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# Guide to Quaking Aspen Ecology and Management with Emphasis on Bureau of Land Management Lands in the Western United States

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with Emphasis on Bureau of Land Management
Lands in the Western United States

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# Contents

# Chapter 1 – Introduction

## How We Got Here

Quaking aspen (*Populus tremuloides* Michx.) have a rich history of both research and management. Particularly in the American West, aspen trees stand out as vibrant icons in forest communities dominated by evergreen-shaded mountainsides (Fig. 1.1). This individuality in the species piqued the interest of early forest scientists working in the region, and the fervor has not abated. Early on, though aspen were not as highly valued as they are today, foresters marveled at the expanses of this species on desert plateaus and its ability to grow profusely following fire. Foresters of the early 20th century, however, felt that the aspen species inhibited development of more valued timber species. In much of the West, this was also a time of new aspen growth and expansion in response to settlement-era cutting, grazing, and burning

***Figure 1.1*** *Aspen leaf.*

(Rogers et al. 2007a; 2011). Later, aspen's value to humans increased, particularly as rich understory livestock forage. Managers and researchers alike became interested in methods of promoting aspen growth and sustainability. Currently, professionals and the public are attracted to the benefits of aspen for biodiversity, fire resistance, recreation, aesthetics, wood products, forage, water conservation, and wildlife habitat.

Realization of aspen's usefulness has paralleled a number of threats to these forest communities. Indeed, some threats may be attributable to past management actions, such as fire suppression, overgrazing, water diversion, wildlife management, and inappropriate timber harvesting methods. In Utah, for example, an estimated 60% of aspen cover was lost during the 20th century due to past practices (Bartos and Campbell 1998). However, such projections warrant caution, as they assume that each location with significant signs of live or dead aspen today was once an "aspen forest" where this species comprised the dominant cover. Nonetheless, the 20th century did witness both increases (Kulakowski et al. 2004) and decreases in aspen cover (Di Orio et al. 2005), some attributed to humans and some to the relatively moist climate (Rogers et al. 2011). More recently, reports of "sudden aspen decline" indicate rapid die-off of both overstory and root systems in some parts of the West (Worrall et al. 2008). Subsequent work has linked regional mortality in aspen and recent climate trends (Worrall et al. 2013). These and other works suggest future climates will acutely affect aspen on southern aspects and at low elevations, conditions commonly found on BLM lands across the West. Land managers, then, face the dilemma of applying the collective knowledge of a large body of aspen science to specific areas of interest, areas that they cannot treat as uniform representations of a single species behaving predictably across its wide range.

In this field guide, I use a "systems approach" to aspen ecology and management. We have learned much, though perhaps not adequately communicated, about varying aspen types around our region (Rogers et al. 2014). For example, what new information is available about fire behavior in aspen, and how might we best apply that knowledge best be applied to forest management practices? Or why do aspen forests vary in their contribution to wildlife management and landscape biodiversity? Are we as land managers making informed decisions about stewardship with processes in mind or working against ecosystem function, which controls such processes? Our driving paradigm in contemporary land management is to first understand, then emulate (to the degree possible), ecosystem function. In terms of western aspen, this means using the best available science and pairing it with local experience. Where there are knowledge gaps, often field monitoring and experimentation are required to move forward. These ideas are not necessarily new, though their application in widely varying quaking aspen communities provides novel opportunities for effective management. One key tactic is agency investment in "learning by doing," which will be required to adapt to the dynamic institutional and ecological conditions expected.

## Why Is Aspen Important?

**Biodiversity**—Among western forests, quaking aspen communities are often the most biodiverse (Kuhn et al. 2011; Chong et al. 2001). Due to the presence of relatively moist conditions and abundant flora, a wide range of wildlife species—both transitory and resident—is drawn to aspen forests (Manley et al. 2000). Thus, it is important to understand that we seek to sustain the range of aspen systems, not just the tree. As wildlife habitat, aspen types are often among the most critical concerns for state and federal agencies charged with managing viable populations in diverse landscapes (Fig. 1.2).

*Figure 1.2 Biodiversity in aspen.*

**Water Conservation**—Relatively high understory biomass, deep snowpack, and rich soils allow aspen systems to retain higherlevels of water in the spring and early summer (Gifford et al. 1983; LaMalfa and Ryle [sic] 2008). While further work is needed on this topic, these preliminary investigations suggest that retention of aspen dominance in seral conditions allows deeper infiltration rates, thereby prolonging water availability later into the season. We expect similar water benefits in stable aspen systems where conversion to sage or other dry nonforest types is a possibility. More water in streams benefits fish as well as downstream human uses.

**Aesthetics**—People often underestimate the benefit of landscape beauty to our well-being. Aspen landscapes are iconic in western North America, especially as their brightly colored autumn leaves appear. Regardless of activity, white trunks crowned with fluttering green or gold leaves often lie at the center of our outdoor experience. In addition to potential spiritual, healing, or calming values found among the quaking aspen, nature lovers gravitate to this tree for its photogenic qualities.

**Recreation**—Skiing, hunting, biking, hiking, motor touring, camping, fishing, photography, and sightseeing are commonly centered on aspen scenes. Many western resorts that focus on recreational activities use aspen backdrops in their advertising. Large aspen die-offs, though perhaps endemic to forest ecosystems, are generally unappealing to recreational visitors.

**Forage**—Historically, livestock growers have depended on the diversity, biomass, and nutrition of understory aspen communities to feed their animals. Often found at high elevations, aspen forests provide cooler and moister conditions for livestock during parched summer months. Use of forage in these locations, provides direct economic benefit to western ranchers, as well as indirect benefits to the municipalities where they reside.

**Fire Protection**—Forests dominated by aspen are less prone to high-intensity burning compared to surrounding conifer types (Shinneman et al. 2013). In wildland urban interface (WUI) situations, aspen may be used as a firebreak around developed areas (Fechner and Barrows 1976). Thus, management that favors aspen (i.e., thinning conifers, light underburning) may be used as a prudent means of protecting homesites.

**Social/Economic Values**—Many of the benefits listed above, combined or individually, contribute to social and economic gains for residents of the West. For example, outdoor experiences not only contribute to our greater well-being and strong sense of place, but they add revenues to state and local businesses. Hunting licenses, in part powered by sustained aspen habitat, contribute to greater wildlife benefits via funding of state agencies. Perhaps rural communities, compared to urban locales, see more direct benefits, though this is probably subject to debate given the strong ties aspen have in promoting skiing and resort development.

## Purpose and Scope of the Field Guide

This field guide applies to quaking aspen ecosystems in the western United States broadly and Bureau of Land Management lands specifically. As we explore "functional types" further (Chapter 4), it will become clear that aspen communities—from southwest to Rocky Mountain to boreal—vary in their responses to natural and human disturbances. This field guide provides a framework for addressing aspen issues on local and regional scales with emphasis on conditions facing BLM managers (Fig. 1.3). While this guide assumes users will have some forest management experience, we acknowledge the interdisciplinary nature of aspen management, and therefore, we strove to minimize technical jargon recognizable only to specific job titles. Appendix 1 provides definitions for the technical terms used.

Aspen acts as a keystone species (Campbell and Bartos 2001), supporting a complex web of plant and animal integration. Therefore, our ability to sustain these communities in the face of various threats is of high priority among broader landscape considerations. Fundamentally,

***Figure 1.3*** *Management.*

this field guide intends to increase the ability of practitioners—foresters, silviculturists, ecologists, range and vegetation managers, botanists, and related professionals—to understand and appropriately manage aspen ecosystems. We do this by placing as many relevant tools, including access to current science, into the hands of those working most closely with these systems.

Another goal of this field guide is to direct users toward appropriate, science-based, resources. Field managers have numerous priorities that claim their work time. This field guide aims to point professionals to relevant sources delivered in a variety of ways to encourage ongoing information sharing and knowledge expansion on aspen-relevant topics. Such resources include specific treatment options, available expertise, current and past literature, webinars, conferences, and field workshops.

Lastly, the theme of system resilience is integral to aspen management, particularly in lower elevation stands subject to increasing droughts expected under warming climate regimes. BLM lands commonly encompass these highly vulnerable aspen landscapes. This guide will focus specifically on what it means to "manage for resilience" with the objective of developing sound adaptive strategies for addressing stressed aspen communities.

# Chapter 2 - Aspen: An Evolving Picture

Ecosystems, by their very nature, are complex. As professionals, we must weigh our understanding of these systems with past and present human actions to implement what we believe are the most prudent management prescriptions. Layers of complexity based in physical science and social dynamics compound our tasks. However, what appears daunting at first we can address, step by step, with a knowledge base and access to resources. In this section, I address the knowledge base. First, I lay out the prominent issues affecting contemporary aspen management. Second, I look at recent science developments of import to field practitioners. Third, I briefly discuss resilience management in aspen forests (a theme revisited in Chapter 5). Using this information as a base will assist in developing sound management actions.

## Issues Affecting Aspen Ecosystems

Many contemporary issues affecting aspen have been around for decades and are familiar to readers. However, while these issues have been evolving with modern impacts and technologies, new issues are arising. The objective here is to describe these new issues and consider how they may interface (or not) with those familiar to us.

**Long-Term Aspen Decline**—Previous messages regarding the long-term decline of western aspen related to conifer “encroachment” deserve reconsideration. There has been recent documentation of both aspen cover loss (Di Orio et al. 2005) and gain (Kulakowski et al. 2004) in different areas, as well as expansion and contraction within the same landscape (Sankey 2009; Elliot and Baker 2004). Climate fluctuations, fire suppression, and other human manipulations affect specific landscapes in varying ways (Rogers et al. 2011). Results are often highly dependent on available time, area of concern (scale), and source materials selected; explicit use of multiple, independent, lines of evidence solidify findings in such investigations. We should not assume long-term decline has occurred—at least not beyond the “natural range of variation”—without making local investigations.

**Short-Term Aspen Decline**—Short-term decline, sometimes called sudden aspen decline, presumes a relatively rapid die-off of overstory trees, as well as supporting root systems. Worrall et al. (2008, 2013) have provided documentation of this phenomenon for southern Colorado and it may range across wider areas. However, in many instances, root system die-off has not followed drought-induced aspen mortality and may simply be a common mode of stable aspen regeneration (author observation, Ashley National Forest, Utah). There appears to be more common instances of combined effects of drought and browsing decreasing aspen resilience (Rogers and Mittanck 2014), sometimes leading to system collapse. Again, assumptions of short-term decline should be avoided without site examination of inciting factors, such as insects, disease, and browsing.

**Ungulate Browsing**—Both domestic and wild ungulates (hooved herbivores) may consume regenerating aspen with long-term implications for viability of stands (Fig. 2.1). These impacts are potentially severe when ungulates are not kept in check by humans or predators. Where aspen are dependent on continuous recruitment (i.e., stable stands) browsing may result in the loss of multi-layer stand structures (sometimes complete stand collapse!) important to local biodiversity. Single-story aspen stands are highly vulnerable to stand collapse as mature trees age and die.

as mature trees age and die.

This phenomenon is visible throughout the West, but is particularly prominent across the Colorado Plateau. Periodic wildfire may rejuvenate seral aspen, though intense browse pressure may eliminate such gains following disturbance (Turner et al. 2003).

***Figure 2.1*** *Browsing.*

**Water Conservation**—Forests dominated by aspen seem to increase water storage capacity, as they tend to accumulate more snow and contribute to increased soil organic matter, a property that helps to retain soil moisture. LaMalfa and Ryle [sic] (2008) found that aspen accumulated more snow than adjacent conifer stands (snow–water equivalent), but higher evapotranspiration rates in aspen forests led to faster summer water loss. Soil storage capacity (i.e., greater porosity), then, became the difference in the net superiority of aspen forests to retain water.

**Biodiversity**—Perhaps the greatest value in aspen communities is their capacity to support so many plants and animals. Among western montane forests, aspen are the most biodiverse communities (Kuhn et al. 2011; Chong et al. 2001). In western Wyoming, southern Idaho, and central Utah, practitioners have found evidence of high numbers of faunal species dependent on relatively small acreages of aspen (D. DeLong and D. Bartos, personal communication). Loss of these forests, regardless of cause, leads to declines in obligate species, such as arboreal lichens (Rogers and Ryel 2008).

**Climate Change/Drought**—Projections of warming, and possibly drying, conditions throughout the Rocky Mountain West suggest that aspen habitat may shrink significantly in the coming century (Rehfeldt et al. 2009). Decreased physical ability to handle low water availability can reduce aspen's resistance to insects and diseases (Anderegg et al. 2013). Conversely, increased wildfires under warming scenarios may pose great opportunities for aspen expansion, and the complexity of multiple disturbances seems to favor aspen dominance over competing conifers (Kulakowski et al. 2013). There is additional evidence that conditions favoring aspen expansion will lead to greater soil storage of carbon (Dobarco and Van Miegroet

***Figure 2.2*** *Drought.*

2014), potentially mitigating atmospheric warming. Certainly, we can expect changing dynamics with climatic warming, though additional empirical and modeling work is required before we can determine whether outcomes will be positive or negative toward aspen forests.

**Fire Management**—Forest fires generally favor aspen rejuvenation, growth, and expansion in seral types. In many instances, particularly where herbivory is problematic, continued fire suppression may result in decreased resilience (Rogers et al. 2014). Judicious use of fire—both prescribed and lightning ignited—holds great promise for improvement of aspen conditions in the West, although post-disturbance protection will be required where elevated herbivory is expected. Moreover, active management favoring aspen as a firebreak near buildings provides practical uses (Fechner and Barrows 1976). Field professionals, however, should be aware that the varied aspen functional types encompass a range of fire regimes (Rogers et al. 2014; Shinneman et al. 2013), thus the maxim of "one size does not fit all" applies here.

**Conifer Bark Beetles**—Infestations of bark beetles can damage or kill entire landscapes of pine species competing with aspen for resources. Theoretically, these situations may create great opportunities for aspen establishment (seedlings) or regrowth and expansion (suckers). Though there has been extensive investment in research addressing either mountain pine beetle (MPB) or aspen, there has been almost no attention on the interface between these elements. A recent review investigating potential positive benefits to aspen after MPB outbreaks was inconclusive, but made a strong call for further research (Pelz and Smith 2013). Similarly, opportunities for aspen regeneration within spruce beetle infestations were common in southern Utah (DeRose and Long 2010). As with many of the other issues here, these authors found complicating factors in post-MPB disturbance in the form of browsing, fire, human uses and management decisions, and climate warming.

