturbance) • Ratio of trees affected by disease, insects, drought, sun-scald, etc.
Herbivory	• % terminal leaders browsed • % of biomass removed from branches • Trampling, amount/type of animal scat

Figure 1. An aspen stand located in an urban interface that has experienced 80 to 100 years of fire suppression, 50 years of moderate to high recreation use, over 100 years of cattle and sheep grazing, and 40 years of elk use. Sites such as this often need active or passive restoration. Even with a good understanding of stand type and history to help determine appropriate restoration strategies, there are many challenging management considerations, including determining if fire is a socially acceptable option, how to best control wild ungulate and domestic livestock use, how to manage human recreation use, and whether or not understory plants will need to be re-introduced.

These include: 1) hormonal stimulation (by interruption of the flow of auxin from shoots to roots); 2) protection from herbivory; and 3) a growth environment with ample solar radiation, soil moisture, and nutrients (Shepperd et al. 2006). In addition, to assess the effects of different management practices, it is necessary to monitor stand attributes that indicate treatment success (e.g., sucker density and recruitment) (Table 2, Figure 2).

Silvicultural treatments

Because aspen are often poor competitors, a commonly used silvicultural treatment is hand or mechanical removal of competing vegetation, typically conifers. Such treatments have been effective in restoring aspen sprout density (e.g., Jones et al. 2005), especially when residual aspen trees still have vigor and when sprouts or suckers are protected from ungulate browsing. However, success after conifer removal can also depend on other site, disturbance, and climate factors. For instance, in the eastern Sierra Nevada, competing lodgepole pine were removed from a seral aspen stand, but over the next three years little sprouting occurred and many residual older (>130 years) aspen trees died due to sunscald (Krasnow et al. 2012). Clearfell-coppice (complete stand removal) has also been used in the past to harvest aspen wood and return stands to early successional conditions. Although clearfell-coppice techniques can stimulate dense reproduction in vigorous seral stands, potential drawbacks may occur.

Figure 2. Visual indicators of aspen health:

a) An aspen stand in good condition with adequate canopy cover, multiple layers of vegetation, and multiple ages of aspen. The view through the stand is often limited by aspen stems, saplings and suckers, and native species of tall forbs, mountain shrubs and shade tolerant grasses.

b) An aspen stand in poor condition with visible, bare soil. The aspen stems are primarily all one age class (mature) and show significant signs of damage and disease. Suckers and saplings are rare or absent. Native mountain shrubs, tall forbs, and grasses are rare.

c) White fir is expanding outward from the center of this aspen stand, possibly due to lack of fire or because livestock or wild ungulate browsing has eliminated understory aspen recruitment. If restoration treatments (e.g., prescribed fire) are required, they are unlikely to be successful if ungulate browsing is not controlled. Reintroduction of native understory plant species may also be necessary.

These include soil compaction, lack of diverse age classes, and altered nutrient cycling. Modifying these traditional coppice methods to retain groups of aspen trees as seed sources can promote sexual reproduction and increase genetic diversity (Long and Mock 2012), as well as decrease site disturbance.

Mechanical root stimulation (root ripping)

Preliminary studies indicate that lateral roots will produce sprouts when severed from the parent tree (thus interrupting the flow of auxin). A dozer-mounted ripper was used successfully to regenerate aspen by severing lateral roots on the periphery of a stand, producing sprouts up to 42 feet (13 meters) away from the existing aspen clone. This technique has not been rigorously tested, but may hold promise as a viable method of regenerating an existing clone without top-killing mature stems (Shepperd et al. 2006).

Prescribed fire

Prescribed fire can be an effective treatment to rejuvenate aspen because top-killing aspen can provide hormonal stimulation, release a pulse of nutrients to the soil, reduce vegetative competition, and increase solar radiation to the forest floor. This technique might be most effective in mixed aspen-conifer, as pure aspen stands may not have the necessary fuel loads or moisture to easily carry fire, and there is little evidence that fire played an historical role in these communities (Shinneman et al. 2013). In the Coconino National Forest in Arizona, the logging slash of removed conifers was scattered to fuel a subsequent prescribed fire that resulted in significantly higher sprout densities compared to conifer removal only (Shepperd et al. 2006). However, prescribed fires can be problematic if they do not burn intensely enough to kill aspen or competing species, if heavy coarse woody debris heat-kills underground lateral roots, or if post-fire aspen sprouts are unprotected from native or domestic browsers.

