Fire Ecology in Colorado

Grass fire on Colorado's Eastern Plains.

Surface fires historically were common in Colorado's ponderosa pine forests.

Mosaic pattern created by a wildfire burning some areas of a forest, while leaving sections intact.

For thousands of years, fires have shaped North American ecosystems. Many species thrived when their habitats burned at predictable intervals. Not surprisingly, some have developed traits that enable them to take advantage of fire to reproduce successfully or compete with other species (Miller 2000). For instance, fires burned some grasslands nearly every year, while some forests and wetlands escaped fire for centuries at a time. In forests, some fires burned only grass and low shrubs under the large trees, others killed nearly every tree, and still others produced a mosaic of fire-killed trees and patches left unburned because of random changes in wind direction or other conditions (Brown and Smith 2000). Within large, severe burns, some patches remain unburned because of change changes in wind direction, weather and other conditions. So the story of fire plays out differently in nearly every plant and animal community on the continent.

In some habitats, plants and animals are actually harmed if fire is not allowed to burn, so land managers attempt to reintroduce fire and use naturally-occurring fires to benefit these landscapes.

What is Fire Ecology?

Fire is a natural component of many ecosystems, which include plants and animals that interact with one another and with their physical environment. Fire ecology examines the role of fire in ecosystems. Fire ecologists study the origins of fire, what influences spread and intensity, fire's relationship with ecosystems, and how controlled fires can be used to maintain ecosystem health.

The main factors addressed in fire ecology are fire dependence and adaptation of plants and animals, fire history, fire regime and fire effects on ecosystems.

Colorado State Forest Service

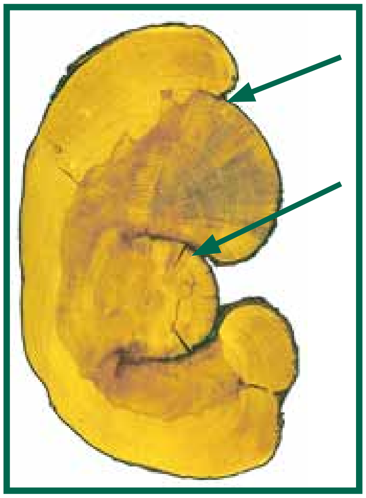
Information in this document courtesy of Pacific Biodiversity Institute, the National Interagency Fire Center and the Colorado State Forest Service.

Lodgepole pine, a fire-adapted species, often produce sprolifically following wildfire.

Aspen regeneration occurs after a wildfire.

Fire dependence

In the 1930's, researchers in the southern United States argued against the negative perspective that has surrounded fire – with the belief that all fire is bad. They realized that the devastating picture painted by huge-scale fires produced fear in the minds of the public and that this generated detrimental results in response to any wildland fires. These researchers recognized that there are species of plants that rely upon the effects of fire to create a more environment for regeneration and growth. Fire in these environments prepares the soil for seeding by creating an open seedbed, making nutrients more available for uptake and often killing plants that are invading into the habitat and competing with native species.



This cross section of a tree trunk indicates that the tree lived through at least two separate wildfire events.

Fire history

Fire history is the study of with how often fires have occurred in a given geographical area. Through recorded history, we can see into the recent past, but trees are our source of information on fires in the distant past. Trees record their history through a system of growth rings that develop on the trees each year. When a fire goes through an area, the growth rings of that particular tree may be scarred. On live trees this is called a fire scar. Fire scars can also be seen on dead trees. Tree origin dates (calculated from the total number of rings) can also tell when fires occurred, in that fires gave way for these new trees to develop. The study of growth rings is called dendrochronology. Utilizing dendrochronology, we can determine when fires have occurred in the past, and sometimes determine their intensity and direction as well as other information about the weather patterns in that era.

Fire regime

Wildland fire is a natural process, and many ecosystems depend upon it. In discussing and addressing fire as a conservation issue, it is important to recognize and understand the different roles that fire plays in different ecosystems.