**Recreation**—In general, recreation impacts to aspen communities are modest. However, there are instances in campgrounds, along trails, at ski resorts, and in surrounding parking areas where stem scarring, soil compaction, root damage, and localized air pollution impacts threaten stand health. Telltale signs include stem "bleeding," excessive bole decay, and chemical leaf damage. We also note that frequent human use of aspen sites (e.g., campsites and roads) may have beneficial effects, such as passive deterrence of ungulate browsing of suckers. Recreation in and around aspen forests generates large economic benefits, too. People who enjoy mountain biking, skiing, off-road vehicle use, hiking, camping, photography, and nature/wildlife viewing place a high premium on healthy aspen ecosystems (Fig. 2.3).

*Figure 2.3* Recreation.

**Development**—Just as they do for recreation, westerners favor aspen landscapes for residential development and therefore we place monetary value, in the form of real estate, on these locales. However, as more people move to such areas and come to appreciate their value, issues arise regarding their preservation. Sometimes small privately owned parcels abut public aspen forests, and other times individuals own wider tracts with limited public boundaries (Fig. 2.4).

Monetary and emotional considerations give additional weight to the numerous reasons for sustaining these forests. The expansion of developed areas will require adjustments to management actions, such as the use of prescribed fire to benefit aspen, on adjacent wildlands.

*Figure 2.4* Development.

## Science-Management Synergy

It seems the job of landscape stewardship has become more challenging, not less, with advancing technologies. The days of simply overseeing field crews and laying out timber sales are far behind us. Field foresters, ecologists, and biologists devote much of their time to email correspondence, computer mapping, National Environmental Policy Act (NEPA) documentation, budgets, personnel management, teleconferencing, and learning new software. Additionally, government agencies have evolved toward a state of much greater public inclusion in the decision-making process. While these tasks are positive developments overall, they certainly absorb considerably more time, which amounts to less time to devote to keeping abreast of scientific developments in the field. The intent of this section is to highlight new developments in aspen science and discuss how these discoveries might relate to contemporary forest management.

**Fire and Functional Types**—Conventional forest management in aspen has focused on successional aspen communities: aspen suckers grow profusely after disturbance, dominate sites for several decades while self-thinning, and eventually succumb to shading by secondary ingrowth of one or more conifer species. While this simple formula still applies to many aspen forests, there is now greater recognition of different "aspen functional types" (Rogers et al. 2014). At the broadest level, there are the above-described seral communities, but also widespread occurrence of stable aspen types. In contrast to an aspen-to-conifer succession, stable aspen communities maintain a nearly pure state (no other tree species), characterized by multiple age classes of aspen, for one to several centuries. Integral to understanding different aspen types is a recognition of varied susceptibility to fire (Figure 2.5). While some seral aspen communities become more fire prone with advancing succession, stable aspen communities may be nearly fire resistant except during uncommonly dry periods (Shinneman et al. 2013). Additionally, long-term co-occurrence of aspen and conifers, apparently devoid of stand-replacing disturbance, have also been noted, though such conditions will require further investigation before we understand even their basic functional traits (e.g., Zier and Baker

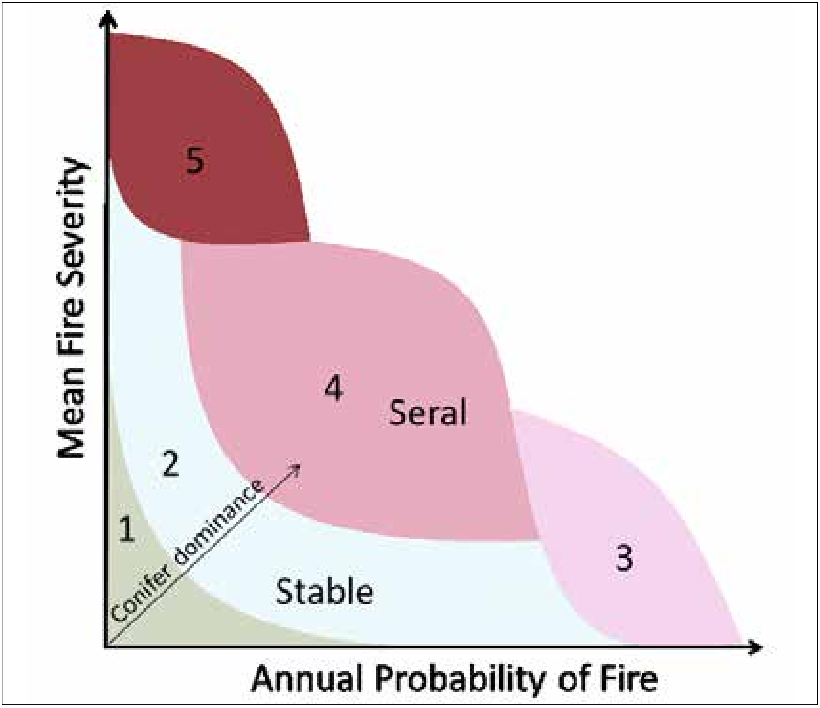

*Figure 2.5 Major drivers of aspen fire types include the interaction of fire probability and severity over time. Fire rarely affects stable aspen types while it more commonly influences seral types. (Adapted from Shinneman et al. 2013).*

2006). These recent advances have clear implications for effective forest management that strives to emulate ecosystem processes in treatment decisions.

**Trophic Cascades**—A great deal of research continues to explore relationships between predators, prey, and herbivory in aspen with the general notion that out-of-balance trophic processes will adversely affect aspen recruitment (Eisenberg et al. 2013). Few dispute, for example, that reduced elk populations resulting from predation will have positive repercussions for heavily browsed aspen sprouts. Moreover, elk and beaver using the same aspen sites can cause a downward spiral in aspen community health if predators don't keep elk numbers in check (Runyan et al. 2014). While science surrounding population numbers is somewhat settled, ongoing investigations regarding animal behavior (i.e., movement and use related to fear of predation) are less well understood (Beschta and Ripple 2013; Kauffman et al. 2013). Changing abiotic factors, such as diminishing snowpack related to climate warming, may affect interactions at multiple trophic levels. In northern Arizona, Martin and Maron (2012) found fewer bird species where duration of winter access by elk to high plateau sites increased herbivory and decreased complexity of aspen forest structure. All of these developments require aspen managers to work more closely with wildlife staff and related agencies to fully understand impacts and ramifications that inform decision making.

**Genetics and Reproduction**—Researchers are making great strides toward understanding the role of sexual regeneration (i.e., new genotype establishment from seed) in quaking aspen. Only a few years ago, aspen researchers thought seedling occurrence was a "rare" event in the arid West, though now it seems clear that the more we look—particularly following forest fires in aspen country—the more we find (Fairweather et al. 2014). Not only are seedling "events" more common than previously thought, but landscape- and regional-level genetic diversity suggests that survival of seedlings has long-term and widespread implications for management (Long and Mock 2012). For example, traditional silviculture prescribes clearfell-coppice management for most situations, when in fact, a greater diversity of aspen genotypes (as well as functional types) requires a range of management options to conserve genetic diversity in the face of climate warming, intensive browsing (see "Defense and Chemical

***Figure 2.6*** *Genetics / Reproduction vegetative suckering (left) and seedling (right).*

Ecology"), and conservation of seed sources. While genetic research in aspen is still in its infancy, it seems wise to manage in such a way as to preserve as many of the genetic "building blocks" as possible. Increased understanding of the long-term role of aspen's genetic diversity in relation to disturbance history will continue to inform our ability to manage for greater resilience.

**Defense and Chemical Ecology**—Researchers are striving to better understand the role of plant chemical defenses in deterring both insect and mammal herbivory. For example, leaves with high phenolic glycosides taste bad to ungulates, while those with elevated tannins repel certain insects (Lindroth and St. Clair 2013). A key tenet is the close alignment of the aspen genotype and allocation of chemical defenses. Aspen may develop high chemical defense levels, possibly fluctuating during their life cycle, at the expense of other physiological functions, such as growth rate. In a simple illustration of this, two adjacent aspen clones may have very different "strategies" for recruitment among browsers: the first grows fast, attempting to escape browsing, and the second grows slower but resists consumption via elevated defensive chemicals. However, many observers have noted that when ungulate populations are high, even "bad tasting" aspen leaves will be consumed. Advancement of our knowledge of chemical ecology, specifically in relation to intense ungulate herbivory, may hold a partial solution to the widespread western problem of regeneration failure related to domestic and wild browsers.

**Air Pollutants**—Air-borne chemicals may directly and indirectly impact aspen trees. An intriguing area of aspen research has been the interactive effects of pollutants, insects, pathogens, and a warming climate. In general, pollutant-related slowing of photosynthesis and weakening of natural defense systems via ozone injury, for example, predispose plants to a host of other potentially damaging agents. Insect herbivores, such as tent caterpillars (*Malacosoma disstria*) and leaf aphids (*Chaitophorus spp.*), appear to be attracted to leaf surfaces with increased ozone damage (Kopper and Lindroth 2003). While there appears to be some level of tradeoff between carbon dioxide fueled growth and ozone damage, reduced aspen root growth combined with growth suppression (from CO2) in competing trees would negatively affect mixed species aspen forests overall (Karnosky et al. 2005). These studies have primarily taken place in more humid, eastern and midwestern environments; while studies have shown that ozone damage occurs in western aspen, further investigations are required to fully understand these impacts, particularly in aspen forests close to cities having high levels of such pollutants.

**Subalpine Fir Facilitation**—The relationships between aspen and dependent species are often complex. More information is becoming available regarding one such species, subalpine fir, which may have ramifications for other conifers or a wider array of obligate plants. Recent work has compiled advances in subalpine fir–aspen research with an eye toward larger questions of resilience (St. Clair et al. 2013). A key finding of these authors brings together a body of science supporting aspen's facilitation role in "nursing" young fir germination, establishment, and growth. For example, Buck and St. Clair (2014) found subalpine fir germination to be to be much more successful in close proximity to mature aspen, as well as on the north (moister) side of these trees. In terms of resilience, then, where aspen forests begin to experience high mortality, there is strong potential for reduced cover of dependent species (St. Clair et al. 2013; Rogers and Ryel 2008). This work is generally in its infancy, though there is much interest in how other conifer species interact at both the individual and stand levels, as well as whether subalpine fir "behaves" similarly across the range of these two species.

## Defining Resilience Management in Aspen

The objective of this field guide is to understand current issues and incorporate credible science toward developing adaptive action plans for sustainable aspen ecosystems. How to develop an action plan is covered in greater detail later in the field guide. Before moving forward, I need to be clear on what we mean by "managing for resilience." Our definition of resilient management of aspen involves maintenance of the ecological processes necessary for communities to remain within the natural range of variability (NRV) (Landres et al. 1999). NRV does not imply a static target and may involve adaptations to changing environments and climates. The core tools for accomplishing resilience management center on a monitor and adapt cycle. To be sure, this approach to resilience management will be challenging. Land stewards will have to develop a strong understanding of ecological drivers in the aspen types they are dealing with. This will require not only a knowledge of current issues and appropriate science, but also familiarity with stakeholder concerns and economic constraints.

***Figure 2.7*** *Resilience and diversity.*

Monitoring forms a key element in an ongoing process; not a one-time task for land stewards to check off. Information, both internal and external to specific landscapes, drives adaptive management. Actions taken on the ground are bound to include errors; it's what managers do with those mistakes that will drive resilience management. For example, if we take actions that result in a strong aspen regeneration response, but 1 year later, we see total loss of suckers from browsing, we adjust our action plan toward a more sustainable outcome. We cannot make credible adjustments without support from monitoring data that documents both successes and failures. This approach—called the monitor–adapt cycle—gives us a strong basis for sound resilience management and allows for unforeseen changes that may be beyond local control.

# Chapter 3 - Landscape Interactions And Other Considerations

## Disturbances

Aspen is traditionally considered a “pioneer” or “seral” species that rapidly colonizes recently disturbed, mainly seral, sites. This traditional label does not always apply in a strict manner (e.g., stable aspen types); nevertheless, there is often a strong interaction between disturbance processes and aspen growth patterns. All levels of disturbance severity, particularly those that directly reduce conifer competitors and aspen, will activate hormonal responses in roots, which stimulate vegetative reproduction (Schier et al. 1985). Generally, more severe disturbance will result in higher densities of aspen regeneration, but this does not ensure that the majority of stems will survive to maturity. In others words, quantity of regeneration is not always the best measure of survival, especially where intense browsing by herbivores is a factor. Still, as in the earlier discussion of aspen functional types, type-specific disturbances play a key role in long-term sustainability of aspen communities. Interruption of such cycles tends to decrease resilience in aspen forests. Examples of disturbance disruptions include fire suppression, introduced or elevated rates of ungulate herbivory, inappropriate harvest practices, land development, and water engineering (Rogers et al. 2007a).

*Figure 3.1* *Fires burn a varying intensities. Around the peak this fire burned hot, while in the still-remaining mature aspen forest there was little fire impact.*

Recent research suggests that multiple, overlapping, disturbance events favor aspen over confer forest types (Kulakowski et al. 2013).

Researchers found that the combination of fire, wind throw, and spruce beetle in northern Colorado allowed aspen, with its quick regenerative response, to flourish over time in seral aspen communities. However, other disturbance combinations, such as drought and ungulate herbivory, appear to have negative effects on stable aspen types (Rogers and Mittanck 2014). Thus, awareness of disturbance processes specific to the site or functional type is critical to effective management.

## Aspen in the Landscape Context

Land managers cannot understand or manage quaking aspen forest in isolation from surrounding vegetation. Not only can adjacent communities provide seed sources for complementary and competing plants, they may encourage or discourage fire, provide wildlife habitat, foster water storage, increase erosion potential, or provide a host of human uses that may benefit or detract from sustainable aspen systems. A couple of examples illustrate this point. First, adjacent forests greatly influence aspen fire types (Shinneman et al. 2013). Where stable aspen are in juxtaposition with coniferous stands, there is greater potential for wildfire to penetrate normally fire-resistant stands. If aspen stands are relatively small, wildfire conditions are extreme, or aspen understory fuels are particularly cured during late season senescence, adjacent fire-prone communities will greatly influence fire behavior within the aspen stands. Second, riparian aspen may be found near moist spruce–fir, near dry ponderosa pine, or in "stringers" surrounded by nonforest meadows. Each of these vegetation communities has vastly different influences on animal use, for example, of the riparian aspen. Similarly, water retention on the broader landscape will be different depending on the composition and structure of these three riparian aspen types (LaMalfa and Ryle [sic] 2008).

***Figure 3.2*** *Landscape context.*

If our intention is to manage aspen through emulation of ecological processes, then we need to understand landscape interactions to the best of our abilities. Thus, it is important to consider the spatial context of aspen, even with the understanding of basic functional types, prior to taking prescriptive action.

