May 2008

Contributions in Education and Outreach

No. 1

An Illustrated Guide to Fire in Central Oregon Forests

Bradley E. Eckert, John D. Walstad
and John C. Tappeiner II

Forest Research Laboratory
College of Forestry
Oregon State University
Corvallis, Oregon

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Abstract

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This pictorial guide is primarily intended to serve as a backdrop for field tours of central Oregon that involve topics surrounding wildland fire. It also is designed to provide an overview of the role of fire in the major ecosystems characteristic of this region. Topics covered include fire history, fire regimes, current fire conditions, fire behavior, fire threats to natural resources, fuel treatments, interactions with the public, and future challenges and management options. A list of key references and glossary are also included.

Keywords: Fire, wildland fire, forest fire, rangeland fire, fire history, fire ecology, fire regime, fire severity, fire exclusion, fuels, fuel treatments, forest types, ponderosa pine, lodgepole pine, true fir, Douglas-fir, western juniper, ponderosa pine forests, mixed conifer forests, high elevation forests, Central Oregon, Deschutes National Forest, Sisters Ranger District, B&B Complex Fire

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This guide to fire history, regimes, and use in central Oregon forests is designed for field tours to the areas around Camp Sherman, Sisters, and Bend. Although most relevant to the B&B Complex Fire of 2003, the information is pertinent to fires in general for this region. Each section includes a brief set of thought-provoking questions, followed by some text and illustrations that address the questions. Some useful references are listed at the end, along with a glossary of italicized terms found in the text.

A Historic Ecosystems and Fire

Questions to Ponder

How would you determine the frequency and severity of historic, natural fires in central Oregon? Are they likely to be uniform or variable across the region? How might they differ for ponderosa pine versus high elevation forest types? What effects might you expect under different fire regimes?

Fire is a natural part of historic *ecosystems* in central Oregon, including the area currently occupied by the Deschutes National Forest (Fig. 1). Major *forest types* in which fires occurred included ponderosa pine, mixed conifer, lodgepole pine, and high elevation (subalpine) spruce-fir forests. Fire was also common in adjacent sagebrush-juniper rangelands of the interior region of central Oregon. Fires occurred when lightning or humans ignited dry, often dead, vegetation and down wood.

Prior to Euro-American settlement of the West, Native Americans used fire to enhance their environs (Fig. 2). Depending on the area, burns were conducted to improve the habitat for hunting, stimulate plants used for food and forage, clear vegetation for defensive purposes, and to meet other needs. Indeed, their use of fire was often quite sophisticated given the multiple objectives involved.

Since Euro-American settlement, fire has continued to play an important role in central Oregon. Natural, intentional, and accidental fires have greatly affected the landscape and

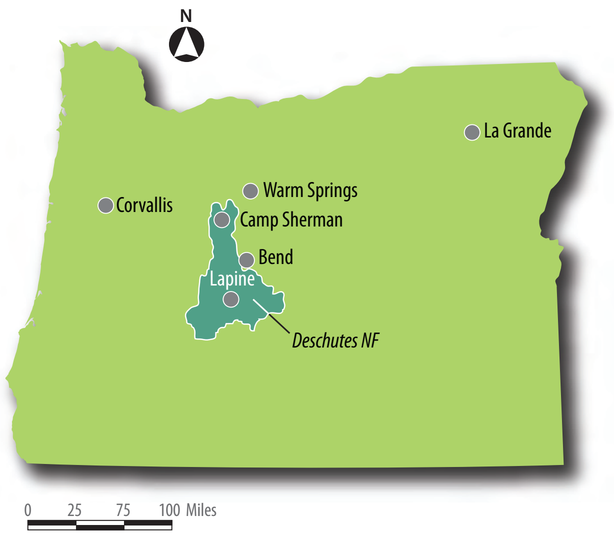

Figure 1. Location of the Deschutes National Forest within Oregon.

Figure 2. This 1908 painting by Frederick Remington depicts Native American use of fire. In this case, a band of Indians is setting fire to prairie grasses for defensive purposes. [Photo of Remington painting from Fire Management Today, Vol. 60, No. 3 (Summer 2000), USDA Forest Service.]

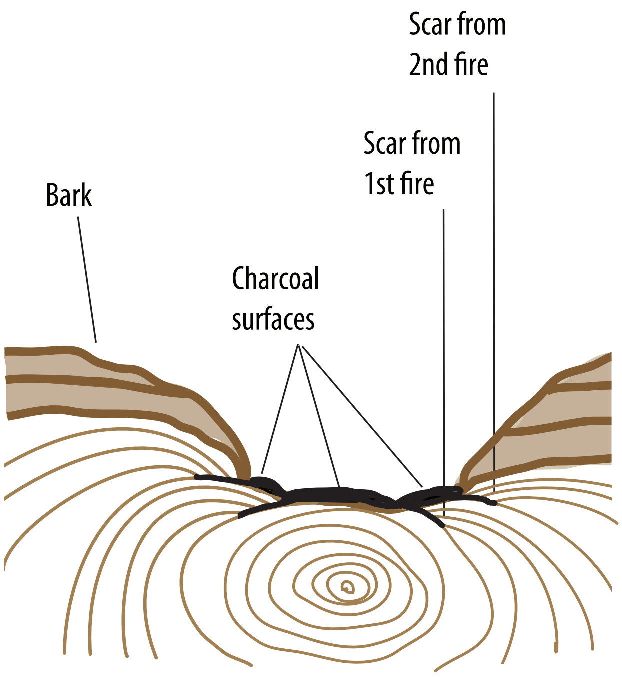

Figure 3. Scars from two fires are evident on this ponderosa pine cross-section of a stump. Dates when the fires occurred can be estimated by counting the annual growth rings (concentric circles) to where they were damaged by the fire and then correlating with dendrochronology records to determine tree age and when the fires occurred. (Adapted from Morrison and Swanson 1990).

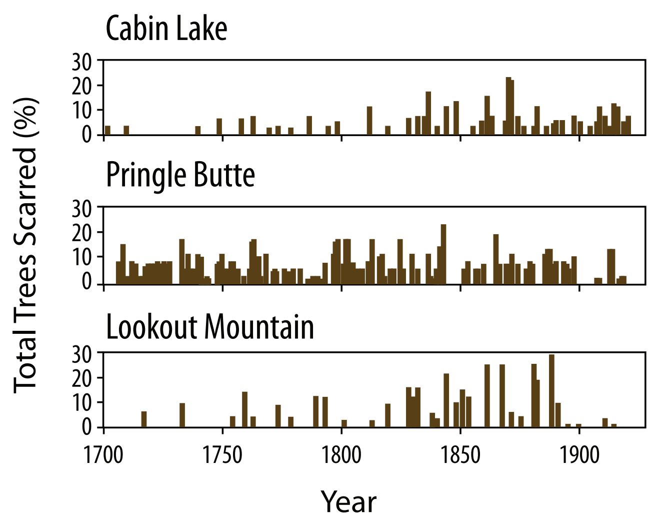

Figure 4. Frequency (in terms of recorded fire occurrence) and severity (in terms of percentage of trees scarred by fire) of historical fire events for three sites on the Deschutes National Forest, 1700-1920. Cabin Lake and Pringle Butte are in the ponderosa pine type. Lookout Mountain is in the mixed conifer type. (Redrawn from Bork 1985).

ecosystems in this region. Concerted efforts to suppress and extinguish fires have also had a profound effect on forest and rangeland conditions we see today. Thus, understanding the important role that fire—and fire exclusion—have played is crucial to intelligent management and protection of these ecosystems in the future.

The role of fire in these ecosystems has become better understood as a result of decades of research conducted by scientists and resource managers. Much is based on *tree ring analysis* and *cross-dating* in which *fire scars* are chronologically dated. Because trees in temperate climates generally produce one growth ring in diameter per year, it is possible to age such trees and often determine when fires occurred due to the interruption of the growth rings caused by fire damage (Fig. 3). Using this technique, scientists can estimate the frequency of fires over time within a given area, thereby establishing the *fire return interval* (or *mean fire return interval*). The effects of periodic burning by Native Americans notwithstanding, different areas have naturally different fire return intervals. Such patterns of *fire frequency* can be quite regular to highly variable, but in general they provide a useful approximation of how often fire—at least one severe enough to leave fire scars and other evidence—traversed a given ecosystem (Fig. 4).

With respect to fire severity, it is important to distinguish this term from fire intensity. *Fire severity* is a qualitative term used to describe the relative effect of fire on an ecosystem, especially the degree of canopy loss or vegetation mortality, wood consumption, and soil heating. Thus, fires are arbitrarily classed as low, moderate, high , and mixed severity. *Fire intensity* (or *fireline intensity*) is a quantitative measure of heat exchange and is related to flame length and difficulty of fire suppression. Specifically, it is the rate of heat energy released per unit of time per unit of length of fire front—generally expressed in numerical units. Fire severity may or may not be closely related to fire intensity, depending on the specific conditions involved. However, as flame length or height increases, conditions are created for more severe fire effects.

Historically, fire return intervals—and corresponding fire severity—varied with forest type along precipitation and temperature gradients associated with changes in elevation, aspect, and topography (Figs. 5, 6). Generally, the lower the elevation and more southerly the exposure, the warmer and drier the climate. This led to relatively frequent, low severity fires in such areas. As elevation increases or topography shifts to a more northerly aspect, the climate becomes cooler and moister. Fires in such environs are relatively rare but are often of high severity when they occur. These general relationships allow construction of generic *fire regimes* that depict the relative severity of fires associated with various forest types along climatic gradients (Figs. 7, 8; Table 1).

