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Guidelines for Aspen Restoration in Utah with Applicability to the Intermountain West

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Abstract

As highly productive and biologically diverse communities, healthy quaking aspen (*Populus tremuloides*; hereafter aspen) forests provide a wide range of ecosystem services across western North America. Western aspen decline during the last century has been attributed to several causes and their interactions, including altered fire regimes, drought, excessive use by domestic and wild ungulates, and conifer encroachment. Today's managers need science-based guidance to develop and implement strategies and practices to restore structure, processes, and resilience to the full range of aspen functional types across multiple spatial scales. In these guidelines, we detail a process for making step-by-step decisions about aspen restoration. The steps are: (1) assessment of aspen condition, (2) identification of problematic conditions, (3) determination of causal factors, (4) selection of appropriate response options, (5) monitoring for improvement, and (6) assessment and adaptation. We describe the need for reference areas in which the full range of natural environmental conditions and ecosystem processes associated with aspen can be observed and quantified, and provide a list of example sites for Utah. These guidelines provide a road map for decision makers to adaptively manage aspen in a time of increasing environmental stress and in anticipation of an uncertain future.

Keywords: *Populus tremuloides*, active restoration, passive restoration, aspen functional type, decision chain, monitoring, ungulate browse pressure, climate change

Cover photo

Aspen with its fall foliage dominates the landscape at Chriss Lake, Boulder Mountain, Dixie National Forest (photo: Mary O'Brien, Grand Canyon Trust, used with permission).

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Scope and Purpose

Healthy quaking aspen (*Populus tremuloides*; hereafter aspen) communities are characterized by high productivity and structural diversity (fig. 1). High-functioning, nonriparian aspen forests support a more diverse array of plant and animal species than any other upland forest type in the western United States (Chong et al. 2001; Mueggler 1985). In addition, aspen communities provide or enhance critical ecosystem services such as functioning as living firebreaks, beneficial soil water storage and discharge, and habitat for sensitive wildlife species; and are valued for recreational activities and aesthetic qualities.

Approximately 9 percent (5.1 million ac, or 2.1 million ha) of the land area in Utah is forested, excluding pinyon-juniper woodlands (10.7 million ac, or 4.3 million ha) (Werstak et al. 2016). Aspen is present, either as the dominant tree species (1.6 million ac, or 0.6 million ha) or as a subdominant (1.2 million ac, 0.5 million ha) on just over half (55 percent) of the forested lands in the State. The abundance of aspen is similar or less in other Intermountain States (Frescino et al. 2016; Witt et al. 2012).

Forested lands in Utah occur on lands administered by the Bureau of Land Management, U.S. Department of the Interior (39 percent); Forest Service, U.S. Department of Agriculture (34 percent); private interests

Figure 1—A diverse understory is characteristic of a healthy aspen stand, such as this stand at the Mason Draw exclosure, La Sal Mountains, Manti-La Sal National Forest (photo credit: Faith Bernstein, Grand Canyon Trust, used with permission).

(15 percent), and State and other agencies (12 percent) (Werstak et al. 2016). Aspen is found across all ownership classifications, but is most prominent on lands administered by the Forest Service.

Researchers disagree on aspen status and trend in the Intermountain West. Kay and Bartos (2000) report that aspen has decreased throughout the region during the 20th century, and that aspen-dominated acreage within the five national forests of Utah has declined by 50 percent or more. Other research based on Forest Service, Forest Inventory and Analysis data (Werstak et al. 2016) indicates that aspen in Utah has not decreased in area in the last 20 years, and that the rate of aspen decline may have been exaggerated. Differences in interpretation about status and trends in aspen may be related to the spatial and temporal scales on which inferences are based (Kulakowski et al. 2013).

Any decline of aspen is cause for concern, as aspen in the West does not reliably reproduce from seed and thus the loss of an aspen stand may be considered to be permanent. Some recent aspen declines have been attributed to severe drought conditions interacting with multiple biotic stressors, especially in areas of marginally suitable habitat (Worrall et al. 2013) (fig. 2). Rehfeldt et al. (2009) predict climate change-driven losses in suitable aspen habitat of 40 to 94 percent in the western United States by the end of the 21st century.

Figure 2—Three lone trees remain of this aspen stand on a marginal microsite on Monroe Mountain, Fishlake National Forest. Increased frequency and severity of drought interacting with other stressors lead to canopy decline and recruitment failure. In this near-terminal example, sagebrush steppe has almost completely replaced the aspen community (photo: Ellen Morris-Bishop, Grand Canyon Trust, used with permission).

Aspen management decisions in Utah have substantial ecological, social, and economic implications. The aspen management strategies that are most likely to achieve desirable outcomes are those grounded in scientific research and careful observation. Land managers are urged to consider landscape-scale conditions, as well as stand-specific factors, when making management decisions about the suitability of disturbance and protection options to restore aspen.

The term “restoration” can mean different things to different people, and definitions can range from broad concepts to narrow applications. Here, “aspen restoration” will refer primarily to actions that improve aspen health or resilience, or both, where the species is currently present and where environmental conditions are suitable for long-term persistence.

We intend the strategies and guidelines outlined herein as a road map for use by managers of public and private forested lands to identify, design, and implement projects to restore aspen forests. We recommend that managers follow a multistep pattern, namely: (1) assess the condition of aspen, (2) identify potential problematic conditions, (3) determine the causal factors that contribute to the identified problematic conditions, (4) select from a range of appropriate response options to address the causes of those conditions, (5) implement appropriate monitoring to establish baseline conditions and to detect changes related to treatments or management actions, and (6) reassess and adapt by using steps 1 through 5. Use of this approach will allow managers to learn more about aspen management in general, and to determine whether different treatments are warranted to achieve success.

This set of guidelines is a revised and updated version of an earlier set prepared by the Utah Forest Restoration Working Group (2010) (see Appendix A). The principles and practices described in this working document will continue to be tested in aspen forests in Utah and elsewhere in the Intermountain West.

At the landscape scale, aspen condition varies due to variability in natural processes including fire, succession, extreme climatic events, and biotic agents; and due to human influences. For instance, much of the historical (20th-century) loss of aspen-dominated acreage is attributable to “encroachment” and overtopping by conifers (Kay 1997) (fig. 3). However, conifer presence with aspen does not by itself indicate unhealthy conditions or an inherent need for restoration. Aspen and conifers have commingled, and will continue to coexist, across a broad continuum of successional stages that are regulated by complex and variable fire regimes and other disturbance processes that vary across time and space (Heyerdahl et al. 2011). These patterns are in turn modified by oscillations and interactions of climate with wildlife and human activity. Restoration activities should have a landscape-scale goal of creating conditions that support a balance of successional stages that collectively foster broad-scale sustainability and resilience to a wide range of disturbances. Even if we cannot precisely determine the natural range of variation in historical conditions, managing for resilience gives us the best chance for minimizing losses to future climate change.

Figure 3—The aspen in this stand on Gentry Mountain, Manti-La Sal National Forest, appears vigorous but is approaching an ecological threshold where shading by dense subalpine fir will lead to aspen decline. Without periodic disturbance, the conifer recruits into and eventually displaces aspen at some locations (photo: Stanley G. Kitchen, USDA Forest Service).

Fire is a keystone disturbance process that shapes all but the wettest, driest, or most fire-protected plant communities of North America (Frost 1998). Fire resets successional processes in upland aspen (see next subsection for description of aspen functional types), and favors shade-intolerant aspen by initiating pulses of root suckering and seedling establishment (fig. 4). Therefore, variations in fire regimes regulate the relative importance or dominance of aspen and conifers spatially and through time, often creating complex vegetation mosaics—legacies of past disturbance (Shinneman et al. 2013; Tepley and Veblen 2015) (fig. 5). Reconstructed, multicentury fire and forest histories document a broad range of historical fire regimes associated

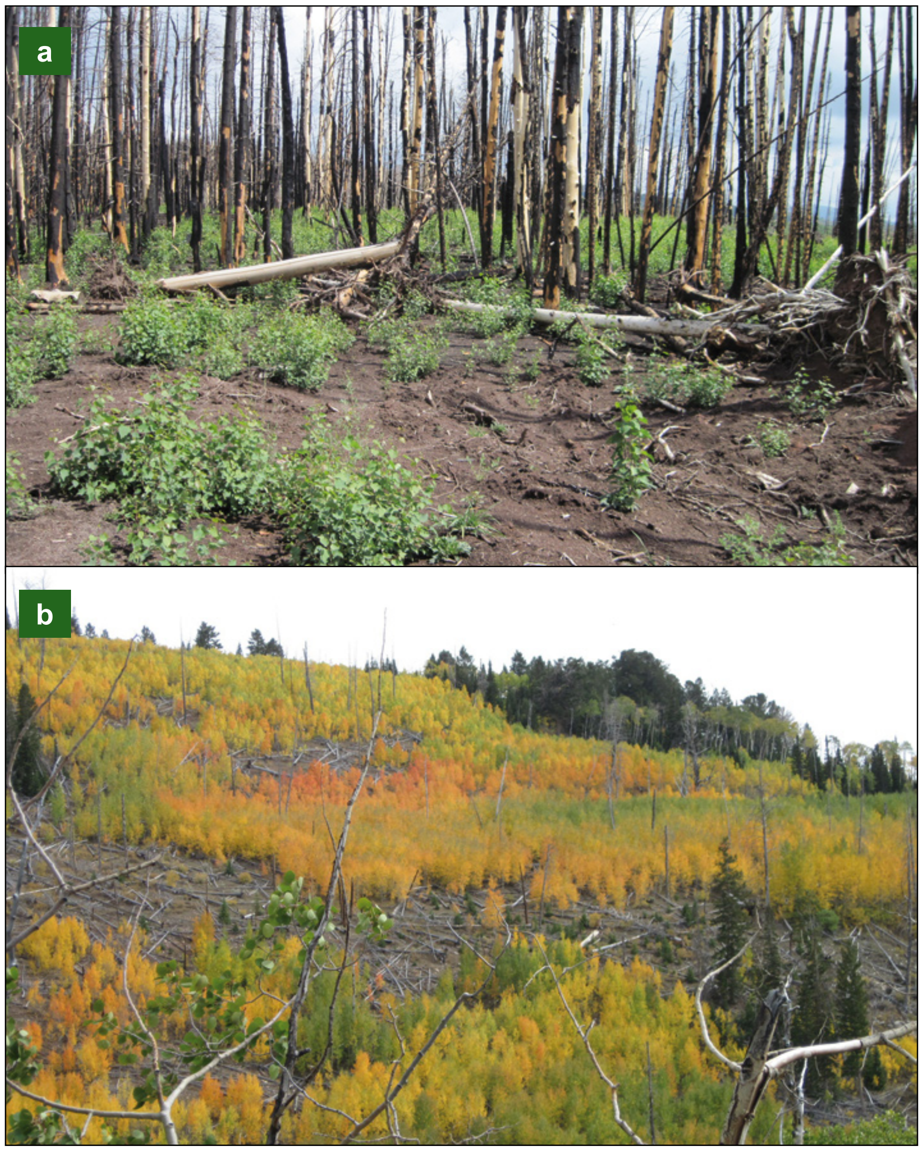

Figure 4—(a) Vigorous aspen regeneration occurred during the first year after the Box Creek Fire at Monroe Mountain, Fishlake National Forest. Initial postfire suckering of aspen is often dense, especially when fire severity is high. (b) Recruiting young aspen within a burn perimeter contrasts with the mixed aspen-conifer stands that did not burn in a relatively recent fire at East Mountain, Manti-La Sal National Forest. Over time, postfire aspen suckers grow to maturity, thus resetting forest succession (photos: Stanley G. Kitchen, USDA Forest Service).

