13 Managing Fire in Forests

Smoky Bear says, "Only YOU can prevent Forest Fires!" But, is Smoky correct? Should you prevent forest fires? Let them burn? Prescribe fire for your forest? The debate over control of fire in forests is, pardon the pun, indeed hot. Fires have occurred in many forest ecosystems for millennia, usually started by lightning. Humans have used fire in forests for millennia as well, to encourage berry and other fruit and vegetable production, to move game animals so that they were easier to kill, and presumably to make movement through forests easier. Now more and more people are building their homes in forests, each wanting to live in a place where they can enjoy the solitude and beauty of forests around them each day, so fire becomes a very significant risk to life and to homes. As our population grows and our economy grows, the expansion of the urban forest fringe increases. We need merely look to examples in Oakland, California; Sydney, New South Wales, Australia; and the Front Range of the Rocky Mountains in Colorado to see examples of fires that have led to human death and property destruction. So, is Smoky correct? Should we prevent forest fires? Perhaps in some places, but forests have burned and will burn again when there is sufficient fuel, the weather is correct, and there is a source of ignition. Why? Despite Smoky's best efforts the forest area burned in the United States has increased steadily over the years (Stephens and Ruth 2005).

There are several conditions that interact to increase not only the probability of a fire occurring but also the size of a fire once it starts. First, conditions that cause lightning vary from year to year, but on average probably have not changed significantly over the past 60 years (Stephens 2005). As indicated earlier, the number of people living in and around forests has increased and human-caused ignitions, either by arson or by accidents have increased substantially in the western and southeastern United States (Stephens 2005). Second, because Smoky has been somewhat effective in keeping fires out of many forests, fuels have begun to build up in some forest systems. Without periodic fire in many dry forests, tree densities increase, some trees experience greater moisture stress due to competition for water, and we can see tree death through competition mortality or through insect outbreaks related to tree stress. All of these activities add fuel to the forest, so that when conditions are dry and an ignition source is provided (lightning, a match, a spark from a chainsaw), then the fire can spread rapidly (especially if there is any wind) and extend over huge areas very quickly. In addition, because the fuel loads are now often higher than they have ever been historically, the severity, or effect on the ecosystem, of the fires can be unusually high (Miller et al. 2009). The best conditions for fire spread are hot, dry, windy weather. As climate change produces more variable and extreme weather patterns, we can expect to see more extreme conditions that support the spread of fire in some (but not all) forests. Indeed, Westerling et al. (2006) found that there is a relationship between earlier and warmer spring and summer temperatures, and the frequency of large wildfires. So what can we do? Fuel loads have increased in many places, climate is changing, more people are providing more sources of ignition, and epidemics of insects are killing more and more trees. We cannot let fires burn uncontrolled everywhere, but we cannot control many wildfires under current conditions once they begin. Given the uncertainty associated with what future conditions might be, strategically located active management of some forests to increase their resistance or resilience to fire may be our only reasonable approach to managing this situation (Millar et al. 2007).

EFFECTS OF FIRE ON HABITAT ELEMENTS AND SUCCESSION

Is fire beneficial or destructive to habitat elements important to forest dwelling vertebrates? The answer of course is "Yes," but of course it depends on the species. The severity of the fire as indicated by the destruction of forest biomass, such as trees, snags, logs, leaf litter, foliage, shrubs, and herbs, can have a significant effect on the structure and composition of habitat elements. A very intense fire moving slowly through an area with high levels of fuel can remove nearly all of the fine fuels and some of the large fuels and leave the forest floor barren of any leaf litter. On the other hand, a rapidly moving ground fire in which fuel moisture levels are high may kill some small plants and seedlings of trees and shrubs and leave an ash layer on top of the leaf litter, but otherwise not substantially change the structure or composition of the stand. Both of these conditions may occur in the same fire, the former more likely on an exposed southwest-facing slope and the latter along a riparian area. The range of fire intensities, severities, frequencies, and sizes influence the successional pathways throughout the burned area.

Species, Fuels, Fire Frequency, and Severity

Some species of trees are adapted to fire. Species such as jack pine and lodgepole pine have serotinous cones that open following a fire, releasing their seeds onto the ash layer that was created by the fire, and the germinating seeds produce another stand of these species. Longleaf pine seedlings persist in a "grass" stage for several years, developing deep root systems while they survive ground fires before erupting in rapid height growth and developing thick bark to protect the cambium from subsequent fires. Similarly, mature ponderosa pine and Douglas-fir may have bark that is 5–10 cm thick, thereby insulating the cambium from fire effects. Many hardwood species such as mountain laurel, manzanita, eucalyptus, and other species that have flammable foliage are able to sprout back and dominate a site following a fire. A fire of a certain intensity (energy per unit area per unit time) may completely kill nearly all trees (e.g., lodgepole pine), the aboveground portion of trees (e.g., oaks), or no mature trees (e.g., ponderosa pine), resulting in different levels of severity.

