Part 4: Forest Succession

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Introduction

The ecosystems within the area that burned in the Hayman Fire have a long history of fire (see part 1 of this chapter). It follows, therefore, that all of the native species and populations in this area probably have one or more mechanisms for enduring fire or becoming reestablished after fire and that no native species is likely to become extinct as a result of the direct effects of the Hayman Fire. It also follows that active rehabilitation is not required for all of the burned area. In fact, much or even most of the area is likely to recover normally without intervention, and in some areas our well-intentioned rehabilitation efforts actually could interfere with natural recovery processes.

Despite the general expectation just stated, ecosystem recovery and native species persistence is likely to be problematic within certain portions of the Hayman burn area. In other parts of the burned area, postfire trajectories may lead to ecological conditions different from what existed just before the Hayman Fire, but nevertheless within the historical range of variability for this ecosystem. Therefore, in addressing this question, we describe three potential postfire trends in vegetation development, and indicate generally where in the Hayman landscape each trend is likely to be manifest. The three trends are (1) development of vegetation structure, composition, and function *similar* to what existed just before the Hayman Fire, (2) development of vegetation that is different from prefire conditions but *within* the historical range of variability, and (3) development of vegetation that is different from prefire conditions and also is *dissimilar* to or at *extremes* of the historical range of variability for this ecosystem. Vegetation structure refers to overall physiognomy, for example, dense forest, open forest, shrubland, or grassland. Composition refers to the species present and the relative abundance of each species. Function refers to ecosystem processes of energy flow, material cycling, disturbances, and others. Our predictions are summarized generally in table 6.

Development of Vegetation Structure Similar to the Prefire Condition

In much of the Hayman Fire area we can expect either a rapid or gradual return to prefire conditions, even without postfire remediation or rehabilitation. In fact, some remediation techniques, such as planting of nonnative grasses, actually may retard the natural course of postfire succession (Robichaud and others 2000). The most rapid return to prefire conditions is predicted where sprouting species predominated before the fire (for example, aspen and meadows) or where tree canopy mortality was low (for example, ponderosa pine forests that burned at low severity). A slower, but nevertheless normal, postfire succession is predicted in lodgepole pine and spruce-fir forests that comprise a small portion of the burned Hayman landscape.

Sprouting Species – Where the vegetation is dominated by sprouting species, a rapid return to prefire conditions is generally expected (fig. 17, 18). Although the fire kills all or most of the aboveground portions of the plants, belowground structures such as rhizomes, roots, and root collars survive the fire because of the insulating properties of soil. After fire, the dormant buds in these belowground structures are no longer suppressed by the aerial portions of the plant, and the buds respond by producing fast-growing new shoots (Miller 2000). In many places, perhaps even most places, sprouting by belowground survivors is responsible for the earliest and most rapid recovery of aboveground plant cover and biomass after fire (Turner and others 1997; Floyd and others 2000).

Some of the major sprouting species in the Hayman area include: trees – quaking aspen (*Populous tremuloides*), several species of willow (*Salix* spp.), cottonwood (*Populus angustifolia*, some *P. deltoides*); and shrubs – mountain-mahogany (*Cercocarpus montanus*), wax currant (*Ribes cereum*), cliffrose (*Jamesia americana*), kinnikinnik (*Arctostaphylos uva-ursi*), wild rose (*Rosa* spp.), and yucca (*Yucca glauca*). In addition to these important trees and shrubs, many – perhaps most – of the native herbaceous species are capable of resprouting after disturbance. These include herbs of the forest floor, for example, Geranium (*Geranium caespitosum*), dogbane (*Apocynum androsaemifolium*), some asters (*Aster* spp.), gayfeather (*Liatris punctata*), which is the obligate flower of the endanged Pawnee montane skipper, as well as the grasses blue gramma (*Bouteloua gracilis*) and Ross sedge (*Carex rossii*).

Riparian areas usually have large numbers of sprouting herbs and shrubs, and consequently riparian areas often recover aboveground cover and biomass more rapidly than surrounding upland areas following a severe fire that kills much or all of the aboveground plant parts. Rapid recovery of prefire vegetation structure may be disrupted in some places by chronic, heavy browsing on aspen, cottonwood, and other species, by either native or domestic ungulates, for example, elk or cattle. Although severe browsing effects are well documented in some parts of the Rocky Mountains

Table 6—Expected trajectories of postfire vegetation development in the Hayman burn area. "HRV" refers to the historical range of variability (see part 1 in this chapter). Data on extent are from the BAER report on the Hayman burn.