Fire regimes, like the rest of the natural world, are diverse and particular to their specific sites. Fire helps determine where different types of habitats exist around the world. Plants and animals have developed different responses to fire, with some dependent on fire and others sensitive to fire.

Fire regime refers to the patterns of fire that occur over long periods of time, and the immediate effects of fire in the ecosystem in which it occurs. There are many ways to define a fire regime. Fire regime is a function of the frequency of fire occurrence, fire intensity and the amount of fuel consumed. The frequency is determined largely by the ecosystem characteristics, the duration and character of the weather (whether the season is drier or wetter than normal, etc.) and ignition sources. The intensity of a fire is determined by the quantity of fuel available, the fuel's combustion rates and existing weather conditions. Interactions between frequency and intensity are influenced by wind, topography and fire history. There are many other factors that can come into play when talking of fire regimes, though this simple definition will work for most cases.

A **fire regime** is a set of recurring conditions of fire that characterizes a given ecosystem. The combination of fire frequency, intensity, severity, seasonality, size of burn, fire spread pattern, and pattern and distribution of burn circumscribe those conditions. Fire regimes can often be described as cycles because some parts of the histories usually get repeated, and the repetitions can be counted and measured, such as fire return interval.

An **ecologically appropriate fire regime** is one that maintains the viability of the ecosystem.

An **altered or undesirable fire regime** is one that has been modified by human activities to the extent that the current fire regime negatively affects the viability of desired ecosystems and the sustainability of products and services that the ecosystem provides.

Fire-dependent ecosystems are those where fire is essential and the species have evolved adaptations to respond positively to fire and to facilitate fire's spread, i.e. the vegetation is fire-prone and flammable. They are often called **fire-adapted** ecosystems. Many plants and animals in these landscapes depend on fire to reproduce and grow. If fire is removed, or if the fire regime is altered beyond its normal range of variability, the ecosystem becomes something different, and habitats and species are lost. Fire dependent ecosystems vary greatly and need to burn under an appropriate fire regime if they are to persist in the landscape.

In many ecosystems, fire regime alteration is a slow and incremental process, sometimes occurring over decades, and is often linked to multiple sources of degradation related to the many ways that people utilize and interact with our landscapes. Therefore, the attention of the public and decision-makers often occurs after a triggering event, like prolonged drought and uncharacteristically severe fires.

Fire Effects

Fire effects refers to the immediate and more long-range effect of fire on all living and non-living organisms in the system. For example, fire can have a range of immediate effects on soils, vegetation, water/watersheds and infrastructure. One of the overall benefits of wildland fire is that it is a catalyst for enhancing an ecosystem's ability to sustain nutrient and water cycles and promote biological diversity. Wildland fires burning in their natural regimes reinitiate succession of vegetation communities. They foster new plant growth, which in turn, supports diverse wildlife habitats.

Lupines are regenerating in previously burned forest.

Fire Suppression/Exclusion Practices

A substantial amount of attention has been paid to the development of dense stockings of small trees in some forests, and the contribution of fuel loading to current fire severity in those areas. Although this may be true of some drier vegetation ecosystems, this observation does not apply well to the piñon-juniper woodland types or many of the high-elevation forests that dominate much of the western Rockies. Nor does it apply to non-forested areas.

Most of the discussions of overly dense forests have focused on fire suppression policies over the last century as the dominant factor contributing to the overstocking. However, in most areas, wildfire suppression practices have been only one of many contributing factors that have resulted in fire exclusion. For example, the development of communities and road systems associated with logging, mining, grazing and recreation practices have all contributed to the change of

An overly dense stand of trees provides abundant fuels for wildfire.

vegetation composition, amount and distribution across the landscape. As a result, fire has been excluded in many areas where it historically played an important role in the evolution of the landscape.

The ecological effects of practices that have excluded wildfire vary with vegetation type. In addition, the frequency of fire historically varies considerably depending upon the type of vegetation in a given ecosystem. Therefore, there is no single way to characterize the effect of fire-exclusion practices on vegetation composition and structure varies considerably (Smith and Fischer, 1997).