Fuel loads influence the effects of fire on trees in a stand. In many eastern deciduous forests, leaf litter accumulates for decades. Litter depth on the uphill side of trees where it is trapped by the tree bole can be much higher than elsewhere on the hill slope. Consequently, when a ground fire occurs, fire burns more intensively and for a longer period in the collected leaf litter, resulting in fire scars and subsequently basal hollows on the uphill side of many trees. Taken to a greater extreme, where insects have killed trees in a stand and there are both fine fuels (e.g., twigs) and large fuels (tree boles), fire can be hotter and last longer, having a more profound effect on the system.

Creation and Loss of Dead Wood

Depending on the intensity, a fire can kill trees and create snags and fallen dead wood, and it can simultaneously consume dead wood as the stand burns. The net effects of a fire, dead wood created minus dead wood lost, is critical to understanding the long-term dynamics of dead wood in forests subjected to fires.

Wildfire creates a pulse of snags, and then snag density declines as snags fall and they are not recruited into the stand until large trees die as the stand matures (Passovoy and Fulé 2006). Following a fire there is an economic incentive for the landowner to harvest any trees killed by the fire through salvage logging. In western coniferous stands, Monsanto and Agee (2008) reported that stands that had been salvage logged had lower log biomass than unsalvaged units, except for the most recently burned site, where salvaged stands had higher log biomass; moist sites had higher log biomass than dry sites (Monsanto and Agee 2008).

The effects of fire on dead wood in managed stands following prescribed burning can be quite different than following a wildfire. Horton and Mannan (1988) reported a 45% net decrease in snags during the first year following a prescribed fire, and they also reported a 42% reduction in the number and volume of ponderosa pine logs following the prescribed fire. With regularly occurring prescribed burning, we would expect that the recruitment and consumption of dead wood would begin to fluctuate around a mean dead wood volume, but it is not clear where that level is for many forests.

Effects on Species Composition

As fire changes in frequency or intensity, the species of plants and animals that can occupy a site will change as well. Following an intense wildfire, plant species adapted to colonizing new sites will do well, as will those that can resprout following the fire. Because some species present before the fire can persist through resprouting or seed germination and a new set of species colonizes the site, species richness and abundance of all vascular plant species tend to be higher in burned than nearby unburned areas (Crawford et al. 2001). The more intense the fire, the more different the plant community is following the fire (Morrison 2002). Unfortunately, exotic species, including invasive species, may be more likely to dominate a site if the fire is intense (Crawford et al. 2001).

Plant communities can also be affected by the size and shape of a burned area. Plant species composition can exhibit a significant change across burn edges that can last for 30 years or more in some forests (Coop et al. 2010). Similarly, tree species that establish following a burn can change with elevation and distance from the edge of the burn to the interior of the burn, but overall species richness can be highest at the center of a burned area because of the increased diversity in grasses and forbs (Coop et al. 2010).

Changes in climate may influence the types of changes that we see in plant communities both through direct effects on temperature and precipitation in a region but also through the effects that the changed climate has on fire frequency and intensity. Cushman et al. (2011) suggested that climate-driven changes to disturbance regimes may have larger effects than fire suppression or fuel reduction treatments. If the suggestion by Cushman et al. (2011) is correct, then management activities may not have much of an effect on the trajectory of landscape change. Because of the overwhelming changes to landscapes from fires, changes to habitat structure and composition for selected species may be much more affected by climate-driven changes in fire characteristics than by local management activities (Cushman et al. 2011). Nonetheless, management of fuel is becoming widespread and could have short-term effects on some species through alteration of vegetation structure and composition and reduction in large fuels (i.e., dead wood).