Figure 5—This aspen-conifer dominated landscape on Monroe Mountain, Fishlake National Forest, contains vegetation patches in various stages of postdisturbance succession (photo: Aaron Rhodes, Brigham Young University, used with permission).

with Utah aspen including frequent, low-severity surface fire; infrequent (possibly rare), high-severity fire; and mixed-frequency, mixed-severity fire that varied through time and across space (Heyerdahl et al. 2011).

Less is known about the role of fire and the nature of historical fire regimes in upland persistent aspen where conifers are largely absent (Shinneman et al. 2013). Though current thinking suggests that sustained crown fires are highly unlikely in this type (DeRose and Leffler 2014), the possibility of high canopy mortality caused by lower intensity burning of herbaceous, understory fuels—leading to pulsed regeneration—cannot be discounted. The necessary curing of what are typically burn-resistant fuels occurs most reliably in the fall when the probability of lightning ignitions from summer thunderstorms has diminished. This timing suggests that Native American ignitions may have been important where late-season fires in persistent aspen prevailed (Kitchen 2016).

In many areas today, a high proportion of late-seral, conifer-dominated stands—including stands in which live aspen tree density is extremely low—has been attributed to the absence of fire over the past 100 to 150 years (Kay 1997). The effects of this change in fire regimes is especially notable for areas in which historical fire-free intervals were short to moderate in length. Late 19th-century disruption in natural fire regimes is well documented for western U.S. forests and has been attributed to the cumulative effects of livestock removal of fine fuels, disruption of Native American burning practices, and various levels of fire suppression (Covington and Moore 1994; Kitchen 2016). Early 20th-century climatic conditions were favorable for conifer establishment and very likely played an important and synergistic role with reduced fire in the regionwide shift to conifer dominance (Rogers et al. 2011). Forest stands which historically experienced long (100+ years) fire-free intervals are least impacted by 20th-century changes in fuels and fire management (Baker 2009).

Expected warming and drying conditions in our region may promote disturbance patterns that are very different from what we have seen in the recent past (Littell et al. 2009; Westerling et al. 2006). Though we cannot predict the future with precision, we can encourage adaptive management strategies that enhance resilience and provide options for future generations. Taking a long-term view may mean, for example, adopting management practices that incorporate more frequent fire to promote aspen suckering or seedling establishment—as opposed to actively thinning conifer regrowth for short-term aspen advantage.

Population dynamics for ungulates and their predators changed dramatically in North America with Euro-American settlement, which in turn effected changes in browse pressure in wildland ecosystems. Variable levels of browsing and grazing within aspen communities by wild and domestic ungulates is another major consideration when planning aspen restoration (Weisberg and Bugmann 2003). Healthy aspen stands tend to sprout prolifically after rapid overstory mortality, but heavy browsing or grazing pressure by ungulates can greatly reduce chances of successful recruitment (Britton et al. 2016; Hessl and Graumlich 2002; Rogers and Mittanck 2014) (fig. 6). Aspen seedlings that establish following fire are particularly vulnerable to ungulate herbivory.

Figure 6—Aspen is both heavily browsed and restricted to protected locations 1 year after the Box Creek Fire at Monroe Mountain, Fishlake National Forest. Excessive postdisturbance browse pressure is evident where suckers are heavily browsed or restricted to protected locations such as within shrubs or under logs. If pressure persists, postdisturbance recovery can fail and aspen will be lost (photo: Stanley G. Kitchen, USDA Forest Service).

Variable intensity and timing of herbivory, in combination with changes in fire regimes, logging practices, and even high genetic variability among clones can alter expected outcomes (Britton et al. 2016; Kanaga et al. 2008). Thus, management decisions on different sites and at different spatial scales should attempt to account for these factors to the extent possible.

In sum, no guidelines for aspen management can anticipate all situations. The intent here is to promote holistic thinking in management decisions. When action precedes understanding—of either the larger ecological context or the agents operating on aspen in specific sites—the probability of irrevocable loss of aspen increases. Conversely, failure to act can also yield negative consequences. Predecision and postdecision monitoring is critical when management outcomes are uncertain. Documentation of restoration failures, as well as successes, is an important component of management.

Aspen Functional Types

Aspen communities are typically classified based on the suitability for conifer establishment and growth, differences in ecological processes (i.e., succession), and the physical environment (fig. 7). Although distinct aspen types are defined for convenience, the environmental conditions and ecological processes that define these types vary incrementally, suggesting that the designation of discrete classes—although useful—is largely artificial in nature. With that caveat, we provide generalized definitions for three primary aspen functional types found in Utah: upland persistent aspen (commonly called stable or pure aspen), upland seral aspen, and riparian aspen.

Figure 7—Three aspen functional types are present on this landscape near Strawberry Peak, Ashley National Forest. Upland persistent aspen occupies broad ridge tops, upland seral aspen occurs with conifers on steep slopes, and riparian aspen follows drainage bottoms (photo: Stanley G. Kitchen, USDA Forest Service).

Upland Persistent Aspen (Commonly Called Stable or Pure Aspen)

Aspen dominates the overstory in all stages of succession, and regeneration and recruitment are generally continuous or pulsed but may also be episodic. Conifers are absent, or, if they are present, numbers and importance remain sufficiently low through time such that they have minimal impact on aspen or understory species (fig. 8). Stands of upland persistent aspen range in size and connectivity from small isolated stands to large, more or less continuous stands.

Upland Seral Aspen

Upland seral aspen is found on sites favorable for conifer recruitment and growth and co-occurs with one or more conifer species. The relative abundance of aspen and conifers depends on the time since last disturbance—aspen dominates early stages and conifers dominate late stages of succession (fig. 9). Aspen recruitment may be episodic in response to synchronized canopy mortality (aspen and conifers) related to discrete disturbance events (e.g., fire or other disturbance). But aspen also may respond to small gap formation in a more nuanced fashion, and thus is maintained across a wide range of spatial scales.

Riparian Aspen

Riparian aspen grows in soils that are affected by their proximity to surface water (fig. 10). Conifer abundance and importance and successional processes vary.

Figure 8—Multiaged aspen stands on East Mountain, Manti-La Sal National Forest, are examples of the upland persistent aspen functional type (photo: Stanley G. Kitchen, USDA Forest Service).

Figure 9—This aspen, pine, and spruce stand in the Tushar Mountains, Fishlake National Forest, typifies the upland seral aspen functional type (photo: Stanley G. Kitchen, USDA Forest Service).

Figure 10—This stand on Monroe Mountain, Fishlake National Forest, is characteristic of the riparian aspen functional type (photo: Mary O'Brien, Grand Canyon Trust, used with permission).

Other aspen stand types exist (e.g., lithic aspen or snow-pocket aspen), but these three types are by far the most spatially extensive, and hence the major ones for which management or restoration decisions are repeatedly made in Utah forests. These guidelines focus on upland persistent aspen and upland seral aspen. Because ecological processes for these vegetation types differ, management strategies may also need to differ to maximize resilience in these two general types of aspen forest. Guidelines for riparian aspen restoration will be developed independently for a separate publication.

Finally, these guidelines focus on restoration of aspen forests, specifically the trees; but the maintenance of healthy aspen communities—including understory shrubs, grasses, and forbs—is of equal importance as a management focus. Given that aspen stands provide critical ecosystem services and support disproportionately high numbers of vascular plant, insect, bird, and mammalian species, an increase in aspen area may be expected to yield much greater increases in species diversity than would increases of other forest types (Chong et al. 2001).

Summary of Major Challenges to Aspen Restoration

- In many areas of Utah, conifer establishment and growth were favored in the early 20th century by a moist climate and lack of fire (Rogers et al. 2011). Today, there is an overrepresentation of late-seral conditions, in which conifers are increasing in density and replacing aspen.
- Aspen sucker abundance and growth following crown-killing disturbance may be reduced by domestic and wild ungulate browsing. In cases where pressure is high, browsing can result in complete recruitment failure and loss of aspen from a site in a matter of a few years (Britton et al. 2016; Hessl and Graumlich 2002). Small-scale pulsed recruitment associated with forest gap formation in mixed aspen-conifer stands and pulsed or continuous recruitment typical in upland persistent aspen stands are particularly sensitive to even moderate levels of chronic browse pressure, which may cause a loss of age cohorts and a reduction in clonal resilience (Rogers and Mittanck 2014). This loss of clonal resilience can lead to a downward spiral, resulting in loss of clones occupying the site (Worrall et al. 2013).
- Severe, prolonged drought due to a warming and drying climate has contributed to aspen decline in some areas, particularly stands at lower elevations (Worrall et al. 2013).
- Budgetary, social, administrative, economic, technical, and ecological constraints may limit response options available to land managers charged with addressing these declines.
- Public understanding of the importance of aspen, the implications of aspen decline, and the rationale for selection of any given management response to decline varies from place to place. Consequently, there are varying levels of support for aspen treatment or management.
- Competing priorities may dilute support for restoration efforts in aspen. For example, wood fiber production, wildlife management, livestock grazing, human habitation, and fire suppression—in combination or separately—can complicate implementation of management actions deemed necessary for long-term aspen health.

Reference Areas as Tools for Aspen Restoration

Aspen restoration programs benefit when management targets are informed by quantifiable reference conditions. Reference areas help separate climate effects (e.g., drought) from management effects and provide indications of aspen community (overstory and understory) potential. Repeated documentation of conditions and changes within reference areas can provide understanding of aspen recruitment, disease, drought, understory development, and succession over long periods of time, shedding light on complex aspen ecosystem dynamics. As such, reference areas have the potential to provide multiple values beyond those associated with restoration.

Reference areas should be selected to represent the full range of environmental conditions, thereby increasing opportunities to address a variety of issues (fig. 11). Areas large enough to capture a wide range of environmental variation, and to include ecological processes that operate across variable spatial scales, are preferred. Ideally, individual reference areas include a range of aspen types and are thus useful in addressing different questions. Areas that retain natural processes and composition are good candidates for reference areas. In contrast, aspen stands used for dispersed camping or livestock grazing, or those with high browse use by native ungulates, do not make good reference areas.

