

## Fire, Forest Health, and Biodiversity: A Summary of the Proceedings of the Second Annual Symposium of the National Commission on Science and Sustainable Forestry

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OVER THE PAST DECADE, FIRES IN WESTERN FORESTS have generated widespread public concern and debate regarding the condition of our forested lands and their apparent increasing vulnerability to extensive and sometimes very intense wildfires. President Bush's Healthy Forests initiative and the Healthy Forests Restoration Act passed in 2003 by Congress propose efforts to restore forest ecosystems on public lands to conditions less prone to catastrophic fire. The vast majority of discussion and legislation has focused around "fuels management" with little reference to the variations in forest structure and composition—i.e., biodiversity—that comprise those fuels and often no consideration of the different trajectories in forest change that determine fuel conditions. Fuel management, whether through prescribed or natural fire or by mechanical thinning, involves manipulating elements of the biological diversity of forests. Furthermore, wildfires, their suppression, and fuel manipulations have consequences for the biological diversity of forests that extend decades, perhaps centuries into the future.

Thus, the goals of this symposium were to:

- Explore the variations in forest biodiversity and associated patterns of climate and geography that influence fire regimes;
- Evaluate the influence of past and current management (e.g., fire exclusion) and land use on forest biodiversity; and
- Consider the likely impacts of fire management alternatives, including suppression, post-fire remediation, prescribed fire, and mechanical thinning for fuel restoration, on various elements of biological diversity.

E.O. Wilson (1992) defined *biodiversity* as "the variety of organisms ... and the physical conditions under which they live." The Montréal Process on sustainable forest management asserts that "biological diversity includes the elements of the diversity of ecosystems, the diversity between species, and genetic diversity in species." Within this broad vision of biodiversity necessary for sustainable management, symposium participants focused particularly on the following elements:

- Species, biological elements such as woody debris, and site and landscape structural complexity that influence fire

behavior;

- Species whose populations may be at risk from changes in fire regimes (e.g., fire exclusion, catastrophic wildfire) or fire management interventions;
- Aquatic species and habitats; and
- Invasive exotic species.

In his keynote address, Jerry F. Franklin, University of Washington, noted that we have learned much about fire ecology, forest development, and the dynamics of important forest tree species in the past two decades. But he also expressed concern that fire scientists are not communicating effectively and that we are not using existing knowledge to develop credible forest and fire management policy. Among these lessons, seven points are particularly important.

1. “One size does not fit all.” The diversity of forest types is related to a diversity of fire regimes. Where low-intensity, high-frequency fire regimes were the historic norm, fire exclusion has resulted in changes in fuels that require management intervention. However, in many forest types that naturally have stand-replacement fires, fuels are not an issue. Existing plant association and habitat classification schemes can and should provide the framework for management in the context of this variability.
2. The causes of excessive fuel accumulations, where they exist, extend beyond historic fire suppression and include the impacts of grazing, logging, and the establishment of fire-prone plantations. The generation of large contiguous expanses of vulnerable forest conditions has produced “simplified” fire-prone landscapes.
3. Fuel treatments must be prioritized. Certainly areas at the wildland–urban interface must receive immediate attention. Among wildland forests, attention is often focused on climax ponderosa pine. However, the higher-productivity mixed conifer types, where shade-tolerant species create fuel ladders and enormous fuel loadings, may have been even more affected by fire suppression and may be at greater risk of catastrophic fire.
4. Fuel treatments must focus on ground fuels, ladder fuels, and the density of the forest canopy (in decreasing order of importance). Because they are resistant to fire, important in ecosystem recovery, the source of coarse woody debris, and critical for habitat, “big, old” trees must be retained. “Big, old” must be defined in the context of the dynamics and stature of particular forests.
5. We cannot get there in a single stroke; multiple treatments and continuing stewardship will be needed. Initial treatments often produce fuel conditions that require prompt follow-up. Without a long-term stewardship plan, treated areas will promptly return to flammable pre-treatment conditions.
6. Restoration goals must encompass multiple models. A single desired future condition, based on pre-settlement conditions, will not always be appropriate. The context for forest development has been greatly altered by landscape fragmentation and parcelization; invasive plants, pests and pathogens; and environmental change at all spatial scales.
7. Where large fires occur, care must be taken so that post-fire actions, such as inappropriate salvage or establishment of dense, fire-prone plantations, do not create new problems. Surviving large-

diameter trees, snags and logs, and islands of unburned and burned habitat should be retained wherever possible.