CHANGING FIRE RISK THROUGH MANAGEMENT

Although Cushman et al. (2011) make a strong case for climate-driven changes in vegetation communities and future fire regimes, there are many local efforts that are designed to mitigate adverse fire effects before a fire occurs. In general, these treatments are designed to remove fine and coarse fuels in an economical manner to reduce the risk of fire occurrence, or lessen fire intensity. Following a fire, salvage logging has long been proposed as a mechanism for reducing the risk of a reburn of the same site by removing fuels. There is a considerable controversy over the fact that indeed salvage logging may actually increase the likelihood of a reburn (Thompson et al. 2007). Although driven largely by economic returns, salvage logging has occurred for decades in an effort to capture the economic value of fire-killed trees before the wood begins to decay. Conceivably this action would reduce fuels that would otherwise contribute to a reburn of the area, but in fact some areas that are salvage logged reburn at a higher intensity than areas that were not salvage logged (Thompson et al. 2007). More recently silvicultural activities have focused well on reducing fuels in stands prior to a fire. By strategically reducing fuels and then, where appropriate, reintroducing prescribed fire, the risk of ignition or intense fire may be reduced, at least temporarily.

Salvage Logging

Salvage logging focuses on removal of trees killed by a disturbance, often fire or wind, which are of a size and species that can be sold to a mill before decay has reduced the value of the wood. Typically, large snags, logs, and residual green trees are more economically valued than small ones, and of course, large trees, snags, and logs are also used by more species of animals than small ones.

So it is not surprising that salvage logging, especially on public lands, has met with opposition and controversy (DellaSala et al. 2006). Consequently, we would expect that, unless sufficient levels of snags and logs were retained during salvage logging, those species of cavity nesters and others that rely on dead wood would be adversely affected by this activity. Indeed, for those species that respond negatively to salvage logging, even moderate salvage intensity had a noticeable effect on populations in the study conducted by Cahall and Hayes (2009). Some areas retained as unlogged burned forests seemed to be important in maintaining areas with high habitat suitability for dead-wood-dependent species (Cahall and Hayes 2009).

D'Amato et al. (2011) also compared the effects of salvaging timber from burned areas and areas with wind-thrown trees, and they reported that impacts on structural legacies persist well into the future. Unless plans are made and implemented that protect these legacy features, ecosystem recovery may be adversely affected (D'Amato et al. 2011). Further, the severity of a subsequent fire (a reburn) in the area of their study in the Lake States of the United States may be higher where salvage logging has occurred due to exposure of bare mineral soil prior to the subsequent fire and adverse effects on soil structure following the subsequent fire.

Diverse early successional conditions that result from disturbances such as fires and windthrow are one of the rarest habitat types in many forests that are managed for commercial values (Swanson et al. 2011). Consequently, we can actively recruit these sorts of conditions through innovative stand replacement management (Franklin and Johnson 2011), or we can allow natural disturbances with limited to no post disturbance intervention to provide these conditions. Or both. Should salvage logging of burned trees be allowed on public lands? That is a question that only has a social or political answer. Depending on the weight society wishes to give economic return from public lands compared to retention of ecological values, we arrive at different conclusions (Eklund et al. 2009). When landowners decide to salvage log but still retain habitat for selected species that require dead wood, they can refer to the information in Chapter 12 for guidance on setting dead wood goals.

Effects of Fuels Treatments on Habitat Elements

Managers of forests, especially along the rural–wildland interface where property values are at stake, resort to aggressive removal and management of fine and coarse forest fuels. This is particularly common in parts of the world with hot dry summers, such as the western United States. The issue is significant because fire has been controlled far longer than the typical return interval for fires in the forest type. Consequently, fuels such as dead needles, twigs, and small trees have accumulated to levels that are outside the range of natural variability for these forests. Further, because fire has been restricted from some of these forests, tree and shrub species that are fire intolerant, but that have flammable foliage, begin to dominate. This makes it very risky, if not impossible, to reintroduce prescribed fire to the forest without first controlling the fuel levels.

Typically, a manager would thin the stand so that the remaining trees are widely spaced and crowns are not close enough to allow a flame to move from one crown to another and the retained trees are resistant to fire, that is, those having a large size and thick bark. Further, the crowns of the retained trees should begin well above the flame height, preventing the formation of a crown fire if a fire starts in the forest. This means that most trees that are cut will be small, fire intolerant, and in many cases dead or dying. In other words, the trees that would be cut will largely be of low economic value. Consequently, either the slash is piled and then burned during the wet season (winter or rainy season), or it is chopped into biofuel and shipped to boilers or other facilities that can convert the wood biomass to energy.

Once the fuels have been effectively reduced and removed, then a prescribed burn may be introduced to the stand to periodically remove the fine fuels and reduce the level of tree regeneration or shrub cover that would otherwise develop. Under the correct weather conditions and with sufficient fine fuels to carry the fire through the stand, the ideal fire would move rapidly through the stand consuming fine ground fuels, but with flame heights that do not reach the tree crowns.

