CHAPTER 7

The Cascading Effects of Fire Exclusion in Rocky Mountain Ecosystems

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The extensive wildfire season of 1910 was a defining moment for wildland fire management in the United States. Although heavy grazing had somewhat altered the primeval role of fire in some areas of the Rocky Mountains since the mid-1800s, the General Land Office had established only a primitive fire control structure to suppress fires in the remote Rocky Mountains prior to 1910. One and a half million hectares (ha), or 5,800 square miles (mi.^{2}), burned during that dry, windy summer of 1910, and the USDA Forest Service initiated an aggressive fire suppression policy (Cohen and Miller 1978). Enactment of the Weeks Law in 1911 improved coordination of fire suppression efforts by providing funding to those states willing to adopt comprehensive fire suppression plans (Babbitt 1995). By 1929, the U.S. fire management organization was fully functional, with hundreds of fire towers built and thousands of men employed. The enlargement of this organization has accelerated in intensity and technological capacity until the present day. Similar advances in fire suppression organizations occurred after 1945 in the Canadian Rocky Mountains (Woodley 1995).

This very effective fire suppression program owes much of its success to strong government support and extensive advertising campaigns. Smokey Bear's message, "Only you can prevent wildfires," was simple and direct, but as we now know, it was shortsighted. In a perfect world, we would have known that there would be adverse consequences of this pervasive fire exclusion policy. But

Box 7.1. Some Terminology

Fire suppression is the act of extinguishing or fighting fires, whereas *fire exclusion* is the de facto policy of trying to eliminate fires from the landscape by means of fire suppression techniques. A *fire regime,* the long-term cumulative fire characteristics of a landscape, is often described by frequency, extent, pattern, severity, and seasonality (Agee 1993). In a *native fire regime,* fires are allowed to burn across the landscape; eventually the character of the vegetation will reflect the character of the fires. It is often assumed that fire regimes prior to 1850 were native fire regimes; however, they may or may not have involved significant numbers of fires caused by Native Americans. *Fire severity* describes the effect of a fire on the biota and is quite different from *fire intensity,* which is the heat output of a fire. *Ecological processes* are those factors that influence the flow of energy in an ecosystem and include transpiration, photosynthesis, and disturbances (Waring and Running 1998).

vegetation grows slowly in the Rocky Mountains, and the buildup of hazardous fuels in forests and rangelands went unnoticed for many years. It was difficult for the first, and even the second, generation of forest and range scientists to observe and agree on the adverse effects of excluding fire from Rocky Mountain ecosystems. Now we are faced with critical ecological issues in the aftermath of our war on forest and range fires. The health of many Rocky Mountain ecosystems is declining because of fire exclusion. Moreover, fires are a fundamental part of many Rocky Mountain ecosystems; exclusion merely postpones the inevitable. This is highlighted by the fire season of 2000, during which more than 3.4 million ha (13,000 mi.^{2}) burned despite a billion-dollar suppression effort. This chapter discusses the diverse and cascading effects of fire exclusion in the Rocky Mountains. A brief glossary is presented in box 7.1.

The Role of Fire in the Rocky Mountains

Early observers recognized the critical role of fire in shaping North American forests. John Muir, Gifford Pinchot, and Aldo Leopold noted the importance of fire in regulating the composition and health of American forests (Pinchot 1899, Leopold 1924). Harold Weaver (1943, 7) remarked that removal of fire would "threaten sound management and protection" of western forests. Yet despite these early warnings, fires continued to be extinguished on the majority of public lands because suppression was the more desirable land management policy. It was not until the late 1970s and early 1980s that wildland fires were allowed to return to some U.S. and Canadian national parks and wilderness areas (Hawkes 1990, Kilgore and Heinselman 1990).