## Past Management

As we continue to modify management techniques based on improved scientific knowledge, we often find that past policies or actions have left deleterious legacies. This evolution of knowledge is not necessarily negative; each generation attempts to steward natural resources using the best available knowledge of that era, and even the most informed science occurs within the social, cultural, economic, and political context of the day. Having said that, some past management practices have had lasting effects on aspen sustainability. We now know that periodic fires of varying sizes and intensities greatly aid seral aspen forests. (see Chapter 4). Similarly, managers often overallocated and livestock producers overexploited the rich forage of aspen communities in the past. Declines in aspen coverage in some locations—due to a combination of management practices and generally wetter 20th century climates—were mostly in seral functional types (Kulakowski et al. 2004; Rogers et al. 2007a, 2011). Particularly in the first half of the last century, managers promoted conifer over aspen for wood fiber as economically beneficial.

***Figure 3.3*** *Past management.*

Perhaps the most cited reason for 20th century aspen decline is aggressive fire suppression. While it is likely that suppression policies have affected large acreages of low- and mid-elevation forests, particularly those areas in accessible terrain, lasting impacts to higher elevation sites are suspect. No doubt in low-elevation, short fire rotation, conifer forests—a minority of which include seral aspen types—suppression has disrupted fire cycles and potentially led to decreases in aspen cover. However, a sound argument has been made that truly effective firefighting where most aspen grow, in montane and subalpine locations, has only been present for 50–75 years (with the advent of aerial suppression tactics), a period too short to seriously disrupt aspen cohort fire regimes (e.g., spruce, fir, some pines) of 200–400 years (Mori and Lertzman 2011; Baker 2009). Nonetheless, continued fire suppression will only offset potential aspen regeneration events further in all vegetation zones, thereby hedging in favor of conifer dominance in future decades. Of course, past suppression has affected stable aspen even less (Shinneman et al. 2013). Overall, modern recognition of the many benefits of aspen communities compels managers to modify or reverse past actions that reduced aspen cover and may have threatened long-term sustainability.

## Ungulate Herbivory

Both wild and domestic ungulates (hoofed animals) have the potential to greatly alter aspen reproduction and, therefore, long-term sustainability not only of trees but also of myriad aspen-dependent species (e.g., Martin and Maron 2012). Highly nutritious aspen suckers are an important seasonal food source for elk, deer, cattle, and sheep. All four of these animals are regulated, to some degree, by management and policy decisions. In some areas, loss of multiple vertical layers of aspen reproduction attests to long-term impacts of herbivory (Binkley 2008; Rogers et al. 2010). Generally, excess herbivory threatens stable aspen stands more because they depend on continuous regeneration and mostly lack stand-replacing disturbance events. Chronic browsing of young suckers, therefore, eliminates the crucial recruitment layer, which greatly lessens the possibility of stand resilience when aging overstory stems begin to die. Browsing may also affect recruitment in seral aspen, but there is greater chance of stand renewal with inevitable disturbance events. Under heavy browse pressure, however, even robust flushes of aspen regeneration following severe disturbance may be swiftly consumed by ungulates (Turner et al. 2003).

*Figure 3.4* *Elk herbivory in the Book Cliffs, Utah.*

Even though documentation of overbrowsing by ungulates has a long history (Murie 1951), it has not been until recently that interagency efforts have begun to address the difficult social, economic, and ecological issues that underlie the problem. Given that state, federal, and private interests govern the management of both wild and domestic ungulates, collaborative efforts to attain a lasting balance between fundamental causes of overbrowsing are imperative. Judicious livestock management, including ample periods of rest, has beneficial outcomes for producers, wildlife, recreationists, and downstream water users. Likewise, parity between livestock and wildlife management so that, at a minimum, recruitment targets at stand-replacement level (100% for stable; 50% for seral) are essential. Other measures of gauging herbivory's effects, such as plant and bird diversity, browse levels, visual evaluations, and regeneration condition, should also play a part in such assessments.

## Development and Private Land Ownership

A recent phenomenon is the expansion of human developments—also called exurban or developed wildland interfaces—into formerly wild areas. (These areas differ from "wildland urban interfaces" in that they are often rural- or resort-based developments at some distance from urban centers.) Private lands, particularly those with recent development, present a unique set of considerations for aspen management. First of all, individuals often prefer to locate in or near aspen forests for their aesthetic and wildlife attractions. In a related manner, many recreational facilities—campgrounds, ski resorts, bike and hiking trails, even golf courses—are specifically sighted in aspen to attract patrons. Thus, we are faced with a burgeoning intrusion into aspen (and other forest) communities that requires concomitant adjustments specific to these forests.

Previous authors have touted the benefits of aspen as a firebreak (Fechner and Barrows 1976), an asset that may be exploited using more active forest manage prescriptions near homesites. For instance, thinning of conifers within at least one tree-fall length of buildings to favor aspen dominance provides an extra line of defense against wildfire. Such cutting also requires removal of associated conifer fuels, such as slash piles, from the same area. In seral aspen, conifer dominance will increase over time without active management and present a rising fire threat. Stable aspen are much less likely to burn, though homes in these forests require other considerations.

***Figure 3.5*** *Alaska development . Photo by: E. Geisler*

While there are clearly advantages to living among aspen, there are also drawbacks. Aspen trees draw large herbivores, which residents may view as a positive. However, these animals may also inhibit regrowth of suckers (see "Ungulate Herbivory"), which eventually will ameliorate benefits. Moreover, frequent interior rot of mature aspen stems may heighten incidence of property or safety threats when these trees eventually crash. Overall, greater vigilance in aspen stewardship in developed sites often must increase with proximity to homes.

PPrivate and public landowners obviously have different mandates for stewardship. Public lands, such as federal and state forests, usually have multiple use policies and public involvement (to some degree) in decision making. Development of private lands with forests containing aspen stands, as previously discussed, is becoming more common. Herbivory may be concentrated on private lands as deer and elk have learned to avoid public forests during hunting seasons. Intensified browsing of aspen suckers leads to, in some cases, decreased resilience to perturbation and potentially complete loss of aspen. In such instances, forest and wildlife management policies incur steep gradients in conditions as they cross ownership boundaries. This may lead to concurrent social tensions between jurisdictions and sets up a prime case for collaborative problem-solving involving diverse and vested parties (see Chapter 5, "Developing an Action Plan"). On the positive side, private aspen landowners have the ability to quickly experiment, monitor, and implement treatments to "course correct" unsustainable trends within the bounds of their properties.

## Climate Considerations

Warming, and in some locales drying, conditions are projected for wide swaths of the western United States landscape and are likely to impact quaking aspen forests. BLM aspen forests, often located at lower limits of aspen habitat, are likely to be among the earliest impacted by climate shifts. In particular, low-elevation, south and southwest facing slopes appear most threatened by expected long-term drought associated with climate warming (Worrall et al. 2008; Rehfeldt et al. 2009; Rogers and Mittanck 2014). Compounded insect, disease, fungal, and fire incidence may further affect these locations. As drought-stricken forests begin to thin from the combined effects of these factors, they will be subject to wind breakage and felling (Hogg and Michaelian 2015), further accelerating rapid die-off. In contemporary low-elevation aspen forests that are experiencing a downward spiral, type conversion is a real and present concern, even without herbivory.

***Figure 3.6*** *Low elevation dry sites are most vulnerable to warming climate.*

Ungulate browsing in combination with drought-affected forests presents the most acute threat across aspen's western range. Maintenance of multilayer and multiage aspen stand structures, via reduction of browsing, can increase resilience to climate change and prolonged drought. Additionally, climate change will have prominent effects on wildfire patterns. Increased burning, alongside interacting disturbances such as wind throw, bark beetle outbreaks in conifers, and incidence of stem and root rots, will likely enable aspen to thrive and grow (Kulakowski et al. 2013). So, divergent trends predicted to accompany climate warming—habitat reduction and disturbance-facilitated expansion—are expected to play out across aspen's wide expanse in widely varying ways. Returning to low-elevation aspen, we would expect habitat depletion to have a more prominent impact; increased aspen coverage will likely center on seral and middle- to upper-elevation sites. However, much more research into climate warming related impacts to aspen communities will be required before we can know which trends will prevail under what aspen functional regimes.

# Chapter 4 - Aspen Types By Ecological Function

## Overview of Functional Types

A key tenet of contemporary natural resource management is to understand and emulate ecological processes to the degree possible. Greater efforts to work within process-based parameters will likely yield desired endpoints while doing little damage to ecosystem function. Moreover, individual components (i.e., species) are likely to thrive where major processes are intact. It therefore follows that linking functionality to vegetation typing will encourage intuitive connections between naming, understanding, restoring, and monitoring landscapes of interest.

Within the present broad range of aspen in western North America (Figure 4.1), there are distinct biogeographic regions with differing edaphic and climatic conditions supporting the species. These distinctions, functional types, occur at both regional (Figure 3.1) and landscape (not shown) scales. To address this situation, a new system of aspen classification based on ecological function was developed (Rogers et al. 2014). These authors defined "aspen functional types" as broad aspen communities that differ markedly in their physical and biological processes and interactions (i.e., functions). Such communities would be expected to respond differently to management actions, which is a central purpose of the current field guide. The concept of plant functional types is derived from previous works (Semenova and van der Maarel 2000, Ustin and Gamon 2010), as well as key recent publications specific to aspen (Shepperd 1990, Kashian et al. 2007, Kurzel et al. 2007). This focus on function is a marked departure from earlier classifications that are plant composition based (e.g., Mueggler 1985), though this doesn't discount the application of such community typing systems for specific locales in which they were developed. The chief benefit of an aspen function type scheme is that it places the focus Within the present broad range of aspen in western North America, there are distinct biogeographic regions with

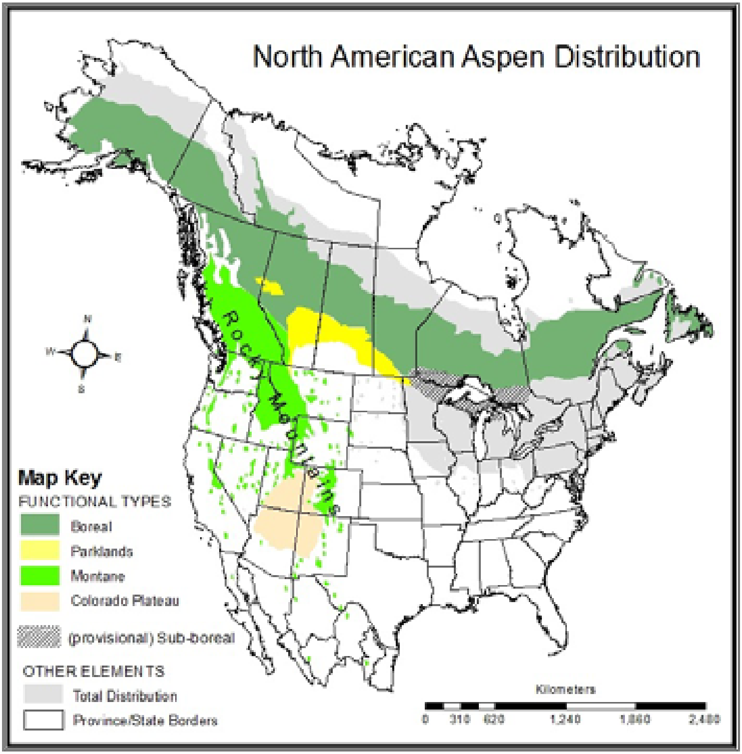

***Figure 4.1*** *Total aspen coverage in North America with overlay of aspen functional types. Adapted from Rogers et al. (2014).*

differing edaphic and climatic conditions supporting the species. These distinctions, or functional types, occur at both regional (Figure 3.1) and landscape (not shown) scales. To address these distinctions, Rogers et al. (2014) developed a new system of aspen classification based on ecological function. They defined "aspen functional types" as broad aspen communities that differ markedly in their physical and biological processes and interactions (i.e., functions). Such communities are expected to respond differently to management actions. The concept

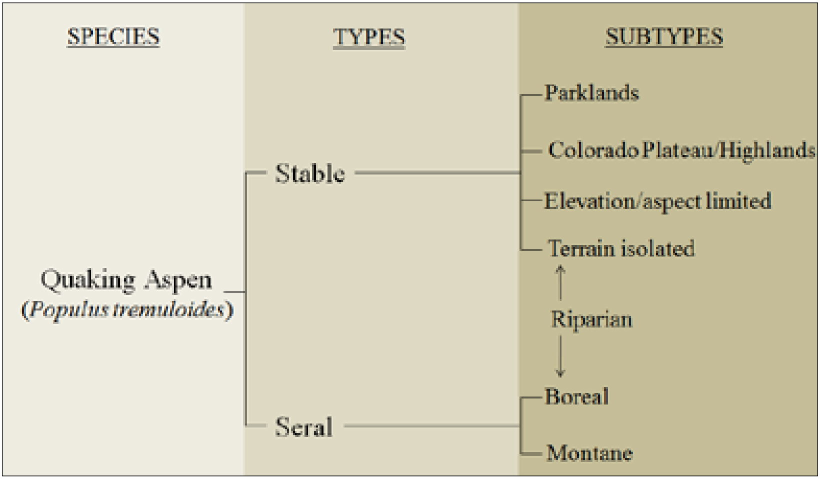

***Figure 4.2*** *Schematic of Aspen Functional Types of North America.*

of plant functional types is derived from previous works (Semenova and van der Maarel 2000, Ustin and Gamon 2010), as well as key recent publications specific to aspen (Shepperd 1990, Kashian et al. 2007, Kurzel et al. 2007). This focus on function is a marked departure from earlier classifications that are plant composition based (e.g., Mueggler 1989), though this doesn't discount the application of such community typing systems for specific locales in which they were developed. The chief benefit of an aspen function type scheme is that it places the focus of prescriptive actions clearly in the realm of ecological processes rather than plant identification. Figure 4.2 presents the schematic of aspen functional types and provides a framework for the remainder of this chapter.

