RESTORING MIXED-CONIFER FORESTS

The historic mixed-conifer forest covered 12 million acres in California and Oregon. It extended from the western slope of the Cascade Range in north-central Oregon to the mountains of Southern California, mainly along the western slope of the Sierra Nevada. Smaller parts of the forest grew in the Coast Range of Southern Oregon and Northern California. The modern mixed-conifer forest grows in roughly the same areas.

Fire History

Pioneer species dominated the historic mixed-conifer forest such as ponderosa pine and sugar pine, which grow to great size, as well as scattered groves of giant sequoia. Like pioneer forests elsewhere, it was sustained by Indian and lightning fires. They were similar to the gentle fires that burned in historic ponderosa pine forests, and they kept this forest open, patchy, and productive in much the same way. As John Muir pointed out, "The inviting openness of the Sierra woods is one of their most distinguishing characteristics."

Fire made the difference between extinction and survival for many species. However, a gentle surface fire that removed the litter was too cool to create an opening. Even a hot fire was not enough. Such a fire could harden the soil and keep out rainwater. It also stimulated the growth of shrubs such as deer brush more than it did trees like ponderosa and sugar pine. The fire had to be very hot to create an opening. This kind of fire flares up in a dense group of large trees, or in logs and piles of debris.

A very hot fire starts a chain of effects that benefit pines. It begins when the flames clear a large sunny opening in the forest. A quarter acre or smaller clearing might provide room for one or a few trees, while a half-acre might be enough for up to twenty trees. Meanwhile, the burned wood provides a fluffy layer of ash that buries the seeds when they land and protects them from direct sunlight. There is also more moisture available for the seedlings because moderately high temperatures make the soil crumbly so that water flows into it more quickly.

Once established, the seedlings have a good chance of survival because the intense heat penetrates deep into the soil and kills root fungi and plant seeds. This reduces losses from disease, and it eliminates faster growing shrubs that might take the moisture and block the sunlight that tree seedlings need to grow.

Surface fires returned to the same place in the historic mixed-conifer forest about once each 5 to 18 years. The period between fires was shorter on dry ridges and upper slopes, and longer on moist lower slopes and in canyons. Upper slopes burned more often because lightning struck them more often. In addition, uphill winds pushed those lightning fires that started on lower slopes to the ridges. Yet these uphill winds, as well as creeks, rock outcrops, and other barriers, often prevented the slow moving fires that

started on ridges from reaching the lower slopes. So, ridges burned more often, and they were usually more open than the rest of the forest.

Sierra Indians contributed to the high frequency of fires in mixed-conifer forests. They set some of their fires inside the forest to enhance hunting and for other reasons. Some of their fires also entered forests from foothill woodlands.

Fires that start at the base of a hill move faster when they climb a slope with the wind. They also have taller flames, and burn hotter than fires that start at the top of a hill and move down slope against upward flowing winds. That means that most lightning fires were slow moving and light since they started on ridges, and many Indian fires were fast moving and hot because they often started below the ridges. Such hot fires are more likely to ignite thick patches of trees and piles of debris than cooler fires. Therefore, Sierra Indians unintentionally increased the number of very hot fires that burned in the historic forest, which probably produced more groups of shade intolerant trees such as the pines than lightning fires alone might have done.

Indian and lightning fires burned so frequently that they cleared debris and young understory trees before they could accumulate. Still, scattered pockets of fuel occurred in the forest where groups of trees died or became thick, or where branches fell. Consequently, a surface fire that crept along the forest floor occasionally flared up, entered the crowns, and became a small but fleeting crown fire. However, those patches of trees that were thick enough to burn were few, and less flammable patches usually kept them apart so that a crown fire could not spread. This kept crown fires confined in small, widely separated patches of trees, usually less than half an acre, although on rare occasions, a few hundred acres of trees might go up in flames.

Large crown fires were almost unknown in this historic forest, as John Muir pointed out. He said "… in the main forest belt of the Sierra, even when swift winds are blowing, fires seldom or never sweep over the trees in broad all-embracing sheets as they do in the dense Rocky Mountain woods and in those of the Cascade Mountains of Oregon and Washington."

Several decades later, foresters S. B. Show and E. I. Kotok supported this observation. They said, "The stands in general are so uneven-aged and broken and have such a varied cover type that a continuous crown fire is practically impossible."

