The Complexity of Managing Fire-dependent Ecosystems in Wilderness: Relict Ponderosa Pine in the Bob Marshall Wilderness

by Robert E. Keane, Stephen Arno and Laura J. Dickinson

ABSTRACT

Isolated wilderness ecosystems with a history of frequent, low-severity fires have been altered due to many decades of fire exclusion and, as a result, are difficult to restore for philosophical and logistical reasons. In this paper, we describe the successional conditions of ponderosa pine (*Pinus ponderosa*) communities along the South Fork of the Flathead River in the Bob Marshall Wilderness following decades of fire suppression, and then summarize the first-year effects of the 2003 fires on these communities. We found that at least 34 percent of the large ponderosa pine trees were dead or dying as a result of the fires, with much of this mortality due to cambial girdling following the burning of duff and litter buildup around the base of the trees. We explore possible strategies for, and barriers to, the restoration of deteriorating ecosystems in wilderness and other similarly managed natural areas that historically depended on frequent, low-intensity fires. We also discuss the complexity of managing fire-dependent ecosystems in wilderness.

Keywords: Bob Marshall Wilderness, wilderness management, *Pinus ponderosa,* ecological restoration, ponderosa pine

In recent years, some wildland fires have been allowed to burn to restore ecological disturbance processes in large wilderness areas and national parks in the northern Rocky Mountains of the United States (Arno and Fiedler 2005). Prior to the application of fire suppression strategies in the early twentieth century, most of these lands had a history of mixed-severity fires or stand replacement fires occurring at intervals averaging between 50 and 300 years (Arno 2000). Programs for restoring fire in wilderness areas and national parks have permitted some managers to use lightning fires as a form of burning under restricted conditions (Parsons and Landres 1998, Zimmerman and Bunnell 2000). These fires have been carefully monitored with some localized suppression used to protect facilities and private property.

Forests that were historically dependent on frequent, low-intensity fires—the "understory fire regime"—represent a major challenge for the restoration of historical wilderness fire regimes. An example of this is found along the South Fork of the Flathead River in the Bob Marshall Wilderness of northwestern Montana (Figure 1). Here, an understory fire regime perpetuated relict old-growth ponderosa pine (*Pinus ponderosa*) communities despite being surrounded by forest types with mixed-severity or stand-replacement fire regimes (Arno and others 2000). During the 1980s, some ecologists observed the successional replacement of ponderosa pine by inland Douglas-fir (*Pseudotsuga menziesii* var. *glauca*) and other conifers, and an unprecedented buildup of litter, duff, and ladder fuels that were endangering these isolated ponderosa pine communities (Wendel Hann, personal communication).

We began studying various ecological features of the South Fork ponderosa pine communities during the 1990s (Arno and others 2000, Östlund and others 2005). The fires of 2003, originating from lightning, burned through many of these stands for the first time in nearly a century or more. In doing so, it provided a unique opportunity to examine effects of returning fire to a fire-dependent forest type after long periods of fire exclusion.

In this paper, we describe the successional conditions in the South Fork ponderosa pine communities and the first-year effects of the 2003 fires. Even though mortality from bark beetle attacks and other secondary effects linked to fire take place during a period of about five years after a burn, the first-year findings already reveal trends that have important implications for these wilderness ecosystems. We interpret the effects of the 2003 fires