## Seral and Stable Functional Types

Here the prime focus will be to distinguish between seral and stable aspen communities so that field practitioners may better manage aspen within appropriate ecological parameters (Rogers et al. 2014). Those authors define stable stands as those that remain dominated by aspen

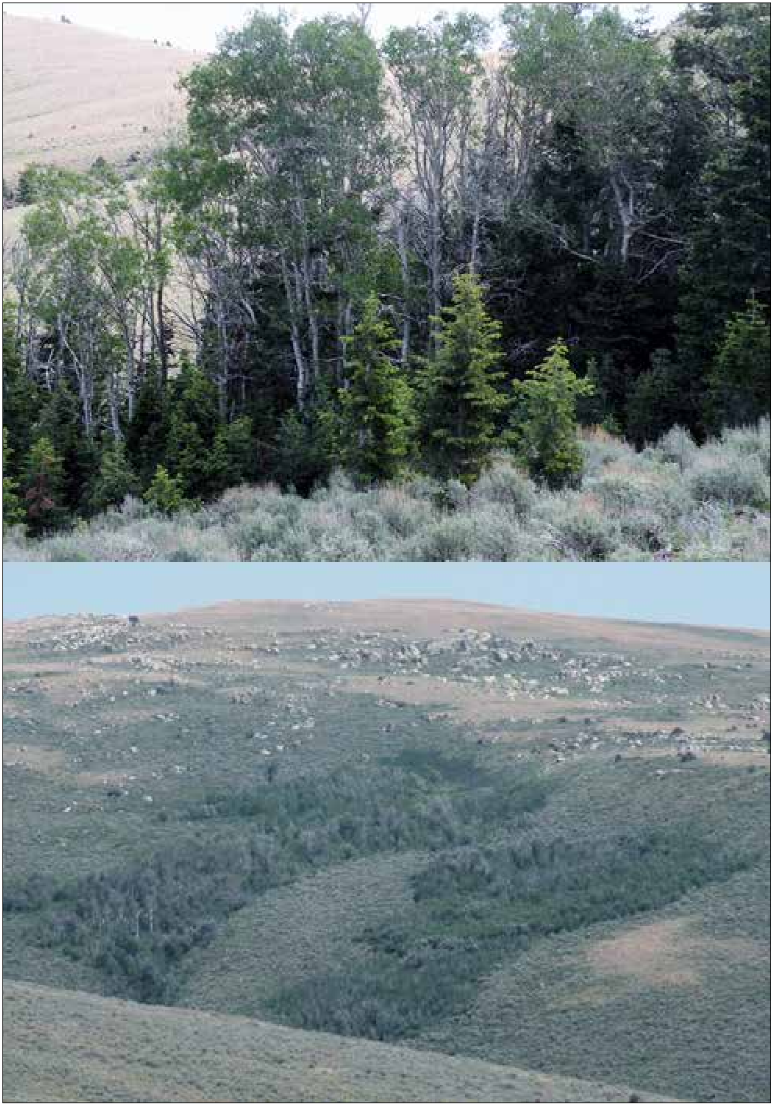

***Figure 4.3*** *Seral (top) and stable (bottom) functional types.*

cover through multiple ecological rotations, with little or no invasion by conifers. Seral aspen stands follow a successional pathway in which aspen dominate early on and are eventually replaced by conifers within a single ecological rotation. (Ecological rotation, the average lifespan of mature canopy trees in a stand, varies considerably over aspen's range; therefore, I avoid assigning a certain number or even a span of years.) This primary division, seral vs. stable, focuses on tree composition; thus, "stable" in no way implies a lack of stand dynamics. In stable stands, tree composition remains constant, though there is regular regeneration, recruitment, and mortality among individuals and small groups of aspen stems. In sum, stable stands remain in aspen cover after small and large disturbances, whereas seral stands are temporarily dominated by aspen and usually transition to alternate vegetative states over time.

An important functional distinction between seral and stable communities is the type and magnitude of landscape disturbance they experience. While seral aspen typically thrive under stand- or landscape-level disturbances, stable types more commonly experience individual tree or small group mortality at a given time. Likewise, disturbance intensities will generally be higher in seral aspen (Shinneman et al. 2013). Disturbance size, intensity, and frequency strongly correlate with regenerative response in aspen. Stable aspen are characterized by continuous regeneration and recruitment, sometimes amplified by clone stressing "events" such as drought, defoliation, or frost damage, which typically result in an overall complex vertical stand structure (Harniss and Harper 1982; Shepperd 1990; Kurzel et al. 2007; Rogers et al. 2010). On the other hand, seral aspen commonly respond to large/intense or mixed disturbances with great even-aged flushes of suckers. Nonetheless, seral stands will produce suckers at low levels even in the absence of disturbance, so we should be cautious when interpreting no suckering in mature stands as "typical" of seral communities. Finally, stable aspen seem to occur in drier conditions and on lower slope angles (Rogers and Mittanck 2014; Mittanck et al. 2014) than seral forests, although further research needs to be conducted to fully understand these relationships. Overall, this basic division has great bearing on management that strives to mimic natural processes (Chapter 1).

## Aspen Subtypes of Western North America

This field guide uses a framework for functional types to more appropriately manage varying aspen conditions (Figure 4.2). The scheme and supporting sources originate from a systematic discrimination of aspen subtypes in western North America based on the following physical characteristics: topography, stand size, annual precipitation, ecohydrology, rooting depth, regeneration type, and disturbance type/frequency (Rogers et al. 2014). Approximation of aspen fire types are from Shinneman et al. (2013). For each subtype, I will distinguish dominant traits by these common characteristics. This guide emphasizes the "framework" nature of this system; expecting and encouraging additional refinement and delineation of subtypes with implementation. Further, the broadest geographic divisions—boreal, montane, parklands, and Colorado Plateau—may be inclusive of seral or stable subtypes at finer scales. The following subtypes, therefore, constitute a first approximation of an aspen functional typology for its western range.

## Seral Aspen

Two seral aspen functional subtypes occur within BLM lands of the western United States. Boreal aspen occur in Alaska and montane aspen are common throughout the major mountain ranges of the Interior West. Generally, aspen communities in seral systems interact with individual and community ecologies of cohort conifers. Aspen dominance may last multiple decades but, in the absence of further disturbance, one or more conifer species will eventually overtake aspen in the successional process.

### Boreal

| Major Associates | Minor Associates |
|---|---|
| *Picea glauca; Pinus mariana;*<br>*Pinus banksiana; Pinus contorta; Populus balsamifera* | *Betula papyrifera* |

**Location:** Alaska and northern Canadian provinces

**Topography:** Undulating to flat, low elevation

**Stand Size:** Large (10s-10,000s acres/ha)

**Annual Precipitation:** 12-19 inches (317–479 mm)

**Ecohydrology:** Top recharge annually; probably linked to adjoining water tables; precipitation less than potential evapotranspiration

**Rooting Depth:** Soils exceed root depth; water table confined

**Disturbance and Fire Type:** Fire and wind throw. Stand-replacing disturbance moderate to high severity depending on conifer amount and composition with 50–200 yr. frequency (Stocks et al. 2003; Flannigan et al. 2001).

**Description**—Very large stands of seral aspen communities are regulated by stand-replacing events and harvest activities. The relative lack of topography and continuous forest facilitates disturbance at large scales and accessibility for resource extraction. However, the remote nature of many boreal aspen forests requires large investment to access wood products and/or reduce wildfire spread. In such locations, undiminished large-scale processes continue to govern this functional subtype.

**Management**—Boreal aspen "mixedwood" forests products comprise a significant industry in the region. However, these forests also contribute heavily to carbon sequestration globally. Care should be taken during and after harvest activities to protect and maintain healthy root systems to ensure adequate reproduction. Stresses related to drought, insects, and diseases are threatening stand health, particularly near the parklands interface. Climate warming is expected to have profound effects on these forests in the coming century. Managers and scientists should consider regionally strategic approaches, such as assisted migration and anticipatory habitat protection, in the face of aspen habitat change. Documentation of aspen seedlings germinating in previously uninhabited locations after conifer harvest may be a

*Figure 4.4a* Mixed seral aspen. Photo by: S. Landhäusser

*Figure 4.4b* Patchy seral Aspen Photo by: S. Landhäusser

***Figure 4.4c*** *Seral aspen white spruce. Photo by: E. Geisler*

***Figure 4.4d*** *Seral aspen with white spruce (Alaska). Photo by: E. Geisler*

harbinger of biogeographic dynamics in this subtype (Landhäusser et al. 2010).

## Montane

| Major Associates | Minor Associates |
|---|---|
| *Abies lasiocarpa; Abies magnifica; Juniperus occidentalis; Picea engelmannii; Pinus contorta; Pinus jeffreyi; Pinus ponderosa; Pseudotsuga menziesii* | *Acer glabrum; Acer grandidentatum; Abies concolor; Acer grandis; Juniperus scopulorum; Larix occidentalis; Libocedrus decurrens; Quercus gambelii; Picea pungens; Pinus albicaulis; Pinus aristata; Pinus lambertiana; Pinus flexilis; Salix scouleriana* |

**Location:** Rocky Mountains from northern British Columbia to central Mexico; Sierra Nevada; Cascades; numerous minor ranges both east and west of the Rocky Mountains.

**Topography:** variable slope, aspect, elevation

**Stand Size:** Large (10s-1,000s acres/ha)

**Annual Precipitation:** 15-71 inches (379–1807 mm)

**Ecohydrology:** Annual top recharge; limited lateral water flow

**Rooting Depth:** Bedrock confined

**Disturbance and Fire Type:** Fire, wind, snow avalanche, gravity/geomorphic, and human caused (e.g., tree harvest, prescribed fire, development, etc.). Disturbances tend to be mixed- to high-severity inducing a strong sprouting response. Fire ecology is well described by Shinneman et al. (2013) in Fire Types 3, 4, and 5 (see Appendix 1). Fire frequencies are dependent on cohort tree associates, time since previous disturbance, previous disturbance type, adjacent vegetation communities, and climatic conditions. In general, fire frequencies are highly variable in ponderosa pine/aspen as frequent as 10 years and in spruce–fir/aspen as long as 300–400 years. After disturbance in seral montane forests, aspen may remain dominant for 60–150 years before conifers overtake them (Baker 2009).

**Description**—The seral montane aspen subtype is what many (in the United States) consider the quintessential or "classic" aspen forest. There is a very long and rich history of science and management featuring this subtype (e.g., DeByle and Winnoker 1985). Disturbance processes, most notably fire, have a strong influence on long-term development patterns. Many believe that lack of wildfire (suppression) over the past century has promoted advanced conifer succession or "conifer encroachment," although this generalization is probably too simplistic where, particularly at upper elevations, there is great variability in fire regimes (Baker 2009). In general, aspen regenerate en masse after disturbance and thus form even-aged cohorts. The dominant reproductive type is vegetative root sprouting, though recent research is uncovering numerous instances of sexual reproduction, germination, and survival, which may have far-reaching implications for evolving management strategies (Long and Mock 2012). Montane seral aspen, because of varied timing and response to disturbance, promote landscape patchiness. In some instances, they are intermixed with elevation/aspect limited and terrain isolated stable subtypes due to the high variation of topography in montane zones.

**Management**—Seral aspen are of great value to a host of users for timber products, wildlife habitat, nature and wildlife viewing/photography, water conservation, recreation, livestock forage, and tourist/business promotion. With so many varied stakeholders, management of aspen lands in mountain regions can be difficult and socially contentious. Thus, these systems must be managed using sustainable, science-driven, prescriptions that are sensitive to long-term sustainability.

This functional subtype is probably the most common in the western United States; gross estimates suggest that seral aspen comprises about two-thirds of all aspen in the region (Mueggler 1989; Rogers 2002; Kashian et al. 2007). (This estimate, of course, varies from location to

***Figure 4.5a*** *Succession from aspen to fir may occur over several decades.*

***Figure 4.5b*** *Flush of vegetative suckering one year post-fire. Much smaller aspen seedlings were discovered in the second year post-fire at this site, too.*

***Figure 4.5c*** *At this subalpine seral site aspen appear much smaller under older firs. It may be that forest expansion is occurring at stand edges with the oldest trees residing at the center.*

***Figure 4.5d*** *Aspen overtopped by Douglas fir in northern Utah.*

location and is in need of a refined calculation based on remotes sensing and/or national forest inventory data.) Even though seral montane is quite common, managers have often inappropriately treated stable types with prescriptions based on conventional seral practices.

## Stable Aspen

Four stable aspen subtypes exist within our region: parklands, Colorado Plateau, elevation/aspect limited, and terrain isolated. Stable aspen are those types that are made of a single-species cohort, where additional species do not compete over time for stand dominance such as occurs during conventional succession. The term "stable" refers to tree species make-up over time and does not reflect stability or stagnation of ecological interactions (Harniss and Harper 1982). We use this term here where other authors have used "persistent" or "pure" aspen to address the same conditions.

### Parklands

| Major Associates | Minor Associates |
|---|---|
|  | *Quercus macrocarpa; Picea glauca; Pinus banksiana; Populus balsamifera* |

**Location:** Canadian Prairie Provinces (major; AB, SK, MB), Northern Great Plains U.S. (minor), and Alaska

**Topography:** low-angle slopes to flat, punctuated by deep valleys; low elevation

**Stand Size:** variable to large (1-100s acres/ha); formerly contiguous stands partitioned by agricultural activities

**Annual Precipitation:** 14-18 inches (350-450 mm)

**Ecohydrology:** Annual top recharge; limited lateral flow

**Rooting Depth:** Soils exceed root depth; water table confined

**Disturbance and Fire Type:** Historically fire and bison use played a larger role. Today, stand-replacing droughts and insect outbreaks dominate (Hogg et al. 2005).

**Description**—The once contiguous stands of parkland aspen are now highly dissected by human activities, such as farming, ranching, transportation, and development. However, it is thought that even prior to settlement, aspen only covered about one-third of this ecological province (Archibold and Wilson 1980); the remaining portions were primarily grassland and shrub cover. The parklands are located between grasslands to the south and boreal forests to the north, with small portions of stable forest extending into the northern tier of the United States (MT, ND, MN).

**Management**—Timber harvest has not traditionally been economically feasible in aspen parklands due to aspen's slow growth rates and relatively short stature. Mostly these forests are used for livestock grazing and, more recently, as recreation and biodiversity reserves. While climate warming is predicted to cause a northward migration of aspen parklands (Sauchyn et al. 2009), field studies have reported clonal expansions into grasslands

***Figure 4.6a*** *Aerial photo of parklands landscape. Aspen regrowth under drought-related dying mature trees. Photo by: B. Pino*

***Figure 4.6b*** *Prairie and aspen parklands forest.     Photo by: B. Pino*

***Figure 4.6c*** *Interior of parklands aspen stand.     Photo by: B. Pino*

to the south due to elimination of both prairie fires and buffalo grazing (Archibold and Wilson 1980). Restoration of large/frequent historical grassland fires that greatly impacted these forests in the past is unlikely because of modern settlement patterns. Burning at smaller scales may be difficult in all but the driest of years where understory fuels are moister than surrounding prairie.

## Colorado Plateau Highlands And Mesas

| Major Associates | Minor Associates |
|---|---|
| | *Abies concolor; A. lasiocarpa; Quercus gambelii; Picea engelmannii; Pinus aristata; P. ponderosa; Pseudotsuga menziesii* |

**Location:** across high-elevation mesas of the Colorado Plateau ecological province (AZ, CO, NM, UT)

**Topography:** slopes flat to moderate, occasionally steep; all aspects, mostly above 8,000 ft (2,440 m)

**Stand Size:** moderate (10-100s acres/ha)

**Annual Precipitation:** 16-31 inches (412-784 mm)

**Ecohydrology:** Annual top recharge

**Rooting Depth:** bedrock confined

**Disturbance and Fire Type:** Fire is uncommon, but may occur with extreme late-season drying or perhaps abundant downslope fuels. Sustained, large-scale fire is rare in this subtype (Fire Type 1, Appendix 1). A wide variety of diseases, insects, and browsing impacts occur, but they tend to affect individual stems, clumps, or clones and not broad landscapes.

