Giant Sequoia National Monument

Vegetation Specialist Report

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Vegetation, Including Giant Sequoias

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Desired Conditions

Forested stands in the Mediterranean climate of the Monument are subject to frequent weather cycles. Years of cooler, wetter weather may be followed by years of hotter, drier weather. The desired condition of a forested stand subject to these extremes is diversity in species composition and heterogeneity in structure (size, age class, and spatial distribution) and spatial distribution that are expected to be more resilient to climate changes over time.

Where applicable, the seral stages (stages of succession in the plant community), which indicate the ecological age of ecosystems, are categorized for forested vegetation types using the diameter ranges which define each size class of the California Wildlife Habitat Relationships (CWHR), as displayed in the following table:

Seral Stage	CWHR Size	Size Class	Tree Diameter (at breast height)
Early	1	Seedling	Less than 1 inch
	2	Sapling	1 to 6 inches
Mid	3	Pole	6 to 11 inches

	4	Medium	11 to 24 inches
Late	5	Large	Greater than 24 inches
	6	Large/medium	No diameter(1)

1. Over 60 percent canopy.

The desired condition statements are written as though the desired outcome has already been achieved. They describe what the vegetation types found in the Monument are expected to look like once the desired condition has been reached. They are not meant to describe any particular stand or place on the ground, but rather provide an overview. Vegetation desired conditions are presented for the following vegetation types:

- Giant sequoias
- Mixed conifer
- Blue oak–interior live oak (foothill woodlands)
- Chaparral–live oak (interior and canyon live oaks)
- Montane hardwood–conifer
- Red fir

Giant Sequoias

Giant sequoias thrive in the mixed conifer forest and vary in density and arrangement, along with associated forest species. Being especially long-lived, giant sequoias dominate their surroundings. Smaller and younger giant sequoias are present. Early seral habitat exists and contains plentiful giant sequoia regeneration. The current and desired conditions for giant sequoia groves are shown in the following table.

Current and Desired Species Composition in Giant Sequoia Groves

	Current Condition	Desired Condition
Percent basal area of giant sequoias	25	65
Percent basal area of mixed conifers(1)	75	35
Percent of giant sequoias	4	10
Percent of mixed conifers	95	90

1. This includes white fir, which is currently 35 percent, but 15 percent is desired.

Mixed Conifer Forest

The mixed conifer forest varies by both species composition and structure—as influenced by elevation, site productivity, and related environmental factors, including disturbance—and is in a condition that is resilient to changes in climate and other ecological conditions. The composition is patchy, consisting of a variable mixture of conifer and hardwood trees, as well as a diverse mixture of shrubs, herbaceous vegetation, and grasses. Spatial arrangements vary from pure, or nearly pure, groupings to complex combinations, often within relatively limited areas. Low- to mid-density forests with frequent canopy openings, varying in size, dominate much of the landscape, especially on south-facing slopes, ridge tops, and mid- to upper-slope positions. Higher density forests are often found on portions of north- and east-facing slopes and canyon bottoms.

More frequent canopy openings with early seral structure and composition (10 percent of the vegetation type) exist within the giant sequoia groves. Some mid-seral structure has converted to a later seral stage as tree sizes increase. Approximately 70 percent of the mixed conifer within groves is dominated by trees greater than 24 inches in diameter. Some of the large trees have multi-layered crowns, producing 60 percent or more canopy cover. See the following table for the acres of mixed conifer types within sequoia groves.

Acres of Mixed Conifer Types by Seral Stage Within Groves[(1)]

Seral stage	Early	Mid	Late	Totals
CWHR sizes	1 and 2	3 and 4	5 and 6	
Current acres	220	11,980	10,690	22,890
Current percent of area	1	52	47	100
Desired percent of area	10	20	70	100

1. Based on local knowledge, LANDFIRE simplified models available at www.landfire.gov, USDA Forest Service Vegetation Type Mapping (VTM) available at vtm.berkeley.edu, and Teakettle Experimental Forest presettlement size class distributions (North et al. 2007).

Outside of giant sequoia groves, 10 percent of this vegetation type is early seral structure and composition (see following table). Approximately 50 percent of the mixed conifer is dominated by trees greater than 24 inches in diameter. Some of the large trees have multi-layered crowns, producing 60 percent or more canopy cover.