Although long-term exclosures are helpful in disentangling cause-and-effect relationships (fig. 12), their value as reference areas is limited for several reasons. For example, full or high-fence exclosures do not allow the full complement of natural processes (i.e., ungulate herbivory), are expensive to maintain, and are typically small in size. Multi-unit exclosures may affect animal behavior in unplanned ways. For example, wild ungulates may be drawn to ungrazed patches caused by cattle-exclosure subunits when livestock grazing outside the exclosure is heavy. Exclosure maintenance is an ongoing requirement, particularly when livestock are drawn to ungrazed “green spots” in the landscape. Within these limitations, exclosures can be useful, especially when conditions are documented periodically. Big-game exclosures provide insight into the effects of wild ungulates, or the cumulative effects of wild and domestic ungulates on local vegetation. Similarly, monitoring data from a high-fence exclosure with an 18-in (46-cm) gap between soil and bottom edge of fence (to allow deer passage only), can provide some evidence of deer impacts separate from those of elk or cattle.

Because Utah’s aspen occurs across a wide range of physical and biological conditions, a network of suitable areas that include the full range of representative environments should be identified and maintained. Table 1 provides a comparison of characteristics for a noncomprehensive list of example areas in Utah that qualify as aspen reference areas.

Figure 11—(a) Twelve Hundred Dollar Ridge, Ashley National Forest, and (b) Cottonwood Allotment, Tushar Mountains, Fishlake National Forest, are aspen reference areas where understory vegetation is dominated by native perennial grasses; (c, d) in other reference areas, such as Walt Muegler-Butler Fork Research Natural Area, Uinta-Wasatch-Cache National Forest, tall forbs with shrubs are often present in a subdominant to codominant role (photo a: Stanley G. Kitchen, USDA Forest Service; b: Mary O'Brien, Grand Canyon Trust, used with permission; c and d: Wayne Padgett, USDA Forest Service).

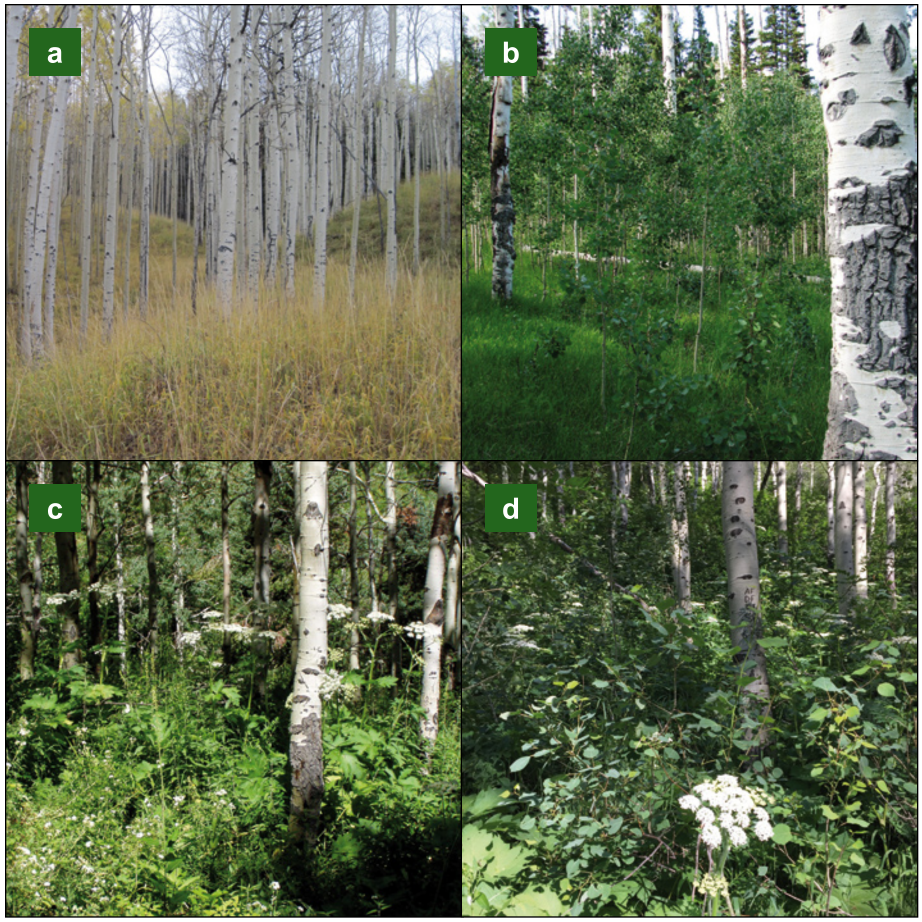

Figure 12—The Grindstone Flat exclosure on the Tushar Mountains, Fishlake National Forest, was originally established in 1934 with two parts: a high fence to exclude all ungulates, and a low fence to exclude cattle only. A wildfire burned through the area in 1996 and the exclosure was rebuilt the next year. The exclosure is used to demonstrate the effects of long-term protection from herbivory on aspen. (photo: Stanley G. Kitchen, USDA Forest Service).

Table 1—Size, administrative unit (national forest), aspen functional types, livestock-free status, and general information for representative aspen reference sites in Utah.

Reference areas with aspen present	Size (ac)	Size (ha)	Location	Aspen type(s)	Time without livestock	Description
Uinta-Wasatch-Cache National Forest						
Walter F. Mueggler-Butler Fork Research Natural Area	1,270	510	Big Cottonwood Canyon	Persistent Seral Riparian	100+ years	Established specifically for aspen; mixed conifer zone
Boxelder Peak (east side)	700	280	American Fork Canyon	Persistent Seral	25+ years (1990–present)	Mixed conifer zone
Mill Peak	4,000	1,600	American Fork Canyon	Persistent Seral	25+ years (1990–present)	Mixed conifer zone
Alpine Loop	1,200	500	American Fork and Provo Canyons along State Road 92	Persistent	25+ years (1990-present)	Mixed conifer zone
Timpooneke Road	350	140	North side of Mount Timpanogos Wilderness	Persistent Seral	25+ years (1990-present)	Mixed conifer and subalpine zones
Strawberry Valley Project Lands	64,000 (~9,700 ac aspen)	26,000 (~4,000 ha aspen)	Strawberry Valley	Persistent Seral	25+ years (1990–present)	Mixed conifer zone
Ashley National Forest						
Vernal Municipal Watershed	6,886	2,789	Ashley Creek drainage	Seral Persistent	42+ years (1973–present)	Mixed conifer zone
Twelve Hundred Dollar Ridge	60	24	4.5 mi (7.2 km) NE of Strawberry Peak	Persistent Seral	Unknown; isolated by steep terrain and distance to water	Native perennial grasses dominate understory; mixed conifer zone
Fishlake National Forest						
Nielson Canyon	700	280	Monroe Mountain	Persistent Seral	Unknown; remote	Mixed conifer and subalpine zones
Cottonwood Allotment	46,516 (~884 ac aspen)	18,839 (~358 ha aspen)	East side of Tushar Mountain Range	Persistent Seral	35+ years	Subalpine zone
Grindstone Flat Exclosure	0.1	0.04	Tushar Mountain Range	Seral	80+ years	Published research; subalpine zone
Manti-La Sal National Forest						
White Mesa Cultural Conservation Area	28,000	11,300	North Elk Ridge – Monticello	Persistent Seral	15+ years; fenced from trespass livestock in 2014	Treatments planned
Dixie National Forest						
Timbered Cinder Cone Research Natural Area	640	260	Markagunt Plateau	Seral	Never had livestock	Subalpine zone; protected from livestock by lava flows

Aspen Restoration Decision Chain

This section describes six primary steps for use in making decisions about aspen forest restoration. It provides the framework and logic for a step-by-step process to identify restoration needs and to select and validate appropriate practices to achieve restoration goals. Literature citations and brief descriptions support the application of the framework across the diverse environmental and cultural landscapes that exist in Utah. Our hope is that it will stimulate discussions within groups of resource specialists and others engaged in planning aspen restoration. Bartos (2007) and Shepperd (2001) describe approaches that parallel the process described in more detail here.

Six Steps of the Aspen Restoration Decision Chain

Step 1. Assess general conditions

Step 2. Identify potential problematic conditions

Step 3. Identify probable agents or underlying cause(s) for problematic conditions

Step 4. Select appropriate response option(s) that address the probable agents or root causes and associated problematic conditions

Step 5. Implement appropriate monitoring to establish baseline conditions and detect changes related to application of selected restoration activities

Step 6. Reassess and adapt by using steps 1 through 5

These guidelines are designed to be flexible across small to large (few to several thousand acres) spatial scales. Given apparent trends in aspen health, abundance, and recruitment across Utah, aspen restoration planning and implementation efforts must be scaled up to adequately address conditions manifested at broad spatial scales, and to effect meaningful change in aspen health trajectories across the landscape (Bartos 2007). For this reason, large-scale aspen restoration projects (even if implemented incrementally) are preferred to truly benefit aspen forest communities over the long term.

Treatments, including simple management modifications (i.e., passive management) on relatively small areas can be useful for testing response options on specific locations, and should not be ruled out when they are used as part of an adaptive management approach. Small treatment areas may also be appropriate when aspen clones of interest are naturally small in size and scattered across the geophysical setting. To make the most positive change on the trajectory of aspen in a watershed, multiple small stands may need to be treated together.

Step 1. Assess General Conditions

The first step in the aspen restoration decision process is to compile an accurate picture of the status of aspen within and across ownerships and jurisdictions of the area of interest. We recommend a two-phase process; however, data collection and compilation efforts are complementary and may run concurrently.

Phase 1

In the first phase, extent and spatial distribution of aspen functional types (i.e., upland persistent and seral aspen and riparian aspen) on the landscape or other area of interest are mapped. Validation of map accuracy through ground or aerial surveys, or both, is highly recommended. Maps and supplemental spatial data that inform the decision process could include:

- Wildlife use and needs (e.g., big-game use patterns and habitat critical for species of management concern);
- Livestock use (e.g., water developments, allotment and pasture boundaries, grazing plans);
- Recreational use patterns (e.g., dispersed camping sites, trails for all-terrain vehicles [ATVs]);
- Infrastructure (roads, buildings, developed campgrounds);
- Private inholdings;
- Special designations (e.g., wilderness, designated roadless areas, municipal watersheds, timber management areas); and
- Historical disturbance regimes (e.g., fire).

Phase 2

In the second phase, the general condition of aspen within each functional type is assessed from data already available or collected for this purpose. Current successional trajectories should be assessed by assuming that no passive (changes in management) or active (treatments) restoration options are pursued. Key parameters may include estimates of stand composition and structure (e.g., variability in live-tree density, aspen-to-conifer ratio, age- and size-class structure), abundance of regeneration and recruits, and understory composition. If data are not already available, the nature of these data typically requires some level of boots-on-the-ground effort to ensure conditions are accurately assessed. Data for Step 2 (identification of problematic conditions) may be collected as part of condition surveys to improve operational efficiency.