### Fire as an ecological process

The relationships between fire and biological diversity within forest stands, across forested landscapes, and with respect to ecosystem processes were considered by Michael Huston (Interdisciplinary Solutions for Environmental Sustainability, Inc.), Andrew Hansen (Montana State University), and Daniel Binkley (Colorado State University), respectively. Although they have long been a matter of speculation and study among community ecologists, the relationships between disturbance and biological diversity defy simple or single-factor explanations (e.g., the intermediate disturbance hypothesis). The effect of particular fire (or other disturbance) frequencies on disturbance is clearly dependent on site productivity and the nature and rate of successional change in different fire types. The responses of different components of total plant diversity—say, trees versus herbs—may differ and even be opposite. These dynamics have significant consequences for biodiversity at the landscape scale as well.

In pre-settlement times, most—though not necessarily all—large forested landscapes in the West probably existed as “shifting steady-state mosaics” of patches representing different fire histories and stages of post-fire succession. The smallest area necessary to capture the full range of such patches and their dynamics is termed “minimum dynamic area” (MDA), and most pre-settlement landscapes are thought to have been larger than their MDA. Variability among patches in their composition of plants and animals species contributed enormously to the biological diversity of the landscape, and the long-term sustainability of that diversity depended on

the maintenance of the shifting steady state.

Exclusion of fire has in many places rescaled the mosaic patches, and particular kinds of patches changed in importance; notably, conifer-dominated patches have increased in importance while aspen-dominated pieces of the mosaic have decreased. Land fragmentation and deforestation have further diminished the size of landscapes which, coupled with changes in the frequency of different patch types and increases in their size, means that most management units now do not encompass the MDA; in many areas managers must now cope with the reality of landscapes that are only a fraction of the MDA.

Today, because of landscape changes (e.g., fragmentation, rescaling) and expansion of human development into fire-prone landscapes, historic range of variation (HRV) in fire regimes on landscapes comprising a minimum dynamic area is not a realistic or socially acceptable management option. Active management is, nevertheless, a necessity to restore ecosystems and prevent the loss of biodiversity, and HRV and MDA concepts are important in selecting appropriate temporal and spatial scales to achieve ecological objectives. This will require a combination of natural and prescribed fire, silviculture, and land-use planning. Furthermore, management must be integrated across public and private lands to achieve landscape-level objectives. As discussed below, restoration efforts must be tailored to particular biophysical settings within and among regions.

The energy released by forest fire varies from the equivalent ignition of a few cups of gasoline per square meter in light understory fires to gallons of gasoline per square meter in intense canopy fires. That energy release is largely the consequence of the oxidation of large amounts of carbon. Nitrogen and sulfur

are also oxidized and consequently “lost” as gases to the atmosphere. Other elements such as calcium, potassium, and phosphorus may be oxidized, but remain in the ash. Even though nutrients in ash may result in soil enrichment immediately following fire, mineral nutrient losses from fire are quite significant. In the case of nitrogen, 4.5 kilograms are lost for each ton of fuel consumed. Nitrogen is replenished between fires by input in precipitation and, to a greater extent, by the activities of nitrogen-fixing microbes and plants. For example, exclusion of nitrogen-fixing alders from successional Douglas-fir forests can result in a 50% decrease in stand production after 80 years. Many ecosystem processes depend on the activities of a diverse array of soil microbes, and the effects of fire on this component of biodiversity has received little study.