Acres of Mixed Conifer Types by Seral Stage Outside Groves[(1)]

Seral Stage	Early	Mid	Late	Total
CWHR sizes	1 and 2	3 and 4	5 and 6	
Acres	1,080	87,720	28,940	117,740
Current percent of area	1	74	25	100
Desired percent of area	10	40	50	100

1. Based on local knowledge, LANDFIRE simplified models available at www.landfire.gov, USDA Forest Service Vegetation Type Mapping (VTM) available at vtm.berkeley.edu, and Teakettle Experimental Forest presettlement size class distributions (North et al. 2007).

Blue Oak–Interior Live Oak (Foothill Woodlands)

Blue oak conditions are maintained at their current condition: a fire regime of low intensity fires, with flame lengths less than 3 feet; naturally-occurring vegetation types; and a highly variable and complex landscape pattern. Blue oak dominates, with grass and occasional shrubs as the understory. There are occasional or periodic flushes of regeneration to replace mortality in older trees.

Chaparral–Live Oak (Interior and Canyon Live Oaks)

Interior and canyon live oak vegetation is a mosaic of varying size and age classes. Large expanses of dense or older chaparral are broken up by recent disturbances of 10 acres or more, to help slow the spread of fire and regenerate chaparral species. Fire susceptibility and severity are low, and fire hazards to adjacent human communities and surrounding forest types are reduced.

Montane Hardwood–Conifer

The montane hardwood/mixed conifer forests vary by both species composition and structure--as influenced by elevation, site productivity, and related environmental factors, including disturbance--and are in balance with climate and other ecological conditions. The composition is patchy, with an abundance of large black oaks. More frequent openings with early seral structure and composition (10 percent of the vegetation type) exist within the groves. Most mid-seral structure has converted to a later seral stage as tree sizes increase.

Approximately 70 percent of the montane hardwood-conifers within giant sequoia groves is dominated by trees greater than 24 inches in diameter. Some of the large trees have multi-layered crowns, producing 60 percent or more canopy cover. See the following table for the acres of montane hardwood types within groves.

Acres of Montane Hardwood Types by Seral Stage Within Groves[1]

Seral Stage	Early	Mid	Late	Total
CWHR sizes	1 and 2	3 and 4	5 and 6	
Acres	70	2,340	140	2,550
Current percent of area	3	91	6	100
Desired percent of area	10	20	70	100

1. Based on local knowledge, LANDFIRE simplified models available at www.landfire.gov, USDA Forest Service Vegetation Type Mapping (VTM) available at vtm.berkeley.edu, and Teakettle Experimental Forest presettlement size class distributions (North et al. 2007).

Outside of giant sequoia groves, 20 percent of this vegetation type is early seral structure and composition (see the following table). Over one-half of the mid-seral structure has converted to later seral as tree sizes increase. Approximately 40 percent of the mixed conifer is dominated by trees greater than 24 inches in diameter. Some of the large trees have multi-layered crowns, producing 60 percent or more canopy cover.

Acres of Montane Hardwood Types by Seral Stage Outside Groves[1]

Seral Stage	Early	Mid	Late	Total
CWHR sizes	1 and 2	3 and 4	5 and 6	
Acres	1,620	74,260	4,160	80,030
Current percent of area	2	93	5	100
Desired percent of area	20	40	40	100

1. Based on local knowledge, LANDFIRE simplified models available at www.landfire.gov, USDA Forest Service Vegetation Type Mapping (VTM) available at vtm.berkeley.edu, and Teakettle Experimental Forest presettlement size class distributions (North et al. 2007).

Red Fir

Red fir consists of a mosaic of varying size and age classes, with structural clumping greater than 10 acres, as necessary for species dependent on this vegetation type.

More frequent openings with early seral structure and composition (10 percent of the vegetation type) exist within the giant sequoia groves. Some mid-seral structure has converted to later seral as tree sizes increase. Approximately 70 percent of the red fir within groves is dominated by trees greater than 24 inches in diameter. Some of the large trees have multi-layered crowns, producing 60 percent or more canopy cover. See the following table for acres of red fir types within sequoia groves.

Acres of Red Fir Types by Seral Stage Within Groves(1)

Seral Stage	Early	Mid	Late	Total
CWHR sizes	1 and 2	3 and 4	5 and 6	
Acres	0	610	400	1,010
Current percent of area	0	60	40	100
Desired percent of area	10	20	70	100

1. Based on local knowledge, LANDFIRE simplified models available at www.landfire.gov, USDA Forest Service Vegetation Type Mapping (VTM) available at vtm.berkeley.edu, and Teakettle Experimental Forest presettlement size class distributions (North et al. 2007).