Fire sculpted this historic forest. Insects and disease also played their roles, as they do in all forests, by killing groups of trees and creating new openings. However, fire shaped the historic mixed-conifer forest and gave it beauty and diversity. The wounds that even a light fire could inflict on mature trees also increased infections and insect attacks which added to the number of openings for young trees and brush.

The lack of undergrowth and the grouping of trees were such striking features of historic forests in the Sierra Nevada that Muir could not ignore them. "The trees of all the species," he said, "stand more or less apart in groves, or in small irregular groups,

enabling one to find a way nearly everywhere, along sunny colonnades and through openings that have a smooth, park-like surface."

In 1916, foresters L. T. Larsen and T. D. Woodbury also noted that these forests were "made up of groups." In addition, they found that the trees in each group were "approximately even-aged" because they were mostly pioneers that filled fresh clearings at about the same time. However, they said that individual trees "of various ages and species" also stood here and there within the forest.

Each tree, shrub, flower, and animal that lived in the historic mixed-conifer forest had its needs, and fire provided for all of them by creating a variety of conditions. It burned hot or cool in various places, returning often or sporadically, and it skipped some places for long periods. Therefore, the forest consisted of a mosaic of patches in different stages of development, and each patch contained a different mixture of trees, shrubs, or other plants. Because fires were so frequent, these were mostly very small patches, usually about two-tenths of an acre. Some patches also covered half an acre or more, and a few covered tens or hundreds of acres.

The species that grew in each patch depended on the availability of seed, which varied from year to year, and their differing abilities to take advantage of the conditions created by the last fire. Ponderosa pine germinates best on bare soil in full sunlight and survives best on light litter. This is just what happened in the historic forest as leaves fell on seedlings while they grew in a fresh clearing. White fir and sugar pine seedlings can also grow on bare soil in clearings, although they do better in light litter. That means that ponderosa pine, white fir, sugar pine, and shrubs, mixed or separately, filled most new openings.

The thick bark of older trees usually protected them as a passing fire cleared the undergrowth, and reduced litter and duff to ash. These were ideal places for white fir seedlings because they grow best where overstory trees shaded bare soil. So, a new generation of seedlings soon replaced the young trees that fire had cleared from the understory. A scattering of single old trees, often the lone survivors of once thriving patches, also stood within the historic forest.

Indian and lightning fires were so frequent in the historic mixed-conifer forest that white fir and incense-cedar seldom had enough time to develop into self-replacing forests. When these trees grew in patches of brush they rarely escaped fire. Shrubs burn easily, but fire also stimulates their growth. So, fire killed the fir and cedar trees, and what few pine trees survived among the shrubs returned within a year. It took many years for fir and cedar, and few pines, to grow above the brush again, and then they often met the same fate.

Clearings also appeared here and there in the historic forest after an extensive surface fire. Some of them formed where young trees burned before they could grow tall enough to escape the flames. Others formed where small patches of overcrowded forest that had been skipped by previous fires burned, or where insects or disease killed a group of trees.

Regardless, these openings developed often enough to produce a continuous supply of young trees. Black oak, the principal hardwood, grew in a few of these openings as well. In addition, this historic forest was rich with meadows, flowery or grassy areas, and patches of shrubs.

The large number of combinations of sun and shade, and bare soil and litter that could exist at a particular time generated an equally large number of different patches in the historic mixed-conifer forest. A single species usually dominated each patch, primarily because the parent trees produced a large crop of seeds when fire or something else prepared a suitable place for them to germinate and grow. Thus, the selective action of frequent surface fires, as well as insects, disease, drought, and other disturbances created a mosaic of amazing diversity.

Modern Mixed-Conifer Forests

Historic forests of the Sierra Nevada have undergone pronounced changes since European explorers first saw them. Many scientists have documented the deterioration of historic forests using old photographs and observations. The results of these studies show that what remains of the magnificent historic forests of the Sierra Nevada is aging and growing unnaturally overcrowded with trees. That means wildfire, insects, and disease will gradually destroy these forests.

For example, in the Redwood Creek watershed of Kings Canyon National Park the area covered by patches of sapling-size trees declined from 17 percent of the historic forest to only 6.2 percent of the modern forest. The area covered by shrub patches dropped from 21 percent of the historic forest to only 10.9 percent of the modern forest. On the other hand, patches of pole-size trees increased from 15.4 percent of the historic forest to 35.2 percent of the modern forest. Mature trees also increased from a range of 17.6 percent of the historic forest to 27 percent of the modern forest.