**Description**—Large, high-elevation, plateaus harbor spruce, fir, pine, and aspen forest types across northern Arizona and New Mexico, as well as southern Colorado and Utah. Seral aspen may co-occur in such locales, though expanses of stable aspen may cover relatively flat mesa tops (e.g., Smith and Smith 2005; Rogers et al. 2010). Colorado Plateau stable aspen are strongly influenced by a southwestern United States summer "monsoon," which normally brings regular precipitation to these forests from July through August. Historically, these stable aspen forests have been highly desirable summer grazing pastures for livestock. Thus, reduction or elimination of native understory diversity has commonly occurred across the plateau. In recent times, the value of high-elevation forests surrounded by seasonally hot deserts cannot be understated. Impacts from intense recreation and livestock uses leave long-term marks on these aspen communities.

**Management**—In many instances, long-term human/livestock uses of Colorado Plateau aspen have reduced structural and biological diversity (Rogers et al. 2010; Rogers and Mittanck 2014). Reduced vertical layering of aspen suggests moderate-to-heavy browsing problems. Management actions, whether mechanical thinning, modified grazing regimes, or reduced wildlife numbers, should stress restoring structural diversity. Past management actions in this subtype have often inappropriately used clearfelling or broadcast burning (seral aspen practices) to stimulate further regeneration. In stable communities, however, it is not the lack of disturbance leading to regeneration that is problematic, but the consumption of available sprouts by browsers that causes single-layer aspen stands. Monitoring for key indicators—regeneration with low levels of browse and increasing aspen recruitment—can form the basis for resilience management metrics. Managers may also pinpoint which browsers are responsible for recruitment cessation by pairing tree indicators with animal feces counts (Rogers and Mittanck 2014).

***Figure 4.7a*** *Colorado Plateau stable aspen in southern Utah.*

***Figure 4.7b*** *Landscape view.*

***Figure 4.7c*** *Regrowth after drought-related mortality.*

***Figure 4.7d*** *Drought, herbivory, and sagebrush invasion, Book Cliffs, Utah.*

## Elevation/Aspect Limited

| Major Associates | Minor Associates |
|---|---|
| | *See Seral Montane Major and Minor Associates;*<br>*Low Elev.: Juniperus monosperma, J. occidentalis, J. osteosperma, Pinus edulis, P. monophylla* |

**Location:** throughout the montane zone of Canada, U.S., and Mexico forests

**Topography:** slopes moderate to steep; most commonly S to SW aspects, but this may vary to any aspects at high elevations

**Stand Size:** small to moderate (1-10s acres/ha)

**Annual Precipitation:** similar to Seral Montane precipitation range, although sites may have higher evapotranspiration rates

**Ecohydrology:** Annual top recharge; limited lateral flow (LaMalfa and Ryel 2008)

**Rooting Depth:** bedrock confined

**Disturbance and Fire Type:** : Periodic or partial burning can occur depending on adjacent vegetation or forest communities and intensity of fire. Fire Type 2 (see Appendix 1). Elevation/aspect limited aspen may be affected by a range of other disturbances, including insect and disease infestations, avalanches, development (e.g., ski resorts, vacation homes, etc.), and drought. Increasing climate warming is likely to affect these types, particularly at low elevations (e.g., Worrall et al. 2008, 2013).

**Description**—As the name implies, these stable aspen communities are restricted by certain elevations or aspects in mountainous terrain. They tend to be relatively small and often abut either seral aspen or conifer forests, but may be bordered by other nonforest vegetative cover, such as sage–steppe, meadow, or alpine communities. Sometimes scientists categorize elevation/aspect limited aspen as being "marginal" aspen forests as they are highly subject to drought impacts and may have originally established during wetter periods. Their presence in relatively dry aspects and elevations has pros and cons: they provide diverse habitats, shade, and moisture compared to downslope communities, but they are frequently susceptible to rapid die-offs. Drought may accelerate mortality of whole clones because they attract browsing ungulates. While mature trees are dying from a complex of insects or diseases initiated by drought, wild and/or domestic ungulates may consume the young suckers that grow in response.

**Management**—Typically, these forests are not favored for wood products. In fact, trees are often short, slow growing, and plagued by damage. As suggested above, elevation/aspect limited aspen may receive high use by browsers. Where recruitment is limited and persistent browsing is documented, a chief goal should be restoration of structural diversity (i.e., increasing layers between forest floor and canopy). Even more critical, if recruitment lapses are present, potential causes should be investigated and addressed. Vegetation manipulation to simulate gap/phase dynamics, not large-scale/high-severity disturbance, is most appropriate. Another telltale sign of stand degradation in these forests is the ingrowth of sagebrush (Artemisia spp.) and/or other shrub components over time. Campbell and Bartos (2001) suggest that when sagebrush becomes a dominant understory species (i.e., >15% cover), that such stands should be considered "high priority" for management action.

***Figure 4.8a** Low elevation drought-prone stable aspen.*

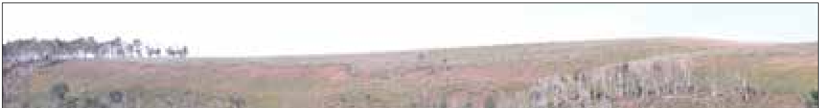

***Figure 4.8b** Stable aspen on south-facing aspect contrasts with montane seral aspen facing north.*

## Terrain Isolated

| Major Associates | Minor Associates |
|---|---|
| | *See Seral Montane Major and Minor Associates;*<br>*Low Elev.: Juniperus monosperma, J. occidentalis, J. osteosperma, Pinus edulis, P. monophylla* |

**Location:** specific topographic conditions within western mountains of Canada and U.S.

**Topography:** diverse formations: concave "snowpockets", talus slopes, moraines, lava fields, avalanche shoots, and other localized geomorphic situations

**Stand Size:** small to moderate (1-10s acres/ha)

**Annual Precipitation:** Similar to Montane precipitation range.

**Ecohydrology:** Annual top recharge; subterranean reserve with high clay content

**Rooting Depth:** bedrock confined (snowpocket and lithic); variable depending on specific situation

**Disturbance and Fire Type:** Fire limited to flammability of surrounding vegetation and/or presence of lithic substrates (e.g., lava flow). Periodic or partial burning can occur depending on adjacent vegetation or forest communities and intensity of fire (Fire Types 1 or 2, Appendix 1). Stands are affected by a range of insects, disease, and physical damages, but often at low-to-moderate levels. Browsing in certain situations, for example on talus slopes and lava flows, is excluded by terrain, thus forming natural refugia in broader landscapes of intense herbivore pressure. Avalanche shoots may act as firebreaks when surrounding by conifer forests (Fechner and Barrows 1976).

**Description**—A single description would not fit the diverse situations under this subtype. Specific situations that allow aspen growth by restricting other tree species from establishing generally isolate these mostly stable types. Examples include snowpocket, krummholz, lithic, moraine, talus, prairie pothole, and avalanche track areas. These isolated situations often display stunted aspen growth forms suggesting water, substrate, or disturbance limitations. Shepperd et al. (2006) describe snowpocket aspen stands as those found in topographic depressions where snow accumulates and is slow to melt. Krummholz occurs where persistent winds blow through exposed aspen stands, severely limiting twig growth via scouring and desiccation.

**Management**—As with other stable subtypes, maintenance or restoration of multilayered stands should guide management. Luckily, the factors leading to isolation of these aspen communities often also assist in their protection from fire, browsing, and other human impacts. Where terrain isolated stands are undergoing degradation, treatments should strive to simulate gap/phase dynamics, not large-scale/high-severity disturbances. Perhaps more than any other aspen

***Figure 4.9a*** *Landscape view of terrain isolated stable aspen in northwest Utah. Subterranean water sources often support these stands.*

functional subtype, these isolated communities will require site-specific considerations in both their assessment and eventual (if any) prescriptions. Adjacent vegetation types, browse level, fire capacity, access to surface and subterranean water sources, periodicity of disturbance (e.g., annual avalanches), and human access will influence specific situations and management options.

***Figure 4.9b*** *Isolated stable aspen growing in subalpine talus.*

***Figure 4.9c*** *Aspen at an outcrop.*

***Figure 4.9d*** *Isolated stable aspen surrounding a spring, western desert, Utah.*

**Seral or Stable Aspen**—As this type implies, functional types under this heading may be either seral or stable. Their distinguishing characteristics lie elsewhere, such as in their proximity to water sources.

### Riparian

| Major Associates | Minor Associates |
|---|---|
| *Abies magnifica; Picea engelmannii; P. pungens; Populus angustifolia* | *Abies magnifica; Acer grandidentatum; Betula occidentalis; Juniperus monosperma, J. occidentalis, J. osteosperma, J. scopulorum, Picea engelmannii; P. pungens; Pinus edulis, P. monophylla, Populus angustifolia* |

**Location:** Throughout montane zone Canada and U.S.

**Topography:** Steep to low gradient; all aspects

**Stand Size:** Small, narrow, linear stands e (1-10s acres/ha)

**Annual Precipitation:** Similar to Montane precipitation range. Available moisture highly supplemented by riparian flow.

**Ecohydrology:** Top recharge; subsurface flow

**Rooting Depth:** Bedrock confined; water table confined

**Disturbance and Fire Type:** Flooding, beaver damage (Johnston and Naiman 1990), browsing/trampling, and fire (infrequent/variable). Fire type not specifically addressed by Shinneman et al. (2013). Fire conditions vary depending on whether seral or stable, as well as surface and subsurface water availability. Wildlife use, as well as browsing/grazing, may be high due to attraction of water source; thus, in some instances, physical wounds from pecking, rubbing, clawing, and bark removal may lead to increased pathogen damage.

**Description**—Riparian aspen subtype includes all stands adjacent to running or standing water. In California, for example, 20th centurychanges to water systems for agriculture and culinary diversions killed some aspen stands (Stine et al. 1984) and spawned others around reservoirs. Riparian aspen, whether seral or stable, stand apart from other aspen communities not only in their susceptibility to difference disturbance mechanisms, but also in their growth and reproduction related to having access to water. When straddling perennial or intermittent streams, aspen may occur in narrow "stringer" stands surrounded by drier uplands of nonforest communities. Occasionally, such stringers may persist below (or above) local tree lines.

**Management**—Management of riparian aspen is often governed by both grazing and timber regulations affecting "buffers" around water sources. Additionally, many of the differences in management approaches between seral and stable aspen mentioned in other subtypes apply here as well. Riparian corridors where aspen are present carry an amplified value as biodiversity oases: in addition to the presence of great floristic diversity of importance to wildlife, available water attracts additional animals and plants that may not utilize upland aspen. So, water quality, quantity, and biodiversity all factor in management decisions and approaches that may not apply in stands distant from riparian areas. Restoration of ecological processes, such as beaver use and occasional flooding, affect (+/-) long-term resiliency (Naiman et al. 1988). Stand replacing disturbances are uncommon and thus, managers should not generally use them as models for restoration efforts. Where loss of vegetation has caused stream incision, artificial replacement of critical elements (e.g., simulated beaver dams) may begin to restore riparian and other wildlife habitat (Marshall et al. 2013).

***Figure 4.10a*** *Riparian seral aspen.*

***Figure 4.10b*** *Riparian stable aspen.*

# Chapter 5 - Developing An Action Plan

## Setting Objectives

*Figure 5.1* Field visits help inform objectives.

Often resource specialists will have some idea of what conditions they are facing and what factors are causing them. Essentially, these are hypotheses, but they are insufficient in and of themselves for formulating objectives. To fully understand resource goals, a deeper knowledge of current conditions is required, preferably a preliminary assessment grounded in one to many lines of evidence. Answers to the following questions provide a framework for formulating initial aspen resource objectives:

1) What aspen functional types are being addressed (Rogers et al. 2014)? While stands are usually comprised of a single type (e.g., seral or stable), larger landscapes may contain a broader range of situations. This step is meant to establish an ecological foundation for subsequent assumptions about expected conditions and potential reactions to treatment, no treatment, and/or climate changes.

2) What currently available resources can inform our objectives? Local expertise, past datasets (climate, management/treatment, grazing, and wildlife records), collaborative group input, published studies, and institutional knowledge and directives may all provide valuable insights.

3) What is the geographic and social context? For example, are current conditions being affected by slope; aspect; proximity to other vegetation

types, water, and developed land (i.e., homes, roads/traffic, industrial facilities); human visitation; grazing allotments; valued wildlife habitat, corridors, or feed/water attractions; or prominent past disturbances?

4) How might the site or landscape limit or enhance treatment options?

5) Resilience is a key goal, but what exactly do managers want these aspen stands to be resilient to? What are the expected threats to resilience and how should the objectives incorporate them?

6) Finally, perhaps most importantly, other than simple observations, how do we know that current conditions require some action? We need to set objectives based at least partially on data gleaned through preliminary monitoring (see the next section).

In sum, resource specialists should support aspen action plans with documentation. The elements presented here provide a structure for science-based management actions.

## Monitoring: Assess Before Action

Monitoring provides at least two advantages within a greater scheme of aspen forest management: it allows a precise understanding of conditions on the ground (rather than guessing at them) and it provides a quantitative baseline for comparison to future measures (e.g., testing results after some treatment action). Given these dual purposes, monitoring requires significant forethought. Not only is it important to thoroughly understand current issues affecting aspen landscapes, but anticipation of likely future forest dynamics is crucial (see "Setting Objectives").

A worthy exercise is to spend a few days conducting test monitoring plots in widely varying aspen situations across the landscape of interest. The amount of total time spent and the level of data collection required will depend, of course, on the geographic scope of the target landscape and available resources. At a minimum, visual assessments and the collection of key indicator data will begin to indicate overall conditions, but more importantly, will guide the magnitude of the monitoring effort ahead. Suggested measures for preliminary surveys include counting regeneration, recruitment, and both live and dead mature trees within fixed sample areas (e.g., belt transects or nested circular/square plots). Additionally, some assessment of recent disturbance and other influences, such as development impacts, will help to distinguish broad characteristics of the landscape. Finally, standard environmental attributes (GPS, elevation, aspect, slope) may also assist in distinguishing different situations and potential methods needs for aspen condition variability across a given landscape. Previous work has determined that a subjective aspen stand condition rating system (Appendix 2) significantly predicts basic stand health, as well as objective measures of stand age, basal area, trees per stand, and scat counts—a surrogate for browser presence (Rogers and Mittanck 2014). In addition to aiding understanding of logistical pitfalls with specific methods, this assessment, along with a review of notes and data, will help to winnow final measures for full-scale monitoring, as well as further refine hypotheses about causes for broad aspen conditions on the landscape. Note that specific targets for key indicators, should be refined based on test monitoring outcomes (see "Document" section this chapter).