Fires affect the local hydrologic budget and soil water infiltration capacity, producing significant erosion and sediment transport. The negative effects of such erosion are well known and include the loss of nutrient capital and sedimentation of reservoirs. However, fire-related sediment transport is important in some areas to the development of features that maintain the diversity and functioning of many stream ecosystems on forested landscapes.

### **Inter-regional variation in fire regimes and fire history**

Patterns of variation among and within the Pacific Northwest (James Agee, University of Washington), semi-arid Southwest (Tom Swetnam, University of Arizona), Sierra Nevada (Jon Keeley, U.S. Geological Survey), Northern Rockies (William Romme, Colorado State University) and Southeast (Joan Walker, U.S. Forest Service) regions were discussed. Participants in this part of the symposium

were in agreement that Agee’s general classification of fire regimes in the Pacific Northwest as ranging from low-severity (high-frequency, low-intensity) to mixed-severity (variable frequency and intensity) to high-severity (low-frequency, high-intensity) provided a useful framework for evaluating fire-biodiversity relationships and forest health conditions throughout the western cordillera.

High-severity regimes with fire return intervals in the hundreds of years are typical of forests in relatively warm and wet regions or high-elevation, cold areas. Such areas include the array of hemlock- and fir-dominated forests of the western Cascades, lodgepole pine forests such as those of the Yellowstone Plateau and in the Sierra Nevada, and the California coast redwoods. Although not typically considered forest, the southwestern chaparral most certainly fits into this category. In such areas, fire initiates a classical successional process that includes a long period of stem establishment, a thinning or stem-exclusion phase, with the ultimate development of old-growth forest, each with its own characteristic array of species and structural elements. The occurrence of fires in such forests is largely related to infrequent dry climatic conditions. Fire return intervals in these forests far exceed the period of active fire suppression and it was agreed that these forests are generally healthy and not in need of fuel restoration.

Mixed-severity fire regimes are typical of many western forest types, including red and white fir and dry Douglas-fir over much of their range and higher-elevation forests in the Sierra Nevada. Such fire regimes may have been important in some of the moister areas where ponderosa pine is dominant. Fires in these ecosystems are typically heterogeneous, with high- and low-intensity patches producing a mosaic of forest conditions across landscapes. Much biological diversity is associated

with this mosaic. Forest health issues are complex in these regimes. Exclusion of high-intensity events can influence species such as knob cone pine that depend on such patches, as well as natural biodiversity in the mixed conifer forests. Historical patterns of logging and fire have modified the mosaic in many areas subject to mixed-severity fires and have thus altered fire behavior. Logging has potentially created even greater fire hazards than fire suppression policy: removing large trees has opened the way for creation of vast so-called dog-hair thickets that present a major restoration challenge since putting low- or mixed-severity fires back into these systems is problematic.

Fire suppression in such forests has adversely affected parts of the landscape (e.g., lower slopes, and north and east aspects) that typically experience low-intensity fires. Restoration can be important in such areas, particularly where potential impacts on human values are large. The 2002 Biscuit Fire in southern Oregon is an example of a mixed-severity event within which fire behavior was influenced by many of the factors described above.

Fire suppression and grazing have had their greatest impact on fuels in forest ecosystems that historically experienced low-severity fire regimes. This includes the drier ponderosa pine forests in the Southwest and the east side of the Cascades, and low-elevation ponderosa pine forests of the Sierra Nevada.