Once completed, the general assessment (Step 1) provides a foundation for determining (1) whether or not aspen restoration is needed, (2) the kinds of barriers and risks that will need to be addressed in the restoration strategy, and (3) a framework for setting realistic goals and metrics for determining when those goals have been met.

Although some indication of possible restoration response options can be made at this time, final decisions should wait until after potential problematic conditions (Step 2) and the probable agents responsible for those conditions (Step 3) are clearly identified.

Although the focus of Step 1 should be at the landscape level, it is important to recognize and map the presence of small isolated stands that may be biologically important and genetically unique. These stands may be particularly susceptible to climate change or current and future management practices and may merit special consideration when potential treatment or management options are evaluated.

Step 2. Identify Potential Problematic Conditions for Aspen

While conducting aspen condition assessments, and opportunistically at other times, managers should document the presence or absence of factors known to be reliable indicators of risk to aspen ecosystems. These risk factors provide a basis for managers to prioritize stands for restoration consideration (table 2).

Low Levels of Aspen Regeneration

Low levels of regeneration (suckers <6 ft tall) (table 3), especially for older, persistent aspen stands with open or declining canopies (aspen canopy

Table 2—Common indicators of potential risk to aspen communities, and their importance in persistent and seral aspen stands.

Risk indicator or potential problematic conditions	Persistent aspen	Seral aspen
	Importance	
Low levels of aspen regeneration	Primary	Secondary
Low levels of aspen recruitment	Primary	Secondary
Evidence of heavy browsing (i.e., hedged shoots)	Primary	Primary
Shading by or competition with dense conifers	Not applicable	Primary
Aspen overstory <40% cover or trees >100 years old	Primary	Secondary
Increasing sagebrush cover in a declining aspen stand	Secondary	Secondary
Degraded understory vegetation (shrubs, grasses, forbs)	Secondary	Secondary
Insects and pathogens	Secondary	Secondary

Table 3—Levels of aspen regeneration and recruitment as indicators of capacity for stand self-replacement.

Aspen regeneration levels (suckers <6 ft [2 m] height)		
>1,000/ac	>2,500/ha	self-replacing
500–1,000/ac	1,250–2,500/ha	marginal
<500/ac	<1,250/ha	not self-replacing
Aspen recruitment levels (stems ≥6 ft and <canopy height)		
<500/ac	<1,250/ha	not self-replacing, recommend investigation

cover <40 percent) (Bartos and Campbell 1998), may be an indication that stands are not self-replacing (Bartos and Campbell 1998; Britton et al. 2016; Campbell and Bartos 2001; Kurzel et al. 2007; Mueggler 1989; Rogers et al. 2010) (fig. 13). However, regeneration for aspen stands with high densities of healthy trees and high canopy cover (typically, but not always, young to middle-aged stands) may be suppressed by apical dominance; hence, low densities of immature stems alone are not indicative of problematic conditions (fig. 14). Such stands often arise after disturbances (e.g., fire, disease, insects), and may thrive with low levels of regeneration for an extended period.

Lack of aspen regeneration alone is an unreliable indicator of risk for seral aspen stands as well. Regeneration for healthy stands of this functional type is typically episodic and prolific with the timing of sucker initiation closely linked to synchronized death of overstory trees (e.g., after fire).

Low Levels of Aspen Recruitment

In persistent aspen communities, the presence of abundant regeneration alone is not sufficient to ensure that stands are self-replacing. In self-replacing stands, evidence of adequate recruitment (subcanopy stems ≥6 ft tall) (table 3) may need to be present if a stand is to be considered healthy, especially for mature stands with open or declining canopies (Bartos and Campbell 1998; Britton et al. 2016; Campbell and Bartos 2001; Kurzel et al. 2007; Mueggler 1989; Rogers et al. 2010). A minimum density of 500

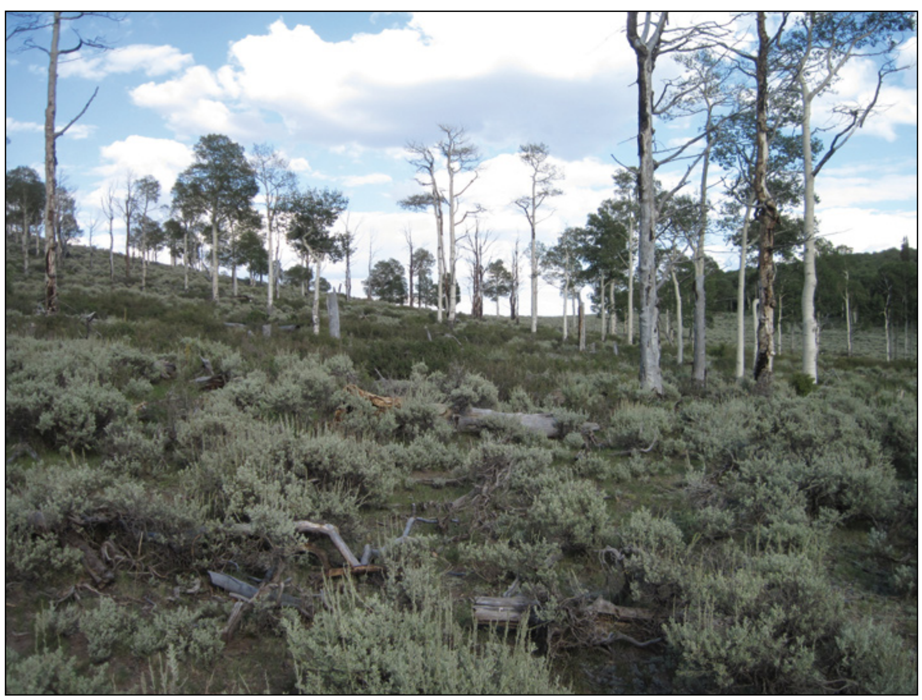

Figure 13—Poor regeneration in aging persistent aspen will lead to loss of the stand if not corrected, Monroe Mountain, Fishlake National Forest (photo: Stanley G. Kitchen, USDA Forest Service).

Figure 14—Regeneration under persistent aspen may be limited due to apical dominance and competition by overstory trees. Sucker density for (a, b) this upland persistent aspen stand in the Ashley National Forest was estimated at 253 stems per ac (625 stems per ha) with all stems less than 6 ft (2 m) tall. Canopy tree density was measured at 664 stems per ac (1,641 stems per ha). A short distance away (c, d) in the same stand, sucker density was estimated at 6,956 stems per ac (17,188 stems per ha)—a 27-fold increase—with 35 percent of the shoots taller than 6 ft. In this portion of the stand, recent mortality had reduced live tree density in the overstory about 60 percent to 253 stems per ac (625 stems per ha) demonstrating that pulsed regeneration can occur when apical dominance and competition are reduced or lost with periodic overstory mortality (photos: Sherel K. Goodrich, USDA Forest Service).

recruits per ac (1,200 per ha) is recommended (Bartos and Campbell 1998) (fig. 15). This applies to small isolated stands as well as to larger, more continuous stands.

Lack of aspen recruitment is an unreliable indicator of risk for seral aspen stands. Recruitment for healthy stands of this functional type is typically episodic following disturbance-initiated, synchronized die-off of overstory trees. Successful aspen recruitment has been documented (DeRose and Long 2010; Kay and Bartos 2000) under the shaded conditions of high conifer canopy cover (60–70 percent) where ungulate browsing was not a factor.

Figure 15—An estimated recruit (suckers ≥6 ft [2 m] tall) density of 1,000 stems per ac (2,500 stems per ha) for this stand in Ashley National Forest with declining overstory exceeds the 500 stems per ac (1,200 stems per ha) minimum threshold recommended for self-replacing stands (photo: Sherel K. Goodrich, USDA Forest Service).

Evidence of Heavy Browsing

Chronic repeated browsing will give aspen shoots a hedged or shrubby appearance, a condition that is easily detected from walking surveys (fig. 16). In extreme cases, live shoots may be restricted to the relative protection of shrub (e.g., sagebrush) canopies or log piles (fig. 17). Stems

Figure 16—Chronic browsing produces aspen that has a shrubby or hedged appearance, and a low probability of ever recruiting into the canopy (photo: Faith Bernstein, Grand Canyon Trust, used with permission).

Figure 17—A sagebrush plant protects hedged aspen (photo: Stanley G. Kitchen, USDA Forest Service).

with heavily clipped apical meristems rarely recruit beyond the reach of browsing ungulates.

Shading by, or Competition From, Dense Conifers

Replacement by dense conifer forests through succession is a pervasive threat to seral aspen stands with long (>100 years) disturbance-free intervals (Bartos and Campbell 1998) (fig. 3). Conifer replacement is not a threat to persistent aspen stands. Increasing cover of subalpine fir shades aspen regeneration and alters soil chemistry in ways that negatively affect aspen growth (Calder et al. 2011). These soil changes reduce aspen height growth and biomass production and lower the production of defense compounds that may deter herbivory (Calder et al. 2011). Decreased light also greatly reduces mycorrhizal associations, decreasing aspen's ability to take up soil nutrients (Clark and St. Clair 2011).

The presence of conifers in seral aspen or mixed aspen/conifer stands is not by itself an indication of problematic conditions. A dynamic interaction between conifer and aspen is characteristic of this functional type, and the relative abundance of either in any point in time may be indicative of successional stage and site-specific conditions that favor aspen or conifer species, or both. Use of historical range of natural variability of aspen and conifers at landscape scales is strongly recommended.

Aspen Overstory Less Than 40 Percent Cover or More Than 100 Years Old

An open, old, or declining aspen overstory in seral stands is often the result of competition from conifers. Persistent aspen stands with an open, declining overstory (<40 percent) (Bartos and Campbell 1998) are at risk if regeneration or recruitment is insufficient (fig. 13). Where both regeneration and recruitment are adequate, a declining overstory is less of a concern; we would expect the stand to be self-replacing (figs. 14, 15).

Increasing Sagebrush Cover in a Declining Aspen Stand

Sagebrush species are shade intolerant but can survive in relatively open aspen stands. Mueggler (1988) describes an aspen/big sagebrush community type. This type may occur as an ecotone between aspen and sagebrush communities or in single-clone islands surrounded by sagebrush-grass steppe. In these settings, aspen stands with a declining overstory and insufficient regeneration and recruitment can be replaced by sagebrush (figs. 2, 13). Aspen stands with sagebrush cover greater than 10 percent may be at risk (Bartos and Campbell 1998). These stands may also be particularly vulnerable due to browsing or drought (Rogers and Mittank 2014).