***Figure 5.2*** *. Monitoring for aspen regeneration.*

Evidence should now be available for a comprehensive assessment of what managers need to understand aspen status within the landscape in question. An underlying assumption is that resource managers will strive for the most credible survey possible with available resources. Such an assumption will make eventual decisions much easier to justify. Weak supporting evidence opens aspen projects to legal, ethical, or administrative challenges; ultimately, even greater inefficiencies and expenditures will be required if managers choose to pursue project implementation further. Thus, getting it right up front is contingent on collecting good monitoring data, as well as ancillary supporting materials (see "The Adaptive Cycle" section). Resource specialists can now answer a few additional questions before approaching administrators for appropriate funding and personnel to begin monitoring. First, how much time can you afford at each monitoring location—1 hour, 2 hours, 4 hours? Second, what are the likely skill sets available in prospective monitoring personnel? Third, what expertise is required and available to train field technicians? Fourth, will monitoring locations be permanently marked and remeasured or will revisits glean useful information without physical markers? This item entails careful consideration and some level of forecasting of future needs, admittedly a difficult task fraught with uncertainty. Fifth, how will managers handle the data so that so that valuable information will not be lost, the project will be well documented, and the data accessed by appropriate personnel with little explanation (since staff can change frequently)? Sixth, what level of quality control is required to ensure accuracy and consistency? Large monitoring programs may need formal quality assurance plans and, potentially, designated people to implement work inspections. Taken together, these considerations help determine the type and final suite of measures possible (see Table 5.1).

## The Adaptive Cycle: Implement, Monitor, Assess

In this section, our objective is to "put it all together" in a restoration plan composed of specific steps toward managing for resilient aspen communities. In years past, land managers have considered project implementation to be the terminal step in resource management. This guide recommends, for nearly any actions involving aspen restoration, implementing an "adaptive cycle" in which actions are checked along the way via monitoring and course corrections are made where on-the-ground results don't match original intentions. Figure 5.3 outlines the adaptive cycle as a systematic approach for gaining desired results. The next sections describe each step in greater detail.

**Table 5.1** Partial List of Aspen Monitoring Variables, BLM Aspen Field Guide

| Measure | Source | Type | Time Estimate (min)* | Description |
|---|---|---|---|---|
| **PLOT LEVEL DESCRIPTORS** | | | | |
| Plot Identifier | office | assigned | 0 | Pre-number all potential sample plots |
| Aspen Cover | field | estimate | 10-30 | Visual estimates at min. 10 distributed points |
| Conifer Cover | field | estimate | 10-30 | Visual estimates at min. 10 distributed points |
| Sagebrush Cover | field | estimate | 10-30 | Visual estimates at min. 10 distributed points |
| Bare Soil Cover | field | estimate | 10-30 | Visual estimates at min. 10 distributed points |
| GPS Location (area center) | office<br>field | instrument | 1-5 | advise to begin with database coordinates |
| Elevation | office<br>field | instrument | 1-5 | derive from area ave. (office) or GPS reading |
| Aspect | office<br>field | estimate | 1 | derive from area ave. (office) of field estimate |
| Slope | office<br>field | estimate | 1 | derive from area ave. (office) of field estimate |
| Aspen Layers | field | estimate | 1-5 | count of number of distinct vertical layers |
| Aspen Condition Rating | field | estimate | 1-5 | visual estimate with guidelines (Appendix 2) |
| Stand Type | field | estimate | 1-5 | seral of stable aspen, > 10% conifer cover = seral |
| Stand Age | field | instrument | 5-10 | > 2 trees. by spp; ave. age, include growth to DBH |
| Recent Disturbance | field | descriptive | 5 | code describe disturbance affecting > 50% of area |
| Breast Ht/Recruitment Age | field | instrument | 15 | ≥ 5 trees, count basal rings, ave. age to reach DBH 6 ft. |
| Comments | field | descriptive | 1-5 | describe notable disturbance or developments |
| | | | | |
| **SUBSAMPLING** (measuring from less than the total area; specified sample frames)** | | | | |
| Tree Species | field | descriptive | 5 | assign name or establish spp code |
| Regeneration | field | count | 30-60 | aspen/multiple spp; ht classes optional |
| Browse | field | count | 10-20 | terminal leaders browsed (Y/N); as % of all regeneration |
| Recruitment | field | count | 30-60 | aspen/multiple spp; > 6 ft. ht., < mature canopy |
| Mature Trees | field | measure | 10 | diameter measured or diameter classes |
| Mature Tree Status | field | descriptive | 5 | live or dead? |
| Mature Tree Damage | field | assess/ describe | 20 | training required; type/severity of insect, disease, etc. |
| Browser/Pellet Counts | field | count | 10-20 | ungulate scat counts by spp & pellet groups/pies |
| | | | | |

* Time estimates are for items completed independently, efficiencies will increase with concurrent variable measurement.

**Typically measures recorded within fixed subsample areas are expanded, post-field, to estimates for the entire area (e.g., acre/ha)

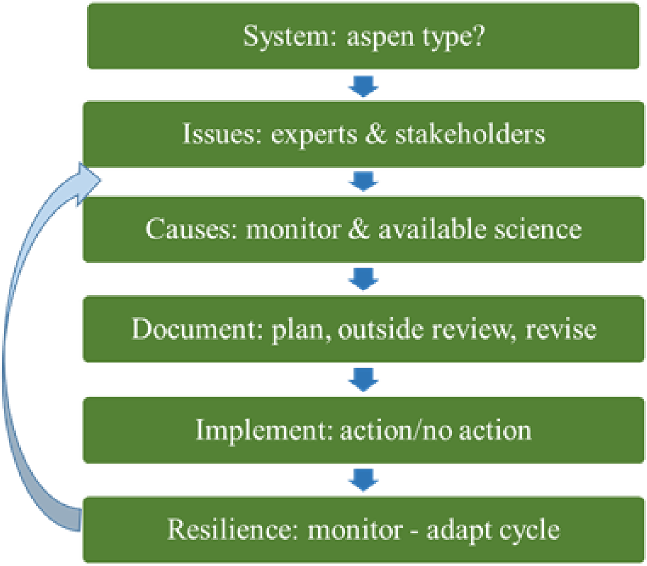

***Figure* 5.3** *Aspen adaptive cycle.*

**System:** Determine what type of aspen community will be the prime recipient of restoration efforts. Perhaps a larger landscape encompasses several aspen functional types (see Chapter 4). This assessment will include gaining an understanding of aspen's ecological variations, as well as some local knowledge of "fit" of target stands/landscapes into the broad functional types previously described (Rogers et al. 2014). The purpose of this step is to provide an ecological framework for subsequent considerations.

**Issues:** Consult with research specialists to gain further perspective of often complex situations. Most land managers are already aware of aspen issues potentially affecting resources; however, sometimes such knowledge may impair alternative explanations of both causes and fixes for declining forests. Consult with additional stakeholders, such as resource users and nongovernmental organizations, through larger collaborative processes or by seeking input directly from a variety of interest groups.

**Causes:** Determine the underlying cause(s) of the current aspen condition, assuming some deviation from a sustainable state. Even after consultation with experts and stakeholders, defensible information is required to calibrate baseline conditions in aspen communities. This is the actual monitoring step discussed in the previous section, but it also involves gathering published materials that address pertinent aspen issues in the landscape of interest. This step probably requires the most consideration and effort. A well-founded monitoring protocol, grounded in demonstrable methods, will form the basis for the entire restoration program.

**Documentation:** Make an initial assessment after data are collected, edited, stored, analyzed, and interpreted. Then evaluate and discuss the "results" with colleagues and partners (if appropriate) and develop an implementation plan. A centerpiece of the implementation plan is to set targets using specific monitoring variables (indicators). These indicator targets will provide specific metrics for triggering adjustments to the adaptive cycle (see Chapter 6, "Adapting Management to Monitoring Results"). At this point, savvy forest practices dictate an outside review: one or more individuals with expertise in resource management should be encouraged to independently review the data, analysis, interpretation, and plan. An interdisciplinary team and/or research specialist may also review the plan. Critical evaluation from those other than sympathetic colleagues will likely save time, resources, and effort in the long run. Objectively consider reviews and make adjustments prior to implementation.

**Implementation:** Make and implement a decision on appropriate actions to take after documenting conditions and developing a plan. This step is one that most forest professionals are very familiar with, so it doesn't require further explanation. Whether managers select active or passive management steps, they will want to ensure they carry out treatments according to prescription.

**Resilience:** Formalize the adaptive cycle. Managers should not consider this step a “final” activity. After implementation, at least one annual remeasurement (and ideally several) of baseline monitoring variables will indicate whether prescriptions had their intended affect: a resilient or sustainable aspen system. A critical look at how the aspen forest responded to actions taken may reveal unexpected causes, more/less intensity of stand deterioration, or ineffective treatments. A reassessment is required, logically placing the restorative actions back at the documentation step, or perhaps further back to take another look at issues and causes. The cycle repeats until the results of monitoring document intended outcomes and/or alignment with ecological pathways.

# Chapter 6 - Aspen 'Monitor And Manage' Toolbox

## Selecting from Restoration Actions

Aspen restoration, like many natural resource measures, rarely takes the form of simple solutions. Rather, there may be multiple causal agents, appropriate treatments, or social considerations for any given situation. This chapter presents a compilation of the most prominent causal agents and restoration options; innovative combinations of these elements will often be required. Thus, weighing the pros and cons of options will assist managers in arriving at the best prescriptions for their particular locales. Table 6.1 organizes aspen restoration "tools" by major causal agents with a brief description of common symptoms of these agents. Chapter 3 of this field guide provides more complete descriptions of disturbances, landscape interactions, and symptoms.

***Figure 6.1*** *This photo suggests drought and herbivory are significant causal agents.*

## Crafting a Functional Aspen Prescription

Field managers must use available tools to craft on-the-ground prescriptions, which is often the central task of vegetation stewards. In recent decades, "ecosystem management" and "resilience management" have relied heavily on the tenet of emulating natural disturbances (as well as the functional aspen type system used here) in selecting forest prescriptions (Rogers 1996). While utilization of wood products is often a treatment outcome, most modern aspen management is initiated with the goal of restoration when measurements (see Table 5.1) indicate an aspen forest or landscape is declining or deviating from its natural range of variation (Landres at al. 1999). This section elaborates on key prescriptions and their applications under a functional type framework (Chapter 4) and an adaptive cycle approach contingent on systematic monitoring (Chapter 5). Appendix 3 provides an annotated management plan outline as a starting point for any aspen prescriptions.

***Figure 6.2*** *Cut and fence.*

**Table 6.1:** Potential restoration actions for aspen communities by causal agent. It is assumed

| Agent | Symptoms | Primary Action | |
|---|---|---|---|
| Herbivory | Cattle, sheep, deer, or elk consistently removing new growth in regeneration and recruitment; browsed terminal leaders; vegetation trampling; mature stem scarring; long-term loss of structural/vertical diversity in aspen stems | Reduce animals | |
| | | Move animals | |
| | | Rest-rotation | |
| | | Fencing | |
| | | Burning | |
| | | Tree harvest - select, patch, or clearfell-coppice | |
| | | Root ripping | |
| | | No action | |
| Conifer encroachment/ fire suppression | Advanced succession of conifers in seral aspen stands reduces ability of aspen to recover after disturbance; low regeneration; dying aspen overstory | Tree harvest - select, thin, patch, or clearfell-coppice cuts | |
| | | Curb suppression - "wildland fire use" | |
| | | Burning | |
| | | No action | |
| Insect & disease outbreaks | Mostly affecting mature trees, may also infest roots; large variety of stem, branch, root, and leaf pathogens, often combined with host-specific insects, may kill large portions of aspen clones; die-off usually takes years and (particularly where multiple clones) does not kill entire stands; should cause moderate-to-strong aspen regeneration response | Tree harvest - select, thin, patch, or clearfell-coppice cuts | |
| | | Spraying (pesticide/ insecticide) | |
| | | No action | |
| Climate/ drought/ frost | Mostly affecting mature trees, may also affect roots; cavitation, embolism, leaf browning | Manage for age, species, landscape diversity using active/passive actions above | |
| | | No action | |

that multiple actions may be combined where appropriate.

| | **Pro** | **Con** |
|---|---|---|
| | Provides immediate relief to aspen and understory regrowth; immediate livestock management increases changes of long-term use; short-term increase in hunter opportunities for success | impact to economics of domestic livestock - proactive management increases costs; reduces long-term hunter success and potentially revenues from license sales |
| | Provides immediate relief to aspen and understory plant regrowth; increases quality of forage in later years | Additional expense/planning required for domestic livestock; possible increase in hunting difficulty or decreased success rate |
| | Provides temporary relief to aspen suckers after disturbance/treatment. Typically animals removed from target area 2-5 years, then allowed to re-enter. Allows producers to continue use. | After reintroduction of livestock, this may prevent continuous, low-level, regeneration between large disturbances. Wildlife are not excluded and may be attracted to target area if more sucker forage is available. |
| | Effectively eliminates browsing for a select period of time - usually until aspen stems grow beyond "browse height"; very effective for small areas and/or demonstration sties | Expense; not realistic for large landscapes or regions due to expense and maintenance; even for small areas, regular fence line checking and maintenance costs must be accounted for |
| | Where appropriate (see Chapter 3), provides relatively low-cost method for stimulating aspen regeneration and potential seedling establishment | Dangers of escaped prescribed fire; possibility of exacerbating lack of regeneration, even complete aspen loss, if plan for herbivory reduction is not in place prior to action |
| | Income may offset costs of restoration; if only for regeneration, partial cuts/leaving logs may be cost effective and provide some protection from herbivory | Possible detrimental effects if direct reduction of herbiory is not addressed; clearfell most appropriate in seral aspen, but comes with greatest risk with herbivory |
| | Sever roots using disc cutter or other form of below ground cutting device to promote suckering; low cost; effective for quick sucker response; most useful where tree harvest not economical | Likely ancillary damage to tree and understory plants; if done without browse protection strategy, may hasten stand die-off; not economical for large landscapes |
| | Low cost; minimal intrusion and possibility that large enough natural disturbances will overwhelm herbivores | Potential for large-scale aspen loss (particularly stable aspen), depending on degree/constancy of browsing |
| | Income may offset costs of restoration; if only for regeneration, partial cuts/leaving logs may be cost effective and provide some protection from herbivory; some evidence suggests greater water retention with conifer removal | Conifer reduction may have undesirable affects on conifer-dependent species; possible detrimental effects if direct reduction of herbiory is not addressed; clearfell most appropriate in seral aspen, but comes with greatest risk with herbivory |
| | Cessation of suppression activities, particularly in remote areas, may save resources and (over time) reduce conifer buildup; | Cessation may facilitate dangerous fire conditions near development; even large burns may not be enough to overwhelm browsers, resulting in aspen cover loss |
| | Where appropriate (see Chapter 3), provides relatively low-cost method for stimulating aspen regeneration and potential seedling establishment | Dangers of escaped prescribed fire; possibility of exacerbating lack of regeneration, even complete aspen loss, if plan for herbivory reduction is not in place prior to action |
| | Conifers will eventually be reduced/removed via disturbance, saves costs with minimal intrusion | Aspen may be lost from certain systems, particularly where exacerbated by herbivory, drought/climate, or stand-replacing insects/disease complexes |
| | Useful for hazard tree reduction; may slow spread of I & D to unaffected areas or clones; will stimulate regeneration and build long-term resilience via structure/age diversity | Only minor effectiveness is likely outcome; expensive with low probability of cost recovery due to decayed or damaged wood product |
| | May stem the tide of local decline over several years with consistent application | Expensive to continually apply; may affect non-target plants; potential of secondary effects to plants, animals, water on site and downstream |
| | Stimulate regeneration to increase resilience; save on time/money expenditures | Some/many mature aspen may die; combined with herbivory and/or drought, I & D complexes may result in local or regional aspen cover loss |
| | Increases landscape/species diversity for many aspen-associated species | No guarantee of success, but increased resilience increases chance of positive outcome; same potential pitfalls of any/all actions employed |
| | Plant tissue may recover quickly from brief drought and frost events; potentilly simulating regeneration and increasing age/structure diversity | Long-term effects may cause broad aspen mortality and/or system conversions and/or migrations |

