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CCE Fire Regimes and Their Management

Robert E. Keane and Carl Key

A spectacular forest in the center of the CCE cuts a 15- by 5-km swath along the Flathead River's South Fork around Big Prairie in the middle of the Bob Marshall Wilderness Area in Montana (Figure 13-1). This wide valley bottom, which contains two patches (of about 1,000 ha each) of the last vestiges of the historic ponderosa pine ecosystem in the CCE, provides a local context and a case example for our discussion of fire dynamics in this chapter. The Big Prairie ponderosa pine (see Chapter 2 for scientific names not given in this chapter) ecosystem is a consequence of a special fire regime that has been altered during the last century. As a result, this ponderosa pine forest is declining rapidly, and the causes of its decline are similar to those in many other fire-dependent ecosystems in this diverse region. Here we discuss the many and varied fire regimes of CCE landscapes, using the Big Prairie ecosystem to demonstrate the challenges of managing fire.

Big Prairie Ponderosa Pine Forest

This forest is confined to dry river terraces along the South Fork of the Flathead River. Historically, this area was a pine savanna or an open, park-like forest where ponderosa pine grew as widely scattered trees above a grass understory (Arno et al. 2000; Figure 13-1a). The forest was maintained by frequent, low-intensity fires that occurred at intervals averaging approximately 25 years. These fires were likely started by Native Americans who used these forests seasonally as they traveled from the Flathead Valley to buffalo-hunting grounds in the Great Plains (Ostlund et al. 2005). Numerous ponderosa pine trees that are living today have distinctive large oval scars where native peoples peeled off the bark layer to harvest the underlying sap layers (Figure 13-1b). Many of these big pines also contain scars from multiple fires, which serve as documentation of fire frequency over the last three centuries. Recurrent fires would kill most of

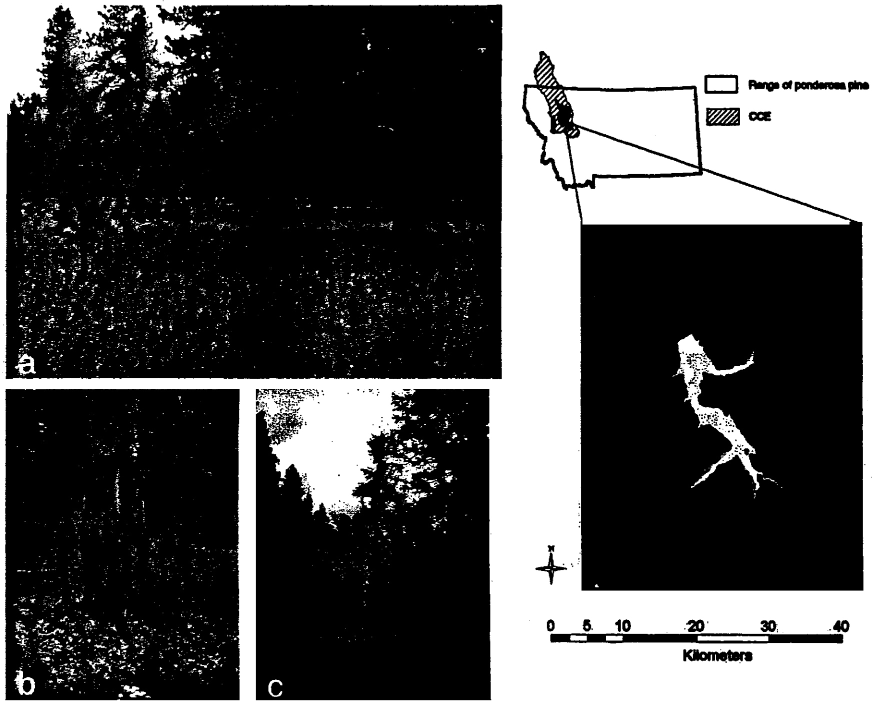


FIGURE 13-1. Ponderosa Pine Savanna Ecosystem of Big Prairie, Bob Marshall Wilderness Area, Montana

Notes: (a) pine savanna; (b) scarred ponderosa pine; (c) open, pine-dominated forest.

the encroaching saplings of competing trees species, namely Douglas fir and lodgepole pine, and maintain the open, pine-dominated forest structure (Figure 13-1c). Because ponderosa pine has thick bark, a high open crown, and deep roots, it is able to survive fires much better than its competitors.