Ponderosa pine forests occur where the climate is warm and dry for this region but still supports a forest (Figs. 7, 9). Historically, these forests experienced frequent surface fires about

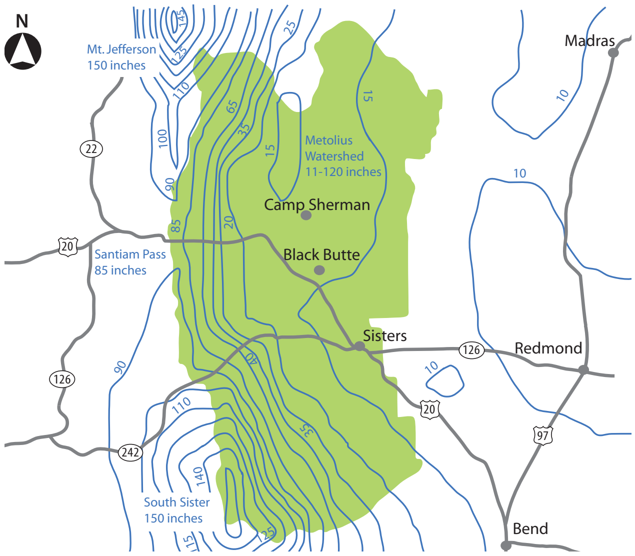

Figure 5. Precipitation gradient within the Sisters Ranger District on the Deschutes National Forest. Note the variation in annual precipitation (wavy blue lines) within the Metolius Watershed (11-120 in.) associated with elevational changes along the eastern flank of the Cascades.

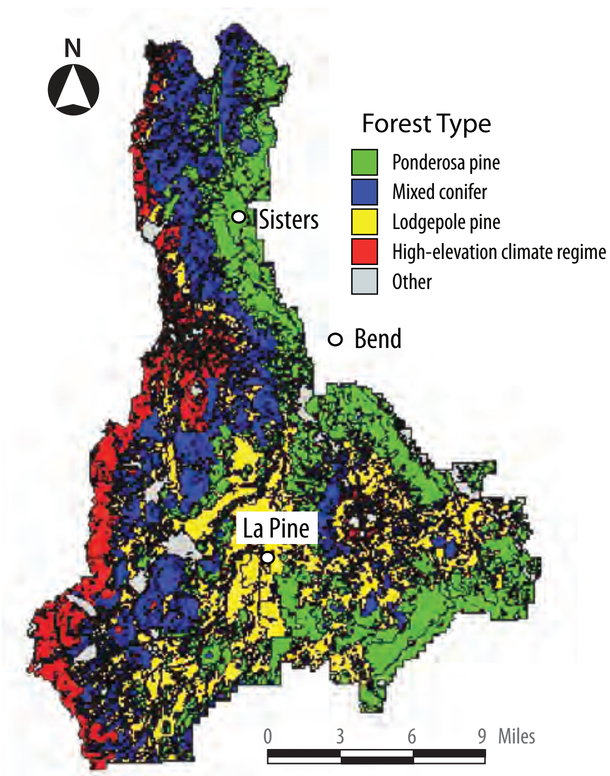

Figure 6. Natural forest types on the Deschutes National Forest.

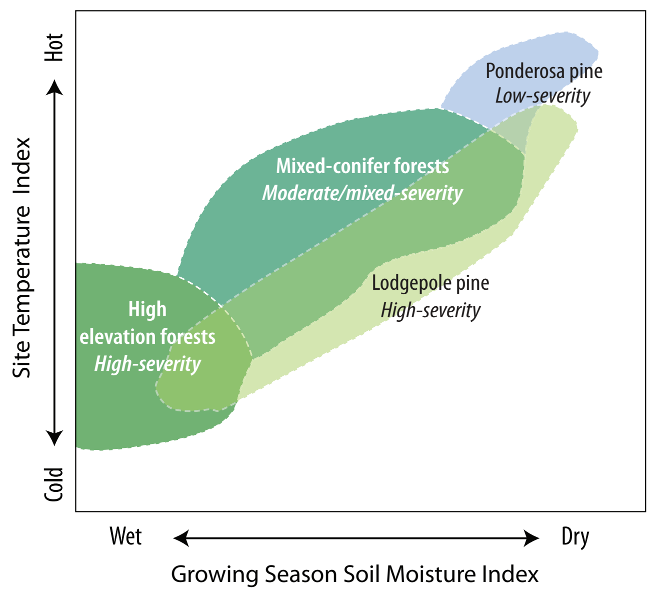

Figure 7. Forest types and fire regimes on the Deschutes National Forest as determined by soil moisture and site temperature indices. Pockets of lodgepole pine can burn at high severity within any of the regimes.

Table 1. Fire regimes for the Deschutes National Forest.

Fire regime (severity)	Fire return interval (years)	Fire effects	Forest type
Low	5–35	Minimal	Ponderosa pine
Low-moderate	10–50	Minimal-substantial	Mixed conifer–dry
Moderate	50–100	Moderate-substantial	Mixed conifer–wet
Severe	50–100	Stand replacement	Lodgepole pine–dry
Severe	> 100	Stand replacement	High elevation (e.g., mountain hemlock, spruce, fir, Douglas-fir, lodgepole pine)

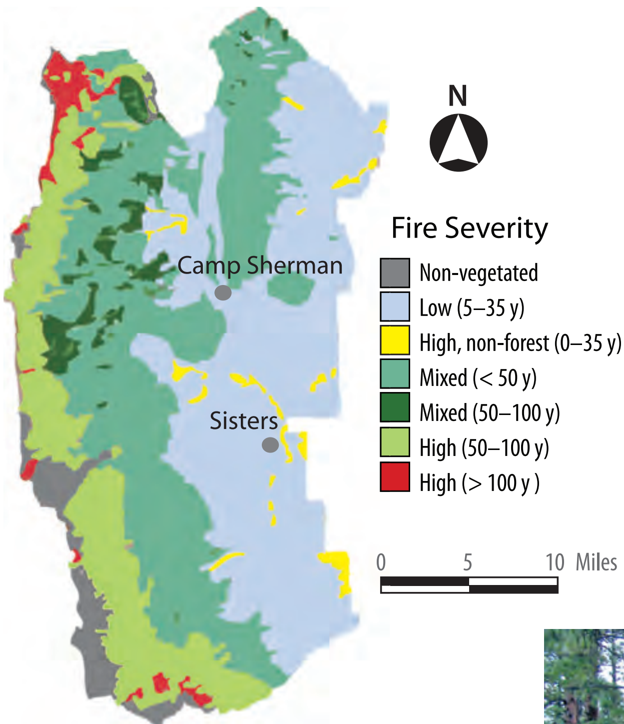

Figure 8. Current fire regimes (severity) and fire return intervals (years) for the Sisters Ranger District on the Deschutes National Forest.

every 5-35 years that limited the establishment and growth of understory vegetation (shrubs and small trees) and the accumulation of dead, flammable material. The fires were generally of low severity and tended to create patchy mosaics of burnt vegetation across the landscape. Large trees with thick bark and high crowns were often scorched but not killed.

Mixed conifer forests cover mid-elevations between ponderosa pine and high elevation forests (Fig. 10). They contain species such as ponderosa pine, lodgepole pine, Douglas-fir, western larch, incense cedar, white fir, and grand fir. With greater precipitation than ponderosa

Figure 9. Contemporary example of a "historic" low-elevation ponderosa pine forest characteristic of those found on the lower eastern slope of the Cascades Range in central Oregon in the early 1900s.

Figure 10. Contemporary example of a "historic" mid-elevation mixed conifer forest on the eastern flank of the Cascades Range in central Oregon.

Figure 11. Mosaics of partially and completely burned stands are a common result of fires in the mixed conifer zone characteristic of central and southwest Oregon.

pine forests and warmer temperatures than high elevation forests, mixed conifer forests are quite productive. Rapid accumulation of vegetation and flammable dead material supports fire every 10-100 years, with more frequent fire on drier sites. Fire impact on ecosystems is more varied within the mixed conifer forest type than in other forest types, creating mosaics of surface, understory, and crown fires (Fig. 11, 12). Generally, fire effects are less severe on drier mixed conifer sites where fire occurs more often.