The underlying assumption of aspen functional types is that is that managers will select those options that most closely mimic ecological processes (Rogers et al. 2014). Thus, seral aspen communities require different restoration approaches than stable aspen communities. For example, prescribed fire in stable aspen is not only difficult to maintain, it has little ecological precedent (Shinneman et al. 2013). Similarly, in most instances, clearfell–coppice harvest would not be appropriate as a means of regenerating stable types, as they would rarely experience stand-replacing disturbance. Further, the aftermath of clearfell–coppice in stable aspen creates a single cohort structure where multiple layers are the natural condition and provide greater resilience (Rogers et al. 2014). The following sections provide brief descriptions and appropriate uses of treatment alternatives.

**Clearfell-Coppice Cut**—A coppice (unlike a "clearcut") indicates total dependence on regeneration from root sprouting, although seedlings will sometimes germinate with this practice (Landhäusser et al. 2010). As the name implies, clearfell–coppice involves total removal of the overstory. Once widely used for all aspen communities, this method is most appropriate for seral types that are subject to stand-replacing disturbance. Even in such instances, particularly if browsing is a concern, a safer approach is to leave small mature aspen clumps and individuals to provide sustained suckering should initial regeneration fail.

**Selective Cut**—Removal of less than half the mature aspen canopy cover is a common forestry practice that is most appropriate in stable aspen where, for whatever reason, recruitment has been unsuccessful. The theory here is to create uneven age classes that mimic those of healthy stable aspen types. Numerous variations of selective aspen harvest exist, most varying by percent of overstory removal. Visiting an intact stable aspen forest is instructive toward selective harvest prescriptions. Mature trees tend to die as individuals or in small groups (root or stem decay infection centers). Thus, simulation of these mortality patterns is likely to restore the multilayer structure of such communities if browsing impacts improve.

**Root ripping**—Mechanically separating roots from parent root systems is a means of stimulating sucker production (Shepperd et al. 2006). A ripping device mounted on a tractor and set to a depth of 6–10 inches (15–25 cm), using only a single tine, will yield ample regeneration without the need for tree harvest (multiple tines can destroy roots by creating many segments that will not sprout). One experiment found that root ripping approximately doubled the number of stems produced when compared to an untreated fenced area (Shepperd 2004). Once again, stimulation is only half the objective; the other half aims to prevent posttreatment browsing.

**Vegetation Removal**—Managers sometimes think that dense understory vegetation prohibits aspen regeneration, but aspen suckers do naturally occur in very dense herbaceous layers. Exotic plants or shrubby understories can overwhelm successful aspen establishment and/or limit sunlight to the forest floor. In such cases, managers may elect either mechanical or burning approaches to reduce cover and stimulate aspen growth. This same principle applies to removal of competing trees, usually conifer species, from all levels of the forest. While reducing cover may stimulate regeneration, there is little ecological precedent for such approaches; thus, managers should pause and reconsider the ultimate objectives. In instances where managers remove competing vegetation, the result is likely temporary, making repeat visits to achieve objectives necessary.

**Prescribed burning**—There are many advantages to prescribed burning, but they usually only apply to seral aspen (Shinneman et al. 2013). Where appropriate, burning often must be moderate to high-intensity to simulate disturbance under natural conditions. "Selective" burning or understory burning may result in death of mature aspen trees where basal scorch can easily kill stems. Wildland fire use, similar to prescribed burning, can provide many of the same benefits and should be used toward aspen restoration to the extent it is safe and possible.

**Aspen as fuel break**—In select areas, such as near homes, campgrounds, or other developed areas, thinning of conifers and management for aspen can act as fuel breaks due to aspen's generally inflammable nature (Fechner and Barrows 1976). Creation of 100–200 foot (30–60 m) localized pure aspen stands will greatly reduce or even stop an oncoming forest fire. This approach is recommended for urban and exurban interface communities bordered by seral aspen types and it defers from our broad recommendation of mimicking natural processes. Generally, greater deviations from the "natural range of variation" are favored, even encouraged, near development.

*Figure 6.3 Prescribed burn.*

**Protection from Browsing**—Often simple protection from browsing will be enough to sustain resilient aspen communities—both stable and seral. However, protection from browsing is particularly important in stable communities that normally cannot rely on stand-replacing disturbances to stimulate suckers. If browsing is the chief causal agent of decline in a given stand (as evidenced by onsite monitoring), then prescriptions ought to target that cause and may forego additional active management. The difficulty lies in finding effective methods of protection within resource budgets. Fencing works well for small targeted areas (<~100 acres/40 ha), but is impractical at landscape or regional scales. Collaborative work with wildlife and/or range specialists to reduce or move ungulate populations is a more direct approach to combating browsing issues. However, administrative, political, and social obstacles (e.g., tax credits awarded for livestock grazing on private lands) that often encumber such actions may require long-term resource and personnel commitments.

**Mixed Prescriptions:** As alluded to throughout this field guide, real solutions will often require commitment to multiple prescription approaches. The most common approaches will, at least, involve concrete plans for aspen stimulation and posttreatment protection. Domestic livestock should be removed from aspen treatment areas for a minimum of 2 years (4–5 years recommended). Wild herbivore hunts may be increased, with wildlife agency coordination, for a similar period after treatments. On average, aspen take 5 years to reach above normal browse height for wildlife (Rogers et al. 2010), which may provide some guidance for the duration of special hunts, as well as livestock rest recommendations. The only way to document whether prescriptions are successful is to institute a systematic monitoring plan.

## Focus on Fencing: pros and cons

Managers and ranchers have used a number of fence designs to prevent posttreatment browsing of aspen suckers (e.g., VerCauteren et al. 2007). Fences are an effective way of temporarily keeping herbivores from browsing emerging aspen suckers. In most instances, managers and ranchers use fencing to allow aspen sprouts to "escape" herbivory until such time as they are above browse height (6 ft./2 m). (In situations of very high elk density, animals have pushed over much taller trees to access leaves and twigs.) Time required to reach this height, in the absence of browsing, varies considerably from 2–10 years or more, depending on growth conditions. Ancillary benefits may include successful reproduction of understory plants, increased

***Figure 6.4*** *Fence allowing access for deer (see gap at base), but not for cattle or elk.*

diversity of animals requiring additional cover and structural diversity, and soil moisture retention from shading. Exclosures have proven to be effective demonstration sites of aspen sprouting potential. Experiments with cutting trees in a fashion to simulate fencing (“hinging”), or at least barriers to access from browsers, are a pseudofencing option that has had some success (Kota and Bartos 2010). Pseudofencing presents a low-cost alternative to traditional fencing techniques that may be effective at low-to-moderate herbivory levels.

Fencing cannot solve all browsing problems. Foremost, it is an expensive management tool that is best when applied in small, targeted, situations such as campgrounds, riparian areas, recreation sites, housing developments, or other noteworthy aspen groves. The cost of fencing herbivores out of large aspen landscapes, whether posttreatment or as a passive treatment alone, is often not feasible. Costs of fencing extend far beyond original construction to active patrolling for fence breaches and timely repairs of missing sections. Even 1 week of animal access, depending on quality forage availability and the number of animals, can result in the loss of long periods of sucker protection. Secondly, serious thought is required to determine exact fencing aims and the duration of fence use. Effective fencing prevents all large herbivore browsing. Is the desired objective to have zero herbivores in designated areas? Often this is the case for short periods, but ultimately managers will need to address base causes. Ideally, long-term management goals will facilitate cohabitation by herbivores, be they wild or domestic, at appropriate levels to sustain aspen communities. Since aspen stems self-thin based on resource availability, there are normally many times more initial suckers than ultimate survivors; thus, modest levels of browsing are permissible without threatening aspen resilience. We recommend striving for process balance, not complete restriction, to simulate ecosystem function (rather than getting into high-cost, high-maintenance, fencing-to-prevent-browsing cycles).

## Adapting Management to Monitoring Results

As discussed in Chapter 5, monitoring results should drive followup actions. While this may seem intuitive, previous experience suggests that there are a number of barriers to establishing these practices, such as neglecting monitoring altogether (assuming positive outcomes), budget shortfalls, insufficient data collection, loss of data or institutional knowledge when key employees leave a position, and lack of employee resources due to other agency priorities. For these reasons, recommends prioritizing monitoring even at the cost of full project implementation. After all, if we cannot gauge success/failure and make appropriate adjustments to implementation, we may find ourselves in a situation where an entire project is deemed a failure before we have appropriate data to make course corrections. This total loss scenario is more common than might be expected.

So what are key trigger points and actions that monitoring should prompt? Specific management objectives set in the document (plan) section of the adaptive cycle should drive actions.

For example, the literature may provide targets for amount of regeneration, recruitment, and browse level may be found in the literature. Managers must weigh the benefits of standardized targets versus those developed through localized studies or past monitoring actions. Normally, local information will yield better results, but standardized targets give a starting point (e.g., Mueggler 1989; Campbell and Bartos 2001). A simple approach for developing a site-based metric for sustainable recruitment (immature stems >6 ft./2 m height) is to derive the percentage of these stems as a portion of live mature aspen. Managers should target 100% recruitment as a minimum goal. A smaller percentage of recruitment-to-mature-trees indicates cause for

***Figure 6.5*** *Browse indicators: clipped aspen leader and elk scat.*

concern. Less than 50% may be deemed "nonsustainable" and trigger adjustment to, for example, allowable browse

levels (Rogers and Mittanck 2014). Similarly, though further along in succession, objectives for conifer encroachment may include basal area of "leave trees," conifers per acre (hectare), light penetration, or a combination of thriving aspen suckers (nonbrowsed), aspen recruitment, and conifer cover, basal area, or stems per area. A wider base of indicators, again dependent on documented objectives, may include understory species diversity or cover, soil conditions (bare soil exposure, erosion level, litter depth), and a range of faunal monitoring targets based on functional groups (e.g., arthropods, birds, mammals). A novel approach used in both Europe and North America to assess aspen community health has been documentation of epiphytic lichen communities (Hedenås and Ericson 2000; Rogers et al. 2007b).

***Figure 6.6*** *Arboreal lichens growing on aspen in Arizona.*

In summary, there are numerous metrics or indicators from which to choose. Resource managers should select indicators based on a combination of immediate monitoring and anticipated needs, plus a selection of standard forest metrics for comparison to other areas (past and present). Appendix 4 presents a sample aspen stand monitoring form that resource managers can easily modify for local use.

Managers should use local pilot studies and review similar studies to determine threshold values, then use those metrics as trigger points when evaluating monitoring results. Adjusting management practices based on targeted data collection is smart management, not a sign of poor planning or a project gone awry.

## Where to Find More Aspen Information

At several points within this field guide, we have urged managers to consult experts, literature, or other existing resources prior to taking action or developing a plan. As a rule, it is prudent to check sources from multiple perspectives and authors before incorporating them into either your personal knowledge base or expected implementation practices. Checking background sources is time consuming, though it is an essential part of making informed resource decisions. Following are some key sources for contemporary aspen ecology to make this task a little easier.

### Science-based Aspen Organizations—

Western Aspen Alliance, Utah State University:
http://western-aspen-alliance.org/

Aspen Ecology, Brigham Young University: http://aspenecology.org/

Poplar and Willow Council of Canada: http://www.poplar.ca/

### Online Databases—

Aspen Bibliography, Utah State University/Western Aspen Alliance:
http://western-aspen-alliance.org/images/searchAspenLit_r2_c1.png

Aspen Spatial Bibliography, Brigham Young University/Utah State University/Western Aspen Alliance: http://byu.maps.arcgis.com/apps/webappviewer/index.html?id=924b25d70cc34cf685e79b57fc2bd8cd

(Aspen) Expertise Database, Utah State University/Western Aspen Alliance: http://western-aspen-alliance.org/ (members login, register their expertise, and search for expertise contact information in dozens of topic/disciplinary categories).