The dog-hair thickets of ponderosa pine in-growth in forests in parts of the Four Corners states have resulted from the historic impoverishment of grassy understories by grazing in the late nineteenth century, followed by a year or two of high seed production and seedling survival over the next few decades. Subsequent fire exclusion has permitted development of a dense understory

tree cover. Although fire frequency in these forests is certainly influenced by periodic drought cycles (e.g., the El Niño Southern Oscillation) and, perhaps, longer-term climatic trends, it is clear that the magnitude and intensity—as well as impacts on hydrology, erosion, and aquatic ecosystems—of events such as the Rodeo-Chedeski and Hayman Fires are well outside the historic range of variation. Fire exclusion in the mixed conifer forests of the Sierra Nevada has facilitated the establishment of shade-tolerant incense cedar and white fir that create ladder-fuel conditions that can initiate crown-killing fires. Current conditions in many of these forests are unhealthy, the impacts of fire exclusion and the recent catastrophic fires on biological diversity at all spatial scales have been negative. Restoration in these forests is needed, and in many places this need is urgent. Restoration may involve mechanical thinning, prescribed fire, or a combination of these approaches. Thinning should be focused on reducing ground fuels, ladder fuels, and, where necessary, the density of the forest canopy (in that order). Removal of large trees, for reasons described above, will be counterproductive from both a biodiversity and fuels management standpoint. Restoration will not succeed as a one-time management intervention.

Our understanding of fire regimes and history for some western forests, such as pinyon-juniper and several higher-elevation forest types, is incomplete and appears to vary considerably among regions.

For example, fire in the southeastern U.S. plays a significant role in forest ecosystems and has a range of fire severity regimes similar to those found in the West. But climatic conditions and a long history of intensive human land use have produced patterns that are quite different than those observed in the West.

Presettlement landscapes were greatly influenced by fires set by Native Americans to clear land and improve conditions for wildlife. Extensive deforestation, land fragmentation, and subsequent reforestation over much of the Southeast during the past 300 years have further modified forests and their fire regimes. Although exclusion of fire from some southeastern forests has resulted in substantial forest change and, in some cases, loss of biodiversity, it has not produced forest health challenges similar to those described above for many western forests. Nevertheless, fire management will be important in restoration efforts for such ecosystems as longleaf pine–wiregrass savannas in the Coastal Plain and pine–heath forests in the southern Appalachians.

### **Perspectives on fire management**

Fire and fuel management includes several actions, such as suppression and post-fire remediation, restoration using mechanical thinning of fuels, and prescribed burning. The biodiversity implications of the use of these management tools were discussed by Penelope Morgan (University of Idaho), Wallace Covington (Northern Arizona University), and Norman Christensen (Duke University).

The effects of fire exclusion on forest biological diversity at the stand and landscape scales have been discussed above. Fire suppression activities also directly affect species and habitat. Fire lines and other suppression-related disturbances can affect habitat and create opportunities for establishment and spread of invasive species. Intentionally set backing fires may be considerably more intense than the wildfire they are intended to suppress, again with locally adverse consequences. Nevertheless, where suppression is necessary, such impacts may be unavoidable

and probably deserve special consideration in post-fire remediation efforts.

Post-fire remediation programs such as Burned Area Emergency Rehabilitation (BAER) are focused on the impacts of wildfire on hydrologic flows and sediment movement. They, nevertheless, have significant impacts on biodiversity that are rarely assessed. Scarification and the establishment of erosion barriers and wattles have potential consequences for habitat of some organisms and may facilitate invasion of some invasive alien species. Seeding, particularly with non-native species, may have a negative effect on establishment of indigenous plants and greatly increase the likelihood of introduction of invasive species. As a general concern, key aspects of biological diversity—for example, re-establishment of indigenous flora and invasion of non-native species—should be currently monitored as part of most restoration programs.

Forest restoration should be viewed as framework to restore forests and forested landscapes to conditions that are consistent with their evolutionary environment. From a social and political perspective, it must be based on collaborative, participatory processes. Reference conditions for restoration may or may not be presettlement landscapes, but they must be consistent with the evolutionary history of the forest and its species, and they should be developed based on converging lines of evidence from among a variety of techniques. To restore toward presettlement conditions in the low- and moderate-severity fire regimes described above, excess understory trees must be thinned and removed and trees that predate settlement as well as additional younger trees retained to re-establish presettlement forest structure. Following this, heavy fuels are raked from the base of trees and prescribed fires applied to emulate natural intensities and spatial distributions. Restoration

may also require seeding with appropriate native plant species as well as vigilant control of invasive exotic species. This particular activity might be modified to accommodate particular management objectives such as habitat improvement for at-risk species, wood extraction, or livestock grazing.