Development of vegetation structure similar to prefire condition:			
Aspen forests and shrublands of oak, mountain-mahogany, and others	Extent: 1.8 percent of the Hayman area.	Trajectory: Reestablishment of dense stands over the next 20 to 50 years.	Mechanism: Aspen and the shrub species re-sprout vigorously from surviving below-ground plant structures and grow rapidly, naturally reestablishing dense stands similar to the stands that burned in 2002 … *except* in areas where chronic heavy browsing suppresses plant growth.
Meadows and grasslands	Extent: 0.6 percent of the Hayman area.	Trajectory: Reestablishment of herbaceous cover within the next 2 to 10 years.	Mechanism: Native herbs resprout vigorously from surviving belowground plant structures, and new seedlings become established, resulting in rapid recovery of prefire cover and biomass … *except* in areas where chronic heavy grazing suppresses plant growth.
Lodgepole pine and spruce-fir forests	Extent: 1.0 percent of the Hayman area.	Trajectory: Reestablishment of dense stands over the next century.	Mechanism: Serotinous cones in lodgepole pine and canopy seed banks in spruce and fir provide onsite seed source for rapid establishment of new trees that naturally grow into dense stands similar to the stands that burned in 2002.
Ponderosa pine and Douglas-fir forests: where fire severity was "low" on the BAER map	Extent: 32.8 percent of these two forest types; 29.4 percent of the Hayman area.	Trajectory: Maintenance of current forest structure.	Mechanism: Canopy mortality varied from almost none to moderate where fire severity was mapped as "low"; consequently, most such stands remain as dense or nearly as dense as in 2002 … herbaceous plants will be more productive over the next several years, and crown fire potential may be reduced.
Development of vegetation structure different from prefire condition, but within HRV:			
Ponderosa pine and Douglas-fir forests: where fire severity was "moderate" on the BAER map … and invasive species are few	Extent: 16.0 percent of these two forest types; 14.3 percent of the Hayman area.	Trajectory: Development of moderately open to moderately dense forests over the next century … increased herb cover next several years.	Mechanism: Canopy mortality varied from moderate to nearly 100 percent where fire severity was mapped as "moderate"; a new cohort of trees may become established within a few years where tree crowns were not severely damaged, but very slowly where seed mortality was high … woody fuels were reduced and herbaceous plants will be more productive over the next several years.
Ponderosa pine and Douglas-fir forests: *small* patches where fire severity was "high" on the BAER map … and invasive species are few	See footnote[1]	Trajectory: Development of open forests or non-forest over the next century … increased herb cover next 1 to 2 decades.	Mechanism: Canopy mortality was nearly 100 percent where fire severity was mapped as "high"; canopy seed banks were severely damaged, and reforestation will occur slowly as seeds blow in from outside (or are planted); some persistent openings will be formed, similar to openings created after large historical fires (such as in 1851) … woody fuels were reduced and herbaceous plants will be more productive over the next several years.

(con.)

Table 6—(Con.)

Development of vegetation structure different from prefire condition, and dissimilar to or at extremes of HRV:			
Ponderosa pine and Douglas-fir forests: *very large* patches where fire severity was "high" on the BAER map … and invasive species are few	See footnote below[1]	Trajectory: Development of very open forests or non-forest over the next century … increased herb cover next 1 to 2 decades.	Mechanism: Basically the same as in small patches of high-severity fire (described above) *except* that some of the large patches of severely burned forest created by the Hayman Fire are substantially larger than in any historically documented fire … consequently, the persistent treeless openings resulting from the 2002 fire may be far larger than any such openings during the historical period… woody fuels were reduced and herbaceous plants will be more productive over the next several years in large patches as in small patches.
Any vegetation type where invasive nonnative species become established in high densities	Extent: The specific areas of nonnative invasion are not yet determined.	Trajectory: Long-term or permanent dominance by nonnative species.	Mechanism: Some nonnative species can aggressively out-compete the native species, ultimately displacing the native species, dominating a site for long periods, and altering or eliminating the normal course of postfire succession … all vegetation types are vulnerable, but the most vulnerable areas are (1) severely burned, (2) close to nonnative seed sources, or (3) in poor ecological condition before the fire (for example, compacted soil or excessive grazing).