Wildfire use

Wildfire has historically been and will likely continue to be a primary disturbance agent for regenerating seral aspen. When socially acceptable and ecologically advantageous, allowing wildfires to burn and create early successional conditions favorable for aspen regeneration has many advantages. Wildfires often burn at higher severity and cover larger areas than prescribed fires, which favors aspen regeneration (Figure 3). Moreover, wildfires open the limited spatial and temporal window for successful aspen seedling establishment, which is increasingly recognized as important for aspen reproduction and genetic diversity (Long and Mock 2012, Krasnow and Stephens 2015).

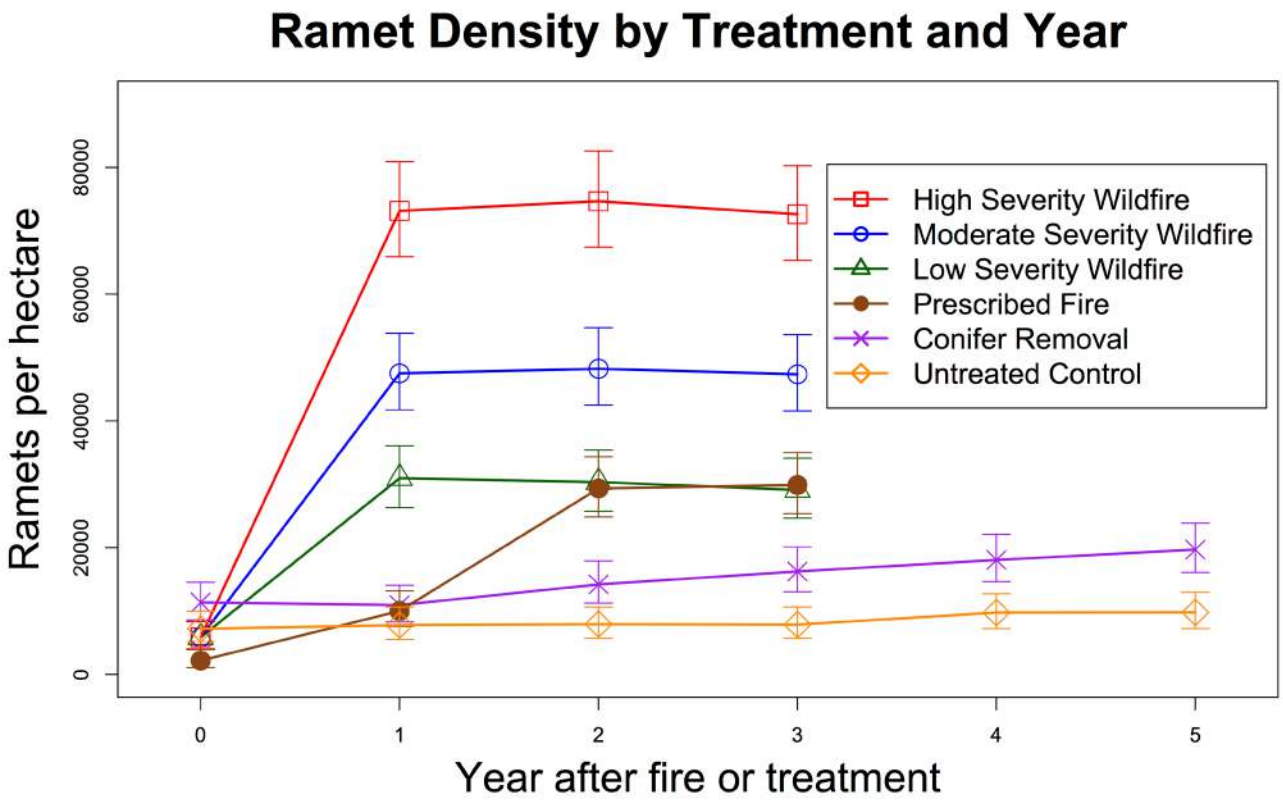

Figure 3. Individual tree (ramet) density over time following prescribed fire, conifer removal and low, moderate, and high severity wildfire in comparison to an untreated control. Points indicate the mean ramet density among plots and whiskers represent the 95% Poisson confidence intervals (from Krasnow and Stephens 2015).