Fire is an essential disturbance that (1) recycles nutrients, (2) regulates succession by selecting and regenerating plants, (3) maintains diversity, (4) reduces biomass, (5) controls insect and disease populations, (6) triggers and regulates interactions between vegetation and animals, and, most important, (7) maintains biological and biogeochemical processes (Crutzen and Goldammer 1993). Fire is neither good nor bad; rather, it is an important ecological process that can produce variable effects. Its removal from the fire-dominated ecosystems of the Rocky Mountains has caused a plethora of cascading effects that have permeated nearly every part of this rugged landscape (Arno and Brown 1989). At first glance, the effects of fire exclusion, such as preservation of timber resources and watershed protection, may seem beneficial to society, but on closer scrutiny there is little doubt that fire exclusion has created many unhealthy features on Rocky Mountain landscapes.

Early native inhabitants of the Rocky Mountains had a profound effect on forest structure and composition, primarily as a result of fires they set (Mullan 1866, Denevan 1992). Native populations started fires for land clearing, wildlife habitat improvement, cultivation, defense, signals, and hunting (Gruell 1985, Kay 1995). Was indigenous burning part of the native fire regime? Did these fires differ substantially in frequency and type from lightning fires? These questions are debated (hotly) in the literature (Barrett and Arno 1982; Fisher, Jenkins, and Fisher 1986; Kay 1995), but in this chapter we assume that Native American ignitions were part of the historical fire regimes of the Rocky Mountains and therefore reflect the native, or natural, fire regimes.

Livestock has played a critical role in the decline of wildland fire in the Rocky Mountains (chapter 5). Extensive grazing by sheep, cattle, and horses from the early 1850s to the present has removed an important layer of fine fuel (i.e., grass and forbs) from the landscape (Covington and Moore 1994). Moreover, the elimination of grass competition allowed rapid conifer encroachment that further reduced grass cover by shading (Hansen, Wyckoff, and Banfield 1995). Intensive grazing on Rocky Mountain landscapes has also exacerbated the effects of modern fire suppression efforts (Swetnam and Baisan 1996).

Extent of the Problem

The effects of fire exclusion are quite different from those of other management actions, such as logging, because they occur gradually and are manifest in nearly every part of the landscape rather than localized to small areas. The effects are also extremely variable in time and space (Agee 1993; Heyerdahl, Berry, and Agee 1995). Today's wildfires differ in severity and aerial extent from those that occurred prior to the exclusion era, circa 1900. Major changes in land use throughout the Rockies, including timber harvest, agricultural development, and urbanization, have completely altered ecosystems, and any discussion of fire exclusion effects must take these changes into account. The role of fire becomes more complex as it interacts with land management.

Only a small fraction of the pre-1900 annual average fire acreage is being burned today. Barrett, Arno, and Menakis (1997) estimated that an average of 2.4 million ha (9,000 mi.^{2}) burned annually in the interior northwestern United States before 1900. Until the extensive fires of 2000, the biggest wildfire years of the century burned less than half the historical average. Approximately two-thirds of annual burning historically occurred in sagebrush and grassland vegetation that today is agricultural land or dry pastureland (chapter 11; Morgan et al. 1998). Presettlement fire maps for the United States reveal that more than half the country experienced fires at intervals of one to twelve years (Frost 1998). Maps of historical and current fire regimes for the interior Columbia River basin show that recent fires have been less frequent and more severe than those that occurred prior to 1900, and the greatest change in fire regimes has been in the shrublands, grasslands, dry forests, and woodlands (Morgan et al. 1998).

Some Rocky Mountain ecosystems have not been affected by fire exclusion. Fire is not an important ecological feature in alpine and desert-scrub ecosystems. In upper subalpine ecosystems, fires have a return frequency of more than 200 years, so there has not been enough time to notice differences from suppression, although there are indications of aging forests in Canadian subalpine systems (Rogeau 1996, Romme and Despain 1989, Veblen et al. 1994).