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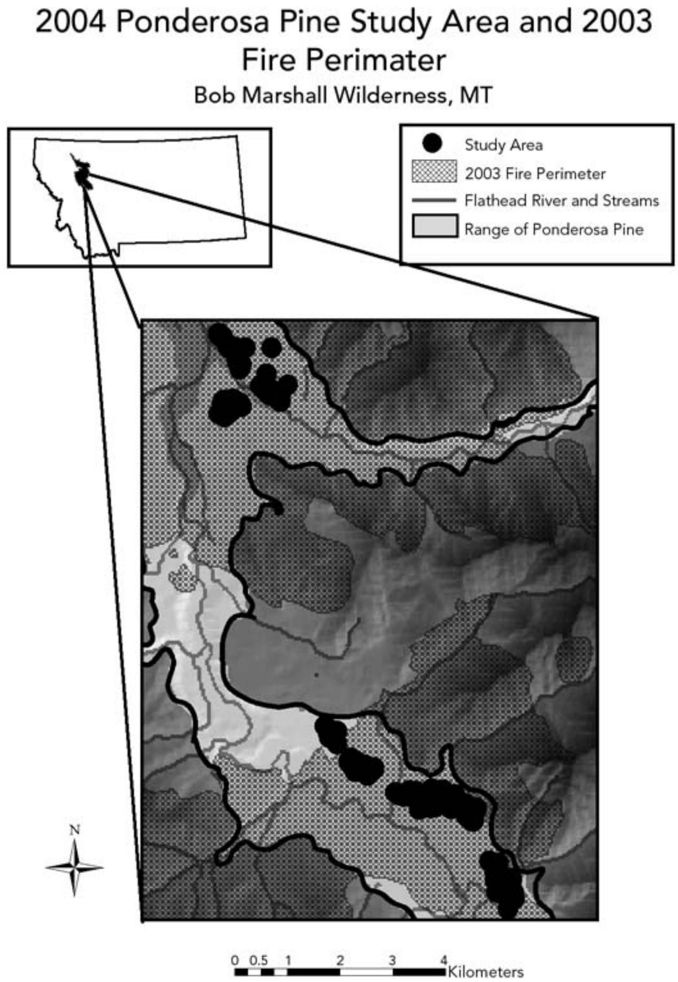

Figure 1. A map of the ponderosa pine ecosystem in the Bob Marshall Wilderness Area. The study area is shown as the area within the black line. The perimeter of the 2003 fires is shown as the cross-hatched area.

in communities that had already undergone profound successional change as a result of fire exclusion. We also discuss possible strategies for, and barriers to, the restoration of deteriorating ecosystems in wilderness and other similarly managed natural areas that historically depended on frequent, low-intensity fires.

Precepts of Fire in Wilderness

The Wilderness Act of 1964 (Public Law 88-577) designates lands as wilderness areas "for preservation and protection in their natural condition… [in a state] untrammeled by man." Untrammeled in this context means "not subject to human controls and manipulations that hamper the free play of natural forces" (Hendee and others 1978, p. 68). In the four decades since this concept of "wilderness" was codified, improved scientific understanding has raised some questions about the foundational premises of the Wilderness Act. Ecologists have determined that most wildland vegetation types in western North America were shaped over thousands of years by characteristic patterns of wildland fire (Agee 1993, Frost 1998). In some regions, Native Americans started many of these fires during a period of many centuries (Anderson and Moratto 1996, Boyd 1999, Kay and Simmons 2002, Stewart 2002, Williams 2004). Most forest ecosystems whose composition and structure was molded by the understory fire regime have now been greatly altered as a result of nearly a century of fire exclusion (Arno 2000, Keane and others 2002).

Language in the Wilderness Act suggests that permitting natural forces to resume without human interference will restore "natural" conditions. Ecological evidence, however, indicates that allowing lightning-caused fires to return after nearly a century of suppression can trigger unprecedented changes in forests that were historically dependent on frequent, low-intensity fires (Keane and others 2002, Mutch 1995). The Wilderness Act also fails to acknowledge the role that aboriginal people, through their extensive burning practices, may have played in influencing wilderness landscapes. Despite the recognition of this history, it is questionable whether, under today's conditions, regulated lightning fires alone can restore and maintain ecosystems that were shaped historically by frequent fires, let alone those landscapes where aboriginal ignitions were important (Brown 1992).