[1] Extent: 37.1 percent of these two forest types and 33.2 percent of the Hayman area were classed as "high severity." However, the distribution of patch sizes within the "high-severity" category on the BAER maps has not yet been developed. Therefore, we cannot identify at this time the actual extent of burned ponderosa pine and Douglas-fir forests that fit the categories "different from prefire vegetation but within HRV" and "different from prefire conditions and dissimilar to or at extremes of HRV."

(Romme and others 2001), the extent to which browsing will interfere with normal vegetation recovery in the Hayman area is unknown. Similarly, chronic heavy grazing of meadows and grasslands may inhibit the rapid postfire recovery that we predict in this kind of vegetation.

Lodgepole Pine and Spruce-Fir Forests – Although they occupy only a small portion of the area burned in the Hayman Fire, lodgepole pine forests are widespread in areas nearby and will likely be affected more extensively by future fires in the Front Range. Lodgepole pine forests are expected to recover rapidly, even after high-severity fire (see the definitions of fire severity in table 2, part 1 in this chapter). Although lodgepole pine is incapable of sprouting, this species tends to have a large canopy seed bank that provides ample seed to restock the stand after fire. Many lodgepole pine trees have serotinous cones, which remain closed at maturity and do not release their seed until subjected to a heat shock – as occurs in a fire. The closed, serotinous cones may afford some small degree of protection to the seeds encased within, but the most important effect of serotiny probably is that many years of seed production are stored in the canopy, ready to be released en mass by the effects of the fire. A fire that consumes most of the forest floor creates an ideal seed bed for lodgepole pine, the canopy seed bank provides abundant seed, and the result is often an exceptionally dense stand of lodgepole pine seedlings

Figure 17—Root sprouts of aspen in the Hayman Fire area in September 2002. (Photo by W. H. Romme)

that become established within the first few years after fire (Muir and Lotan 1985; Tinker and others 1994; Turner and others 1997). Because most of the lodgepole pine forests that burned in the Hayman Fire probably were greater than 100 years old, it will be many decades before the new lodgepole pine forests exactly resemble the forests that burned. Nevertheless, the new postfire stands are on a natural successional trajectory leading to stands much like those that burned in 2002. Spruce and fir often grow in association with lodgepole pine. Although these species do not have serotinous cones like the lodgepole pine, they do generate after fire from seed stored in canopy seed banks and from unburned areas nearby. Reforestation is often slower in spruce and fir than in lodgepole pine, but burned spruce-fir stands in the Hayman area also are likely to follow a normal postfire successional trajectory (Veblen 1986; Turner and others 1997).

Figure 18—Rapid recovery of herbaceous vegetation in a riparian area. The Hayman Fire consumed nearly all of the aboveground biomass of the herbaceous plants in this scene, but roots and other belowground structures survived the fire and sprouted vigorously in late July 2002. (Photo by Laurie Huckaby)

Ponderosa Pine and Douglas-Fir Forests in Low-Severity Burns – We also can expect a rapid return to prefire conditions in ponderosa pine and Douglas-fir forests that burned at low severity (Arno 2000). These conifer species are not capable of resprouting; if fire kills the aboveground portions of the tree, the entire tree is dead. However, in most places where the fire burned at low intensity through the forest floor, few or none of the mature trees were killed (fig. 19a). Some small trees may have been killed, but the density of canopy trees remains about what it was before the fire, and the canopy's general dominance over the understory (that is, its ability to capture most of the available light, water, and nutrients) is unaffected. Even though the herbaceous plants will likely exhibit a brief episode of increased productivity because of the temporary flush of nutrients released by the fire, and even though the fire consumed some of the woody material on the forest floor, these effects on the understory and forest floor are relatively transient (lasting a few years at most).

Although we predict a rapid return to prefire conditions for most characteristics of the stand, it is important to point out that low-intensity surface fires can have some persistent and important effects on stand structure and function if they scorch and kill the lower branches of the canopy trees. Because the scorched branches will gradually fall and not be replaced (the trees put their energy into the well-illuminated upper branches), the effect of the fire will be to raise the height of the lower canopy, thereby increasing the distance between surface fuels and canopy fuels, and thus reducing the probability that a future fire will ignite the canopy (Lynch and others 2000).