The last 75 to 100 years have brought an increase of Douglas fir and lodgepole pine in the Big Prairie area because of the absence of aboriginal burning and an active fire-exclusion program in the wilderness area, especially prior to 1980 (Figure 13-1c). This relic forest is found near the upper elevational limit of ponderosa pine in the CCE, so the species does not reproduce and grow as well as its frost-hardy, shade-tolerant competitive tree species. Ponderosa pine is a shade-intolerant or sun-loving tree species that does not grow and regenerate in the dense forests that result from excluding fire. Without recurrent fire, large, old ponderosa pine trees become stressed and die as the forest becomes crowded with Douglas fir and lodgepole pine. This theme is repeated in many forested ecosystems in the CCE, where shade-intolerant, fire-adapted tree species are eventually replaced by more shade-tolerant species in the absence of wildland fire.

Historical Fire Regimes

The CCE is unique in that a diversity of fire regimes is represented in the region. This diversity has created a varied array of fire-dependent ecosystems, along with a distinctive landscape mosaic of plant communities that has arisen after differential burning (Figure 13-2). Because it has dictated the structure (patch distribution) and composition (plant communities) of most CCE landscapes, wildland fire has had a dominant impact on CCE ecosystems.

Fire regime is a general term that describes the temporal and spatial characteristics of fire dynamics and includes such attributes as frequency, severity, seasonality, and pattern (Agee 1993; DeBano et al. 1998). *Fire frequency*, described by the mean fire-return interval (in years), is usually defined by how often a fire burns a point on the landscape. *Severity* describes the impact of fire on the biota and soil and is often, but not always, related to fire intensity (the heat produced from the fire). Because of plant phenology, the *seasonality* of burn can produce differential effects. Finally, *pattern* refers to the size, shape, and spatial location of the burned area. For simplicity, we will confine our descriptions of CCE fire regimes to frequency and severity.

Brown and Smith (2000) describe the four major fire regime types that we consider in this chapter: (1) the nonfire (NF) regime, in which fire does not occur; (2) the understory or nonlethal surface fire (NLSF) regime, in which approximately 80% of dominant vegetation survives; (3) the stand-replacement fire (SRF) regime, in which approximately 80% of the aboveground dominant vegetation is consumed or dies; and (4) the mixed-severity (mixed) fire regime, which results in selective mortality with patches of understory and stand-replacement burns.

Historically, fire regimes in the CCE tended to be governed by the distribution of fuel moistures and loadings in space and time. Because forests at lower elevations are warmer and drier, more dry fuel tends to be available for burning over a longer period (Agee 1993). Forests at higher elevations are usually colder and damper, so they tend to be moist for most of the year and to burn only during years when the upper-elevation landscape is dry for long periods. Fires burn the most area in years of severe drought, such as 1910 and 1988, when the entire landscape is parched, ignitions (lightning strikes) are abundant, and the weather is windy (Schmoldt et al. 1999).