The Fire Dilemma Exemplified

The fate of relict ponderosa pine stands in the Bob Marshall Wilderness illustrates the dilemma associated with maintaining an understory fire regime in a wilderness area. The Bob Marshall Wilderness Complex (including the adjacent Great Bear and Scapegoat wildernesses) covers 1.5 million acres (0.6 million ha) of rugged terrain straddling the Continental Divide. The majority of this area is characterized by forests that burned historically at medium to long intervals (50 to 250 years) in mixed-severity or stand-replacement fires (Gabriel 1976, Keane and others 1994, Arno and others 2000). In contrast, some river terraces in the broad valley of the South Fork of the Flathead River support old-growth ponderosa pine that developed under the influence of relatively frequent, low-severity surface fires (Figure 1). Until the early 1900s, historical fires typically occurred at 20- to 30-year intervals and burned mostly through herbaceous fuels, consuming light litter accumulations under the large pines while killing many of the small trees of Douglas-fir and other conifers that became established since the previous burn (Arno and others 1997).

Ponderosa pines ranging from 75 to 600 years of age (with a few younger individuals that are mostly found in mixed stands with other conifers) occupy about 2,000 to 3,000 acres (800 to 1,200 ha) in the driest part of the South Fork valley. On one exceptionally dry terrace (White River Park), mature ponderosa pine trees form pure, open stands above an extensive grass layer (Figure 2). However, in most of

Figure 2. The ponderosa pine (*Pinus ponderosa*) savanna ecosystem of the Bob Marshall Wilderness Area. This photograph was taken at White River Park, which is located near the northern end of the study area shown in Figure 1. *All photos by Robert Keane, United States Forest Service*

the valley area, this species is accompanied by an abundance of sapling- and pole-sized trees of Douglas-fir, lodgepole pine (*Pinus contorta*), and other conifers that developed in the modern period when fires were actively suppressed.

The Fires of 2003

During July 2003, several lightning fires gradually merged and formed the Little Salmon complex. They burned southward and eastward until early September, entering more than half of the area in the South Fork valley that harbors ponderosa pine. The Little Salmon complex fire was not actively suppressed (measures were taken to protect administrative cabins and pack bridges) because exceptionally dry conditions across the region focused most suppression activities on non-wilderness areas where wildfires threatened developed areas. This return of fire after a prolonged period of fire exclusion offered an opportunity to assess the effects of these fires on the relict ponderosa pines (Arno and others 2000).

When lightning fires swept through many of the South Fork ponderosa pine stands in 2003 after a significant absence, land managers were concerned that the old pines, especially those surrounded by heavy fuel accumulations and weakened by excessive competition with Douglas-fir and lodgepole pine, would suffer high levels of mortality. Previous studies of fire effects in similar forest communities showed that mortality is greatest among old trees that had scars from pre-1930 fires (Harrington 2000, Gray and Blackwell in press). Open scars, surrounded by thick layers of litter and duff, provide a means for fire to burn deeply into the trunk and kill cambial tissue (Figure 3). The vulnerability of scarred trees might also extend to the old trees that have bark-peeling scars made when Native Americans harvested the cambium for food. In the South Fork valley, bark-peeling scars on living pines date back as far as 1665, and any accelerated mortality of these trees would represent an unprecedented loss of living artifacts of a former culture (Östlund and others 2005).

Study Area

Ponderosa pine communities are scattered along an 8-mile (13-km) section of the South Fork valley in the vicinities of Big Prairie and White River junction (Figure 1). They occupy elevated terraces, mostly on the east side of the river, that have well-drained, coarse alluvial soils. The ponderosa pine communities consist largely of mature trees, sometimes accompanied by younger individuals in the 70- to 100-year range. In some stands, ponderosa pines appear as widely dispersed, old trees within a community now dominated by Douglas-fir, lodgepole pine, and other conifer species. In other stands, ponderosa pine is a major component.

Nearby low-lying, frost-prone sites have few, if any, ponderosa pine and are dominated by lodgepole pine accompanied by subalpine fir (*Abies lasiocarpa*) and Engelmann spruce (*Picea engelmannii*). Isolated fescue (*Festuca* spp.) grasslands occupy exceptionally dry microsites, often bordered by ponderosa pine (Koterba and Habeck 1971). Surrounding upland sites without ponderosa pine are largely dominated by Douglas-fir and lodgepole pine. Small numbers of western larch (*Larix occidentalis*) occur with the ponderosa pine, although larch is more abundant north of these ponderosa pine communities and on the north-facing slopes above the ponderosa pine ecosystem.