Development of Vegetation Structure Different From Prefire Conditions, But Within the Historical Range of Variability

The Hayman landscape has a long history of fire and a dynamic forest mosaic. Ponderosa pine and Douglas-fir forests that burned at moderate severity or in small patches of high-severity in 2002 are predicted to be significantly different from their prefire state for several decades after the Hayman Fire. However, even though different, these forests should not be regarded as abnormal or degraded because historical fires produced similar forest structures. The ponderosa pine and Douglas-fir forests that burned at moderate severity or in small patches of high-severity in 2002 are predicted to exhibit a trajectory of natural reforestation over the next several decades. In most of these areas, planting or other forms of postfire remediation probably are not needed and could even inhibit the natural course of succession.

Ponderosa Pine and Douglas-Fir Forests in Moderate-Severity Burns – We use the term "moderate severity' in the context of the BAER maps produced immediately after the fire, that is, the term refers to areas where the fire scorched but did not consume the forest canopy. This fire severity category actually encompasses a wide range of overstory mortality. Some of the scorched trees will not suffer permanent injury: they will shed the injured leaves and produce a set of new leaves over the next 1 to 3 years. Other scorched trees are already dead. Where a substantial portion of the canopy has been killed in these "moderate severity" burns, say 25 to 75 percent of the canopy trees, we can expect establishment of a new cohort of ponderosa pine seedlings over the next several years. The major seed source will be seeds that survived the fire in the canopy seed bank, plus some seeds that blow in from unburned areas nearby or are planted as part of the fire rehabilitation process. The density of this postfire cohort probably will vary greatly from place to place, depending on (1) local numbers of viable seed that survived the fire or are produced soon after, (2) local soil and environmental conditions, including erosion, hydrophobicity, and herbivory, (3) degree of local competition from native or planted herbaceous plants, and (4) weather conditions during the next several years. Seed survival in the canopy, and postfire soil and environmental conditions, are strongly dependent on local fire severity and vary greatly from place to place. Herbaceous plants, notably some native grass species (for example, *Calamagrostis rubescens*), have been shown to suppress conifer seedlings. Some of the grasses that have been planted to retard erosion, if they persist more than a year or two, may potentially inhibit conifer seedling establishment and growth (Robichaud and others 2000). Weather is a critical, and highly unpredictable, factor in this set of conditions influencing the density of postfire ponderosa pine regeneration. If the next few years are moist and cool, then seedling survival will likely be high, but if the warm, dry conditions of the years 2001 and 2002 continue, seedling survival will be low in many places. All of the reasoning just presented assumes that these burned areas are not invaded extensively by nonnative plant species, which could result in a novel postfire successional trajectory unprecedented in the historical range of variability (see below).

The upshot is that we cannot predict with any precision the postfire tree densities likely to develop in areas that burned at "moderate severity." However, the probable range of postfire seedling densities and the high degree of variability in local density probably are typical of responses to historical fires. Thus, even if some of the exceptionally dense ponderosa pine forests that burned in 2002 come back as less dense or even open stands, this pattern will not be abnormal. In fact, the exceptionally high density of many ponderosa pine stands in 2002 was probably not typical of the historical period, and the effect of the Hayman Fire may be to move some of these stands onto a developmental trajectory that will result in forest structure more like historical conditions. Monitoring and research are needed over the next several years to critically test and refine the predictions that we offer here.

Ponderosa Pine and Douglas-Fir Forests in Small Patches of High-Severity Burns – "High-severity" burned areas on the BAER map are places where the fire consumed the foliage of the canopy, and we can assume that essentially all of the pine and Douglas-fir trees in these areas are dead (fig. 19b). By burning in the crowns of the trees, the fire also probably killed most of the canopy seed bank, which is generally the most important seed source for postfire reestablishment of these species. Consequently, tree seedlings are likely to be sparse in the areas where the canopy was killed and consumed by high-intensity fire. Where this occurs in relatively small patches, the treeless openings that result actually will be a normal component of this landscape (assuming that these openings are not invaded by nonnative plant species – see below). Historical fires produced similar persistent openings, for example, in 1851, especially on dry, south-facing slopes (Brown and others 1999). Nonforest patches and patches of low-density forest were important components of the historical landscape that have gradually disappeared over the last century (see part 2 of this chapter). Consequently, even though the forests that develop after the Hayman Fire in many places will be substantially different from the forests that burned (that is, far less dense or even nonforest), these open areas actually will contribute to the diversity of the Hayman landscape, as well as an overall landscape structure that more closely resembles historical conditions (Kaufmann and others 2000, 2001).