Livestock and Wildlife Management

It is important to assess the effects of livestock and wild ungulates (deer and elk) in a restoration project area and to develop mitigation measures to minimize possible impacts to aspen regeneration (Figure 4). Season-long and intensive browsing by livestock and wild ungulates in aspen stands will reduce aspen establishment and recruitment, suppress understory shrub and tall forb density, and may create openings for non-native plants. To escape heat and find succulent vegetation, cattle often gather in and heavily use aspen stands. Small, low-elevation stands are often at greatest risk to damage from livestock browsing pressure, especially when combined with other factors, such as drought and wildlife herbivory. Post-disturbance aspen stands are also often susceptible to ungulate browsing pressure that can inhibit recruitment and seedling establishment.

Several management options may be effective to reduce the negative impacts of browsing on aspen regeneration, including removing or selectively controlling ungulates to allow aspen ramets to grow above browse height. Effective herding or removal of livestock in late summer can reduce many negative grazing impacts. In some cases, conifer and aspen trees can be cut and felled horizontally and layered to create a barrier to browsing by livestock and deer (Kota and Bartos 2010). Elk are not as easily deterred, and successful recovery of small and isolated aspen stands may require taller ungulate-proof fencing. Recovery of aspen will likely be more successful if browsing is eliminated or reduced for eight to ten years, with effective duration depending on browsing species and pressure, and the time required for suckers to grow above browse-height (Shepperd et al. 2006).

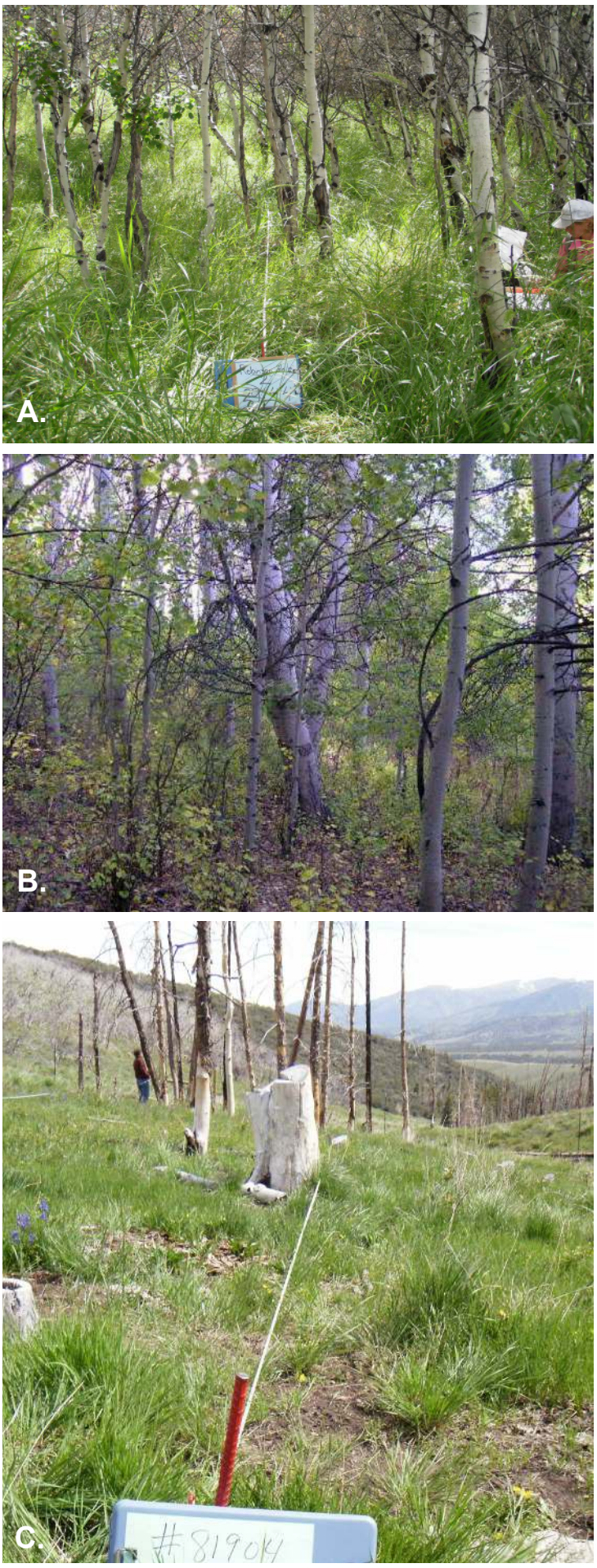

Figure 4. Long-term grazing and associated effects on aspen health:

a) This aspen stand has been grazed by sheep for more than 80 years. The understory is primarily grass with few forbs and no shrubs. Aspen regeneration is poor. Changes in grazing management have improved the understory cover, but forbs and shrubs may need to be introduced and timing of grazing altered to allow for aspen regeneration.

b) This aspen stand has been grazed by cattle for more than 80 years. The understory has some forbs, but grasses and shrubs are missing. Aspen regeneration is occurring due to a shorter grazing season. Shade tolerant grasses from nearby areas may move into the stand over time, but tall forb species are limited and may need to be seeded.

c) Although the fire return interval was appropriate, a degraded understory before fire combined with heavy ungulate browsing after fire resulted in a loss of this aspen stand. This site was fenced with an eight foot wildlife enclosure three years post-fire, but snow and ungulate pressure allowed openings in the fence, and grazing by elk and cattle over 10 years resulted in a loss of tall forbs and prevented successful aspen suckering.

Long-term Management Considerations Under Climate Change

Earth's climate is becoming warmer, and the amount of snow and ice is decreasing. In the Great Basin, temperatures are increasing, relative humidity is decreasing, and seasonal precipitation is becoming more variable. Recent, drought-induced aspen dieback events have occurred throughout the western U.S and Canada, and more extreme and prolonged drought events may become more common under future climate (Anderegg et al. 2013). Great Basin aspen located at low elevation and south or west facing aspects may be particularly susceptible to drought-induced mortality, as documented in other western U.S. regions. In addition, shorter and warmer winters are leading to reduced snowfall or snowpack persistence in the Great Basin (Chambers 2008), thereby reducing snow-water subsidies that support aspen, especially at lower elevations. Unlike in many other ecoregions, Great Basin aspen communities have little opportunity to migrate under climate change, because they are surrounded by low elevation sagebrush steppe and semi-desert.

In addition, recent fire-climate trends and predictive models suggest an increase in average annual area burned by wildfire under climate change (Dennison et al. 2014). Although it seems likely aspen will decline due to a warmer and drier climate, increased fire activity could benefit aspen in locations with sufficient growing season moisture. Recent modeling suggested that, although the range of aspen in the northern Great Basin would be restricted under future climate change, fire could facilitate aspen movement into higher elevations that are currently dominated by subalpine fir (Yang et al. 2015). Thus, allowing desirable wildfires to burn in some high elevation locations may create suitable conditions for the establishment of new aspen stands.

Many current management strategies presume that the past is a good predictor of the future; however, in times of climate change there is no single solution that fits all cases. Managers are encouraged to be flexible, innovative, and implement experimental approaches at small scales to explore which options result in the desired outcome. A range of management options may need to be considered, including managing some ecosystems for resistance to undesirable change, promoting ecosystem resiliency after disturbance, and facilitating inevitable ecosystem change to result in acceptable rather than catastrophic conditions (Millar et al. 2007). Indeed, it may become necessary to manage for different plant communities in areas that are not likely to support aspen into the future, while simultaneously implementing management practices that promote aspen in areas most likely to remain or become suitable for future regeneration and growth. We also suggest implementation of monitoring programs for detecting changes in regeneration, growth, and mortality in a variety of management situations (i.e., no action; active and passive management regimes).

If lack of regeneration and growth is observed in a stand, it is important to attempt to identify stressors (e.g. herbivores, conifer succession, drought). Finally, realistic management goals are important because loss of aspen may reflect ongoing successional or climate-induced trends, and future losses are likely in certain biophysical settings (e.g., low-elevation, southwest-facing slopes).

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Great Basin Factsheets are developed and produced collaboratively by the groups below. Jeanne Chambers edited the factsheets, Lael Gilbert created the design and was responsible for layout, and Nolan Preece shot the photo for the masthead, which is of Monitor Valley in central Nevada.