The relict ponderosa pine communities occupy some of the warmest and driest sites in the South Fork valley, situated in a climatic rain shadow on the lee side of 9,000-ft (2,743-m) peaks in the Swan and Mission ranges immediately to the west. These sites receive less snow and rain than areas upstream or downstream (Figure 1). In major valleys farther to the west, north and south, ponderosa pine occupies only the warmest and driest sites. The species is absent to the east in valleys subject to a harsher, continental climate (Arno and Hammerly 1984). Part of the reason for ponderosa pine's limited extent in the South Fork drainage is that this rain shadow area occurs in a relatively high valley (near 4,600 ft or 1,402 m), where the frost-free season appears to be marginally short and probably hinders ponderosa pine cone production and subsequent regeneration (Lunan and Habeck 1973, Arno and Hammerly 1984, Jacobsen 1986).

Due to fire exclusion, the South Fork ponderosa pine communities experienced very few small fires between roughly 1930 and 2002, even though the Spotted Bear Ranger District of the Flathead National Forest has had an active wildland fire use program for more than 20 years (Arno and others 2000, Östlund and others 2005). Lack of fires during this period allowed young lodgepole pine and Douglas-fir to colonize or increase in formerly open stands of mature ponderosa pine (Figure 3). Mature lodgepole pines associated with the ponderosa pine communities commonly exhibit one to four well-formed fire scars created prior to 1930. Old-growth ponderosa pines sometimes possess scars from five to seven fires. Fire-scar dating thus far indicates that for three centuries prior to about 1930, fires occurred at average intervals of about 20 to 30 years in the ponderosa pine communities (Östlund and others 2005). Fires clearly allowed individual ponderosa pines to survive for several centuries, and the species to dominate in relatively open stands. Östlund and his colleagues (2005) aged more than one hundred Native American bark-peeling scars and found the peel scars were made between 1665 and 1938. This, and other archeological evidence and information, suggests a significant amount of human occupation of these sites for several centuries and that many of the historical fires may have been started by these Native Americans (Flanagan 2001).

Figure 3. Deep duff mounts surrounding the bole of large ponderosa pine (*Pinus ponderosa*) with an Indian scar in the Big Prairie area of the Bob Marshall Wilderness Area. Also note the increase in Douglas-fir (*Pseudotsuga menzeisii*) in the understory where it is crowding the large ponderosa pine and weakening these trees.

Tree Sampling

We sampled all mature (20 inches [50 cm] or greater in diameter, and thus probably at least 100 years old) ponderosa pines in broad transects (more than 100 meters wide) extending through portions of the study area that burned in 2003 (Figure 1). On these transects, measurements and evaluations taken for all sampled trees that were alive prior to 2003 included: health status (1-satisfactory, 2-weak, 3-near death, 4-died recently), probable cause of mortality (fire, beetles, unknown), and percent crown scorched by fire. We also recorded diameter at breast height (DBH), presence of fire scars, and bark-peeling scars (Figure 4). Geographic location was identified with a GPS receiver, using UTM coordinates for zone 12 and NAD 83 projection. During visits prior to the 2003 fires, we noted many trees on the site that were weakened by competition and mountain pine beetle. We also observed duff mounds that were 6 to 15 inches deep (15 to 40 cm) surrounding the base of many old-growth ponderosa pines in areas outside the 2003 burns.