Effects on Landscapes and Stand Structure

Native fire regimes create shifting mosaics of patches, processes, and habitats on Rocky Mountain landscapes (Agee 1993, Romme 1982). These landscapes become more homogeneous as fire is excluded (figure 7.1; Turner et al. 1994). In Glacier National Park, for instance, plant communities less than ten years old are rare, and forests are aging in Banff National Park (Habeck 1970, Rogeau 1996). After ninety-one years of fire exclusion in the northern Rocky Mountains, there have been major declines in whitebark pine and young lodgepole pine stands, and subalpine fir has greatly increased (Tomback, Arno, and Keane 2001). Fire control policies reduce landscape richness and patchiness in areas

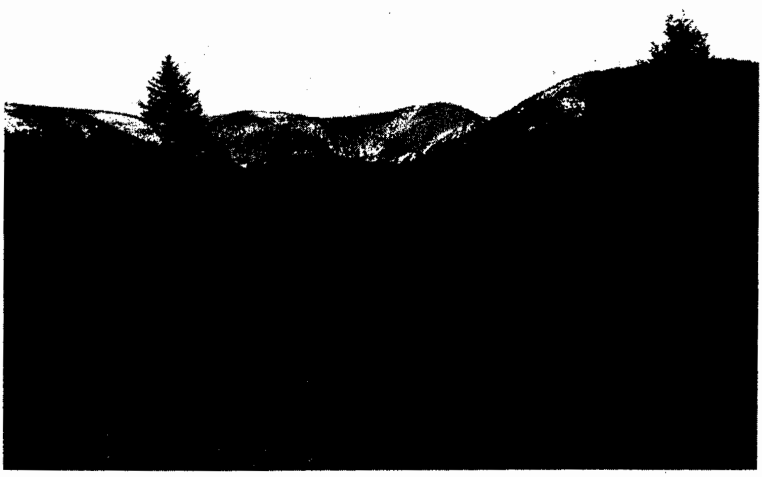
(a)

(b)

(continued)

FIGURE 7.1 *Historical and Current Photographs Illustrating Changes in Vegetation Structure and Composition Due to Fire Exclusion.* Warm-dry ponderosa pine stand near Lick Creek in Bitterroot National Forest, Montana: (a) recently cut stand, 1909; (b) change in stand structure from single to multiple strata, circa 1979. Moist Douglas-fir stand near Blake Creek in Lewis and Clark National Forest, Montana: (c) effects of recent wildfires, 1909; (d) extensive regeneration of Douglas-fir on all mountain slopes after some seventy years of fire exclusion, 1980. Crown Mountain, eastern front of the northern Rocky Mountains, Montana: (e) extensive grasslands on ridge in foreground, 1900; (f) grasslands replaced with stands of limber pine, 1981. Photographs (a) and (b) from the U.S. Geological Survey Library, Denver, Colorado, in Gruell 1983; photographs (c–f) reprinted with permission from K. Ross Toole Archives, Maureen and Mike Mansfield Library, University of Montana–Missoula.

(c)



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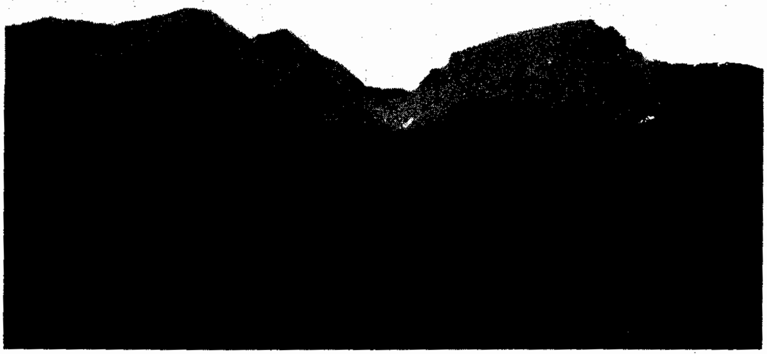