Thinning and prescribed burning will reduce fuel loads at least temporarily so that treated stands are more resilient to high-intensity wildfire (Stephens et al. 2012). Generally, there are few adverse effects of such management actions, though short-term changes in dead wood dynamics is clearly one, but many of the ecosystem components (vegetation, soils, wildlife, bark beetles, carbon sequestration) exhibit very subtle effects to these treatments (Stephens et al. 2012). Indeed, some treatments can be beneficial for some species of animals. Thinning and prescribed burning can provide better foraging opportunities for elk during spring, while unburned stands provide better forage during summer (Long et al. 2008a); so a patchwork of burned and unburned stands may be beneficial for elk forage throughout the growing season. In the same study, mule deer were not so selective of burned or unburned stands (Long et al. 2008b).

Use of Prescribed Fire in Managed Forests

Once prescribed fire can be reintroduced safely to a forest, then repeated burns are necessary to maintain desired fuel loads. Making fire a periodic low-intensity disturbance in a forest in many cases is consistent with the disturbance regimes to which species have evolved or adapted. Fire in longleaf pine stands can create conditions that are often suitable for nesting red-cockaded woodpeckers. Even species of old-growth forests, such as the California spotted owl, seem to tolerate low to moderate severity fires, which have been historically common in the Sierra Nevada mountains of California (Roberts et al. 2011). Managed fires that emulate the historic fire regime of these forests may maintain habitat for California spotted owls and red-cockaded woodpeckers and also reduce the risk of an intense fire that would remove habitat elements important to these species (Roberts et al. 2011).

It should be apparent by now that doing the same thing everywhere is never a good strategy for managing forests to conserve biodiversity. Thinning and prescribed fires may mimic low to moderate-severity fires in a forest, but low/moderate-severity fire is not a substitute for high-severity fire, which may produce habitat elements important to another suite of species (Fontaine and Kennedy 2012). Fontaine and Kennedy (2012) advocated for including high-severity fires in fire-prone forests in order to be more consistent with historic fire regimes and contribute to conservation of regional biodiversity. Such an approach would suggest that managers let some wildfires burn where they are not endangering humans. Indeed some land managers have begun to recognize the need to adopt a let burn policy on some public lands (Bradshaw 2010).

CASE STUDY: TO SALVAGE LOG OR NOT? A SCIENTIFIC DEBATE WITH A SOCIAL SOLUTION

Five separate fires were ignited by lightening in the Siskiyou National Forest over a 3-day period beginning on July 13, 2002. The five fires merged to form the Biscuit Fire, which burned almost 500,000 acres in southern Oregon and Northern California and cost over $150 million to extinguish (U.S. Government Accounting Office [U.S. GAO] 2004) (Figure 13.1). Following the fire there was significant pressure to salvage some of the burned timber, despite protests from individuals concerned about the long-term effects of salvaging on the Siskiyou forest ecosystem. Due to the unusual size, intensity, and social controversy associated with the burn, a number of studies were conducted that investigated the response of the forest to the burn and to salvage logging following the burn (e.g., Thompson et al. 2007).

In 2006, five authors published a paper in *Science*, arguably the most prestigious science journal in the world, entitled "Post-Wildfire Logging Hinders Regeneration and Increases Fire Risk" (Donato et al. 2006a). A graduate student at that time, Dan Donato was the senior author, and here is the abstract from that paper:

> We present data from a study of early conifer regeneration and fuel loads after the 2002 Biscuit Fire, Oregon, USA, with and without postfire logging. Natural conifer regeneration was abundant after the