Results

We sampled 455 mature ponderosa pine trees within the 2003 fires in the vicinities of White River Park and Big Prairie (Figure 5). This sample represents an appreciable proportion of all mature ponderosa pine trees in the study area. The distribution of trees by health status and scar type (Table 1) shows that about 16 percent of all ponderosa pine had died within a year after the fires, many from secondary effects—possibly bark beetle attacks. Another 18 percent are dying and will probably be dead within a year or two. Thus, we estimate that at least 34 percent of the mature ponderosa pine trees will be dead within a few years of the 2003 fires (Table 1). Trees with old fire scars or bark-peeling scars comprised about 25 percent of the mature ponderosa pines in our sample (Table 1). About 42 percent of all scarred trees were dead and dying as a result of the 2003 fires compared to the 31 percent of unscarred trees (Table 1). The fire commonly burned into old scars inflicting heat damage to the cambium or consuming wood needed for structural support, causing the tree to eventually fall. We estimate that about half of living trees with historic bark-peeling scars will die within two years of the 2003 fires (Table 1).

Figure 4. Measuring diameter at breast height on an Indian-scarred tree that was burned in the 2003 fires in the Bob Marshall Wilderness Area. Note the lack of vegetation surrounding these trees because of severe soil heating from the thick duff and litter layer resulting from fire exclusion.

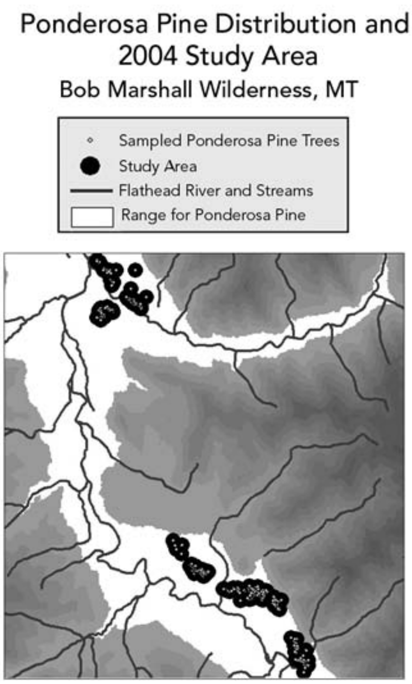

Figure 5. Trees sampled during the summer of 2004. Only ponderosa pines that were more than 20 inches DBH were sampled.

Discussion

Tree Mortality

The 2003 fires generally burned with low intensities through the South Fork ponderosa pine communities causing only moderate crown scorch in many places (Figure 6). In this sense, the effects of the fires may be the best that can be hoped for without management intervention (that is, raking the duff away from the base of the tree) considering the abundance of duff, woody, and ladder fuels. Canopy torching and passive crown fire occurred locally in small patches, up to about 5 acres (2 ha), mostly in dense lodgepole pine/Douglas-fir stands.

The estimated ponderosa pine mortality after the fires of 2003 (34 percent) may well increase as insects and disease invade weakened trees (Table 1). This may be a high rate of loss for a species that in the past survived most fires and benefited competitively as a result of them (Arno and Fiedler 2005). We speculate that most of the observed mortality came from cambial girdling at the ground line probably linked to the heavy duff and litter accumulations that almost always were completely consumed. However, the heavy crown scorch in the recently dead trees also contributed to the fire-caused tree mortality (Figure 6). Some post-fire mortality, which we estimate at about 20 percent, was attributed to observed mountain pine beetle infestations in the weakened trees, although the specific cause of death was difficult to determine. Beetle mortality has also expanded to those ponderosa pines not exposed to recent fires.

Several conditions in the South Fork ponderosa pine stands that lie outside the boundaries of the 2003 fires suggest that unburned stands are also vulnerable to accelerated attrition with or without fire.

1. Duff layers around mature trees have accumulated for 75 to 100 years, three to four times as long as pre-1930 intervals between fires. Thus, any fire will produce an unusually severe heating effect on tree cambium and roots (Harrington and Sackett 1992).
2. Competing conifers have had 75 to 100 years to become established instead of the 20- to 30-year intervals between fires that were common historically. This has favored Douglas-fir, which is quite fire sensitive when young but begins to develop corky bark and a higher, more fire-resistant canopy after about 30 years. Douglas-fir is considerably more shade-tolerant than ponderosa pine and is the pine's most abundant and aggressive competitor. It also produces cone crops more frequently than the pine.
3. Crowded ponderosa pines have low vigor and are vulnerable to bark beetle attack. Thus, they are unlikely to retain dominance and survive several hundred years, as was the case historically (for example, see Arno and others 1995 and Biondi 1996).
4. Ponderosa pine cone crops and seedling survival are generally poor in such relatively cold sites, and are made worse by excessive competition linked to fire exclusion.