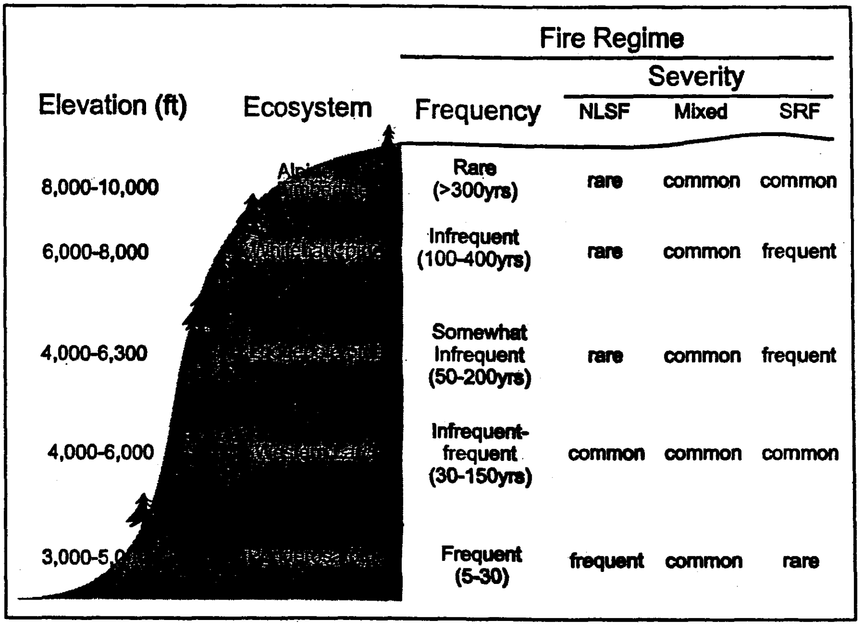
Fuel loadings are usually adequate to carry most fires in CCE ecosystems except for those that have recently burned (1–5 years old), the rockiest slopes (talus and scree), and some parts of the alpine tundra. Fuels can be the fallen litter (needles, leaves, cones, and buds), twigs, branches, and logs that collect on the ground; they can be "duff," which is the result of litter decomposition; and they can be living or dead plants. Fuel loadings generally increase with time since the last fire. Depending on ecosystem productivity, these loadings tend to reach equilibrium after about 100 years. Historical fire ignitions have tended to be less anthropogenic and have typically been caused by lightning with increasing elevations because of the fuel-moisture limitations (Boyd 1999). Many high-elevation fires, though, have resulted from low-elevation ignitions. The severity of CCE fires also tends to increase with time since the last fire because high fuel loadings foster more intense fires that generate higher heat and cause higher biotic mortality (DeBano et al. 1998). The invasion of shade-tolerant trees into the understory— and eventually the overstory—of a mature stand of shade-intolerant trees often increases the density and lowers the height of canopy fuels. This contributes to "torching" (when fire engulfs the overstory) and to more severe and intense fires called *crown fires* (Keane et al. 2002).

Indigenous peoples probably played an important role in fire regimes on the CCE landscape. Substantial evidence indicates that Native Americans used many portions of the Rocky Mountain landscape extensively by the early sixteenth century (Denevan 1992) and likely much earlier. John Mullan (1866) recognized that these early inhabitants had a profound bearing on forest structure and composition, resulting primarily from fires they set. They started fires for reasons including land clearing, wildlife-habitat improvement, crop cultivation, defense, signaling, and hunting (Lewis 1985; Kay 1995). There is great debate about whether lightning could have produced the same fire regimes that the Native Americans maintained (Barrett and Arno 1982; Gruell 1985), and also about whether anthropogenic burning should be considered part of the native fire regime (Arno 1985; Kilgore 1985). Fires set by Native Americans often differed from lightning fires in terms of seasonality, frequency, intensity, and ignition patterns (Kay 1995). We believe that fires set by Native Americans influenced fire dynamics in the CCE and that this factor should be recognized in the management of this vast region.

Major CCE Fire Regimes

High-elevation CCE forests were historically dominated by whitebark pine ecosystems that usually experienced infrequent fires at greater than 200-year intervals (see Tomback et al. 2000 and Figure 13-2). These rare fires were large and quite severe, killing the most trees of all species. The bird-dispersed whitebark pine, however, gained the colonization advantage because the Clark's nutcracker could plant the seeds farther into the burned area than wind could disperse seeds of the pine's major competitors. Whitebark pine is eventually supplanted by subalpine fir and sometimes by Engelmann spruce. The spread of the exotic white pine blister rust into the CCE during the last 70 years has severely reduced whitebark populations in the northern Rocky Mountains (Keane et al. 1994).

The subalpine forests below the whitebark pine zone were dominated primarily by lodgepole pine trees with infrequent SRFs racing through the forest



Elevation (ft)	Ecosystem	Fire Regime: Frequency	Severity: NLSF	Severity: Mixed	Severity: SRF
8,000-10,000	[illegible]	Rare (>300yrs)	rare	common	common
6,000-8,000	[illegible]	Infrequent (100-400yrs)	rare	common	frequent
4,000-6,300	[illegible]	Somewhat Infrequent (50-200yrs)	rare	common	frequent
4,000-6,000	[illegible]	Infrequent-frequent (30-150yrs)	common	common	common
3,000-5,0	[illegible]	Frequent (5-30)	frequent	common	rare