Degraded Understory Vegetation

In addition to the status of trees, understory species (forbs, grasses, or shrubs, or a combination thereof) are a major source of aspen community diversity and productivity (fig. 11) and may be depleted relative to potential (fig. 18). Indicators of understory degradation may include excessive bare soil exposure, increased dominance by shrubs, short stature of the herbaceous component, or dominance by grazing-tolerant, nonnative species such as smooth brome (*Bromus inermis*) or Kentucky bluegrass (*Poa pratensis*). Reduction of understory vegetation due to grazing and browsing may sufficiently reduce fine fuels to prevent the occurrence and spread of beneficial low-severity fire (DeRose and Leffler 2014).

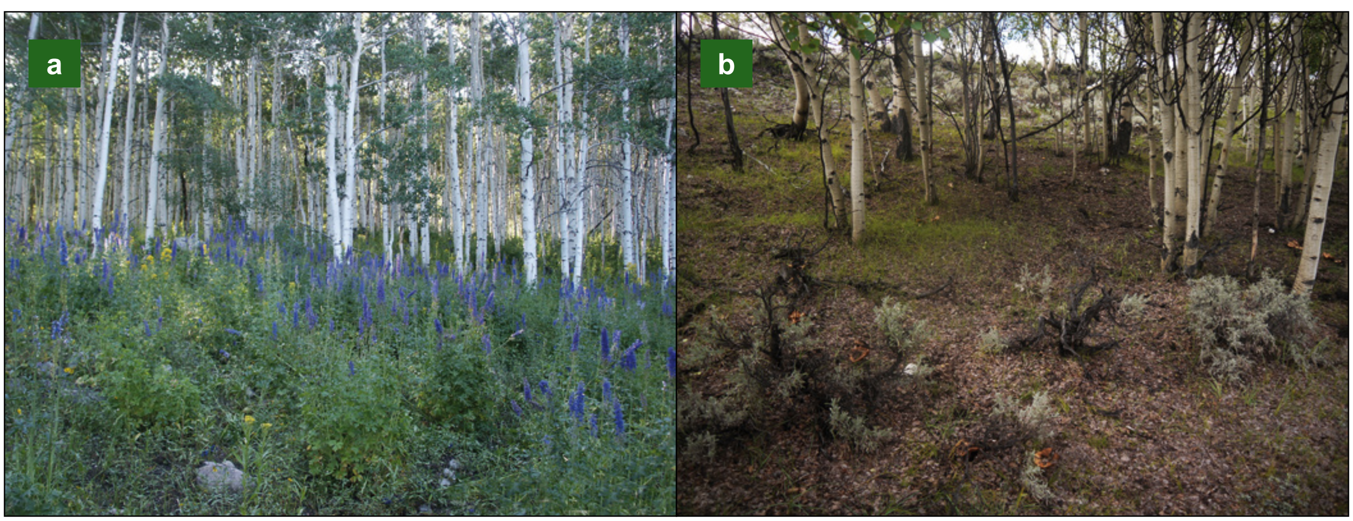

Figure 18—(a) Dense cover by a diverse community of native tall forbs, shown here in Ephraim Canyon, Manti-La Sal National Forest, or perennial grasses (see figure 11) are characteristic of healthy aspen understory communities. (b) Bare ground, low productivity, and dominance by nonnative species are clear signs of understory degradation, shown here on Gentry Mountain, Manti-La Sal National Forest (photo a: Stanley G. Kitchen, USDA Forest Service; photo b: Mary O'Brien, Grand Canyon Trust, used with permission).

Insects and Pathogens

Aspen are host to a plethora of native insect and disease agents (Hinds 1985) (fig. 19; see also Appendix B). Episodic disturbance due to these agents is a normal part of many aspen ecosystems, and otherwise healthy stands can recover from these events. Extreme climatic events such as drought and freeze-thaw cycles that are projected to intensify under future climate scenarios are expected to reduce aspen vigor through cavitation and defoliation events (Anderegg et al. 2012; Worrall et al. 2008). Competition with conifers and greater exposure to extreme climatic events can be expected to constrain physiological function, resulting in carbon depletion that will compromise aspen's defense against defoliators and pathogens. Together these changes lead to decreases in aspen overstory growth rates (Shepperd 2001), and reduction in aspen regeneration vigor (Smith and Smith 2005).

Figure 19—(a) Bronze poplar borer is a common insect pest recognized by characteristic zigzag galleries under aspen bark. (b) Sooty bark canker is a common disease of aspen. These pests are two of the most common agents of aspen mortality in western North American landscapes (photo a: Brytten Steed, USDA Forest Service; photo b: John Guyon, USDA Forest Service).

Step 3. Identify Probable Agents or Underlying Cause(s) for Problematic Conditions

Problematic conditions provide symptomatic evidence that one or more aspects of the environment are no longer compatible with aspen sustainability. It is critical to correctly identify and characterize the agent or agents responsible for the development and perpetuation of problematic conditions manifested across the landscape. It is also essential to distinguish root causes of unfavorable conditions from the conditions themselves. For example, we have identified the development of dense stands of conifer within late successional seral aspen stands as a problematic condition. Thus, conifer "encroachment" is best thought of as a symptom rather than a cause in relation to aspen decline.

An understanding of the possible causes of successional imbalance is needed to properly inform managers of best strategies for implementing corrective measures. In this case, changed fire regimes, climate anomalies, or reduced competition for seedlings due to chronic overgrazing of the herbaceous understory could each—alone or cumulatively—be contributing factors to increased conifer dominance. An understanding of the relative importance of each of these factors would in turn provide the basis for selecting the most appropriate response (including no response)—or suite of responses—to restore the aspen-conifer balance over the long term.

We propose that there are relatively few root causes for aspen decline in Utah. Here we identify major factors, link them to problematic conditions, provide examples of how they interact, and make inferences about the likely effectiveness of mitigation efforts for each.

Altered Disturbance Regimes

We have established that some forms of disturbance (e.g., fire, conifer insect and disease outbreaks, avalanches, wind-throw) favor aspen over conifer by temporarily eliminating competition and by inducing pulses of aspen regeneration. Sprouting shrubs and herbaceous species that are present in the forest understory may also benefit from fire. Calder and St. Clair (2012) note that gaps in conifer overstory may be extremely important in creating high light conditions within late successional aspen-conifer stands that allow aspen to persist without larger disturbance. Shading or competition from conifer is often inaccurately blamed for a lack of aspen recruitment. The underlying causes described next are more likely to be the sources of the lack of recruitment.

Changes in disturbance regimes (e.g., reduced fire frequency) can lead to aspen and understory decline relative to historical conditions, and can have cascading detrimental effects. Shaded aspen have reduced root system reserves and produce weaker regeneration responses and lower levels of secondary compounds that protect against herbivory (Donaldson and Lindroth 2007). These changes, in turn, make aspen stands more susceptible to even moderate browse pressure and drought. Reduced understory cover and vigor result in a reduced forage base for wild and domestic ungulates, increasing pressure on aspen suckers and the remaining herbaceous understory.

Response options such as prescribed fire, allowing lightning-ignited fires, and actions that remove or thin conifer are designed to correct the effects of lack of disturbance. Restoring disturbance regimes may, however, require a commitment to multiple actions over time rather than single treatment entries.

Climate Change

The most conspicuous aspect of climate change comes in the form of increases in mean temperature over time. Precipitation patterns are projected with greater uncertainty, but we can expect changes in annual totals, seasonality, and class (i.e., rain versus snow). Although increases in atmospheric carbon dioxide (CO2) are not climatic in nature per se, they are linked to climate. Elevated CO2 levels have differential impacts on plant metabolism among species, and are expected to affect biotic relationships.

Climate change is a present reality in Utah, as manifested by milder winters, increased drought severity, reduced snowpack, and longer fire seasons. Future changes are expected to be more extreme and are predicted to have major impacts on the distribution, composition, and function of natural ecosystems, including aspen communities (Rehfeldt et al. 2009). Stands that occur near the warmer and drier limits of aspen are most vulnerable (Rogers and Mittanck 2014; Worrall et al. 2013). Climate change is likely to interact with other drivers, such as disturbance regimes, to affect the extent and distribution of aspen in the future (Anderegg et al. 2012; Yang et al. 2015). Today, climate change may be inferred as a root cause of decline in stands that show problematic conditions (e.g., declining, weak overstory, weak regeneration, increased sagebrush cover in the understory) and where other possible root causes (e.g., excessive browse pressure) have been eliminated.

Restoration activities that increase genetic and age-class diversity, or reduce the impacts of other stressors, improve aspen resilience to climate change. Increased use of high-severity fire is one way to promote younger age classes through suckering and increased genetic diversity through establishment of seedlings. Susceptible stands may require higher levels of protection from browsers to accommodate longer regeneration timeframes dictated by more frequent and severe drought and insect or disease outbreaks. Treatments that reduce or eliminate competition from conifers are also expected to improve resilience to climate change.

Excessive Browsing by Wild or Domestic Ungulates

Browsing of aspen suckers is excessive when the timing or duration of domestic and wild ungulate foraging on aspen results in insufficient recruitment of aspen shoots into the canopy to ensure that stands are self-sustaining (Hessl and Graumlich 2002; Rogers and Mittanck 2014). Factors that affect whether browse thresholds are exceeded may be fairly constant (e.g., livestock stocking level or wildlife population size), under continual unidirectional change (e.g., reductions in forage base without disturbance), or variable from year to year (e.g., winter snowpack, summer monsoonal rains). Aspen stands that are near water, on gentle topography, or near livestock bedding grounds are particularly susceptible to ungulate herbivory (Kay 2003). Heavy browse pressure on regeneration after aspen canopy removal (i.e., fire or clearcut) can result in depletion of root reserves and permanent loss of aspen in a matter of a few years (Britton et al. 2016) (fig. 20). Where browse pressure is high, ungulates are attracted disproportionately to small treatment areas where the flush of growth makes for an easy meal. In some cases, multi-unit exclosures can be used to assess the relative impacts of different classes of ungulates present at the site.