Today's Sierra Nevada national forests show changes from their historic condition that are even more dramatic than in national parks. Historically, scattered patches of pole size trees covered about 17-29 percent of the mixed-conifer forest. Today, dense stands of pole-size trees dominate 87 percent of the mixed conifer-pine forest and 91 percent of the mixed conifer-fir forest. In addition, white fir, and in some places incense-cedar, are growing out-of-control in the understory of forests in both national parks and national forests.

White fir can germinate in thick litter and grow in the shade of larger trees. Incense-cedar also grows in shade. However, most understory thickets are composed of white fir. On the other hand, pioneer trees such as ponderosa pine, sugar pine, giant sequoia, and black oak require gaps large enough to allow sunlight to reach the forest floor. The soil also must be nearly free of litter for these trees to germinate and survive. Indian and lightning fires created these gaps in the past. Small gaps in the forest stopped opening

when we suppressed lightning fires and removed Indians from their ancestral lands. As a result, pioneer trees are declining, and white fir is becoming the dominant tree species.

Now, because of pressure from urban residents who know little about forests, current plans for national forests, including the Sequoia National Monument, will increase dense multi-layered forests and the invasion of white fir even more. Such dense multi-layered forests covered about 10 percent of the historic Sierra landscape, but current plans will increase them to the unnaturally high and dangerous level of 55-64 percent. Such changes present a serious threat to wildlife and the biological diversity of mixed-conifer forests, as well as a fire hazard that is worse than today.

Goal for Forest Restoration

This desired future condition is an old growth Sierra mixed-conifer forest that averages about 70 trees per acre or less, distributed in small patches. Patches were generally less than 0.2 acres in size in historic mixed-conifer forests, or 5 patches to the acre. Other patches were at least 0.8 acres in size, or 1.25 patches per acre. Simulations show that about 5 percent of the patches in historic mixed-conifer forests were larger than one acre. Even so, an opening of about 1.5 acres, or 2.6 times the average height of surrounding trees, may be optimum for tree growth. However, restoration favors natural conditions, meaning smaller patches, more than optimum tree growth.

It takes trees of all ages and sizes to sustain a healthy forest. Therefore, vegetation should fit within the historic range of variability for this forest. That means 16-24 percent of the Sierra mixed-conifer forest should consist of patches of mature trees or old growth, about half of which should have one or more layers of smaller trees in the understory. This is consistent with other forest types throughout the United States. For example, ponderosa pine forests in the West had about 17-40 percent old growth, although most of it was open and park-like, southern Douglas fir forests in southern Oregon and northern California had about 12-23 percent old growth. However, northern Douglas fir forests had about 42-60 percent old growth because fires burned only about once each 400 years.

Patches of pole size trees in Sierra mixed-conifer forests should cover about 17-29 percent of the forest, and seedling and sapling patches should cover about 20-34 percent of the forest. Patches of shrubs should cover about 17-24 percent of the forest and about 7-9 percent should consist of grasses and forbs. Finally, patches of black oak should cover about 1-2 percent of the forest.

Silvicultural System

Clearcutting is not used for restoring mixed-conifer forests, although it is a cost-effective and scientifically sound way to regenerate commercial forests. Furthermore, individual tree selection harvesting that concentrates on crown thinning or thinning larger trees from

above rather than smaller trees from below, is not appropriate for restoring mixed-conifer forests. Single tree selection creates a multi-storied, uneven-aged forest. The natural structure of a native Sierra Nevada forest is patchy not uneven-aged. So single tree selection cutting would be ecologically inappropriate in a mixed-conifer forest except to thin overcrowded patches.

In single tree selection harvesting, understory or overtopped trees are not thinned and most intermediate trees are not harvested. These intermediate trees add substantially to crown bulk density, which already is high enough in this forest to carry a crown fire. Ladder fuels also are abundant and the post-harvest debris adds to an already high surface fuel load. Opening the overstory by thinning from above further exacerbates understory growth and ladder fuels by providing more sunlight below the canopy and encouraging tree growth. This increases the fire hazard.