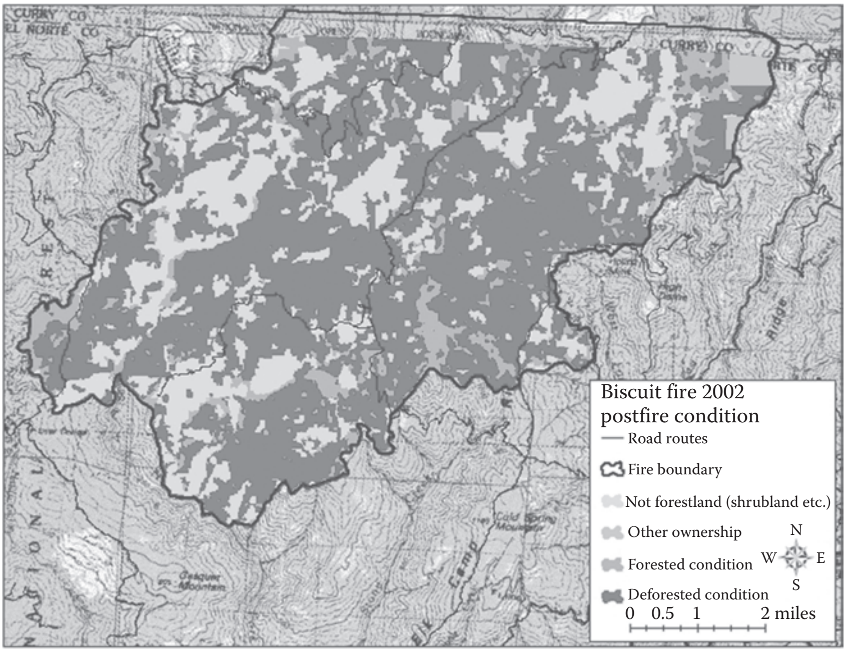

FIGURE 13.1 Boundaries and pattern of the Biscuit Fire, 2002. (From http://www.fs.fed.us/r5/rsl/projects/postfirecondition/2002/.)

> high-severity fire. Postfire logging reduced median regeneration density by 71%, significantly increased downed woody fuels, and thus increased short-term fire risk. Additional reduction of fuels is necessary for effective mitigation of fire risk. Postfire logging can be counterproductive to the goals of forest regeneration and fuel reduction.

The paper ignited a firestorm of its own in the region. Almost immediately after the publication of Donato's paper, seven other scientists sent a critique of the work to the editor of *Science*, stating, "Donato et al. (*Brevia*, 20 January 2006, p. 352) concluded that logging after wildfire kills natural regeneration and increases fire risk. We argue that their paper lacks adequate context and supporting information to be clearly interpreted by scientists, resource managers, policy-makers, and the public" (Newton et al. 2006). Donato et al. (2006b) defended their work in a response, but the debate did not end there. A U.S. Congressman also commented on the lack of statistical rigor in the study and the press fueled the debate even further with newspaper articles, news spots on television, and articles in news publications such as *Evergreen Magazine*, the *Klamath Forest Alliance*, *High Country News*, and others. A number of arguments ensued, such as allegations that the original authors did not follow protocols on authorship and release of data, and counter arguments by the authors that their academic freedom to express their interpretation of the data was being attacked. The work was even questioned in the political arena when Representatives Greg Walden and Brian Baird questioned Donato in a public meeting. The controversy affected the perception of the role of science in solving problems in a unique way. Data collected, analyzed, interpreted, and published were challenged in the scientific community and in the political arena while the public looked on asking questions about the role of science in societal decisions. Two sets of scientists had different views on an issue. So which side was correct? What was the resolution? The issue continued to brew among the scientists for some time, but in reality the decision about whether to salvage log following a wildfire is not one made by scientists. Donato et al.'s (2006) findings are simply one more piece of information that can inform a decision made either by land managers or by the general public who must take into consideration all available information, weigh its limitations and strengths, and then decide what is in the best interest of society now and for many years in the future. It is truly unfortunate that those who challenged Donato initially, and the politicians and others who were subsequently involved, could not recognize the value of the Donato et al. (2006) data to inform decisions, and consequently the role of science in contributing to thoughtful decision making. Their actions instead decreased the credibility of science in the eyes of many members of the general public and will make it that much more difficult for society to trust the weight of scientific evidence in an issue.

SUMMARY

Fire is a natural part of many forest ecosystems. It can create diverse early successional conditions and shape the plant and animal species composition over a landscape for decades into the future. Fires kill trees but create snags and logs. When conditions are correct, with sufficient continuous and dry fuel and an ignition source, fires can creep across the forest floor or race through fine fuels or climb into the tree crowns. Attempts to reduce the number and extent of fires over many parts of the world has resulted; in some forests, with an unusually high accumulation of fuels, when fire does occur, the fire intensity is unusually high. Whether to prevent forest fires, extinguish them, attempt to control them, set prescribed burns, or let wildfires burn are decisions that result from social pressures through political systems. Each decision has a set of ecological consequences affecting the structure and composition of the forest and the availability of habitat elements for species.

Additional decisions must be made after a fire has occurred. If the fire was unusually intense, then are ecosystem restoration efforts necessary? Or will the forest recover to form another forest? Or be transformed into a chaparral? If most trees are killed, can some be cut and sold for economic gain? If so, then how many and what sizes and species? All of these questions are being asked following wildfires, especially those on public lands. Decisions can be guided by science, but even scientists do not always agree on the appropriate actions and associated risks. Public debate, policy development, and monitoring of the effects of policy to guide revisions are all steps underway in issues that deal with fire in forests.

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