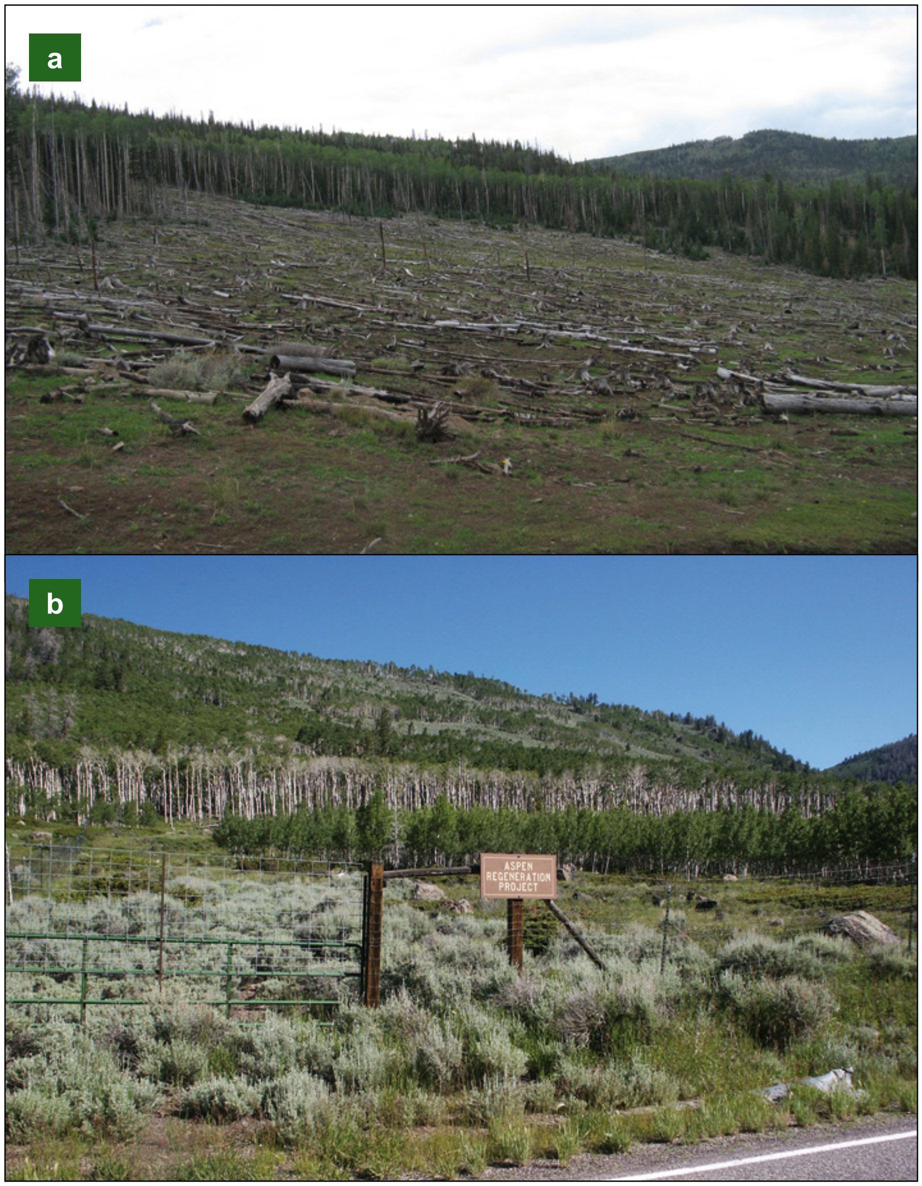

Figure 20—Aspen and conifers were removed in these clearcuts on the Fishlake National Forest on (a) Monroe Mountain and (b) a portion of the giant Pando clone with the expectation that the treatments would result in aspen regeneration. Subsequently, intense browse pressure prevented aspen recruitment and resulted in the complete loss of aspen from treatment areas. Young aspen trees in the background of panel b were also in a treated area but are within an exclosure protected by an 8-ft (2.4-m) tall fence (photo a: Aaron Rhodes, Brigham Young University, used with permission; photo b: Stanley G. Kitchen, USDA Forest Service).

The extent and severity of this driver of aspen instability are likely to expand in the future as average snowpack decreases (longer grazing season) and the frequency and severity of drought increase with changing climate. The greater challenge may be to develop public and institutional support for active and passive response options that are effective in proactively reducing the amount of browsing of aspen by wild and domestic ungulates to sustainable levels.

Recreation and Development

Although negative effects of recreational activities on aspen are not generally observed at the same scales as those previously discussed, they can be consequential at local scales (fig. 21). Impacts such as physical damage to mature trees and suckers, crushing of herbaceous vegetation, and soil compaction and increased soil erosion are generally associated with dispersed camping, off-trail use of ATVs, and similar activities (Shepperd et al. 2006). The effectiveness of response options such as public education programs and development of improved campsites and trails will vary by site, depending on the nature of improvements and the degree of public support.

Exurban development into forested settings is becoming increasingly widespread in Utah and throughout the West (fig. 22). Activities associated with this change in land use can have substantial detrimental impacts on forested communities, including aspen. Besides the obvious loss of habitat and damage from construction of infrastructure and buildings, increased human use can have impacts similar to those of recreational activities.

Figure 21—Dispersed camping in aspen stands, Fishlake National Forest can cause negative impacts. (photo: Stanley G. Kitchen, USDA Forest Service).

Figure 22—Exurban development impacts aspen communities directly and limits future management options (photo: Stanley G. Kitchen, USDA Forest Service).

Step 4. Select Response Option(s) Relevant to the Particular Aspen Functional Type, Problematic Condition(s), Underlying Causes of the Problematic Condition(s), and Landscape Context

The phrase "response options" is used rather than "treatment options," because some management actions are passive in nature and hence the term "treatment" does not apply. Response options that require treatments are classified under active restoration. One or more response options may be appropriate for any given combination of aspen functional type, problematic condition(s), and causes of those condition(s). Conversely, specific response options may be inappropriate when the goal is to protect particular resource values.

One option will always be to continue with current management. If a publicly owned aspen forest or community exhibits problematic conditions, action is probably warranted. However, various circumstances can sometimes prohibit action. Where this is the case, managers should clearly document and communicate the reason(s) for no action, detailing the expected consequences of the decision.

Response Option Selection—General Recommendations

1. Select response options that address identified underlying cause(s) of problematic conditions. Some responses may be inappropriate for particular areas (e.g., roadless areas) or incapable of addressing the causes of the problematic conditions.
2. Rely on best available science and local experience to identify and select response opportunities that have the greatest probability of success in restoring and maintaining resilient aspen communities.
3. Establish quantifiable measures of restoration goals (overstory and understory) and develop baseline and post-implementation monitoring protocols as part of the restoration decision. Include monitoring costs in restoration project budgets.

4. When strong disagreements prevent consensus on the causes of problematic conditions, preferred response options, or expected outcomes, trials with side-by-side treatment alternatives for comparison over time may be useful.
5. For areas designated as wilderness or with wilderness potential (including designated roadless), select restoration practices that have a reasonable probability of success and have minimal impact on wilderness or roadless values. A few likely scenarios in practice include prescribed burning over logging-related options and reliance on natural fuel breaks or substantially inconspicuous fuel break construction (e.g., use of masticator, flush-cut stems, and graduated or feathered edges of treatment areas), or a combination of these types of fuel breaks.
6. Document boundaries of pretreatment and desired posttreatment aspen extent. (Note: This is appropriate where there is concern that stand area may be reduced after treatment.)

A Menu of Possible Responses

Note: It is possible to combine several responses at the same time, or move to other options following monitoring.

Many management activities, alone or in combination, have been considered and tested for restoring aspen (DeRose et al. 2014; Long and Mock 2012). Aspen stands vary considerably by functional type, stage of succession, and genotype. It is important to understand this variability and manage accordingly (Long and Mock 2012; Rogers and Mittanck 2014). Ultimately, the selected option(s) should be based on the likelihood of achieving well-defined, data-driven management objectives focused on reducing the risk of aspen loss.

Active restoration (active vegetation treatments)—

1. Prescriptively burn aspen and conifers.
2. Selectively cut overstory conifers or aspen, or both. The practice of leaving scattered large legacy trees (coppice with reserves) on the site does not seem to hinder sucker establishment, but the reserve trees are often subject to sunscald and insect and disease damage (Bartos et al. 1994; Shepperd 2001).
3. Cut subdominant conifers.
4. In conifer-dominated stands, create scattered canopy gaps in the conifer overstory to promote aspen suckering in the gaps (Long and Mock 2012). This must be accompanied by close monitoring and actions (e.g., fencing, pasture rest, jackstrawing) to ensure that aspen sucker recruitment reaches the 6-ft+ height class in those cases where browse pressure appears to be contributing to recruitment problems.

   For conifer-overtopped or late successional aspen-mixed conifer types found in potential wilderness or roadless areas, canopy gap creation or group selection (depending on tree number or gap size) may be recommended in lieu of a coppice and regeneration harvest prescription. In these cases, a number of associated mitigation measures are available to ensure consistency with WUI and potential wilderness or roadless values. These include jackstrawing tree boles to impede ungulate grazing in canopy gaps (and mitigate cost of fencing), flush-cutting smaller boles even with the forest floor, limiting stump heights on sawtimber-sized boles, and helicopter skidding.

5. Girdle conifers.
6. Cut aspen roots to stimulate suckering ("root separation"). Cutting roots has been used successfully to stimulate suckering in some settings (e.g., isolated clones) and may be useful when the objective is to expand the area covered by smaller clones (Shepperd et al. 2006). One value of root separation is that mature trees are left relatively undisturbed and remain a potential resource for further action in case the treatment does not reach the stated objective. At the same time, this treatment may have unacceptable impacts on site productivity.
7. Improve or increase the availability of native vegetation for wildlife nutritional opportunities outside of the aspen stands of concern.
8. Coppice (clearcut) aspen and conifers. Coppice has been commonly used in the past to promote even-aged aspen stand regeneration (Shepperd et al. 2015). There are ecological concerns that should be addressed when this option is used for aspen restoration, particularly if the cut trees are removed. These concerns include the following:
    a. Some nutrients and opportunity for soil carbon enrichment are lost from the site when overstory tree biomass is removed from the site.
    b. While many understory plants benefit from full sunlight, some may be impacted negatively by loss of shading.
    c. Although the coppice option (cutting all trees) can introduce a new age class of aspen within cutting units, old standing (live and dead) trees that provide important ecological services (including potential seed trees and continued suckering) are eliminated from treatment units.
    d. Recent practical experience (Shepperd et al. 2006) supports leaving large aspen trees inside a coppice treatment, as well as down jackstrawed trees to address the preceding issues and herbivory concerns.
    e. Old-growth conifer trees which predate fire suppression activities and probably coexisted in or near the aspen stand during a more active fire regime are likely to resist fire when retained. Consideration should be given for retaining these legacy trees.
9. Plant aspen seedlings or rooted cuttings. Although further development of the techniques required for successful implementation of this response option is needed, this approach provides an opportunity to increase genetic diversity and expand restoration to locations where aspen has been completely eliminated.