In general, we are dealing with overcrowded second growth forests filled with pole size trees, ladder fuels, and heavy debris. There also are scattered multi-layered older forests that no longer exhibit a patchy structure. Changing most forests to an overcrowded multi-aged condition, which is the purpose of thinning from above, will make the fire hazard worse and further reduce the growth of overstory trees. Such a forest structure is not natural and it poses a serious fire hazard, as well as severely reducing the diversity and abundance of wildlife.

Instead, the silvicultural system should concentrate on group selection (harvesting trees in small groups of 0.25 to 0.5 acres, with a few larger groups represented in the mosaic), and thinning from below (thinning understory trees), as appropriate for each site. Group selection mimics torching and thinning from below mimics surface fires. Together they will reproduce the small-scale mosaics and open and park-like conditions that characterized historic mixed-conifer forests.

Standards

Check with a professional forester or a Registered Professional Forester (RPF) before acting on these guidelines.

Surface fuel: Remove surface fuel by piling and burning, lopping, crushing or other methods over the entire area as appropriate to meet a four-foot flame length goal under severe fire weather conditions.

Ladder fuel: Retain conifer regeneration, hardwoods, and shrubs in patches dispersed within the forest as specified under desired future conditions.

Openings: Openings should be created periodically by group selection harvesting according to a sustained yield plan. This will produce revenue from wood products, regenerate desired conifers and hardwoods, reduce the continuity of crown fuels, and create an age class distribution of trees that will sustain the forest indefinitely.

Most openings should be less than 0.5 acres, although a few openings can be larger covering one to tens of acres as occurred in the historic forest. Trees within these openings should be located outside the drip lines of adjacent overstory trees. In addition, regeneration should be thinned to ensure it doesn't touch the crowns of adjacent overstory trees as it matures. Also thin shrubs if they begin overtopping tree seedlings. This occurs in about three years.

The edges of an opening should be feathered (i.e., irregular or jagged) rather than linear. That is, blended into the adjacent forest so that the opening looks like fire or some other natural disturbance created it. These openings should vary in size as well. Similarly, fires rarely destroyed all of the trees in an opening. Some dead trees remained standing after the fire and others lay in heaps on the ground. During fires that created larger openings, wind often drove flames along narrow paths, leaving behind stringers of scorched live trees, as well as scorched trees around the edge of the opening. Occasionally the flames would leap over, or skip around, protected areas and leave groups of trees untouched. As a result, snags, fallen logs and patches of live trees usually remained on the site after the fire passed. These remnants of the former forest provided habitat for wildlife and the foundation for a new forest. Therefore, group selection openings should include some of these features.

Randomly scattered large and small trees also were part of the historic forest and should be maintained or regenerated to create a more natural and dynamic forest structure.

Crown fuel: Canopy cover should be 50-60 percent between regeneration openings with few crowns touching until measurements are available to determine crown bulk density, which should not exceed the critical threshold of 0.0062 lb/ft^3 to prevent crown fire. However, crown bulk density can exceed this threshold within a patch as long as it is isolated from other flammable patches.

Planting and retention: Interplant trees as necessary to maintain the historic species composition of the forest, and release the largest and healthiest black oak from being surrounded and overtopped by conifers. This will improve wildlife habitat and aesthetics without diminishing crown fire resistance.

Snags and logs: The Forest Service and the California State Board of Forestry and Fire Protection have different standards for snags and logs in the general forest. Even so, they are trying to achieve a similar objective by providing adequate wildlife habitat.

In general, retain an average of 2-6 of the largest snags over 16 inches dbh and 20 feet tall per acre, and 5-10 of the largest down logs over 16 inches dbh and 20 feet long per acre, as well as den and nesting trees to enhance wildlife habitat, biodiversity, and aesthetics. Use the upper end of these ranges for area restoration.

Brush fields: Release overtopped seedlings and saplings in brush fields. Create openings in brush fields where there are few seedlings and saplings, and plant young trees in

groups using local seed sources and species in proportions that match what existed in the historic forest.

Species mix: Sugar pine, ponderosa pine, and Jeffrey Pine should occupy a minimum of 50 percent of the canopy. Canopy cover of white fir should be lowest on upper slopes and south-facing slopes. Use prescribed burning to reduce fuels and regenerate fire-dependent plants after mechanical harvesting and thinning.

Marking rules: Restoration requires developing marking and harvesting rules (rules that guide decisions on which individual trees and other plants to remove) tailored to each forest type and local conditions.