Lodgepole pine forms pure, relatively even-aged stands within several forest types and commonly experiences stand-replacing fires every 50-80 years or longer. Lodgepole pine can be found at high elevations, but may also occur at lower elevations in frost pockets or on sites with thin soil and where harsh conditions limit establishment of other species (Fig. 7, 13). Dense post-fire regeneration and subsequent mortality associated with *bark beetle* outbreaks often lead to large accumulations of flammable material (Figs. 13, 14). Indeed, bark beetle outbreaks are the primary disturbance factor affecting lodgepole pine forests when they

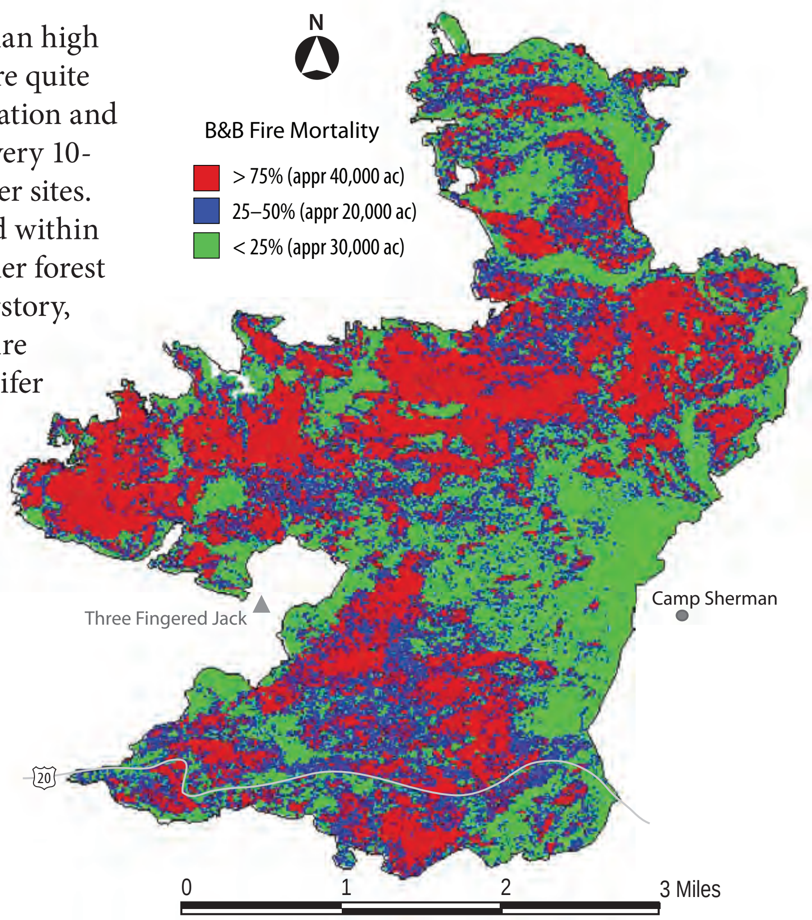

Figure 12. Fire severity within the B&B Complex Fire on the Sisters Ranger District of the Deschutes National Forest. Tree mortality ranged from more than 75% in the high elevation and mixed conifer zones to less than 25% within the ponderosa pine zone. But there was lots of variation within zones.


Figure 13. Typical low-elevation lodgepole pine forest in central Oregon. Many of the stands, including this one, have been riddled by bark beetles and contain lots of dead trees and down woody material.


Figure 14. Widespread tree mortality caused by bark beetles in a dense, low-elevation lodgepole pine stand on a hillside adjacent to Paulina Lake in central Oregon.

get to be 80 years or more in age. Beetle outbreaks notwithstanding, lodgepole pine has thin bark and is susceptible to fire-induced mortality, even from low-intensity surface fires.

High elevation forests are often dominated by subalpine fir, Pacific silver fir, Douglas-fir, mountain hemlock, Engelmann spruce, or lodgepole pine (Fig. 15). They experience infrequent fire every 100 years or more. Moist conditions reduce forest flammability, resulting in long fire-free periods that allow significant amounts of fuel to accumulate. Fires still occur, however, especially during periods of exceptionally dry, hot, and windy weather. When fire does occur, it is usually so intense that a majority of vegetation is killed, including most large trees. In addition to crown scorch, tree species common in high elevation forests are also vulnerable to surface heat during a fire because many have thin bark and shallow roots. Consequently, fires in these forests are often high-intensity, stand-replacing events.

Finally, fire is an important factor in maintaining productive **rangelands** characterized by native sagebrush, bitterbrush, bunchgrasses, and forbs. Historically, frequent fires prevented the encroachment of western juniper and other tree species from adjacent **juniper woodlands** (Fig. 16). However, simply reintroducing fire in rangelands can be a problem if native plants have been displaced

Figure 15. Typical high-elevation conifer forest on the eastern flank of the Cascades Range in Oregon.

by invasive weeds like cheatgrass that thrive on recurrent fire. Thus, careful application of fire and other restoration treatments is needed to maintain or rehabilitate rangeland communities.

Not only does vegetation type vary across the landscape of central Oregon, but fire behavior also varies within each type and even within individual fires (Figs. 12, 17). These variations in fire behavior are due to numerous factors ranging from weather and topography to fuel loads, season of year, and diurnal conditions.

Range and variability of fire characteristics on a given site may be more important than average conditions in terms of ecosystem effects. For example, ponderosa pine seedlings may establish quickly following fire, but then be killed by subsequent fire that occurs before development of thick, fire-resistant bark and branches beyond the reach of flames. Occasional fire-free periods are necessary to allow seedlings to survive and grow to sapling and pole size.

Figure 16. Western juniper invading a sagebrush rangeland community characteristic of central Oregon.

Figure 17. Mosaic of meadow (foreground) and dead timber (background) after a stand-replacing fire in the high-elevation forest zone of central Oregon.

B Recent Fires vs. Natural, Historic Fires

Questions to Ponder

How do conditions of today's forests in central Oregon differ from those of historical times? Does this have any effect on the kinds of fires we have witnessed in recent years? What patterns do you see emerging in contemporary fire behavior and impact?

Recent fires on the Deschutes National Forest have been larger and have burned at higher severity than those experienced during the past century (Figs. 18, 19). For example, the 2003 B&B Complex Fire burned 90,692 acres (Fig. 20). The portion that burned on the Deschutes National Forest (67,112 acres) constitutes the largest fire on record for that Forest. The B&B Fire had impacts on natural resources that were also greater than those experienced historically. Within the fire perimeter, about 25% of the ponderosa pine forest type experienced moderate to high mortality, and almost three quarters of all other forest types experienced moderate to high mortality. There were concomitant effects on other ecosystem components such as understory vegetation, wildlife habitat, animals, microorganisms, forest floor, and soil.

Other major fires in Central Oregon during recent times include the Skeleton Fire (1996, ~18,000 ac), Eyerley Fire (2002, ~23,000 ac), Cache Mountain Fire (2002, 4,200 ac), Davis Lake Fire (2003, ~21,000 ac), Link Fire (2003, 3,600 ac), the Cascade Crest Complex Fire

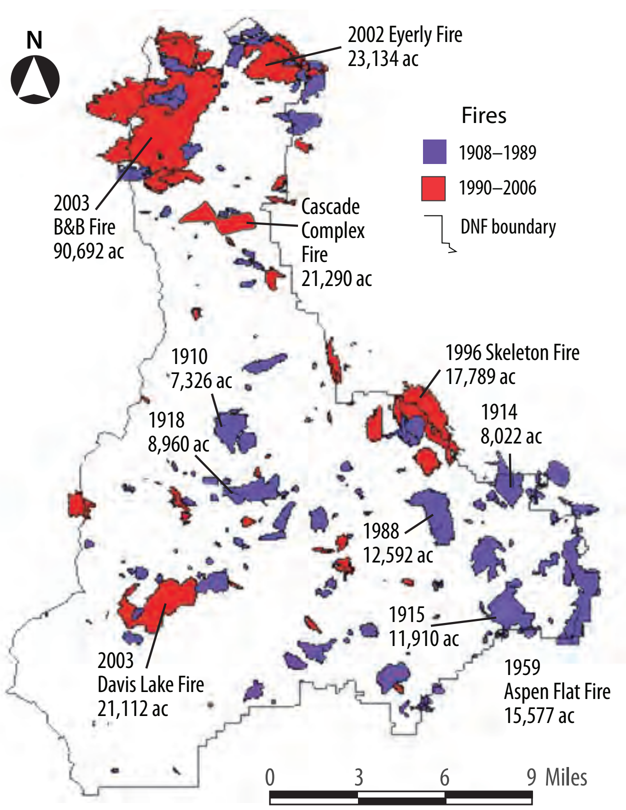

Figure 18. Size of significant fires on the Deschutes National Forest, 1908-2006. Note that many fires since 1990 (shown in red) are among the largest on record for this area.

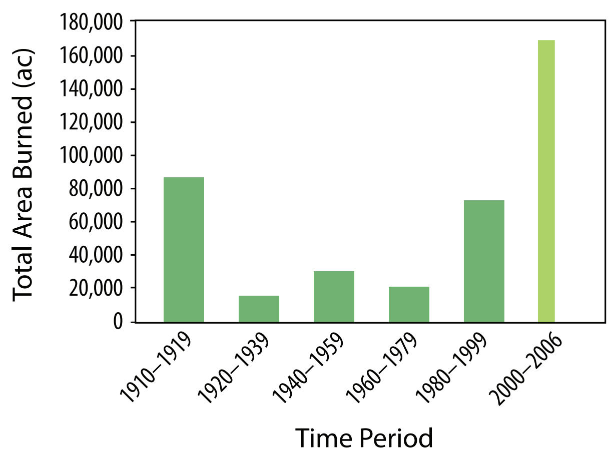

Figure 19. Acres burned on the Deschutes National Forest during five 20-year periods between 1910 and 1999, and during one 7-year period from 2000 to 2006. The upswing since 1980 is presumably due to fuel accumulation as a result of decades of fire prevention and suppression, perhaps coupled with warmer and drier climate conditions.

consisting of the Lake George, Black Crater, and Puzzle fires (2006, 21,290 ac), and the GW Fire (2007, 7,360 ac). So there have been major conflagrations every few years since the mid 1990s. Indeed, the average area burned in these recent fires is over 23,000 acres versus about 11,000 acres for fires that occurred earlier in the past century.