Restoration efforts should be undertaken at a pace and scale appropriate to the forest health challenges in different regions. Furthermore, such restoration must be followed by careful monitoring and an integrated fire management program that will ensure that forest landscapes do not return to unhealthy states.

“Prescribed fires” are those that are allowed to burn within predetermined parameters of weather, terrain, and behavior, such that they can be controlled or extinguished. Using artificial and natural ignitions, prescribed fire has become an important tool for fuels and habitat management over the past century. It is nevertheless important to remind ourselves that prescribed fire is not necessarily equivalent to fire as a natural landscape process. Prescribed fires are generally set or allowed to burn at smaller scales and with considerably less variability in behavior than would occur naturally. There is a strong bias against extremes in fire behavior even when they are within the historic range of variation. Prescribed fires are often set in a season other than that which is typical for natural fires, and prescriptions often pay little attention to “legacies” such as snags and woody debris that affect habitat quality. These differences between prescribed and natural fire have important implications for biodiversity management.

### **Perspectives of managers and stakeholders**

A panel of four managers and stakehold-

ers was the centerpiece of the symposium’s capstone discussion. Rick Cables, regional forester for the Rocky Mountain Region of the U.S. Forest Service, emphasized the important consequences of fire and fire management with respect to water and watershed protection. Gary Roloff, wildlife biologist with Boise Cascade, emphasized the importance of clarity regarding goals and definitions; it is, for example, not helpful to discuss the connections of fire to biodiversity without being very clear regarding the specific components of biodiversity of interest (e.g., populations of threatened and endangered species, invasive non-native species, umbrella species, etc.). Greg Aplet of the Wilderness Society presented three core principles for forest restoration efforts. First, restoration should focus on key ecosystem processes and emphasize resiliency. Second, appropriate economic incentives must be put in place to ensure this focus. Third, restoration must include training and compensation necessary to create and retain a skilled workforce. Finally, David Parsons, director of the U.S. Forest Service’s Aldo Leopold Wilderness Institute, emphasized the need for institutional commitment and continuity with respect to fire and forest restoration policies.

### **Conclusion**

Whether prescribed or wild, fires today occur in a context that is vastly different from the past. As discussed previously, landscapes have been “rescaled” and modified by human activities—the area and relative abundance of successional patches have been modified. Climates have changed, perhaps as a consequence of human activities—consider that the dominant trees in many forests were established over 200 years ago during the Little Ice Age, in some cases before that. In many areas—even in remote wilderness—air quality

has been diminished in ways that affect forest health and most certainly influence our ability to use prescribed fire. The biogeographic barriers that once isolated species have through human actions have become increasingly irrelevant, so that even natural disturbances can have undesirable consequences with regard to the invasion of exotic species.

In the context of this complexity, it is important to recall that fire and fuel management—fuel manipulation, prescribed fire, suppression—is not *the* end in itself, only a means to other ends. Such management actions do not create *states*; rather, they determine *trajectories*. The primary goals of fire and fuel management may not be the protec-

tion and maintenance of biodiversity, but it is elements of biological diversity that are being manipulated (what are “fuels,” after all?) and affected. Where biodiversity management is the priority, goals must be explicit and monitoring programs focused on those goals. Goals must be operational, measurable, unambiguous, and feasible. We have learned a great deal, but our knowledge base is still incomplete. Most important, these goals must form the basis for a program of management that is adaptive to variations among forest types, changes in the environment, changes in our knowledge base and understanding, and ever-changing societal needs and values.

### Reference

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