Passive restoration (reduce or remove browsing and other pressures on aspen)—

1. Allow lightning-caused fires to burn. Lightning-ignited fires frequently burn at higher severity and with greater extent than do prescription fires, resulting in stronger suckering response, opportunities for aspen seedling establishment, and better dispersion of herbivores (Wan et al. 2014).
2. Fence to exclude domestic or wild ungulates, or both, depending on prior determination of type of ungulate pressure. In situations where the relative impact of domestic livestock versus wildlife has not been determined, a livestock exclusion fence alone may be a reasonable first choice. The effectiveness of livestock exclusion on aspen recruitment should be documented using appropriate monitoring protocols. Large exclosures (especially high-fence exclosures) are expensive to build, difficult to maintain, and generally not practical. Rest, whether provided by fences or other management action, may be needed for 3 to 5 (occasionally up to 15) years, or until aspen suckers reach a height that is relatively safe from browsing (≥6 ft tall).
3. Change livestock grazing management (e.g., length or timing of grazing, class or number of livestock, water development, placement of salt and nutritional supplements). For example, Jones (2010) found that the crude protein content of aspen suckers increases relative to other available forage in the later part of the grazing season. With this relative increase, livestock may site-specifically select for aspen suckers in the fall. The avoidance of fall grazing may therefore offer protection for suckers.
4. Establish and enforce annual browse utilization limits in grazing systems with the objective of ensuring that adequate densities of aspen regeneration reach the minimum recruitment height class (≥6 ft tall).
5. Rest livestock allotments or pastures where aspen stands are excessively browsed. Resting is an appropriate option when passive restoration options 3 and 4 are not sufficient or feasible, or when actions are needed across a landscape.
6. Explore evolving technologies and strategies to mitigate wild ungulate impacts on aspen regeneration and recruitment. Because wild ungulates can be wide-ranging and variable in their migratory habits, it can be difficult to achieve reduced browse impacts at the stand scale by using behavior modification or other non-fencing techniques while maintaining animal numbers over broader spatial scales (but see Weisberg and Bugmann 2003).
7. Working within the existing framework for wildlife management, develop specific big-game herd objectives that are compatible with resource conditions within the area.
8. Prevent or reduce dispersed camping within aspen stands.
9. Post or sign dispersed camping restrictions in appropriate locations.

Other possible influences on selecting response options—

1. Interagency or public working groups (including a variety of stakeholders and interests) may be able to propose solutions for addressing complicated, site-specific problems using existing mechanisms and other creative options.
2. Local outreach and education efforts on the value of aspen forests and the need for aspen management may increase feasibility of particular response options.
3. Treatment options that increase fuel hazards on site may at times conflict with WUI management objectives.
4. The coppice option (with or without reserves) may conflict with potential wilderness or roadless area values.
5. Jackstrawing trees in some cases has limited ungulate access, thus allowing suckers to grow into the 6-ft+ height class. However, jackstrawing is unsightly and increases dead woody fuels for some time.
6. Exploration of landscape-scale response options may help avoid ungulate browsing complications that may arise when the focus is on a single response option at a smaller geographic scale.

Step 5. Implement Appropriate Monitoring to Establish Baseline Conditions and Detect Changes Related to Application of Selected Restoration Activities

Do not treat monitoring as an afterthought, or optional activity. Baseline monitoring should be implemented before initiating response options, and monitoring should continue throughout the aspen restoration process. Consistency in protocols and data management is essential.

1. Clearly state project objectives and post-implementation desired conditions.
2. Monitor according to the schedule and methods for obtaining quantifiable desired conditions established prior to restoration implementation.
3. Develop, test, and document monitoring protocols (previously used methods should be documented in a central location for easy access, but may be modified for local conditions and issues).
    a. Monitoring sites should be systematically or randomly based for objectivity and repeatability.
    b. Monitor adjacent control sites for each action wherever possible.
4. Monitoring should be budgeted as part of the project.
5. Proper data management is a part of any monitoring program. Plans should include protocols for preserving and sharing the data.
6. Interpret monitoring data in reports.
7. Consider altering monitoring or restoration methods on the basis of monitoring results.

Refer to Appendix C for protocols that have been used to monitor the condition of aspen regeneration and recruitment following a variety of treatment or management changes.

Step 6. Reassess and Adapt by Using Steps 1 through 5

Aspen restoration programs should be flexible and incorporate learn-as-you-go and adaptive strategies. Managers need to anticipate and plan for unexpected outcomes.

- Robust monitoring provides both a way of comparing realized versus expected outcomes and objective data needed either to validate the efficacy of restoration activities to date, or to justify consideration of a change of course.
- A resetting of the decision process by periodically revisiting one or more of the prior steps—even when restoration efforts may appear to be on target to meet predetermined goals—can provide the platform for a transparent, healthy program reassessment.
- Documentation of lessons learned (including successes and failures) should be peer-reviewed and shared to maximize learning among managers and to build a library of case histories to inform the decision processes of future managers.

Key Terminology

Aspen community: Aspen community types are communities containing aspen, as a foundational species, and its associated flora and fauna regardless of successional status.

Best available science: Scientific data that are available at the time of a decision or action and that are determined to be the most accurate, reliable, and relevant for use in that decision or action. Reliable scientific information is objective and repeatable. Multiparty monitoring, collaborative or independent (or both) peer review of methods and interpretations can be useful means of assembling best available science.

Clone (genet): A genetic individual, potentially represented by many trees that have generated vegetatively and that originated from a single tree.

Coppice: Regeneration method in which "all trees in the previous stand are removed and the majority of regeneration is from sprouts or root suckers" (Helms 1998). In mixed aspen-conifer stands most of the regeneration will be aspen root suckers, but there may be some seedlings, both aspen and conifer, as well.

Coppice with reserves: Regeneration method in which "reserve trees are retained to attain goals other than regeneration" (Helms 1998). In mixed aspen-conifer stands, the reserve trees are typically mature aspen kept as insurance against excessive browsing of the root suckers. Some conifers may be kept as reserve trees to meet other management objectives such as wildlife mitigation or visual aesthetics, which may apply to both aspen and conifer reserve trees.

Exclosures: Exclosures are fenced areas designed to exclude one or more class of herbivore (usually ungulates but may also include small mammals such as rabbits, hares, or rodents). They are typically used to assess the effects of protection or exclusion on vegetation, such as aspen regeneration. Multi-unit exclosures (e.g., three- or four-way exclosures) are clusters of exclosures in which each subunit has fencing characteristics that restrict access to a different set of ungulates. For example, high fence subunits exclude all ungulates, low fence subunits exclude livestock while allowing deer and elk, and subunits that combine a high fence with bottom gap (18 in, or 48 cm) allow only deer or sheep. Exclosure size varies from a few feet on a side to several hundred acres. Benefits and drawbacks of exclosures vary with size, location, and monitoring or research question being asked.

Isolated persistent aspen stands: A description that refers to small or moderately small aspen stands (typically less than 50 ac [20 ha] in area) that are scattered across the landscape surrounded by nonforest vegetation types. Visually, these appear as individual units, but may represent fragments of larger, formerly connected stands.

Jackstraw treatment: Using fallen trees to provide refugia from ungulate browsing (Ripple and Larsen 2001).

Ramet: Any individual stem of a larger aspen clone (whether juvenile or mature). A ramet has the same genetic makeup as all other stems from that clone.

Recruitment (of aspen): A process that refers to the addition of new individuals to a population of canopy trees. The term (or its shortened form, recruits) is sometimes used in reference to those individual aspen shoots that have reached sufficient height—at least 6 ft (2 m)—to indicate that recruitment is taking place but are not yet mature (distinctly shorter than canopy trees). Shoots taller than 6 ft are less vulnerable to browsing of terminal buds and are thus more likely to become future canopy trees.

Regeneration (of aspen): Production of new aspen suckers or seedlings. The term (or its shortened form, regen) is sometimes used in reference to those individual shoots that are generally less than 6 ft tall, with terminal buds vulnerable to browsing.

Restoration – active: Activities such as logging, burning, seeding, tree girdling, root ripping, or active reintroduction of a native species in order to restore conditions or processes considered ecologically essential, or to increase resilience.

Restoration – passive: Allowing restoration of desirable ecological conditions through natural processes. May include removal or modification of management activities that delay or prevent attainment of restoration goals. Examples include allowing lightning-ignited fires to run their course (rather than suppressing these fires) and reducing or removing stress agents (e.g., changing management of grazing and browsing, or recreation) that have suppressed aspen recruitment.

Suckers: Vegetative shoots growing from lateral roots of a clone. Suckers have the same genotype as the root from which they are produced.

Wildland-urban interface (WUI): The wildland-urban interface is composed of the boundary or gradient where urban development and wildland vegetation meet and often intermix. Interface communities are areas with housing within 1.5 mi (2.4 km) of areas with greater than 50 percent wildland vegetation. Aspen may act as a firebreak within a WUI; generally, the higher the ratio of live aspen to conifers, the less flammable the landscape will be.

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Appendix A: Aspen Restoration Guidelines: Development and History

"Guidelines for Aspen Restoration on the National Forests in Utah" was the first major project of the Utah Forest Restoration Working Group (UFRWG). The UFRWG is a collaborative group formed for the purpose of reaching consensus while applying the best available science to critical forest issues primarily affecting national forest lands in Utah. As a consensus-based entity, UFRWG is composed of a wide variety of interest group representatives: the USDA Forest Service, State agricultural and natural resource agencies, county government, private citizens, and nongovernmental organizations (environmental, resource utilization, and industry). A complete list of 2018 UFRWG participants and members is shown below.

In 2009, a UFRWG Ecology Committee was given approximately 1 year to compile the first set of guidelines and recommendations for aspen management in a form agreeable to all parties. During this period the Ecology Committee gained input from managers around Utah working directly with aspen.

A December 2009 draft was circulated among a group of scientists who have both conducted aspen research and observed aspen conditions in Utah and the West, and the final report was published in 2010, and was reissued in April 2011, with minor corrections.

In 2015, the UFRWG initiated a revision of the 2010–2011 guidelines to incorporate new scientific research and lessons learned during 5 years of use of the guidelines in various Utah sites. An Aspen Guidelines Revisions Committee was formed and the work of that group is found in this publication.

We believe that these revised guidelines incorporate the most current aspen science with the intent to guide the diverse interests to move forward on a range of aspen-related restoration projects in Utah and throughout the Intermountain West.

Utah Forest Restoration Working Group Members 2018

- Grand Canyon Trust
- Mule Deer Foundation
- Rocky Mountain Elk Foundation
- Six County Association of Governments
- Society of American Foresters, Utah Chapter
- Trout Unlimited, Utah Council
- U.S. Department of Agriculture, Forest Service, Intermountain Region (Region 4)

- U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station
- U.S. Department of the Interior, Bureau of Land Management
- U.S. Department of the Interior, National Park Service
- Utah Cattlemen's Association
- Utah Department of Agriculture and Food
- Utah Department of Environmental Quality
- Utah Division of Forestry, Fire and State Lands
- Utah Division of Wildlife Resources
- Utah Farm Bureau
- Utah Grazing Improvement Program
- Utah State University Extension
- Utah Woolgrower's Association
- Western Aspen Alliance

Appendix B: Common Diseases and Insects of Aspen

The agents listed in table B1 include those most commonly observed in a survey of aspen insects and diseases conducted in 2007–2008 (Guyon and Hoffman 2011), and the personal experiences of the authors. Several of these agents cause significant damage only when their hosts are under stress. The most important stress agents include drought, grazing and browsing pressure, freezing damage, and competition from other plants.

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Table B1—Common insects and diseases in aspen forests in Utah, the type of damage they cause and the impacts they have when present.