Figure 20. Aftermath of the B&B Complex Fire of 2003 on the Sisters Ranger District of the Deschutes National Forest. Over 90,000 acres were burned before the fire was extinguished.

C Drivers of Current Fire Behavior

Questions to Ponder

Why have fire effects changed over the past century? Do forest type and location matter? What forces and factors are responsible for today's wildland fire situation? What are some tradeoffs between aggressive fire prevention and suppression versus other management options or considerations?

Since 1900, fire exclusion, human-caused fires, logging, livestock grazing, rural development, and other activities have been largely responsible for the recent increase in stand-replacing disturbances, including insect and disease outbreaks and high-severity

Figure 21. Typical low-elevation ponderosa pine forest today on the eastern flank of the Cascades Range in central Oregon. Note the dense understory of ponderosa pine reproduction.

fires. **Post-Euro-American settlement impacts** on forest composition and structure have been greatest in ponderosa pine and mixed conifer forests, which historically experienced more frequent fire than high elevation forests. At these lower elevations, almost a century of grazing, selective logging, fire prevention, and fire control has led to dense understory development, large fuel accumulations, changes in tree species composition, and the creation of *fuel ladders* that can carry fire from the forest floor into the overstory tree canopy (Figs. 21–23).

Fuel ladders, in particular, are now common in mature **ponderosa pine and mixed conifer forests** throughout central Oregon. In some instances they consist of dense thickets of young ponderosa and lodgepole pine invading older ponderosa pine stands (Figs. 21, 23). In other instances, they involve shade-tolerant (but fire-intolerant) Douglas-fir, true firs, and incense cedar growing up beneath ponderosa pine and western larch (Fig. 24). In both cases they create a ready conduit into the overstory canopy, thus setting the stage for a severe, stand-replacing fire event.

During prolonged fire-free periods, pine needles and dead branches accumulate at the base of large trees. When fire occurs, these fuel accumulations may take a long time to burn, allowing heat to penetrate through soil and tree bark, causing direct tree mortality.

Figure 22. Typical mid-elevation mixed conifer forest today on the eastern flank of the Cascades Range in western Oregon. Note the dense understory of mixed conifer reproduction.

Figure 23. Invasion of understory lodgepole pine beneath a low-elevation ponderosa pine stand in central Oregon.

Figure 24. Invasion of shade-tolerant Douglas-fir, true fir, and incense cedar beneath a ponderosa pine overstory in central Oregon.

Figure 25. Pitch tubes (exudations of resin) indicative of bark beetle attack in a dense, low-elevation lodgepole pine stand. Such attacks can occur both before and after fire when trees are under stress.

Additionally, damage to roots and stem tissues can impede water uptake, leading to *physiological stress* and subsequent bark beetle attack and tree mortality (Fig. 25).

The impact of humans on fire in **high elevation forests** is more difficult to discern because of the long intervals involved in historic fire regimes for these areas. However, it is likely that a century of concerted efforts to exclude fire has prolonged the natural fire return interval, changed the normal species composition, and reduced the proportion of early *seral stages* on the landscape. Such changes may account for some of the vulnerability of these

Figure 26. Tree mortality caused by a western spruce budworm outbreak in a mid-elevation mixed conifer stand in the Cascade Mountains. Note that the ponderosa pine on the left is not vulnerable to this defoliator, whereas species of Douglas-fir and true fir to the right are quite susceptible.

Figure 27. An area adjacent to the one in Fig. 26 that burned during the B&B Complex Fire of 2003. Widespread insect outbreaks like those caused by defoliators and bark beetles are often precursors to wildfire.

Figure 28. Exclusion of fire allows western juniper to encroach into rangelands. The different size junipers depicted here indicate that recruitment has been going on for many years surrounding this pasture in central Oregon.

high-elevation, old-growth forests to periodic outbreaks of insect pests. For example there were massive outbreaks of the *western spruce budworm* in the 1990s that created ideal tinder for subsequent wildfire, as shown in Figs. 26, 27.

In low-elevation **rangeland settings,** the purposeful exclusion of fire has allowed western juniper to expand its range at the expense of more characteristic shrub species like sagebrush and bitterbrush (Fig. 28). Over time, the western juniper may dominate such sites, thereby excluding many of the native shrubs and bunchgrasses.

The timing of **seasonal fire starts** in central Oregon is quite predictable. Regardless of where or how frequently fires have occurred in this region, virtually all of them start during the summer (Fig. 29). This is not surprising given the dry conditions, probability of lightning storms, and high levels of human activity (e.g., recreation) during that season. Prospective warming and drying of the climate in this region could further exacerbate these conditions.

Timber harvest of large trees over the last century has occasionally increased problems associated with fire. In some areas, selective logging has converted landscapes of widely spaced trees of fire-resistant species (e.g., ponderosa pine) to mosaics of small patches that are densely stocked with young, small trees of fire-sensitive species (e.g.,

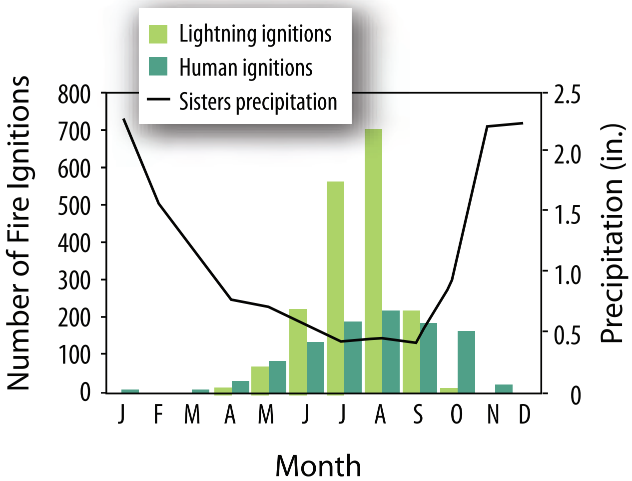

Figure 29. Seasonality of ignition types on the Deschutes National Forest in relation to precipitation, 1987-2001.


Figure 30. Selective logging in the ponderosa pine and mixed conifer zones of central Oregon has often led to patchy establishment of fire-sensitive species like small Douglas-fir, true fir, and lodgepole pine.

thin-barked fir species) (Fig. 30). Young pine plantations established after clearcut logging are also vulnerable to fire. In other cases, the easy access to forested areas provided by logging roads has increased the probability of human-caused ignitions.

Livestock grazing has contributed to reduced fire frequency in ponderosa pine and mixed conifer forests by limiting growth of understory vegetation that would have periodically carried surface fire. Livestock grazed heavily within central Oregon forests from the mid 1800s well into the 20th century. Current practices restrict the size of livestock herds so that grazing is often compatible with other forest values and management goals (Fig. 31).


Figure 31. This scene of cattle grazing on the Ochoco National Forest in central Oregon indicates that carefully controlled grazing is compatible with contemporary forest management goals. In this case the grazing is light enough that sufficient fuels can accumulate to carry benign understory fires characteristic of the ponderosa pine zone.

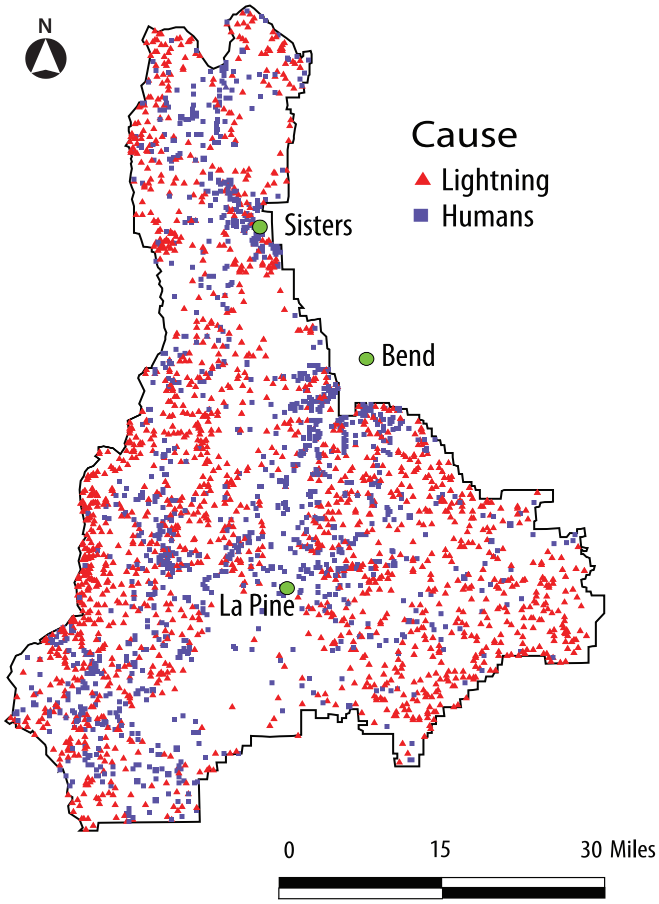

Figure 32. Fire starts caused by lightning and humans within the Deschutes National Forest, 1987-2001. Note that most human-caused fires are concentrated near popular recreation areas around Sisters, Bend, and La Pine.

Table 2. Causes of ignition on Deschutes National Forest fires, 1987-2001.