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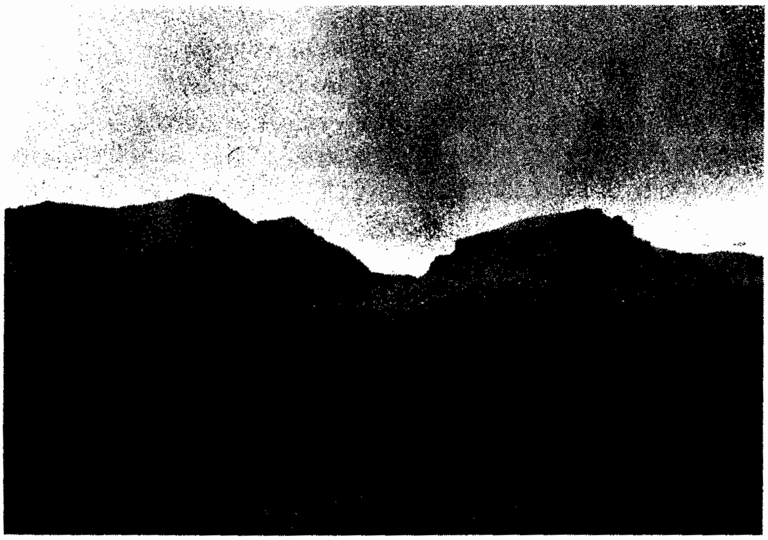

(f)

such as Yellowstone National Park and throughout the Rockies (Romme 1982, Baker 1992). This creates a "fire exclusion" spiral wherein large forest patches and high homogeneity result in a continuous supply of crown and surface fuels, which foster large fires, which create still larger patches, and so on.

In general, forest composition has changed with fire exclusion from early successional, shade-intolerant tree species to mature, shade-tolerant species. Many forests used to have single-layer canopies; now there are multiple layers. Although individual plant species may differ, the multi-layer structures of these mature stands are now nearly identical all across the Rocky Mountains (figure 7.1; Oliver and Larson 1990; Taylor 1998). This fundamental change in vegetation composition and structure affects myriad other ecosystem characteristics (table 7.1).

Fire exclusion increases stem density, biomass, and number of woody species (Ogle and DuMond 1997). Longer fire return intervals allow fuels to accumulate on the ground. Shade-tolerant species have more biomass in the forest canopy because of their high leaf areas and the branch and twig wood needed for leaf support (Waring and Running 1998, Landsberg and Gower 1997). Since late seral (successional) species are shade-tolerant, there can be many smaller seedlings and saplings present in the understory to take advantage of canopy gaps. Thus, greater crown leaf and branch biomass, coupled with high seedling and sapling densities, can create "ladder" fuels that allow flames from surface fires to climb into the forest canopy and cause crown fires.

Invasion of shrubs and trees into grasslands and shrublands is evident from New Mexico to British Columbia (figure 7.1; Taylor 1998; Veblen and Lorenz 1991; Allen, Betancourt, and Swetnam 1998; Patten 1969). Shade-tolerant conifers have increased in density three- to fivefold in formerly open ponderosa pine forests (Habeck 1994). Southwestern ponderosa pine density has increased tenfold since European settlement (chapter 12; Covington and Moore 1994). In contrast, where natural fires have been allowed to burn in recent decades, such as in Idaho wilderness, major shifts in vegetation composition and structure have not occurred (Brown et al. 1994).

Biodiversity

As ecosystems become more homogeneous without fire, the diversity of plants, animals, and ecological processes declines (chapter 8; Martin and Sapsis 1992, Romme 1982). Rocky Mountain plant diversity decreases with advancing succession because higher numbers of species are adapted to early postfire settings. In the United States as a whole, 135 of the 146 threatened, endangered, and rare

TABLE 7.1. Documented Effects of Fire Exclusion, by Organizational Level and Ecosystem Attribute