## Agency Reviews, Proceedings, Reports:

O'Brien, M., P.C. Rogers, K. Mueller, R. MacWhorter, A. Rowley, B. Hopkins, B. Christensen, and P. Dremann. 2010. Guidelines for aspen restoration on the National Forests in Utah. Western Aspen Alliance, Utah State University, Logan, Utah. 47 pp.

http://western-aspen-alliance.org/pdf/AspenRestoration.pdf

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http://www.treesearch.fs.fed.us/pubs/24485

Shepperd, W.D., D. Binkley, D.L. Bartos, T.J. Stohlgren, L.G. Eskew (compilers). 2001. Sustaining aspen in western landscapes: Symposium proceedings, June 13–15, 2000, Grand Junction, Colorado. RMRS-P-18. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO. 460 pp.

http://www.treesearch.fs.fed.us/pubs/4696

Peterson, E.B. and N.M. Peterson. 1992. Ecology, management, and use of aspen and balsam poplar in the Prairie Provinces, Canada. Special Report 1, Forestry Canada, Northwest Region, Northern Forestry Centre, Edmonton, AB. 252 pp.

http://digitalcommons.usu.edu/aspen_bib/2512/

DeByle, N.V. and R.P. Winokur (eds.). 1985. Aspen: Ecology and management in the western United States. RM-GTR-119. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. 283 pp.

http://digitalcommons.usu.edu/aspen_bib/6964/

## Journals and Special Issues—

-*Forest Ecology and Management,* Elsevier

Special Issue: Resilience in Quaking Aspen: restoring ecosystem processes through applied science. 2013. Vol. 299. (review articles on the state-of-the-science in ten aspen subject areas: resilience management, molecular tools/genetics, chemical defense, fire regimes, recent declines/climate, historic cover change, aspen/mountain pine beetle, wildlife/trophic cascades, ungulate herbivory, and facilitation/competition).

http://www.sciencedirect.com/science/journal/03781127/299

-*Forest Science,* Society of American Foresters

-*Journal of Forestry,* Society of American Foresters

-*Western Journal of Applied Forestry,* Society of American Foresters

-*Canadian Journal of Forest Research,* Natural Resources Canada Research Press

-*Journal of Vegetation Science,* International Assoc. Vegetation Science (Wiley Online)

-*Biological Conservation,* Elsevier

-*Restoration Ecology,* Society for Ecological Restoration (Wiley Online)

-*Rangeland Ecology and Management,* Elsevier

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# Appendix 1:  Key Terms

**Active Management:**
Human actions that intend to physically, directly, manipulate vegetation or wildlife towards a goal of restoring ecosystem composition or function. Examples include tree cutting, burning, root ripping, seeding, introduction of plant or animal species, or soil disturbance.

**Adaptive Cycle (of management):**
An approach to stewardship that is highly dependent on ongoing monitoring to inform adjustments to management actions over time. This approach contrasts with some traditional practices involving design and implementation of prescriptions without followup monitoring and/or course correction if undesirable outcomes persist.

**Auxins:**
Hormones that regulate plant growth, usually via cell elongation. In aspen, auxins located in the apical meristems may suppress ramet sprouting when trees are healthy. Interruption of auxin transfer to the roots, such as when the aboveground ramet dies, facilitates a flush of regeneration.

**Boreal:**
Forested region just south of the Arctic zone (also called taiga). These forests comprise very large areas of northern Canada and Alaska where North American aspen mix with conifers, as well as lesser amounts of birch and poplar.

**Catkins:**
The flowering portion of aspen trees. Catkins may be either male or female in aspen, allowing distinction in genotypes by sex (see Dioecious).

**Clearfell–Coppice Harvest:**
Complete harvest of aspen overstory with the intent of encouraging regeneration via root suckering (vegetative reproduction) rather than seeding or planting. This traditional aspen harvest approach is more appropriate for seral than stable aspen, but there are additional concerns about impacts to associated plant/animal communities with this approach.

**Community:**
Synonymous with "ecosystem." Refers not to individual species (often aspen), but to whole communities that are ecologically linked to, or even dependent upon, that species.

**Cytokinins:**
A class of plant hormones responsible for increased cell division and plant growth. Cytokinins in aspen root tips

may be the key chemical responsible for active ramet sprouting, particularly following aboveground disturbance.

**Dioecious:**
Plants having distinct male or female reproductive organisms on different individuals or, in the case of aspen, clones. Thus, entire aspen clones are either female or male.

**Elevation/Aspect Limited:**
Relatively small, stable aspen forests set apart from conifer or mixed types by their preference for specific aspects, elevations, or combinations of both.

**Fire Regime:**
Measurable parameters, often expressed in terms of an average, which characterize wildfire in specific forest types or communities. Common measures expressed in fire regimes are size, frequency, seasonality, and severity. Fire regimes in aspen vary considerably based on functional type and age, presence, density, and species of forest cohorts. See Shinneman et al. (2013) for a detailed discussion of aspen fire types.

**Fire Severity:**
The measurable change in vegetation (amount or biomass) from before to after a given fire event. In general, stable aspen will burn less severely—often not at all—compared to seral types. See Shinneman et al. (2013) for a detailed discussion of aspen fire types.

**Fire Type:**
Categories per Shinneman et al. (2013):

- Fire Type 1—Fire-independent, stable aspen
- Fire Type 2—Fire-influenced, stable aspen
- Fire Type 3—Fire-dependent, seral, conifer–aspen mix
- Fire Type 4—Fire-dependent, seral, montane aspen–conifer
- Fire Type 5— Fire-dependent, seral, subalpine aspen–conifer

**Genet:**
The entire group, or clone, of genetically identical stems. These groupings comprise aspen as a genotypes, as opposed to as single stems (see Ramet).

**Herbivory:**
The eating of plants by animals. Relating to aspen, herbivores generally come in two types: mammals and insects. Generally speaking, insects prey on herbaceous (soft) material and can have great impacts in mass attacks on mature trees. Mammalian herbivores, often ungulates, consume juvenile aspen. A notable exception is the beaver, which harvests both young and

relatively mature aspen stems for food, habitat modification, and lodge building.

**Indicators:**
Key monitoring indices that, in theory, represent broader conditions of a community, landscape, or region than simple mensuration measures. Examples include recruitment rate (long-term herbivory and structural stand health), percent bare soil (trampling, erosion, and plant diversity), and lichen diversity (greater biodiversity, human alteration, and air quality).

**Natural Range of Variation (NRV):**
The concept that a given ecosystem is dynamic over time within a broadly defined range of conditions determined by disturbance and climate. Species compositions fluctuate over time. Status outside the NRV may require restorative management.

**Parklands:**
A wide arc of stable aspen communities found in south-central Canada (AB/SK/MB) and small portions of the United States (MT/MN). Agricultural development has impacted much of this area over the previous century.

**Passive Management:**
Activities that do not directly manipulate plant or animal species to restore ecosystem composition or function. Examples include fencing herbivores out, using noises or scents to dissuade herbivory, reducing human use to encourage wildlife, allowing wildfires to burn, and changing livestock use patterns.

**Ramet:**
A stem or branch of a larger group of genetically identical organisms. In aspen, each stem within a clone, whether remaining attached via roots or not, is known as a ramet.

**Regeneration:**
Recently sprouted suckers or new seedlings. Density of regenerating stems on a per area basis provides estimates of response to disturbance, ongoing growth, or general root system health. Regeneration stems are distinguished from recruitment, as a general rule, by being <6 ft. (<2 m) in height.

**Recruitment:**
Aspen suckers that are most likely to replace mature canopy stems in the future. Recruitment stems are those >6 ft. (<2 m) in height. Stems taller than 6 ft. are assumed to have "escaped" browsing from elk, deer, cattle, and sheep (in most instances).

**Riparian Aspen:**
Aspen forests growing within ready access to water (riparian zone) and often surrounded by nonforested

conditions. These functional aspen types, both seral and stable communities, display different characteristics and disturbance regimes than upland types.

**Resilience:**
Ability of an ecosystem to respond positively to human or natural disturbance over long periods. Commonly, this does not necessarily mean that an ecosystem retains exact plant/animal composition, but that it retains key ecological processes over time and in the face of stochastic, intrinsic, and extrinsic forces. With the number of unknown outcomes expected under human-caused climate change, "resilience" provides a practical goal for many management prescriptions at a variety of scales.

**Seedling:**
Aspen regeneration originating from sexual reproduction (i.e., seeds and not root suckers) and comprising a new genotype (i.e., genet). Recent research has shown that seedling occurrence, traditionally described as being rare, is much more common following fire (and potentially other disturbances) than previously thought.

**Seral Aspen:**
Functional aspen types subject to succession, usually from shade tolerant conifers. Seral aspen, in general, are more likely to be governed by stand-replacing disturbance events than stable types. Following such events, fast-growing aspen regeneration will dominate sites initially, though aspen will eventually compete with conifers for resources.

**Stable Aspen:**
Aspen communities with little or no competition from other tree species. These pure or nearly pure aspen forests are commonly multilayered and rarely subject to stand-replacing events. Replacement of the overstory over time occurs through individual and small group mortality and subsequent gap infilling.

**Sucker(ing):**
Aspen ramets originating asexually from root meristems. The process of sprouting ramets from lateral roots.

**Sudden Aspen Decline:**
Death of overstory AND root systems within a relatively short period (3–5 years). While the term is frequently used, it has not been widely documented without invocation of longer term browsing, fire suppression, drought, or altered vegetation and disturbance types. Commonly, local or regional rapid overstory die-offs are followed by vegetative root regeneration and, less

often, seedling establishment; this pattern does not qualify as sudden aspen decline.

**Terrain Isolated:**
Relatively small, stable aspen forests surrounded by nonforest communities for reasons related to physiographic position. Examples of terrain isolated aspen include those found in landscape depressions or on moraines, avalanche chutes, volcanic outcrops, or talus slopes. Vegetation communities surrounding these isolated types, as well as the unique substrates in which they occur, clearly influence their functional ecology.

**Trophic Cascades:**
Ecological processes, often predator–prey–vegetation interactions, affecting three or more trophic levels. An abundance of research affecting aspen communities has investigated negative influences (or not) that the absence of apex predators (e.g.,wolves) has on key herbivores and subsequent aspen reproduction.

**Wildland Urban Interface (WUI):**

Where suburban or exurban human development intermixes with forest communities. Interface communities are more technically defined by the Forest Service as those lands with development within 1.5 miles (2.4 km) of >50% wildland vegetation. With respect to aspen, the WUI may be actively managed to promote aspen communities as firebreaks. Generally, the higher the aspen composition of a forest (versus conifers), the greater the likelihood of reducing fire spread and overall impacts.

# Appendix 2: Aspen Stand Condition Rating System

The purpose of the visual rating system is to provide a quick subjective assessment of aspen conditions at the stand level when resources and time are limited. This system has been tested (and peer-reviewed) as a significant measure of key, objective, field-measured variables (Rogers and Mittanck 2014; Rogers et al. 2015). This measure works best when supplemented by 1–5 field metrics (see Table 5.1), in particular recruitment, browse level, and mature tree status and damage.

Estimate the overall visual stand condition using this subjective ranking tool. The key indicators include aspen mortality, the condition of stems under 6 ft./2 m tall (regeneration) and over 6 ft./2 m tall but short of the overstory or canopy (recruitment), and the overstory/canopy. Record one of these categories on the field form:

1. Good (meets all three criteria):
    - Minimal overstory mortality and stem disease present (< 5%);
    - Several aspen layers (> 3) visually identifiable; AND
    - Browsing impacts on regeneration uncommon (< 25%).
    - To be ranked 'good,' all three criteria met.
2. Moderate* (stands not fitting into categories 1 or 3).
3. Poor (meets two criteria):
    - Overstory mortality and/or stem cankers common (> 25%);
    - Visual aspen layering absent or minimal (1-2 layers only); OR
    - Browsing impacts clearly evident (> 50%) on regeneration.

*The system is designed to favor ratings of moderate by making rankings of "good" or "poor" more difficult to achieve.

# Appendix 3: Annotated Management Plan Outline

This annotated management plan outline provides a "starter kit" for those wishing to begin a large and potentially complex aspen project. The BLM's Vernal Field Office in Utah completed a management plan using a similar approach (Rogers et al. 2013).

## Summary

Provide a brief overview of the project using laymen's language Include geographic scope of project.

### Introduction

1. **Purpose and Need**
   Define objectives.
   Provide an overview of quaking aspen and key local issues (cite relevant literature).

2. **Data Collection**
   Provide a detailed summary of the aspen adaptive cycle steps 1–4.
   Select key indicators for aspen system, supplement with traditional and locational measures (optional). Use remote data sources: available mapping databases, remote sensing data, and photos.
   Collect field monitoring data, check for errors/correct, and store in secure location.

3. **Analysis and Results**
   Summarize data in descriptive figures and tables. Perform basic data analysis—baseline or change analysis.
   Interpret and document results (are they reliable, what do they mean).

4. **Implement Plan**
   Acquire necessary public input and administrative approvals.
   Implement management actions (aspen adaptive cycle step 5).

5. **Posttreatment Monitoring**
   What is the appropriate time gap between action and monitoring?
   Collect remeasure data, photos.
   Do results confirm/reject expectations?

6. **Management Recommendations and Adjusted Plan**
   (Repeat 3 above.)
   Formalize adaptive cycle (step 6).
   Is target aspen stand or landscape more/less resilient? What actions, if any, are required based on monitoring results?

7. **References**
   (If appropriate.)

# Appendix 4: Sample Monitoring Form

## Page 1

**Data Sheet: Book Cliffs Aspen Monitoring 2012**

**plot#:** ____ date ______ GPS X ________ GPS Y _________ Elev. ________ Stable (1) or Seral (2)____

# Stand (aspen) layers ______ 1st Disturbance _____ 2nd Disturbance _____ Stand condition_____ Percent polygon aspen ______

Cover: Tr #1 A__ C__ S__ A__ C__ S__ A__ C__ S__ A__ C__ S__ A__ C__ S__ A__ C__ S__ A__ C__ S__ Aspen stand age ____

Cover: Tr #2 A__ C__ S__ A__ C__ S__ A__ C__ S__ A__ C__ S__ A__ C__ S__ A__ C__ S__ A__ C__ S__ Understory cover____

Plot-level comments: ____________________
____________________
____________________

| Fecal Count (transect): | 1 | 2 |
|---|---|---|
| Cattle | | |
| Sheep | | |
| Elk | | |
| Deer | | |

**Tree Tally (classes = 1 Regeneration; 2 Recruitment; 3 Mature):**

| Line | transect # | class | species | count | browse | dead | dbh class | comments |
|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | |
| 2 | | | | | | | | |
| 3 | | | | | | | | |
| 4 | | | | | | | | |
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| | Photo Point ID |
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| N | |
| S | |

## Page 2

| Line | transect # | class | species | count | browse | dead | dbh class | comments |
|---|---|---|---|---|---|---|---|---|
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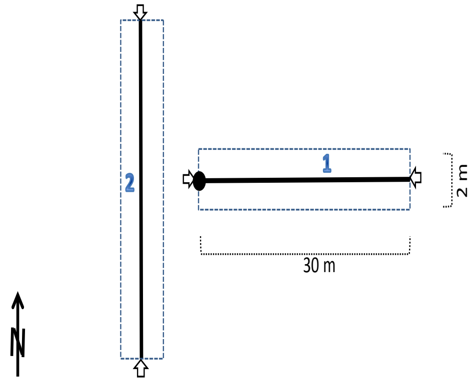
| 40 | | | | | | | | |

### Plot layout: Book Cliffs Aspen Monitoring 2012

● Plot center
⇦ Photo point & direction
— Sampling transects



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