Ignition source	Number of ignitions
Lightning	1,794
Campfires	482
Smoking	223
Arson	186
Debris burning	51
Equipment	41
Children	31
Railroad	7
Unknown	330
Total	3,145

Lightning ignites most fires on the Deschutes National Forest (Fig. 32). From 1987 through 2001, lightning was responsible for 64% of the 2,815 fires with identified ignition sources (Table 2). Not much can be done to limit lightning strikes other than largely impractical measures such as cutting down tall trees, which might shift the electrical discharges to less flammable material. Instead, managers must quickly suppress lightning-caused fires or proactively reduce fuels to alter fire behavior and reduce fire impacts.

If actions are too aggressive or pervasive, however, some relatively benign surface fires might be suppressed, contributing to higher fuel build-up over time. Indeed, this is believed to be one of the reasons for uncharacteristically severe fires in recent years in some ecosystems. On the other hand, failure to extinguish new fires—particularly during dry, windy conditions—can lead to fires “escaping” and becoming major events. Clearly, careful planning, thoughtful analysis, and appropriate action are called for when managing wildfire.

Humans were responsible for the remainder (36%) of known fire starts on the Deschutes National Forest between 1987 and 2001 (Table 2). As shown in Fig. 32,

Figure 33. New residential developments at the wildland-urban interface have increased the frequency of human-caused ignitions.

human fire starts appear to be concentrated near Sisters, between Bend and La Pine, and near recreation areas northwest of La Pine. Human ignitions are increasing, especially in areas with high recreational use and near residential developments (Fig. 33). Furthermore, the priority given to protecting such areas can divert fire-fighting resources away from protecting wildland areas and other resources.

Snags (standing dead trees) near ridge tops and other high places pose a special challenge for natural resource managers (Fig. 34). Historically, many were cut down to reduce the chance that they would become ignition sources. Once aflame, they can become "Roman candles," casting burning material considerable distances, thereby starting spot fires and endangering fire suppression crews. Today, however, snags are valued for the wildlife habitat they provide. This is an example of one of the many difficult tradeoffs associated with contemporary natural resource management.

Figure 34. Snags provide important habitat for a variety of wildlife species, but they also can be a dangerous cause of spotting during wildfires once they are ignited.

D Threat of High-Severity Fire to Multiple Resources

Questions to Ponder

Why are high-severity fires of such concern? Are they a concern everywhere? What approaches are forest managers using to reduce the threat and impact of high-severity fires?

In many ecosystems, high-severity wildfire threatens multiple resources., Because such fires burn at high temperature and may have a long residence time, they generally have significant impacts on ecosystems such as:

- high tree mortality
- loss of wildlife habitat
- delays in the establishment of new seedlings
- invasion of other tree species less resistant to fire
- accelerated soil erosion
- formation of *hydrophobic soils*
- destruction of old-growth forests
- impacts to aquatic habitat
- adverse effects on scenic and recreational resources.

These impacts are particularly problematic for the ponderosa pine and mixed conifer forests of central Oregon (Figs. 35–37). They have

Figure 35. Severe fires that consume protective vegetative cover and organic layers of forest soil can lead to erosion, land slides, debris flows, and other adverse effects. This scene shows a debris rack installed in a stream to impede the movement of woody material downstream.

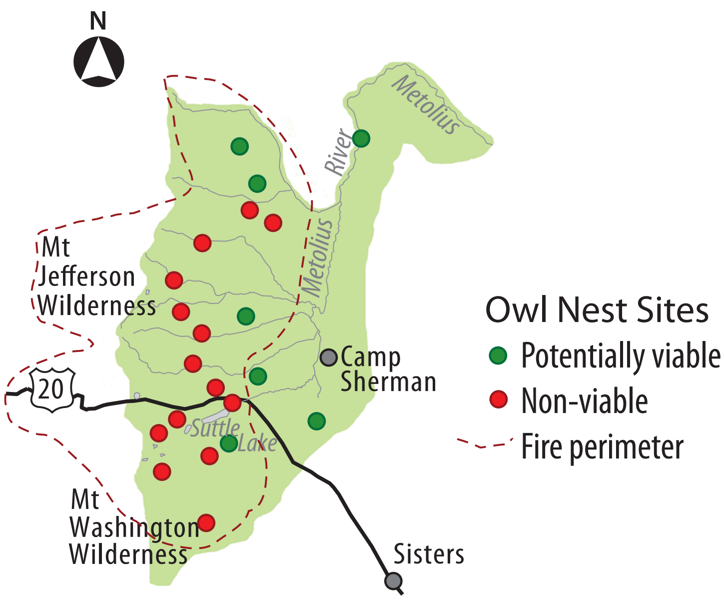

Figure 36. Loss of northern spotted owl habitat within the Metolius Watershed on the Sisters Ranger District of the Deschutes National Forest due to fires in 2002 and 2003 (Cache Mountain, Link, and B&B Complex). The dashed line marks the general perimeter of the burned area, and most of the nest sites within it are no longer viable.

become highly vulnerable to shifts in tree species (e.g., ponderosa pine to fir) and to loss of critical habitat (e.g., northern spotted owl nest sites). Management activities that reduce the quantity of vegetation and fuels (Fig. 38) may restore these forests so they can support low-severity fire comparable to that experienced historically, thereby avoiding some of the consequences associated with high-severity fires.

For high elevation forests and other forest types adapted to infrequent, high-severity, stand-replacement fire, it may be prudent to let periodic fires perform their natural function. Of course, that is provided conflagrations in these forest types do not seriously jeopardize the health, safety, and welfare of human communities and valuable natural resources. Having a well-developed rationale, strategy, and approach for dealing with such circumstances is essential.

Figure 37. Destruction of scenic vistas and recreation sites is another consequence of wildland fire, as illustrated by this burned over picnic area within the boundary of the B&B Complex Fire.

Figure 38. Removal of forest fuels is the primary management technique to reduce the risk and impact of subsequent wildfire. Use of a hand-held drip torch to carefully ignite small patches of debris is one of the common methods. (Photo courtesy of J. Boone Kauffman, Pacific Southwest Research Station, USDA Forest Service, Honolulu, HI).

E Fuel Treatments

Questions to Ponder

Given the negative consequences of fire suppression (e.g., high cost, environmental impact, gradual changes in forest composition and structure, increased risk of high-severity fire), what should be done to restore forests and associated fire regimes closer to those existing pre-settlement? Should all forests be treated in the same way?

Although vegetation, climate, and topography all affect fire occurrence and behavior, managers can only influence vegetation and associated fuels (Fig. 39). Vegetation and fuels can be treated many ways to reduce the risk of both ignition and spread of fire. Treatments include prescribed burning, manual removal, and mechanical operations. Such treatments may involve *slashing, thinning, slash piling, salvage logging,* chipping/grinding, mowing, and pruning. A combination of treatments is often applied.

Pre-fire treatments are generally strategic in nature and are often components of long-term silvicultural prescriptions. They are designed to create a more fire-resistant forest by reducing surface

Figure 39. Pruning, slashing, and lopping, to remove understory ladder fuels reduces the risk of subsequent crown fire, particularly in areas with heavy fuel loading.

Figure 40. Periodic clearing of understory vegetation can sustain the long-term presence of fire-resistant species like ponderosa pine and western larch. Broadcast understory "strip burns" are one method of doing so. (Photo courtesy of J. Boone Kauffman, Pacific Southwest Research Station, USDA Forest Service, Honolulu, HI).

fuel loads, raising canopy base height, disrupting crown continuity, reducing crown density, protecting large trees and special stand structures, or concurrently favoring fire-resistant species such as ponderosa pine and western larch (Fig. 40). These treatments primarily remove flammable litter on the forest floor and small trees and shrubs, thereby reducing the likelihood of a severe, stand-replacement fire.

During-fire treatments are opportunistic and involve *back-burning* to help contain a wildfire. In some instances, simply allowing wildfires to burn naturally through areas where fuels can be safely reduced is appropriate (Fig. 41). Such "treatments" are an application of *prescribed fire* and *prescribed natural fire,* respectively. Both approaches can help limit the expansion of a wildfire as well as benefit the residual stand over the long run.

Post-fire treatments, when appropriate, usually involve salvage logging to harvest dead or dying trees, followed by treatment of surface fuels (e.g., *logging slash, fine fuels*) and then reforestation—either by natural seeding (if there are residual seed trees) or by planting (Fig. 42). In addition to generating revenue and helping restore the forest, these practices can also reduce *fuel loads* from

Figure 41. An area where a wildfire was allowed to "underburn" through a forest stand in central Oregon. If fuel loads are not excessive and weather conditions are suitable, allowing wildfires to naturally remove some of the understory vegetation is a useful fire and forest management practice.

Figure 42. Prompt salvage of fire-killed timber, if done quickly and carefully, can generate revenue and facilitate regeneration of the next stand.

Figure 43. If not removed or otherwise treated, deterioration of fire-killed timber can create hazardous fire conditions for years to come. In particular, the fine fuels depicted in this scene from the B&B Complex Fire can lead to high intensity, quick spreading fires during a reburn.

the previous fire, thereby reducing probabilities and intensities of a *reburn*—particularly if fine fuels are removed (Fig. 43). Removal of at least some dead and dying trees is occasionally necessary to prevent insect outbreaks that might otherwise jeopardize adjacent, unburned stands. And some surviving patches of forest might still be overly dense and would benefit from a *thinning*. However, it is usually not necessary (nor economical) to remove all of the trees or most of the coarse wood during salvage and thinning operations. Some of these components are often retained to provide important ecological legacies such as snags and down wood for wildlife habitat and *nutrient cycling*. In some cases it may be prudent to simply allow the area to recover on its own, following natural pathways of *secondary plant succession*. Much depends on the particular situation and landowner objectives.