Scale	*Ecosystem Attribute*	*Fire Exclusion Effect*
Stand	Composition	Increase in number of shade-tolerant species
		Decrease in number of fire-tolerant species, forage quality, plant vigor, biodiversity in plants and animals
	Structure	Increase in vertical stand structure, multi-storied canopies, canopy closure, vertical fuel ladders and continuity, biomass, surface fuel loads, duff and litter depths
	Ecosystem processes	Increase in fire intensity and severity, chance of crown fires, insect and disease epidemics; short-term increase in stand productivity
		Decrease in nutrient cycling, individual plant vigor, decomposition
	Ecosystem dynamics	Increase in leaf area, evapotranspiration, rainfall interception, autotrophic and heterotrophic respiration, snow ablation
	Soil dynamics	Increase in pore space and water-holding capacity, hydrophobic soils, seasonal drought
		Decrease in availability of nutrients (nitrogen, phosphorus, sulfur), soil temperatures
	Wildlife	Increase in hiding and thermal cover, coarse woody debris, insects and disease
		Decrease in forage quality and quantity, biodiversity
	Resources	Increase in timber production, risk to human life and property, fire-fighting efforts, air quality
		Decrease in aesthetics, visitation
Landscape	Composition	Increase in landscape homogeneity, dominance of one patch type
		Decrease in early seral communities, patch diversity
	Structure	Increase in patch evenness, patch size, patch dominance, contagion
	Disturbance	Increase in crown fires, size and severity of fires, insect and disease epidemics and contagion (resulting in more severe epidemics)
	Carbon and water cycles	Increase in water use, drought, emissions of carbon dioxide from respiration, water quality
		Decrease in streamflows, stream sediment
	Resources	Decrease in visitation, visual quality, viewing distance

Note: References for each effect are detailed in the chapter.

plant species benefit from wildland fire or are found in fire-adapted ecosystems (Hessl and Spackman 1995). Although local species extirpation can occur with severe or too frequent fires, locally rare plants have a greater chance of thriving on landscapes with diverse vegetation communities created by diverse disturbance histories (Gill and Bradstock 1995).

The plants that define many fire-adapted ecosystems (e.g., aspen, ponderosa pine, whitebark pine) are often keystone species, critical for the survival of many animals in that ecosystem (deMaynadier and Hunter 1997; Tomback, Arno, and Keane 2001). The open canopy of whitebark and ponderosa pine forests promotes undergrowth forage quality and production. More than 110 animals consume whitebark pine seeds in this important high-elevation ecosystem. DeByle (1985) documented more than 134 bird species and 55 species of mammals that regularly utilize aspen forests. Because of fire exclusion, many of these keystone species are declining.

Stand-replacing fires are important in creating habitat for many Rocky Mountain bird species (Hutto 1995). Approximately fifteen species are associated solely with postburn communities, and more than eighty-seven species are found in burned stands. Landscapes with intact fire regimes have high variability in patch size, shape, and type, which is extremely beneficial for the existence of many avian, insect, and rodent species (Hejl 1992). Fire exclusion, on the other hand, favors generalist bird species that can utilize all stages of succession rather than specialist bird species found primarily on heterogeneous landscapes created by fire (Finch et al. 1997). Populations of small mammals may increase with the number of downed logs as fuels accumulate during succession, but many mice, shrews, and gophers are found mostly in those early seral communities that directly follow fire.

The encroachment of conifers at the expense of grasslands and aspen affects species abundance and distribution of grazing animals (DeByle 1985). The high canopy cover and multi-storied stand structure in late stages of succession improve thermal and security cover for large ungulates. These cluttered stands are difficult to traverse, however, because of the abundance of downed logs and thick understory (figure 7.1). Dense canopies shade out as much as 99% of the shrubs and grasses with high food value. Deer populations increased from 1930 to 1970 because of rapid rangeland succession from grasses to shrubs, although they have declined since (Gruell 1986). In Canada, wood bison require prairie, a vegetation type maintained by frequent fire (Gates et al. 1998). Fire can be beneficial to animal health through parasite reduction. Bighorn sheep have reduced lungworm infections and other ungulates have significantly lower tick abundances with burning (Peek et al. 1985, Drew et al. 1985).