Outside of giant sequoia groves, 10 percent of this vegetation type is early seral structure and composition. Most mid-seral structure has converted to a later seral stage as tree sizes increase. Approximately 70 percent of the mixed conifer outside groves is dominated by trees greater than 24 inches in diameter. Some of the large trees have multi-layered crowns, producing 60 percent or more canopy cover. See the following table for acres of red fir types outside sequoia groves.

Acres of Red Fir Types by Seral Stage Outside Groves(1)

Seral Stage	Early	Mid	Late	Total
CWHR sizes	1 and 2	3 and 4	5 and 6	
Acres	130	30,870	7,980	38,970
Current percent of area	0	79	21	100
Desired percent of area	10	20	70	100

1. Based on local knowledge, LANDFIRE simplified models available at www.landfire.gov, USDA Forest Service Vegetation Type Mapping (VTM) available at vtm.berkeley.edu, and Teakettle Experimental Forest presettlement size class distributions (North et al. 2007).

Affected Environment

This section is presented in two parts. The first part presents an overview of the vegetation in the Monument, and highlights the ecology of giant sequoias. This discussion is included due to the emphasis on the protection and restoration of this species in the presidential proclamations. The second part of this section provides a more detailed look at the current condition of the vegetation types in the Monument, with an emphasis on the characteristics most relevant to promoting heterogeneity and resiliency in the ecosystems in which giant sequoia occur. These characteristics include composition, structure, patterns, and ecological processes.

Disturbance and Patterns of Vegetation

Vegetation or ecosystem disturbances may be triggered by events such as drought, fire, disease, vegetation management, avalanches, or landslides. Disturbance results in changes in vegetation structure and composition, and large areas of high tree mortality often represent the more noticeable changes. Successional or seral stages refer in part to changes in forest soils, structure, and composition over time. Vegetation composition and structure are affected by disturbance regimes.

> With few exceptions, these disturbances have occurred for millennia, and plant species and communities have evolved and adapted to them over time. Disturbance performs important functions within the Sierran ecosystems… An insect outbreak within a stand not only regulates species composition and structure by thinning individuals and creating openings, it creates spatial diversity across the landscape and it can provide opportunities for shrubs, forbs, and other low vegetation to maintain species diversity through time… Because of these types of interactions, disturbances cannot be viewed as necessarily destructive or damaging. They are major processes that develop resources for use by other components of the ecosystem and establish system structure (Potter 1998).

For many vegetation types in the Monument, fire or the exclusion of fire has had a great effect on distribution, species composition, and stand structure. The forest vegetation between 5,000 and 7,000 feet in elevation is dominated by mixed conifer and has a high degree of variability in density, age class, and species mix as a result of the varied interaction of the factors listed above. This variability is also a result of change such as that brought about by wildfire or fire suppression and exclusion.

Trees and forested stands within the Monument exist in varying degrees of health in terms of insect, disease, crowding, climate adaptations, and age. Most insect and disease populations are endemic or within a degree of severity that allows for the host to survive as a species. Conversely, white pine blister rust, an invasive and damaging fungal agent of sugar pine and other white pines, is common within the Monument and results in or contributes to uncontrolled mortality at any age. The combinations of tree age, site utilization, mistletoe, root disease, and bark beetles, in conjunction with changing climactic conditions in the Monument, currently contribute to increased tree competition for limited growing space, soil moisture, and nutrients, stress, and mortality. Crowding or full site occupancy of trees in many forested stands has contributed to tree mortality through more aggressive insect infestations, larger and more severe wildfires, and soil water limitations.

Vegetation Types

The vegetation within the Giant Sequoia National Monument occurs as three groups that reflect similar climate, geology, soils, and vegetation communities. These groups are: oak woodlands/grasslands, shrublands/chaparral, and coniferous forestlands (including giant sequoia). Within these three groups, there are five vegetation types that will be discussed:

- Blue Oak-Interior Live Oak (foothill woodlands)
- Chaparral-Live Oak (interior and canyon live oaks)
- Montane Hardwood-Conifer
- Red Fir
- Mixed Conifer (including giant sequoias)

See the tables that follow for the acres of each vegetation type, both within and outside of giant sequoia groves. The tables also display the amounts of seral stages by vegetation type. Seral stages are discussed following these general descriptions of each vegetation type.