Development of Vegetation Structure Different From Prefire Condition, and Dissimilar to or at Extremes of HRV

In some portions of the Hayman Fire, we predict postfire vegetation responses that are do not resemble the responses to historical fires. These areas include extremely large patches of severe crown fire, where tree seed sources may be inadequate to reestablish forest cover, and places where invasive nonnative species displace the native flora. It is in these areas where well-conceived postfire remediation efforts may enhance the development of more normal postfire successional trajectories.

Figure 19—Ponderosa pine forests that burned at (a) low and (b) high severity in the Hayman Fire, as they appeared in September 2002. (Photos by W. H. Romme)

Ponderosa Pine and Douglas-Fir Forests in Large Patches of High-Severity Burn – Some of the patches of high-severity burn, where the fire consumed the canopy foliage and seed banks (see above), were substantially large – notably the immense area that burned during the spectacular fire run of approximately 60,000 acres on June 9, 2002. As explained above, natural conifer regeneration is likely to be limited in this area because of high seed mortality within the burned area and long distances to seed sources outside the burned area. In one sense, the patches of low-density forest or even nonforest that will develop in these areas are normal because historical fires produced low-density stands and persistent openings. However, the patches of this kind that were produced by historical fires on the Cheesman landscape were relatively small, on the order of less than 1 ha to a few hundred hectares at most (Kaufmann and others 2000, 2001). In contrast, the patch created by the June 9 run probably is an order of magnitude larger than anything produced in historical burns. Because of this striking difference in scale, we regard postfire development within the large patches of high-severity burn in 2002 to be an extreme condition for the Hayman ecosystem. It is important to note, however, that this conclusion would not necessarily apply following large and severe fires elsewhere in the Colorado Front Range. Similarly large, severely burned patches clearly would be a normal component of fires during exceptionally dry years in subalpine forests (see part 1 in this chapter). Moreover, fire history studies conducted farther north in the Front Range (for example, in Rocky Mountain National Park) suggest that large, severe fires were a part of the historical fire regime even in some ponderosa pine and Douglas-fir forests (Ehle and Baker in press). Although the research at Cheesman Lake clearly shows that the large patch of high-severity burn produced on June 9 was unprecedented during the past 700 years in this particular location, additional research is needed to determine the extent to which such extreme fire effects would be regarded as normal or abnormal in other parts of the Front Range montane zone.

Any Vegetation Type Where Invasive, Nonnative Species Become Dominant – As explained elsewhere in this report, invasive, nonnative plant species pose a serious threat to ecosystem integrity in many places throughout the Rocky Mountains and the world (D'Antonio 2000). These invasive plants can displace the natives by directly outcompeting them, or by changing fundamental ecosystem processes such as nutrient cycling and disturbance frequencies. Unfortunately, the environment created by fire – especially by high-severity fire – is generally suitable for the establishment of invasive plant species that thrive in an environment of high light intensity and high nutrient availability (Hobbes and Huennecke 1992). In some places, these invaders are transient and have no long-lasting impact on development of the vegetation after fire, especially in the long term (50 to 100 years). In other places, however, the invaders persist indefinitely and may even dominate postfire plant communities for many decades. This latter kind of situation clearly is outside the historical range of variability for Front Range ecosystems. At this time we cannot predict with certainty where invasive nonnative species will cause significant departures from natural postfire trajectories in the Hayman burn area. Generally, though, we predict that the most serious problems are likely to be seen in places that were (1) severely burned, (2) in proximity to seed sources of invasive nonnative species, for example, roads and other disturbed lands, and (3) in poor ecological condition before the Hayman Fire, for example, as a result of excessive grazing or soil compaction. The burned areas being seeded for erosion control also may be at higher risk of invasion by nonnative species because of impurities that exist in even the best commercial seed mixes. Even where the applied seed mixes are not contaminated with weed seeds, if the planted cultivars persist more than a year or so they may interfere with reestablishment of the native plant community. Careful and extensive monitoring should be conducted over the next several years to test the predictions stated above and to detect problem areas early so that remediation can be attempted.

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