Non-native Species

The introduction of exotic species into Rocky Mountain ecosystems has complicated and, in some cases, intensified fire exclusion effects. Some exotic plant species colonize efficiently following fire, so restoration of fire regimes may actually increase exotic dominance (Covington et al. 1994). Severely burned areas created by the intense wildfires on fire-excluded landscapes might accelerate exotic invasions (chapters 10, 11). Low-severity burns favor native plants adapted to survive fire. The invasion of the non-native annual grass cheatgrass (*Bromus tectorum*) into sagebrush-steppe vegetation types has actually increased fire frequency because of abundant fine fuels. In some places, the increased fire frequency has eliminated sagebrush (Whisenant 1990). Some exotic diseases and pests accelerate the successional cycle, resulting in mid-seral stands having compositions and structures similar to old-growth stands. For example, white pine blister rust (*Cronartium ribicola*) has killed many mature pines in northern Montana and Idaho, rapidly converting stands to subalpine fir (Tomback, Arno, and Keane 2001). Blister rust has also speeded succession in western white pine forests to grand fir, western red cedar, and western hemlock.

Biogeochemical Cycling and Hydrology

In fire-prone ecosystems, fire can directly affect decomposition and nutrient cycling (Neary et al. 1999). Fire increases soil pH as a result of ash accretion, which directly increases the availability of many nutrients. Although there is abundant nitrogen in organic matter, decomposition alone releases only a small amount to plants. Combustion releases nitrogen and phosphorus sequestered in fuels, consumes volatile organic compounds that inhibit decomposition, and may stimulate bacterial growth via soil warming, enhancing nitrogen (N) availability (Neary et al. 1999). The absence of fire lowers rates of nutrient cycling and also decomposition because cooler soil temperatures lower microbial metabolism, enhancing the buildup of even thicker duff layers. Endo- and ectomycorrhizae, soil fungi that live commensally with vascular plants, are particularly sensitive to soil heating by fire because they are concentrated in the organic and upper mineral soil layers. Although historical fires killed some of these microorganisms, severe fires can greatly reduce their populations (DeBano, Neary, and Ffolliott 1998; Neary et al. 1999). Carbon stores in woody biomass and forest floors can dramatically increase without fire, but this increase is temporary, of course, until the next conflagration (Tilman et al. 2000).

Transpiration, snow ablation, and canopy rainfall interception increase with the higher leaf areas that result from fire suppression (table 7.1). This causes periodic depletion of soil water, increased canopy evaporation, and decreased streamflow (Waring and Running 1998). Less solar radiation penetrates to the forest floor, and this, when coupled with lower soil moisture, can delay soil thaw (Kaufmann et al. 1987). When thick organic horizons finally burn, organic matter may form a water-repellent layer that impedes infiltration. This enhances water runoff and erosion. In grasslands, fire suppression has encouraged establishment of deep-rooted shrubs; these persist because they tap into groundwater (Link et al. 1990).

Hydrologic changes are especially pronounced when stand-replacing wildfires inevitably occur. Severe fires outside historical fire frequencies cause excessive erosion, which degrades water quality and aquatic habitat (Covington et al. 1994). Snow melts faster from the large patches created by modern wildfires. Peak flows usually increase severalfold after large, intense wildfires. The increased vegetation cover near streams on fire-excluded landscapes decreases stream water temperatures, increases long-term inputs of coarse woody debris to streams, and delays and reduces peak runoffs. However, when wildfires eventually occur on these protected watercourses, their high intensity can severely reduce shading, increase sediment inputs, and increase water temperatures by 3°C to 10°C (Amaranthus, Jubas, and Arthur 1989).

Human–Fire Interactions

Effects of human–fire interactions range from influence on aesthetic and recreational preferences to endangerment of life and property. Dense tree growth in forests without fire restricts viewing and detracts from the outdoor experience. Open-grown, park-like stands of ponderosa pine created by frequent surface fires have high aesthetic value and are preferred by today's outdoor enthusiasts (Warskow 1978).

Air quality has improved with fire exclusion policies (Covington et al. 1994). Smoke emission production from prehistoric wildland fires in British Columbia is estimated to have been three to six times greater than the average annual contemporary production because of the vast area burned prior to the 1900s (Taylor 1998). Less smoke from fires lowers atmospheric particulate levels, improves visibility, and decreases natural pollution, but this is only a short-term advantage because fires are inevitable (Leenhouts 1998).