Roads and development in Colorado's wildland-urban interface (WUI) have altered forest composition.

Coloradoss's forests experienced increased density of trees and numbers of saplings and pole-sized trees while large trees have decreased.

Fuel Types in Colorado

Fire played a major role in shaping the composition, structure and function of the vegetation types throughout Colorado – particularly those of the Ponderosa pine, piñon-juniper woodland, mountain shrublands and sagebrush grasslands at lower elevations in Colorado (Covington et al., 1994; Romme et al., 1994; Crane, 1982) and the high-elevation subalpine forests, which are composed mainly of subalpine fir, Engelmann spruce, Douglas fir, lodgepole pine, and aspen in the central mountains in Colorado. However, the ecological changes brought about by traditional land management practices that have resulted in the exclusion of fire have greatly altered conditions in many of the plant communities and greatly affected many species occurring in Colorado (Uncompahgre Field Office Fire Management Plan Environmental Assessment 1999, White River Fire Use Fire Management Plan).

These changes have moved vegetation conditions in areas with heavy human use away from their pre-European-settlement range of natural variation for community structure, fire frequency, and fire size (Covington et al., 1994; Romme et al., 1994). Post-settlement changes include increased density of trees, invasion of trees into formerly shrub or grass dominated areas, increased abundance of saplings and pole-sized trees, decreased abundance of large trees, increased fuel accumulations in the form of litter and fine woody debris, dominance of older age shrubs, and decreased abundance of native bunchgrasses and forbs.

Piñon-Juniper Woodlands

Piñon pine and juniper woodlands are widespread at the lower elevations, particularly on the Western Slope of Colorado. Juniper-dominated woodlands tend to include open savannas of scattered trees without a significant shrub component, except in areas where big sagebrush has become dominant as a consequence of grazing. Woodland communities have expanded considerably over the course of the century, and now dominate many sites (2001 Report on the Conditions of Colorado's Forests). Average fire intervals vary considerably in piñon-juniper woodlands, with some historically ranging from 200-400 years (Romme year2008). Piñon pine and juniper do not usually survive a high intensity fire. The rate of stand recovery after a fire depends on the season, availability of seed from adjacent surviving trees, post fire precipitation, competition from other plants, and the amount of area burned.

Piñon-juniper woodlands are widespread at lower elevations in southern Colorado and on the Western Slope.

Ponderosa Pine

Ponderosa pine is generally the dominant lower elevation species in Colorado's montane zone, particularly at elevations from 5,800 to 9,800 feet. However, through a century of fire exclusion, shade-tolerant Douglas-fir has increasingly encroached on ponderosa pine stands, changing the fire characteristics and fire regime (2001 Report on the Condition of Colorado's Forests). In low-elevation ponderosa pine and dry Douglas-fir forests, average fire intervals have historically ranged from 5 to 20 years, and low to medium intensity fires were common (Arno 1980, Smith and Fisher 1997). Fire exclusion has been fairly effective in reducing the number of fire cycles that these low elevation dry coniferous forests have experienced over the last century. Fire exclusion leads to more intense fires in these areas when fires do occur. When fire occurs in these mixed forests, the understory Douglas-fir tend to carry fire in ladder fashion into the pine crowns, making the fire much more likely to reach unnatural, stand replacement proportions (2001 Report on the Condition of Colorado's Forests).

Ponderosa pine generally evolved with a cycle of frequent, low-intensity fire, which killed competing seedlings but allowed the ponderosa to mature.

Ponderosa pine ecosystems occur as transitions between grasslands and deserts at lower elevations and higher level alpine communities. These ecosystems occur sometimes as nearly pure stands of ponderosa pine but are sometimes mixed with other species, such as Douglas-fir. This forest community generally exists in areas with annual rainfall of 25 inches or less.

Douglas-fir tend to carry fire in ladder fashion into ponderosa pine crowns.