Fuel breaks are a special treatment that can be used in both

Figure 44. Fuel breaks are sometimes constructed to provide defensible space in the event of wildfire.

Figure 45. Widely spaced overstory trees with moderate ground cover provide a shaded fuel break along this ridge.

pre-fire and during-fire situations. To create fuel breaks, strips of forest vegetation are selected based on their strategic location (e.g., along a road, near a development, between stands or timber types). In the case of standard fuel breaks, flammable vegetation and woody material are largely removed from the area (Fig. 44).

Alternatively, shaded fuel breaks may be created in which widely spaced overstory trees are retained (Fig. 45). The increased moisture, cooler temperatures, and reduced growth of understory vegetation in shaded fuel breaks may help reduce the spread of wildfire.

Fuel breaks usually do not stop fires by themselves. Instead, they are designed to reduce fire intensity, flame height, and rate of spread, and to provide defensible space for fire suppression crews. Large transects need to be treated and maintained, however, in order to effectively reduce the potential for severe, large fires.

On the Deschutes National Forest, 100-500 foot-wide fuel breaks have been installed near some homes, popular recreation areas, major roads, and northern spotted owl habitat (Fig. 46). Emphasis has also been placed on treatment of ponderosa pine and lower-elevation mixed conifer forests to create and maintain stands of large, fire-resistant trees that will tolerate relatively benign fires more characteristic of those experienced historically (Fig. 47). Much of the Deschutes National

Figure 46. Fuel breaks, understory removal, and branch pruning near homes, major roads, and other strategic locations are effective fire prevention and management measures.

Figure 47. Restoration of more natural, historic conditions is an effective strategy for sustaining fire-resistant species like ponderosa pine and western larch, as indicated by this "Turn of the Century" stand near Camp Sherman, OR.

Forest has not been treated, however. Fuel treatments are expensive, vast areas are involved, and most of the agency's fire budget necessarily goes toward fire suppression.

Several methods are used to implement the above fuel-reduction measures: manual, mechanical, and prescribed fire. **Manual treatments** that reduce litter, vegetation on the forest floor, and small trees lower the likelihood of ground fire spreading upward to the canopy via ladder fuels, particularly if the resulting piles are carefully burned (Fig. 48). In contrast, thinning overstory trees disrupts horizontal continuity of the canopy, reducing the likelihood of fire spreading from one tree crown to the next (Figs. 49, 50).

Figure 48. Hand piling of thinning slash and other woody debris is a common method of fuel reduction after mechanical treatment in dense, overstocked stands. The piles can then be burned or otherwise disposed of during safer times of the year.

Figure 49. Thinning of overstory trees will reduce the contact among tree crowns, thereby reducing the ability of fire to spread through the forest canopy. Except for the scorched tree in the middle foreground, note that most of this mixed conifer stand—thinned prior to the B&B Complex Fire—was largely undamaged

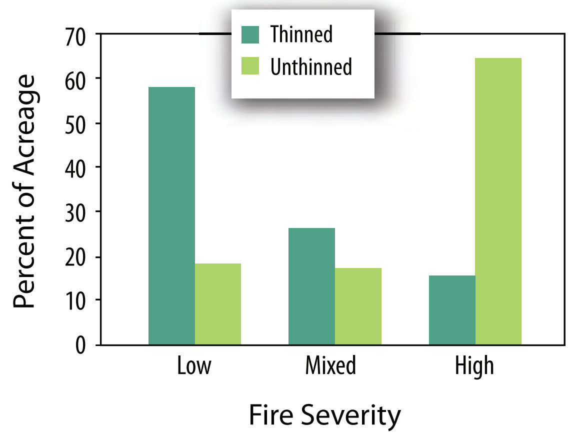

Figure 50. Fire severity as affected by pre-fire thinning within the B&B Complex Fire area on the Sisters Ranger District of the Deschutes National Forest. Note that thinned areas suffered less tree mortality. (From D. Robbins 2006, unpublished data on file at the College of Forestry, Oregon State University, Corvallis, OR).

Figure 51. Prescribed fire in a ponderosa pine stand in central Oregon to reduce understory fuels and fire ladders. Keeping flame heights less than about three feet is important to avoid damage to residual trees. (Photo courtesy of J.R. Boyle, College of Forestry, Oregon State University, Corvallis, OR).

Prescribed burning is used to reduce forest litter and understory vegetation and to favor fire-resistant tree species. Prescribed fires usually do not have severe ecological effects on overstory trees or soil, because they are conducted during conditions that produce relatively low fire intensity (Fig. 51). Alternatively, prescribed fire can be used to prepare recently-logged sites for regeneration via natural seeding or planting. Burning the slash after logging can greatly facilitate such activities and accelerate establishment of the next forest.

Mechanical treatments are often necessary to reduce fuels before stands can be burned safely or in areas where burning is not feasible. For example, on the Deschutes National Forest an understory of lodgepole pine has occupied some sites within the ponderosa pine forest type since fire has been excluded (Fig. 23). Now, ladder fires from a prescribed burn would lead to high mortality of both lodgepole and ponderosa pine.

Mechanical treatments generally involve tracked vehicles equipped with cutting or grinding attachments (Fig. 52 A and B). Operators

Figure 52. Machines equipped with (A) cutting blades and (B) grinding teeth are used to reduce understory trees and shrubs in some forest types to lower fuel loads.

Figure 53. A grinder mulching understory trees and shrubs in a pine forest to reduce fuel loads and continuity.

can selectively remove unmerchantable material, thereby reducing fuel loads and disrupting fuel continuity (Fig. 53).

Often mechanical treatment followed by periodic prescribed fire (either broadcast burning or burning of piles) is recommended (Fig. 54). In some cases, mechanical treatment alone may be the only practical option.

Regardless of treatment type, they are effective for only a finite period of time due to vegetation recovery. Therefore, treatments often must be repeated every 10-20 years.

Treatment costs are an important consideration in selecting the most appropriate prescription for a given area. As one might expect, they vary considerably depending on factors such as treatment type, vegetation type, topography, operator skill, labor availability, etc. Some approximate cost ranges for understory treatments are:

- Manual (pruning, thinning, slashing, and piling): $50-800/ac

Figure 54. Burning of piles and windrows after manual or mechanical treatments is often done to reduce fire hazard and maximize the area available for forest regeneration. The burning is done at a time of the year when the risk of escape is minimal.

- Prescribed fire (pile and understory burning): $50-200/ac
- Mechanical (cutting, grinding, chipping): $100-600/ac

Although these costs are considerable, they are generally far less than the costs of wildfire suppression, which routinely exceed several hundred to more than a thousand dollars per acre. And these costs do not include the damage to natural resources, loss of commercial timber, and investments needed in rehabilitation and restoration.

The **response of understory vegetation** to different burning and other *silvicultural* treatments is another important consideration. For example, shrubs like snowbrush *Ceanothus* and greenleaf manzanita are well adapted to the disturbance caused by fire (Fig. 55). They can colonize burned-over sites quickly and provide important ecological services ranging from soil nutrition to wildlife habitat. However, they can also dominate sites for decades, thereby impeding the establishment of tree species (Fig. 56). If the fire is of relatively low intensity or if the overstory is only moderately thinned, there may be only a slight response, and the shrub understory will be kept at a

Figure 55. Buried seeds of snowbrush Ceanothus, *an evergreen shrub, often germinate after fire.*

Figure 56. Evergreen shrubs such as snowbrush Ceanothus *and greenleaf manzanita may dominate forest sites for decades before shade-tolerant conifers can eventually emerge through the shrub canopies.*

Figure 57. Sparse recovery of snowbrush Ceanothus *after thinning and underburning in a relatively dense ponderosa pine stand in central Oregon.*

Figure 58. Vigorous recovery of snowbrush Ceanothus *after heavy thinning and underburning in a formerly dense ponderosa pine stand in central Oregon.*

low density (Fig. 57). However, heavy thinning combined with burning that greatly opens up a stand can lead to vigorous growth of shrubs (Fig. 58).

In the case of snowbrush *Ceanothus,* heat from prescribed fire can stimulate germination of seeds that have accumulated in the forest floor during prior fire-free periods. Thinning also contributes to increased sprouting and shrub growth by allowing more sunlight through the canopy and increasing soil moisture availability. At such sites, light thinning may be the best way to reduce flammable understory vegetation, yet avoid excessive colonization of shrubs like snowbrush *Ceanothus.* This is not true with all species, however. For example, thinning plus burning is better than thinning alone when trying to control bitterbrush because bitterbrush generally does not sprout after a fire. Thus, a thorough understanding of the ecology of an ecosystem, coupled with effective silvicultural practices, is essential for sound stewardship.

F Future Challenges and Management Options

Questions to Ponder

What are some future challenges that may complicate implementation of fuel treatments and fire control? For example, should priority be given to protecting homes at the expense of protecting nearby natural resources? What about protecting sensitive areas like riparian zones, wildlife habitat, and river basins? What about protecting private timberlands adjacent to public forests—and vice-versa? Who should be responsible for protecting such areas? How can the public be enlisted to help in setting appropriate policies and priorities?