FIGURE 13-2. Characteristics of Fire Regimes along Elevation and Aspect Gradients

Notes: NLSF = nonlethal surface fire regime; SRF = stand-replacement fire regime.

canopy and killing most trees (Figure 13-2). On these sites, lodgepole pine could colonize burned areas because its cones, which remain on the tree, are sealed in wax (Tait et al. 1988). Intense fires melt the wax, open the cones, and allow the protected seeds to disperse from the fire-killed trees. This abundant "seed rain" from lodgepole pine creates dense stands of crowded trees. Subsequently, the natural mortality of pine because of crowding creates heavy fuel loads of small stems. When these heavy loads were added to the eventual dense regeneration of the shade-tolerant subalpine fir, crown fires of high intensity and severity resulted, especially in dry years, and then the cycle would repeat (Lotan et al. 1985). Similar to whitebark pine, lodgepole pine is eventually replaced by Douglas fir and subalpine fir, and sometimes by Engelmann spruce.

The montane forests below lodgepole pine were mostly composed of mixed tree species but usually dominated by western larch, Douglas fir, and sometimes western pine (*Pinus strobes*; Figure 13-2). Western larch, and, in limited areas, western white pine grow exceptionally tall and have thick bark, allowing them to survive fires of varying frequencies and severities (Arno et al. 2000). When fires were intense, the tall larches were often the only surviving trees, supplying the only source of seeds to populate burned areas. This ensured the continued presence and dominance of the western larch. Some fires, though, were low-intensity, understory surface fires that killed many smaller trees but maintained open, larch-dominated forests because the thick-barked larches could easily survive less-intense fires (Schmidt and McDonald 1995). Native Americans might have started fires in montane forests to open the forests for travel and to increase visibility, allowing them to see their enemies (Lewis 1985).

Western larch and white pine are often successionally replaced by a wide variety of more shade-tolerant conifers including Douglas fir, western red cedar, subalpine fir, and western hemlock. Similar to its effect on whitebark pine, the invasion of blister rust has almost extirpated western white pine from the CCE landscape.

Last, we come to the low-elevation ponderosa pine forests (Figures 13-1, 13-2). As we mentioned previously, these forests experienced frequent fires of aboriginal origin because the fuel, primarily grass, was dry for relatively longer periods of time. Although this ecosystem has limited distribution in the CCE, where it is confined to riverine terraces, dry south slopes, and wide valley bottoms, it was often the ecosystem most heavily used by Native Americans for travel routes, camping areas, hunting grounds, and wintering areas.

Unique landscapes are created by the cumulative effects of the interactions of these diverse fire regimes across a spatial domain. In these landscapes, composition and structure are dictated by burn patterns, fire severity, vegetation development rates, and time since the last fire. The complex terrain and the availability of fuel control the pattern and extent of burned areas. Fire spread is often confined to small drainages because snow, rock, talus, and alpine landforms at the head of watersheds prevent fire spread into adjoining lands, except in severe drought years or when the fires are wind-driven and firebrands can "spot" into adjacent watersheds. The spatial pattern of fuel moisture and loading dictate the subsequent fire severity, which then governs postfire response and successional trajectories (Kessell and Fischer 1981). These diverse fire regimes create the shifting mosaics of vegetation communities that give the CCE its distinctive ecology.

Current Fire Regimes

Since the early 1930s, extensive fire-suppression programs have successfully reduced wildland fire in many portions of the CCE region (Keane et al. 2002). The absence of fire has created landscapes with atypical species compositions and accumulations of contagious fuels (i.e., fuels in close proximity that allow fire to spread) that pose a hazard to many ecosystem characteristics and human settlements. The health of many CCE landscapes appears to be declining because shade-tolerant species have been invading and sometimes replacing the forests of shade-intolerant, fire-adapted species. The continued suppression of fire has actually made it more difficult to fight fires, posing greater risks to firefighters and residents of the CCE and surrounding areas. The diverse and cascading effects of attempting to exclude fire from the northern Rocky Mountain landscapes have wide-ranging impacts, including (1) less water runoff; (2) larger, more intense fires; (3) less landscape and community diversity; (4) frequent insect and disease epidemics; (5) loss of biodiversity; and (6) loss of wildlife habitat (Keane et al. 2002). Since the 1980s, however, some land-management agencies in the United States and Canada have begun to restore fires on the landscape.