Table 1. Summary of sampled ponderosa pine trees greater than 20 inches DBH by scar status and health.

	Number of ponderosa pine trees (% of grand total)				
Scar Type	Healthy	Sick	Dying	Dead	Total
No Scars	174 (38)	60 (13)	66 (15)	38 (8)	338 (74)
Fire Scarred	21 (4)	13 (3)	6 (1)	16 (4)	56 (12)
Indian Scar	25 (6)	5 (2)	9 (2)	14 (4)	53 (12)
Fire/Indian Scars	3 (1)	2 (>1)	1 (>1)	2 (>1)	8 (2)
Total	223 (48)	80 (18)	82 (18)	70 (16)	455 (100)

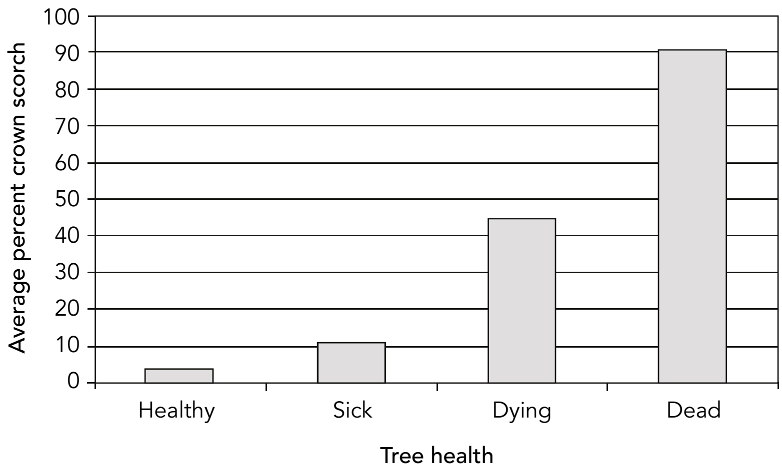

Figure 6. The average percent crown scorch by health class of the 455 trees sampled within the 2003 burned area near Big Prairie, Bob Marshall Wilderness Area.

Management Dilemma

It is difficult to confirm that lightning ignitions alone could have been responsible for the relatively high frequency of pre-1930 fires in the South Fork ponderosa pine stands. Ponderosa pine communities cover less than 2 percent of the 1.5 million-acre Bob Marshall Wilderness Complex, and they are surrounded by forest types that had considerably longer fire intervals (Gabriel 1976, Keane and others 1994). Furthermore, these ponderosa pine forests are located in valley bottom sites that are less frequently struck by lightning than forests in higher mountain topography (Barrows and others 1977, Renkin and Despain 1992). Severe drought years probably provide the only opportunity for lightning fires to spread from higher elevations downslope into the South Fork valley. Long-term use of the South Fork ponderosa pine communities by Native Americans and evidence of significant Native American burning elsewhere in western Montana suggest that aboriginal burning was likely an important ignition component of the historical fire regime in the South Fork valley (Barrett and Arno 1982, Gruell 1985, Arno and others 1997).

Prolonged exclusion of fires, from both the direct suppression of fire and the elimination of the Native American culture of burning, has had compounding negative consequences for ponderosa pine stands of the Bob Marshall Wilderness Area regardless of the origin of historical fires. These include allowing other, more fire-sensitive conifer species to increase competitive stress on ponderosa pine as well as creating dense ladder fuels and deep duff and litter accumulations that now allows fire to kill the competition-weakened ponderosa pine. Considering that many of the ponderosa pines are 400- to 600-years-old and survived numerous pre-1930 fires, but now appear highly vulnerable, it is difficult to conceive that today's communities can be considered "untrammeled by man."