The characteristic surface cover in a ponderosa pine forest is a mix of grass, forbs and shrubs. The natural fire regime has a cycle of five to 25 years, with moderate regularity. These fires tend to be low-intensity ground fires that remove woody shrubs and favor grasses, creating open, park-like ponderosa stands. These fires burn litter and release soil nutrients, thus providing a good seedbed for ponderosa pine seeds. For the first five years of their life cycle, ponderosa pine seedlings vigorously compete with grasses for survival and are vulnerable to fire. Eventually, at about five or six years of age, the tree begins to develop thick bark and deep roots and shed lower limbs. These factors increase its ability to withstand fire and decrease the possibility of a fire climbing to the crown; crown fires can kill ponderosa pines. Ponderosa needles on the ground facilitate the spread of low intensity ground fires and reduce grasses that can intensify ground fires.

Douglas-fir is commonly found in association with ponderosa pine, but is able to survive without fire. Additionally, Douglas-fir possesses characteristics that enable them to withstand fire when it does occur. For example, this species is more resistant to fire than most other conifers. Additionally, Douglas-firs' abundantly produced seeds are lightweight and winged, allowing the wind to carry them to new locations where seedlings can be established. Douglas-fir regenerates readily on sites that are prepared by fire. One of the main benefits of fire in these forest communities is the removal of fuel and consequent reduction of the chance of severe crown fires.

The return interval for naturally-occurring fires within a spruce-fir forest may be 300 years or longer.

High-elevation subalpine forests

Colorado's high-elevation subalpine forests are composed mainly of sub-alpine fir, Engelmann spruce and Douglas fir, lodgepole pine, aspen, and high-elevation sagebrush. These forests are situated at higher elevations, which are considerably wetter and colder than the dry forests. Subalpine forests typically burn rather infrequently, though often at a much higher intensity than do dry forests. Fire intervals in high-elevation forests are difficult to determine with certainty since fires generally kill, rather than scar, the species that survive at these altitudes. However, studies have shown that historic fire-return intervals in subalpine forests range from 50 to 300 years (Arno 1980, Smith and Fisher 1997, Agee 1990, Agee 1993).

In many cases, historic fire-return intervals for subalpine forests are longer than the period of time in which the current fire exclusion practices have been in effect. Fire exclusion due to wildfire-suppression activities has not yet measurably altered the structure and composition of the subalpine forests since they have, in general, not missed sizable fire cycles like the dry forests have. (Smith and Fisher 1997). It can be assumed, though, that historic fire suppression practices have resulted in some loss of mosaic patterning and diversity of age classes, which has allowed larger, more contiguous areas which can carry a stand replacement fire.

Lodgepole Pine

Lodgepole pine are most prevalent in the montane and subalpine forests of Colorado's northern Rocky Mountains, generally in unmixed stands at higher elevations. Studies have shown fire-free intervals in lodgepole pine to vary between 150-300 years. On unproductive sites, however, intervals of 400-600 years may be more typical (White River Fire Use Fire Management Plan). Some of the conifer species present in sub-alpine forests are killed by moderate-intensity fire (Bradley, et al. 1992). In contrast, lodgepole pine often reproduces prolifically following wildfire (Agee 1993). Lodgepole pine is intolerant of shade and thrives in the aftermath of fire. Many lodgepole produce serotinous cones, which open in response to extreme heat and release an abundance of seeds. These long-lived cones may remain viable for decades, waiting for a fire to release their seeds. Natural lodgpole regeneration in open, sunny areas often produces very dense stand of 20,000 or more trees per acres. (2001 Report on the Condition of Colorado's Forests).

At 40 to 50 years following a stand-replacing fire, herbaceous plants and lodgepole seedlings grow between snags and logs that were damaged by the fire. The forest tends to resist fire at this stage, in that the only fuels available are large logs that do not readily burn. From the age of 50 to 150 years, seedlings grow to a height of 50 feet, and the stands become so dense that little sunlight reaches the forest floor, therefore suppressing the growth of the understory. The sparseness of undergrowth also discourages the possibility of wildfire.