For a variety of reasons, the effects of the decades of fire exclusion are not always evident on CCE landscapes today. First, many CCE landscapes comprise ecosystems with long fire-return intervals (e.g., whitebark pine and lodgepole forests; Figure 13-2), so sufficient time may not have elapsed to force these landscapes out of the historical fire rotation. An unusually high number of old forests, however, are currently growing on many landscapes. Second, the last 20 years have seen an increase of fire on the CCE landscape. This increase results from changes in fire management that allow some lightning-caused fires to burn, increases in the loading and contagion of fuel, and severe drought that followed several decades of wetter conditions. Since the 1980s, managers have allowed some wilderness and remote fires to burn within the CCE. This has increased the burned area and started us on the long road toward restoring historical fire regimes. Once called "prescribed natural fires," this fire-management strategy is now known as "wildland fire use." Approximately 10% of the central CCE has burned during the last two decades, with the most fires occurring in the montane and subalpine ecosystems.

Fire-Management Issues

Perhaps the most important factor influencing fire management within the CCE is that the majority of the lands are protected wilderness areas, roadless areas, or national parks (see Chapter 1). Wilderness areas, de facto wilderness, and national parks comprise more than 50% of the CCE. In these wilderness settings, the set of fire and fuel treatments that can be implemented to reestablish historical fire regimes is limited. Another important factor is the extensive development on lands along the edge of the CCE. Fires occurring in and around the region now have a greater chance to burn private property and harm people. A last consideration is the introduction of exotics into the CCE ecosystem. Non-native plants, animals, insects, and diseases have wreaked havoc with native ecosystems and altered fire regimes in some local sites. Fires have actually accelerated the spread of weed in some cases.

The most immediate problem facing CCE fire managers is restoring some semblance of the historical fire regimes in the region. The decades of fire exclusion have created landscapes where fuel loadings are so high and contagious that, if a wildfire burns these areas today, it may have effects that have rarely occurred in recent history, possibly resulting in the loss of important ecosystem components. The Big Prairie ponderosa pine stand serves as an example. The first-year mortality of large, relic ponderosa pine after the fires of 2003 was approximately 34%, even though fire intensities and scorch heights were low to moderate. This was primarily because the smoldering consumption of the deep duff accumulations around the trees increased root and cambial mortality and ultimately killed the trees (Keane et al. 2006). It appears that we may need to apply proactive fuel treatments to reduce fire sizes and intensities and protect the remaining endangered CCE ecosystems, especially if these ecosystems are near homes or developments. Even though research has shown that managing fuel within 50 m of a home is more important to protecting the home than managing fuels in the forests that surround the home (Cohen 2004), the surrounding forests must nevertheless be managed to avoid losing critical ecosystem elements after they burn.

Many CCE ecosystems can benefit from reintroducing fire. Whitebark pine forests, for example, are declining rapidly because of mountain pine beetle epidemics and the spread of the exotic blister rust disease. Subalpine fir replaces the dying whitebark pine. Fires are needed to kill the subalpine fir to create openings where Clark's nutcrackers can plant whitebark pine seed caches and where new whitebark pine trees can successfully regenerate from unclaimed caches with little competition (Tomback et al. 2000). Because they were harvested from trees that survived the rust epidemic, the cached seeds are likely to produce trees with an increased level of rust resistance. Losing this keystone ecosystem would adversely affect more than 110 wildlife species that depend on this pine for food, especially the grizzly bear. Whitebark pine seed is a high-nutrition food source for grizzly and black bears and typically constitutes a major part of bear diet.

Without fire, many lodgepole pine cones do not open, limiting the species' ability to propagate. Subalpine fir will eventually replace lodgepole pine and those species dependent on lodgepole pine forests will decline. The large western larch trees still living on the montane CCE settings will eventually succumb to competing conifers or they will eventually be killed by abnormally severe wildfires. This loss will greatly reduce larch seed crops and change the composition and structure of postfire montane landscapes. In addition, ponderosa pine forests can rapidly be replaced by shade-tolerant conifers, also resulting in the loss of a unique ecosystem that many plants and animals have selectively utilized. Continuing our attempts to exclude fires in the CCE will spell the demise of these unique ecosystems.