Common name	Genus and species	Type of damage	Aspen impact
Bronze poplar borer	*Agrilus liragus*	Cambial mining and wood boring	Primary tree killer
Poplar borer	*Saperda calcarata*	Wood borer; weakens and causes physical damage	Usually found on stressed trees
Eastern poplar buprestid	*Poecilonota cyanipes*	Wood borer; weakens and causes physical damage	Attracted to damaged trees
Aspen bark beetles	*Trypophloeus populi* and *Procryphalus mucronatus*	Bark beetles found in the outer bark; expedite cambial death	Attack trees under stress
Large aspen tortrix	*Choristoneura conflictana*	Foliar feeding insect; defoliates	Occasional defoliator
Aspen twoleaf tier	*Enargia decolor*	Foliar feeding insect; defoliates	Occasional defoliator
Sooty bark canker	*Encoelia pruinosa*	Canker disease; kills cambium	Primary tree killer
Cytospora/Valsa canker	*Cytospora chryosperma*	Canker disease; kills cambium	Damaging only on stems under stress; presence coincides with other damage agents
Ganoderma root rot	*Ganoderma applanatum*	Causes root system decay; causes windthrow	Present in many stands as cohorts age
White trunk rot	*Phellinus tremulae*	Causes stem decay; can lead to stem breakage	Increasingly prevalent in older ramets and cohorts
Marssonina leaf blight	*Marssonina* spp.	Foliar disease; defoliates	Occasional defoliator; often associated with wet spring weather

Figure B.1—Zigzag galleries characteristic of the bronze poplar borer are found under the bark after ramet mortality (photo: Brytten Steed, USDA Forest Service).

Figure B.2—Chunky frass falling from large bore holes is typical external evidence of attack by the poplar borer (photo: Tom Zegler, USDA Forest Service).

Figure B.3—The larvae of the eastern poplar buprestid, shown here as an adult, bore through the wood of living or dead aspen (photo: Tom Zegler, USDA Forest Service).

Figure B.4—Galleries made by the aspen bark beetle are visible in the outer bark (photo: Brytten Steed, USDA Forest Service).

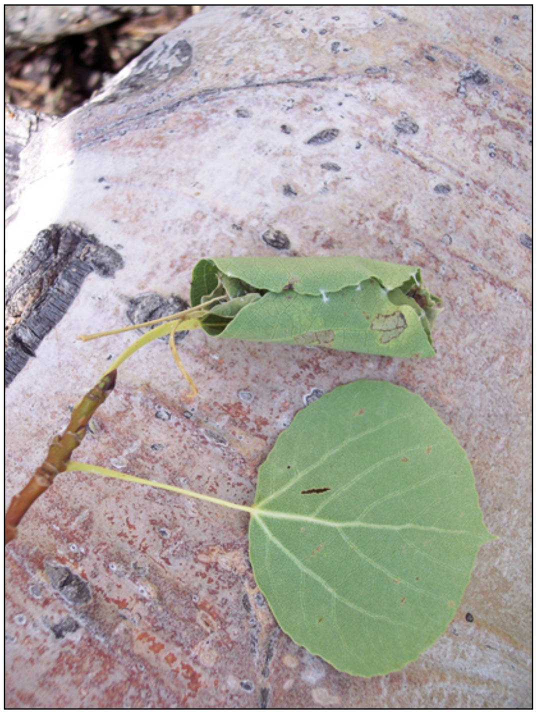

Figure B.5—Larvae of the large aspen tortrix commonly roll two to three leaves together (photo: Tom Zegler, USDA Forest Service).

Figure B.6—Larvae of the aspen twoleaf tier tie two leaves together without rolling (photo: John Guyon, USDA Forest Service).

Figure B.7—Blackened cambium recently killed by sooty bark canker emerges through the outer bark (photo: Tom Zegler, USDA Forest Service).

Figure B.8—Minute, white-tipped perithecia (spore-forming fruiting bodies) of the Cytospora canker become visible on the bark surface (photo: Tom Zegler, USDA Forest Service).

Figure B.9—The fruiting body of the pathogen that causes Ganoderma root rot is attached to the base of the tree on the left. The tree on the right fell due to rotted roots (photo: Brytten Steed, USDA Forest Service).

Figure B.10—The characteristic fruiting body of the fungus that causes white trunk rot indicates substantial decay within the stem (photo: Brytten Steed, USDA Forest Service).

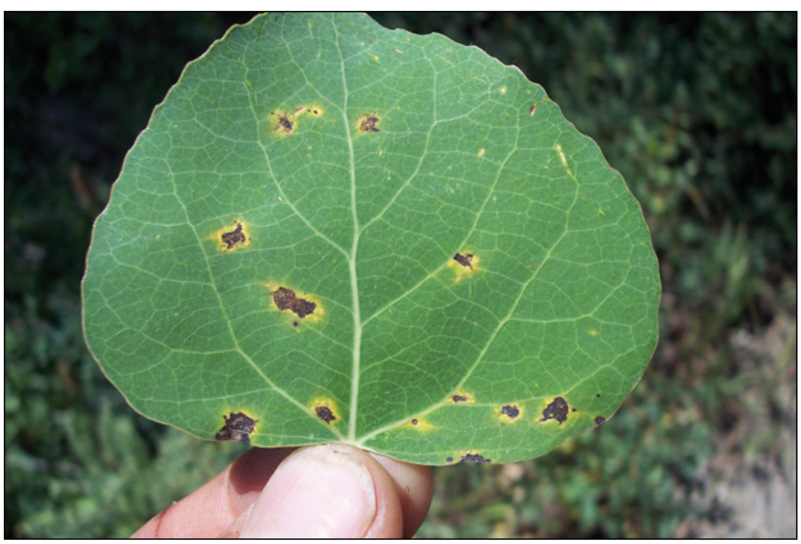

Figure B.11—Lesions on the leaf surface caused by Marssonina blight typically exhibit a brown center surrounded by a yellow halo (photo: Tom Zegler, USDA Forest Service).

Appendix C: Comparison of Key Attributes of Forest Service Monitoring Methods for Aspen Ecosystems, and a Method Used by Brigham Young University

Table C1—Comparison of four methods used for monitoring aspen trend.

Attribute	Aspen assessment method			
	USDA Forest Service Pacific Southwest Region (USDA FS 2004)	**Jones et al. (2005)**	**Campbell and Bartos (2001)**	**Monroe Mountain Working Group Aspen Regeneration/Recruitment Monitoring (Rhodes et al., n.d.)[a]**
Flexibility of installation (can be adapted to specific situations)	Easy	Involved	Easy	Easy
Permanence	Temporary	Permanent	Temporary	Permanent if staked; or temporary
Plot shape	Roughly linear transect	Belt transect; shape can be modified	Typically circular	Belt transect; shape can be modified
Plot size	Indeterminate length; typically 90 hits of sprouts or young aspen	600 ft^2 (6 ft × 100 ft) ≈ 60 m^2 (2 m × 30 m); other sizes can be used	Typically 0.1 ac (0.04 ha)	1,280 ft^2 (119 m^2; two perpendicular 2 m × 30 m transects)
Ease of implementation	Rapid assessment	Robust, involved	Rapid assessment	Rapid assessment
Timing of monitoring relative to treatment	Typically after	Before or after, or both	Typically before	Before or after treatment, or used to monitor within-year or between-year variation
Elements monitored	• Percentage of stems with terminal leader's current-year growth browsed. Method measures the primary stems of aspen sprouts and young trees ≤5 ft (1.5 m) in height.	• Percentage of stems with terminal leader's current-year growth browsed • Trend for aspen regeneration density in four size classes	• Percent conifer cover • Percent aspen cover • Percent sagebrush cover • Estimated age of dominant aspen • Number of aspen stems 5–15 ft (1.5–4.6 m) tall	• Percent browse of apical meristems on leading (tallest) stems and subleaders within a 6-in (15-cm) sphere of the leading stem • Height distribution of suckers in 3.9-in (10-cm) increments • Aspen sapling recruitment: number of aspen 6–12 ft (2–3.5 m) in height • Mid-canopy aspen >12 ft and below the dominant overstory • Density, composition, and basal area of overstory tree species (point-quarter method at 16-ft [5-m] increments along the center of the belt transect) • Percent defoliation (an ocular estimate of leaf removal at the site averaged across all aspen stems recorded in 5-percent increments)

(continued on next page)

Table C1 (continued)—Comparison of four methods used for monitoring aspen trend.

Attribute	Aspen assessment method			
	USDA Forest Service Pacific Southwest Region (USDA FS 2004)	**Jones et al. (2005)**	**Campbell and Bartos (2001)**	**Monroe Mountain Working Group Aspen Regeneration/Recruitment Monitoring (Rhodes et al., n.d.)[a]**
Quantities or thresholds for elements monitored	Yes	Yes	Yes	Yes
Ease of conversion of results	Easy	Moderate	Easy	Easy
Data analysis	Tabular data sheet	Tabular data sheet	Tabular data sheet	Tabular data sheet
Ease of interpretation	Easy	Moderate	Easy	Easy
Complexity	Simple	Moderate	Simple	Simple
Provides response recommendations	No	Yes	Yes	No

[a] Rhodes, A.C.; St. Clair, S.B.; Maxwell, J. [n.d.] Monroe Mountain Working Group aspen regeneration/recruitment monitoring Unpublished data on file at: Department of Plant and Wildlife Sciences, Brigham Young University, Provo, UT.

Summary of the Methods

USDA Forest Service Pacific Southwest Region (USDA 2004)

Simple and quick method designed to determine the percentage of aspen sprouts and young stems that are less than or equal to 5 ft (1.5 m) tall, with the terminal leader browsed.

Jones et al. (2005)

Robust and involved method designed to measure percentage of regenerating aspen plants with terminal leaders utilized and the trend in density for four size classes. Can be used before and after treatments.

Campbell and Bartos (2001)

Walk-through rapid assessment of aspen stand health and condition. Quantitative data that would be meaningful before and after a project are typically not collected.

Monroe Mountain Working Group Aspen Regeneration/Recruitment Monitoring (Rhodes et al. n.d.)

Simple belt transect method focused on measuring height and browse on top leaders, combined with point quarter method for density of mature trees. Ocular estimates of recruitment and defoliation.

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Appendix D: Literature Relevant to Aspen in Utah and the Intermountain West

The following references include syntheses of information and important recent contributions regarding the ecology and management of aspen with specific emphasis on restoring resilient aspen communities in Utah. Some, but not all, were cited herein. For a more complete listing of aspen-related literature see the continually updated bibliography maintained by Utah State University, Western Aspen Alliance at: https://western-aspen-alliance.org. A searchable spatial bibliography developed in a joint effort by the Utah State University, Western Aspen Alliance, and the Plant and Wildlife Sciences Geospatial Lab at Brigham Young University is also available on the Western Aspen Alliance website.

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