Most of today's lodgepole pine forests regenerated after widespread fires and some logging activity in the mid to late 1800s and early 1900s.

It is during the next successional stage of 150 to 300 years that the threat of wildland fire increases. Because of overcrowding, some of the lodgepole pines begin to die, which allows sunlight through, spurring vegetative growth. After 300 years, the original lodgepole pines die, making the forest highly susceptible to wildland fire. For example, the lodgepole pine stands in the Yellowstone area during the 1988 fires were 250–350 years old.

When fire does not occur, lodgepole pines are sometimes gradually replaced by Engleman spruce and subalpine fir, although the successional pathway is site dependent. Fire regimes in lodgepole pine communities can be very irregular, thus community dynamics are difficult to predict.

Wildland fire management in lodgepole pine communities can be problematic. Because there tend to be high intensity crown fires, allowing lightning ignited fires to burn can result in fires which are difficult to contain within management units. Prescribed fire is difficult to manage for the same reasons, and can endanger nearby human communities. Fire suppression, however, creates a fuel buildup that is difficult to manage, and suppression is not consistent with maintaining ecological communities.

A serontinous cone from a lodgepole pine.

Wildfire in lodgepole pine forests tend to be high-intensity crown fires.

Oak Shrublands

These shrublands account for 10 percent of the forested lands in Colorado and are found throughout most of western Colorado, along the southern Front Range and in the central part of the state. Their appearance can range from dense thickets with little understory to relatively moist sites with a rich understory of shrubs, grasses and wildflowers.

Fire usually plays an important role in maintaining oak shrublands; it promotes regeneration, controls the invasion of trees, and increases the density and cover of Gambel oak (Quercus gambelii) and serviceberry (CNHP 2009)1. Many of these landscapes currently suffer from altered fire regimes due to extensive fire suppression, especially in the wildland-urban interface. Wildlife species associated with oak shrublands include sharp-tailed grouse, mule deer, elk, Abert's squirrels, black bears, blue grouse and Merriam's turkey.

Gambel oak landscapes have undergone altered fire regimes due to extensive fire suppression.

Sagebrush, Alpine Grasslands and Aspen

Fire intervals in high-elevation sagebrush, alpine grasslands and aspen are shorter than coniferous forest, and range from 30 to 100 years (White River Fire Use Fire Management Plan).

Fires also burn in US Forest Service Inventoried Roadless Areas and designated Wilderness Areas. Many of the forests in these areas have not been severely altered from their historic fire regimes, and are difficult to access due to steep, rugged topography.

Prescribed fire is used after forest thnning to reduce surface fuels.

Why prescribed fire?

Fuels treatments of some sort – whether mechanical treatments, prescribed burning or a combination of methods – are the most effective form of fuel management in these areas where the effects of fire exclusion and the potential for severe wildfire are greatest

But the presence of additional social, political and ecological management concerns, such as human occupation, threatened and endangered species, cultural/heritage resources, and habitat concerns, make fire use management in these areas more difficult. Fire use is still an option, but often requires much more restrictive management constraints.

Severe soll erosion often occurs after a high-intensity wildfire.

A deer browses the new growth in this forest opening, which occurred after a wildfire.

Advantages/Disadvantages of Fire

Disadvantages: Fire can cause soil damage, especially through combustion in the litter layer and organic material in the soil. This organic material helps to protect the soil from erosion. When organic material is removed by an intense fire, erosion can occur. Heat from intense fires can also cause soil particles to become hydrophobic – rainwater then tends to run off the soil rather than to infiltrate through the soil, which can contribute to erosion. There is also the potential for alien plants to become established after fire in previously uninfested areas.

The ashes that remain after a fire can add nutrients often locked in older vegetation to the soil for trees and other vegetation. Fires can also provide a way for controlling insect pests by killing off the older or diseased trees and leaving the younger, healthier trees. In addition to all of the above-mentioned benefits, burned trees provide habitat for nesting birds, homes for mammals and a nutrient base for new plants. When these trees decay, they return even more nutrients to the soil.