Returning fire to these historically fire-dominated forests is not as easy as it might seem. In some stands, fire has been excluded for so long that surface and canopy fuels have accumulated to levels that, when burned, will have abnormal and undesirable consequences, such as killing the old ponderosa pine trees in Big Prairie (Brown 1985). Reducing fuel loadings using only prescribed fires—those sparked by lightning or humans—is difficult because there is a small window of opportunity to light the fire under moisture conditions that would not damage or kill the desirable ecosystem legacies and yet would still carry the fire. We can reduce these fuels using silvicultural cutting techniques, but this strategy is generally confined to scattered patches along the wildland–urban interface and near roads. These mechanical treatments are often costly and contentious and may have to be augmented with pile burning or prescribed burning for optimum efficacy. Many believe it may take two or more mechanical or fire treatments to restore some fire-excluded ecosystems.

Wilderness and Fire Management

The historical impact of anthropogenic burning in the CCE, which is now composed predominately of protected areas, presents a philosophical dilemma for management. The Wilderness Act of 1964 states that wilderness should be managed so as to be "untrammeled by man," but the very character of the landscape was probably shaped by thousands of years of burning by Native Americans (Stewart 2002). Ignoring the effect that aboriginal burning had on the flora and fauna of CCE wilderness settings would lead to the eventual creation of landscapes unlike those of the past. Yet the Wilderness Act specifically states that wilderness "not be subject to human controls and manipulations that hamper the free play of natural forces" (Hendee et al. 1978). Were aboriginal fires "natural forces" or were they "human manipulations"? Were the people who occupied North America for more than 20,000 years not a part of the natural environment? If all types of historical fires are deemed natural, the ecosystems that these fires created should indeed be conserved through frequent burning. Humans will probably need to light these fires.

Another complicating factor is the assumption in contemporary wilderness fire management that humans have not hampered the free play of natural forces. Modern humans actively suppressed most fires on wilderness landscapes for many decades before the Wilderness Act was passed. And, by definition, the act of suppressing fires and the policy of excluding fires are major human controls and manipulations. Since the 1980s, we have allowed a few fires to burn in CCE wilderness when they originated from natural ignitions (such as lightning). These fires were allowed to burn as prescribed fires under predetermined weather conditions. We have, however, suppressed the majority of wilderness fires. This exclusion of fire has led to wilderness settings where humans have hampered the most important disturbance process, wildland fire, for several decades.

In summary, two diametrically opposed anthropogenic actions have contributed to the quandary in which we find ourselves when deciding how to properly manage the CCE landscape. Humans have had their hands on wilderness ecology for a long time, yet the Wilderness Act does not fully recognize this reality or furnish any guidance for resolving this issue.

Human intervention is probably needed to save some of the remaining fire-dependent ecosystems such as the Big Prairie ponderosa pine forest. Proactive treatments might include raking around the base of the pines to minimize heating of the stem and roots, igniting prescribed burns during periods when lower duff is still moist to reduce fire intensities, and cutting encroaching conifers to reduce their potential for crown fires. These treatments may compromise the wildness character of the CCE and reduce the quality of the wilderness experience for some people.

A Crossroads in Wilderness Fire Management

We find ourselves at a crossroads in the management of wilderness and large natural areas such as those that comprise the CCE. Land management practices in the recent past have resulted in a buildup of surface fuels and a thickening of crown fuels, factors that lead to large, more-severe, and more-intense fires. This has put forth yet another dilemma for wilderness managers. If we decide that conserving historical CCE fire regimes is important, we must accept a small loss of wildness so that historical ecological processes and vegetation types can be restored. This can also protect the valuable ecosystem elements, such as the old-growth ponderosa pines, from future wildfires. Conversely, if we decide that wildness is more important, we must accept the consequences of the new fire regime, which will probably create landscapes that do not resemble those of the last 10,000 years. But important CCE wilderness legacies, such as large, cone-bearing whitebark pine forests, will dwindle to nothing if we do nothing, especially in light of the concomitant adverse effects of exotics, climate change, and human development in the CCE.

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SUSTAINING ROCKY MOUNTAIN LANDSCAPES

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