Fire exclusion will continue to heighten the fire hazard to forest homes as increasing numbers of people develop and settle lands along the urban-wildland interface (Fischer and Arno 1988). The fires of 2000 burned more than 800 structures in New Mexico, Colorado, and Montana (chapter 12).

Cross-Scale Disturbance Effects

Fires become less frequent and more severe with active suppression on the landscape. Modern wildfires tend to be large, intense, and severe because of high biomass loading, multi-layer stand structure, and high connectivity of the biomass at the stand and landscape levels (Keane et al. 1997, Knight 1987). Covington and colleagues (1994, 59) stated that "the end result of fire exclusion in fire-prone forests is increasingly synchronous landscapes dominated by large, catastrophic disturbance regimes." There is a significant inverse relationship between available fuel and mean fire frequency, so fuels increase with increasing fire return intervals, and with increasing fuels comes increasing fire severity. As illustrated in figure 7.2, the area burned has recently been increasing despite escalating suppression efforts and advanced technology. Fewer fire years will also create less diversity in patch age and size because large areas tend to burn in one year, as demonstrated by the Yellowstone fires of 1988 (Baker 1989, Romme and Despain 1989).

High surface fuel loads and complex vertical stand structures increase the chance that modern surface fires will become crown fires and burn overstory trees (Steele 1994). Early successional tree crowns are heat porous and high

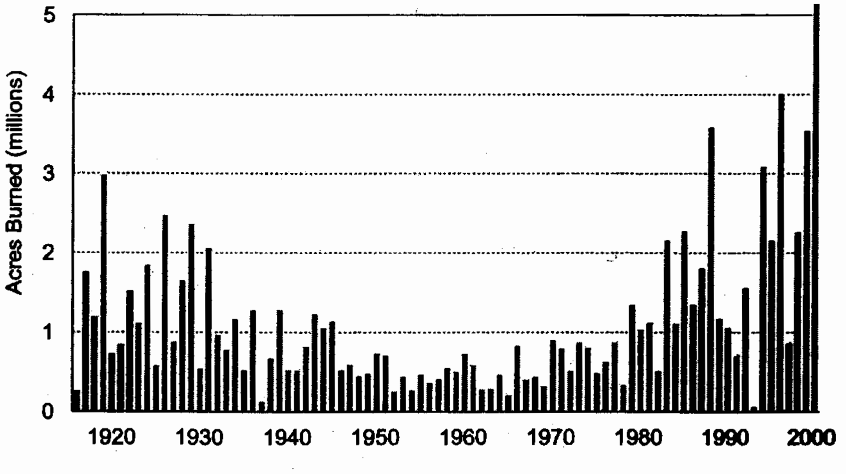

FIGURE 7.2 *Acres Burned in Wildfires in Eleven Western States, 1916–2000.* Annual area burned is increasing despite recent advances and increases in fire suppression technology and resources. States represented are California, Oregon, Washington, Idaho, Nevada, Arizona, Utah, New Mexico, Colorado, Wyoming, and Montana.

off the ground, whereas late seral trees have dense crowns extending nearly the entire length of the stem. High flame lengths due to more surface fuels, coupled with lower and thicker shade-tolerant tree crowns, rapidly turn a surface fire into a crown fire. Once a crown fire has started, the high leaf areas and high crown bulk densities favor expansion of fire throughout other crowns in a stand. Furthermore, these crown fires are more likely to propagate across homogenous landscapes because of high contagion between multilayer stands. Taylor (1998) estimated that the proportion of landscape susceptible to crown fire increased from 7% to 14% from 1952 to 1992 and projected that proportion to increase to 29% by 2032.