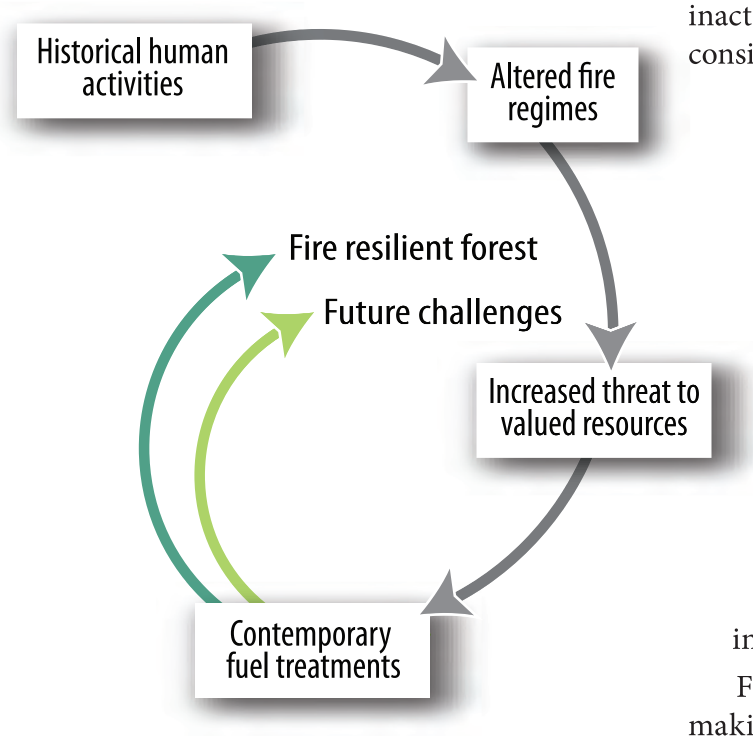

Figure 59. Fire scenarios in relation to historical human activities and contemporary fuel treatments.

Natural resource managers are challenged not only by uncertainty in forest response to treatment and disturbance, but also by complex policy directives, budgetary constraints, social conflicts, considerations for wildlife and aquatic habitats, protection of threatened and endangered species, *wildland-urban interface* issues, climate change and carbon flux, and many other factors. Despite the challenges, fuel treatments and fire suppression are often compatible with most forest management objectives. Proactive fuels management is especially appealing once the long-term risks of inaction and the high cost of fire suppression are considered.

Strategic planning at the landscape level is a crucial aspect of contemporary natural resource management. Whether it involves prioritizing fuel reduction activities, anticipating bark beetle outbreaks, creating more drought-resistant forests, or mitigating other risks inherent in forest and rangeland ecosystems, it is important to integrate a long-term, multi-resource perspective. In particular, a comprehensive, holistic approach to wildland fire management is needed if we are to protect the natural resources at stake in our forests and rangelands (Fig. 59).

Finally, engaging the public in decision-making processes surrounding wildland fire and fuels management programs is another crucial aspect of contemporary natural resource management (Fig. 60). Coalitions ranging from special interest groups to local homeowner associations have a legitimate stake in how forests are managed and protected. Without their involvement, support, and trust, it is difficult—if not impossible—to implement the policies and practices needed to restore and maintain healthy, fire-resilient forests. Fortunately, a number of guides are available to foster communication, cooperation, and citizen-agency partnerships (Fig. 61).

Figure 60. Engaging the public in discussions and decision-making surrounding topics in wildland fire is an important aspect of contemporary natural resource management. This group is learning about the historical role of fire in the ponderosa pine forests of central Oregon. (Photo courtesy of B. A. Shindler, College of Forestry, Oregon State University, Corvallis, OR).

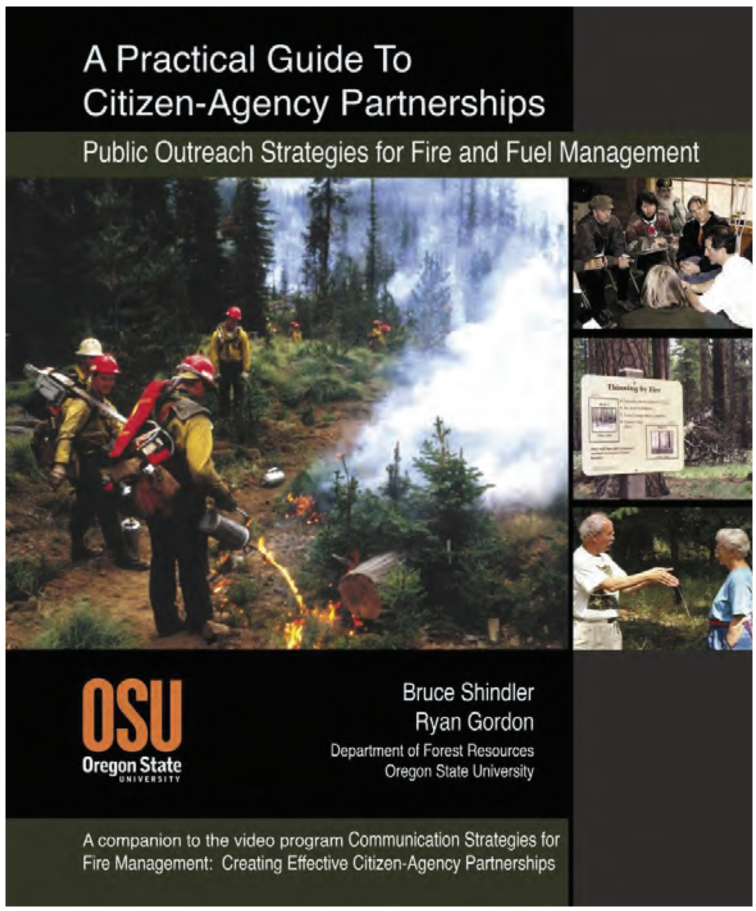

Figure 61. An example of one of the guides available for facilitating citizen-agency interaction surrounding wildland fire issues. (Photo courtesy of B. A. Shindler, College of Forestry, Oregon State University, Corvallis, OR).

G Closing Comments and Caveats

It is clear from research and observation that fire commonly occurred in central Oregon forests. Also the effects and occurrence of fire varied by forest type. Understanding the history of fire is an important beginning point for the use of fire to reduce fuels (i.e., prescribed fire) and the potential for severe fire (i.e., wildfire). This is particularly important in places where the goal is to return forests to a "pre-Euro-American settlement condition." For example, frequent application of prescribed fire should probably not be used in forests where fire naturally occurred at long intervals, such as high elevation forests. Regardless, it is unlikely that today's use of prescribed fire to manage forests—even at lower elevations—can fully duplicate fire occurrence and effects in pre-settlement forests for the following reasons:

- Research has not fully documented the effects of many pre-settlement fires. The severity, frequency, cause of ignition, and extent of fire on a particular landscape are difficult to reconstruct, and therefore uncertain in some cases.
- The expansion of rural communities, roads and highways, agricultural areas, wilderness areas, timber management, and other factors have altered the landscape and changed fire occurrence and behavior from its historical patterns.
- Forests where fire burned frequently with low- or mixed-severity are now prone to severe, large, stand-replacing fires, simply because of fuel accumulation due to fire exclusion for many decades.
- It is difficult for forest managers to replicate historical fire because of timing constraints. Smoke management regulations and limited "windows of time" for safe, effective burning often restrict prescribed burns to early spring and late fall. Consequently, managers need the flexibility to use manual and mechanical treatments like thinning and chipping—especially where fire is likely to be dangerous, difficult to use, or expensive.
- Trade-offs are involved. Should a low fire risk area treated five years previously be retreated at the expense of not treating some untreated areas? Where should priorities be placed with respect to protecting homes, timberland, wildlife habitat, riparian strips, or wilderness areas? Budget, time, and personnel constraints pose difficult policy and management choices.

Obviously, the future course of events regarding wildland fire will depend on collaborative efforts among citizens, researchers, managers, and policy makers. And, undoubtedly, there will be a significant measure of risk and uncertainty involved as the vagaries of weather, climate, and other natural forces intercede.

H Summary

Natural fire regimes in central Oregon prior to Euro-American settlement differed among forest types. Lower and drier ponderosa pine forests experienced frequent, low-severity fires. Mixed conifer forests grew at mid-elevations above the ponderosa pine forests. They were very productive and experienced moderate- or mixed-severity fires, with more frequent fire in drier areas. High elevation forests of the Cascades were less productive due to cold temperatures but received the greatest moisture. They experienced infrequent but severe fires. Lodgepole pine forests occupied areas ranging from high to low elevation and were characterized by periodically severe stand-replacement fires. Fire also affected rangelands in the interior of central Oregon by limiting the expansion of western juniper and favoring the native shrubs and grasses. Thus, forest and rangeland types varied across the landscape of central Oregon. And fire behavior and effects varied within these types and even within individual fires.