The recent exclusion of fires presents a dilemma for wilderness land managers. For several decades before and after the passage of the Wilderness Act, land managers have suppressed the vast majority of natural (lightning) fires in wilderness areas (Parsons and Landres 1998). This constitutes a profound human manipulation of ecosystems (Keane and others 2002). In some of the largest wilderness areas, including the Bob Marshall, an increasing proportion of natural fires have been allowed to burn since 1970. This may well help restore ecosystems in mixed or stand replacement fire regimes that historically burned at intermediate or long intervals (Arno and Fiedler 2005). However, in most of the South Fork ponderosa pine communities, successional replacement by other conifers and an excessive accumulation of fuel now portend a continuing loss of ponderosa pine communities given either continued fire suppression or the resumption of lightning fires.

The impact of anthropogenic burning in the South Fork river valley presents yet another dilemma for the management of wilderness. Native Americans are now thought to have set many fires in the South Fork valley for several centuries prior to European settlement (Boyd 1999, Kay and Simmons 2002, Östlund and others 2005). Their contribution to the ponderosa pine fire regime is difficult to determine, but the evidence supports their probable influence on maintenance of the old-growth ponderosa pine ecosystem. Neither today's landscapes nor pre-European settlement landscapes can be considered "untrammeled by man." Humans have been manipulating wilderness ecology for a long time, yet the Wilderness Act requires that wilderness be "not subject to human controls and manipulations that hamper the free play of natural forces" (Hendee and others 1978).

To have any hope of conserving the late-successional ponderosa pine communities in the South Fork, management intervention is necessary to restore a semblance of historical fire regimes, stand structure, and fuel conditions (Figure 2). Fuel treatment options might include raking duff away from the base of old ponderosa pines to minimize excessive heating of the stem and roots, cutting some of the competing conifers and perhaps burning them in piles to reduce the potential for crown fires, and/or conducting prescribed burns during cool or moist seasons (early spring or autumn) to reduce fire intensities (Covington and others 1997, Harrington 2000, Friederici 2003, Arno and Fiedler 2005). Such treatments are commonly practiced to restore old-growth ponderosa pine communities outside wilderness. A notable example of this kind of fire regime restoration is beginning on 200,000 acres (80,000 ha) of wilderness and non-wilderness in Idaho's Salmon River canyon (Nez Perce National Forest 1999). Although such treatments in the South Fork ponderosa pine communities would involve human manipulation, they should be limited to that necessary to reverse the degradation caused by a history of indirect human manipulation (fire suppression) that cannot be reversed without active intervention (Brown 1985, Mutch 1995, Agee 2002, Thomas 2002). The South Fork ponderosa pine forests may be somewhat easy to restore because they represent a small area and more than 50 percent of this area was burned in 2003. Yet, even with human intervention, it is still questionable whether managed lightning ignitions can create fire regimes that will sustain the older ponderosa pine trees (Brown 1992). These isolated ecosystems will surely decline if nothing is done to ensure the continued survival of these relic ponderosa pines.

Conclusions

The relict ponderosa pine communities in the Bob Marshall Wilderness are characterized by ancient trees that are often living artifacts of Native American land use as witnessed by bark-peeling scars. To sustain these communities, land managers would need to reduce fuel hazard and excessive competition before applying prescribed fire for more beneficial effects. After initial restoration treatments, it is possible that natural fires can be permitted to return with outcomes similar to those of the historical fires that perpetuated these communities. It will also be necessary to monitor stand conditions and ensure that fire continues to occur at frequencies and severities that mimic historical conditions. Until restoration of historical fuel and structural conditions has progressed, both protection from fire and focused human manipulation, and future wildfires will contribute to the downward spiral of forest health and the eventual loss of the successional ponderosa pine communities. Without fire and limited fuel treatments, competing conifers will rapidly replace these ponderosa pine forests.

Contrasting philosophical questions remain: Will society accept the loss of ponderosa pine communities in wilderness because human intervention is undesirable? Or, will society tolerate fuel treatments in wilderness because the loss of ponderosa pine forests is unacceptable?

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