Land use changes on Rocky Mountain landscapes have altered ignition and spread patterns of historical fires. Barrett, Arno, and Menakis (1997) noted that the majority of historical fires burned sagebrush grasslands that are now interrupted by agriculture, grazing, and land development (chapter 11). Fires in grasslands often gained access to adjacent forestlands before European settlement and grazing. Currently, the continuity of fine fuels across the nonforest landscape has been reduced or eliminated because of human land use activities, thereby limiting forest ignitions.

Insect and disease processes are affected across a landscape as fires are suppressed (chapter 8). Increases in insect and disease activity are attributed mostly to increased stress and reduced vigor of the early seral, fire-dependent tree species (Harvey 1994, Heinrichs 1988). In Colorado spruce-fir forests, outbreaks of spruce beetle (*Dendroctonus rufipennis*) do not affect postfire stands younger than eighty years of age, implying that long-term fire exclusion in the subalpine zone will eventually cause increased beetle activity as a larger portion of the landscape enters old-growth stages (Veblen et al. 1994). Outbreaks of mountain pine beetle (*Dendroctonus ponderosae*), bark beetle, and dwarf mistletoe are more common in southwestern United States ponderosa pine forests because tree densities have increased as a result of lack of fire (Covington et al. 1994). The absence of fire is implicated in chronic epidemics of western spruce budworm (*Choristoneura occidentalis*) in many Douglas-fir and true fir stands in the Rockies (Holland 1986, Swetnam and Lynch 1993). Persistent defoliation by budworm outbreak can predispose host trees to infestation by Douglas-fir beetle (*Dendroctonus pseudotsugae*) and root rots. Bark and pine beetle and blister rust epidemics are replaced by root rot and fir decline diseases as the landscape converts from whitebark pine to subalpine fir and spruce cover types (Tomback, Arno, and Keane 2001).

What's Next?

The exclusion of fire on landscapes has had profound implications for natural resource management. Exclusion affects livestock and big game forage, biodiversity, recreational experiences, air quality, and human health and safety. However, restoration of a native fire regime will not be easy. Even though restoration of native fire regimes seems a critical step toward improving the health of many Rocky Mountain ecosystems, the immensity of such an effort is daunting. Future fires will need to burn three to seven times more than at present to make up for past suppression activities. Seventy years of fire suppression has caused unusually high accumulations of live and dead fuel in many stands, which, when ignited, will create abnormally severe fires that will kill most trees, combust much soil organic matter, and possibly kill plant and microbial propagules residing on the forest floor. Land management agencies are limited in their restoration treatments because of competing government regulations and the high cost of implementation, from environmental assessment to execution of treatment. Despite these challenges, a functional restoration program is possible and necessary (Babbitt 1995, Hardy and Arno 1996).

Many believe that silvicultural thinning is the only feasible method to remove some combustible biomass and reduce fire intensities so fire severity will be similar to historical events (Covington and Moore 1994). Baker (1992) believed that landscapes altered by settlement and fire suppression cannot be restored using only the traditional methods of prescribed burning. Moreover, fire restoration cannot be done with just one or two prescribed burns or silvicultural treatments. It may take fifty to seventy-five years and as many as seven fire treatments or rotations to restore native fire regimes where fire has been excluded (Baker 1994, Keane et al. 1997). Additionally, more than one treatment might be required to accomplish the objectives for one prescribed burn. For example, it may take two low-severity prescribed burns to achieve 90% mortality in shade-tolerant species for a stand. Site-specific studies and careful monitoring of the consequences of prescribed burning are essential to achieve goals related to ecosystem restoration.

The role of fire will continue to change in the Rocky Mountains as fire continues to be excluded from landscapes. Landscapes will burn regardless of the intensity of any suppression effort, and when they burn, it is important to reduce the subsequent severity and adverse effects. Modern fires will be large and severe, killing more plants and altering many ecosystem processes. Extreme fire years will burn most plant communities regardless of fuels or ecosystem health, but the severity of these burns at the stand and landscape levels will be dictated by resident fuel loadings. One can only wonder what would happen if the extreme weather conditions of 1910 were to occur today on the fire-excluded landscapes of the Rocky Mountains.

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