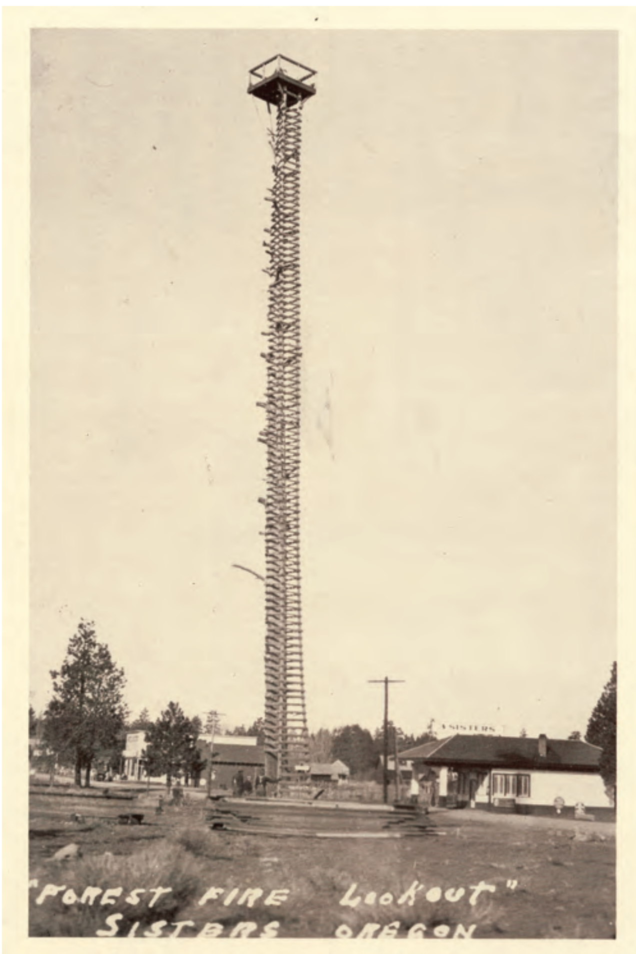

Figure 62. Fire tower in Sisters, Oregon circa 1925. The tower was constructed around a 110-foot-tall ponderosa pine.

Forest and rangeland ecosystems have changed in central Oregon over the last century. Fire suppression, grazing, logging, development, and a host of other factors have significantly altered the landscape. In the case of rangelands, the exclusion of fire has led to substantial expansion of western juniper—at the expense of sagebrush and other valuable forage species. In the case of forests, there has been a notable increase in insect outbreaks, fuel loads, stand-replacing fires, and other major disturbances.

Proactive fuel treatments and other management strategies are needed to restore the resilience of these forests and rangelands. On the Deschutes National Forest, manual and mechanical treatments, along with prescribed burning, have been implemented to reduce fuel loads, alter fuel distribution, and favor fire-resistant species. Fuel breaks have been created to moderate fire behavior and aid in fire suppression. They have been strategically located to protect high value resources at the interface between wildland and developed areas, near recreation sites, along major roads, and within sensitive wildlife habitats. Emphasis has also been placed on treatment of ponderosa pine and mixed conifer forests to create and sustain stands of large, fire-resistant trees and move stands toward more historic conditions. Much of the Deschutes National Forest has not been treated, however, and investments in proactive fuel treatments are costly. More costly, though, are suppression of wildfires and the losses incurred when wildfire devastates an area.

Although numerous ecological, social, and economic challenges remain, actively reducing fuels is a practical, viable approach to wildland fire management, and it is often compatible with many other natural resource objectives. Enlisting public support, along with ongoing research and experimentation, will be crucial to effective, enlightened approaches to wildland fire management in the future.

Figure 63. Current fire lookout on Lava Butte in central Oregon.

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Glossary*

Back-burn: A form of prescribed fire in which an area is burned—usually into the wind—in order to establish a line of defense against an oncoming wildfire by reducing fuels and fire intensity.

Bark beetle: A small beetle about the size of a rice grain that kills trees as a result of both adults and larvae boring galleries in the inner bark, effectively girdling the trees. The most common species in central Oregon is the mountain pine beetle, *Dendroctonus ponderosae*.

Cross-dating: Validating the chronological diameter growth of a tree. It is done by comparing the growth patterns of tree rings in a sample tree to those of a "master tree-ring chronology" developed for the area. See dendrochronology.

Dendrochronology: The study and interpretation of annual diameter growth rings of trees and their use in dating past variations in climate, seasonal weather, fire events, and other aberrations detectable in growth rings.

Ecosystem: Any complex of living organisms with their environment. It includes all interacting organisms and associated components and can be of any size; for example, ranging from a log to a forest.

Fine fuels: Fuels that ignite readily and are consumed rapidly by fire (e.g., cured grass, fallen leaves, needles, small twigs less than 1/4 –inch in diameter).

Fire frequency: The periodicity of fires within a given ecosystem over a given time frame (i.e., number/time/area). The size of the area and the time period involved must be specified for accurate interpretation.

Fire intensity (or fireline intensity): A quantitative measure of the rate of heat energy release per unit of time per unit length of fire front or fireline. Usually expressed as Btu/sec/ft or kW/sec/m.

Fire regime: A qualitative characteristic based on the general frequency, extent, intensity, severity, and seasonality of fires within an ecosystem. Generally used in conjunction with fire severity to characterize various forest types as prone to low-, moderate-, high-, or mixed-severity fire.

Fire return interval: The number of years between successive fires in a given ecosystem. The size of the area and the time period involved must be specified for accurate interpretation. See also mean fire return interval.

Fire severity: A qualitative term used to describe the relative effect of fire on an ecosystem, especially the degree of organic matter consumption (vegetation, wood, and litter) and soil impacts (erosion, hydrophobicity). Often used in conjunction with fire regime in which fires for a given area or forest type are classified as low-, moderate-, high-, or mixed-severity.

Fire scar: A healing or healed-over injury on the lower trunk of a tree caused or aggravated by fire. Usually evidenced by a charred area of bark and wood and often useful for dating fire events using dendrochronology.

Forest type: A category of forest within a given area that is usually distinguished by the dominant species of trees present (e.g., ponderosa pine, mixed conifer, juniper woodland) or geographic location (subalpine, high elevation).

Fuel break: Any natural or constructed barrier utilized to segregate, stop, and control the spread of fire or to provide a line of defense from which to contain a fire.

Fuel ladder: A vertical continuity in fuel between the ground and canopy of a forest stand.

Fuel load: The dry weight of combustible materials per unit area. Usually expressed as tons/ac.

Hydrophobicity: The property of repelling the infiltration of water into soil. Caused by the presence of colloids that have little attraction for water. Usually occurs following a high-intensity

* Most of the definitions in the Glossary were derived or adapted from the following sources:

Helms, JA (ed.) 1998. *The Dictionary of Forestry.* Society of American Foresters, Bethesda, MD. 210 p.

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fire that consumes the protective litter and organic layers of the forest floor.

Litter: The uppermost layer of organic debris on the forest floor. Essentially the freshly fallen or only slightly decomposed leaves, needles, bark, twigs, and other detritus.

Logging slash: The unmerchantable residue left on the ground after logging. Includes tops, branches, defective logs, stumps, and other noncommercial residue.

Mean fire return interval: The average time between successive fires in a given ecosystem (i.e., mean number of years for all fire return intervals). The size of the area and the time period involved must be specified for accurate interpretation. See also fire return interval.

Nutrient cycling: The pathway that nutrients follow as they flow through an ecosystem. It involves the exchange or transformation of chemical elements among the living and nonliving components of an ecosystem.

Physiological stress: The disruption of normal metabolic and physiological processes (e.g., water uptake, photosynthesis) within a plant caused by drought, fire, insect attack, disease, and other factors. The functions affected make the plant vulnerable to further decline and death.

Prescribed fire: The controlled application of fire to wildland fuels under conditions of weather, fuel moisture, soil moisture, etc. that allow the fire to be confined to a predetermined area with desired effects, thereby meeting management objectives.

Prescribed natural fire: A naturally ignited wildland fire that is allowed to burn unimpeded under specified conditions, is confined to a predetermined area, and produces the fire behavior and results desired to meet management objectives.

Reburn: Subsequent wildfire—usually within a few years or decades—of an area burned previously.

Salvage logging: The removal of dead, dying, or damaged trees as the result of a disturbance such as fire, windstorm, insect outbreak, or disease. Usually done to "salvage" some economic value from the affected stand, but it is also used to foster regeneration and development of the next stand.

Secondary plant succession: The sequential replacement of one plant community by another until ecological stability occurs or disturbance reinitiates the cycle.

Seral stage: A distinct but transitory plant community in the process of secondary plant succession.

Silviculture: The art, science, and practice of establishing, tending, and reproducing forest stands with desired characteristics, based on knowledge of species attributes and environmental requirements.

Slash: See **logging slash.**

Slash piling: A method of concentrating unmerchantable material in a disturbed forest setting for subsequent disposal via burning, chipping, or natural decomposition.

Slashing: The practice of cutting and lopping—by manual or mechanical means—the unmerchantable trees and shrubs in order to facilitate forest regeneration and management activities.

Snag: A standing dead tree from which the leaves and most of the branches have fallen.

Thinning: The removal of trees to reduce stand density, tree-to-tree competition, canopy continuity, or otherwise change the structure of a forest stand to meet silvicultural and forest management objectives.

Tree ring analysis: The use of dendrochronology to reconstruct the diameter growth pattern and occurrence of damaging events such as drought and fire during the course of a tree's life. It involves analyzing the annual growth rings produced as a tree grows in diameter.

Western spruce budworm: An insect pest (Choristoneura occidentalis) that periodically defoliates several western coniferous species (e.g., Douglas-fir, true firs, spruce). The larval stage does the damage by feeding on needle foliage.

Wildland-urban interface: The zone where residential and municipal areas abut wildland areas, often leading to problems and conflicts between competing uses (e.g., forestry vs. development; protecting forests vs. protecting homes).

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