Blue Oak–Interior Live Oak (Foothill Woodlands)

This more open woodland group is scattered along the western foothills of the Sierra Nevada, generally where moderately steep slopes and open flats mix with steep slopes. The Hot Springs Work Center (formerly the Uhl Work Center) is a point of reference within the group. The mean annual precipitation, mostly rain, is about 18 to 30 inches. The mean annual temperature is about 52 to 64 degrees Fahrenheit. The mean elevation for this group is 3,900 feet. Soils are deep and well drained, supporting blue oak and annual grasslands variably mixed with interior live oak trees. All but the larger streams are dry during a normal summer. Steeper inner gorges with shallow, somewhat excessively drained soils contain chaparral and a shrub form of interior live oak.

Changes to the species composition and burning season have occurred due to the introduction of nonnative annual grass species, which occurred in the mid-1800s. The effects of invasive, nonnative species have probably played as great a role in causing change to the composition of the native plant communities as the change to the fire regime. Chaparral and live oak vegetation types currently make up around 55 percent of the type, which may indicate that fire suppression has been the most prevalent force. Portions of this unit are a combination of live oak and blue oak, but are mapped as live oak.

Invasions of exotic annual plants into blue oak woodlands and the loss of perennial grass dominated ecosystems have changed fire behavior. Fuels are more continuous and support a longer fire season because annual grasses cure earlier than perennials. More continuous fuels cause today's fires to be larger and less patchy than historical fires. This means that, in any single fire, the chances of a small tree within the fire perimeter being burned are increased. Also, the lengthening of the fire season toward early season fires may have negative effects on plants because early fires burn when plants have less stored energy for recovery than in late season fires. Increased mortality of small trees, and higher stress levels on re-sprouting trees and shrubs, may prevent stand sustainability and reduce biodiversity in foothill woodlands.

In some portions of the foothill zone, fire exclusion has allowed fuels to accumulate, generally as understory shrubs. Hence, when fire occurs, they tend to be more intense. Blue oaks are generally not adapted to high intensity fires and they do not readily sprout following stand replacing fires. Over time, this results in some foothill woodland vegetation types being replaced with chaparral, or in an increase of more fire tolerant interior live oak relative to blue oak.

Chaparral–Live Oak (Interior and Canyon Live Oaks)

This shrub-dominated group is at low elevations scattered along the western edge of the Monument in drainages and along steep inner gorges. Slopes in these areas are often steep and include the inner gorge slopes of the Middle Fork Tule River, the Kings River, and the Kern River. The mean annual temperature is about 52 to 64 degrees F. The mean elevation for this group is 3,860 feet. The mean annual precipitation, mostly rain, is about 18 to 30 inches. Runoff is rapid to the major rivers and their tributaries. There is a complex of deep and shallower soils. Rock outcrops and openings are common and become dominant in steeper areas. The droughty nature of these soils is reflected in the occurrence of schlerophyllous (hard-leaved) vegetation that dominates this group. Common shrubs include white leaf manzanita, mountain mahogany, and wedgeleaf ceanothus (buck brush). Interior live oak and canyon live oak are prevalent in the mapping area with interior live oak more abundant on south facing, warm slopes and canyon live oak on north facing, moister slopes and at higher elevations.

Montane Hardwood–Conifer

This forest vegetation group is scattered throughout the Monument in eight distinct areas that range in size from 760 to 11,060 acres. The mean elevation of this group is 4,950 feet. Soils in this group are often moderately deep and/or rocky. Rock outcrops and openings occur throughout the area. Mean annual temperature is about 50 to 60 degrees F, and mean annual precipitation, mostly rain, is about 25 to 50 inches. Runoff is rapid to the major rivers and their tributaries. California black oak is the major tree species with ponderosa pine present on deeper soils. Chaparral is prevalent on rocky, shallow soils and on hotter, south facing steep slopes. Landforms have developed through geological mass wasting processes such as rock falls, rockslides, debris flows, and channel erosion. A high amount of natural disturbance and low snowfall help maintain a high proportion of hardwood species (California black oak, canyon live oak, and interior live oak), even in areas where soils develop strong surface horizons. At higher elevations, this group includes more conifer vegetation.

Within a montane hardwood-conifer stand, conifer cover may have been as high as 35 percent, based on data collected in a similar vegetation type in the San Pedro Martir mountains of Mexico that has experienced little to no fire suppression (Stephens, 1999, personal communication). Conifer cover in existing montane hardwood-conifer stands in the Monument tend to be more dense than that, with only 23 percent having densities less than 40 percent.

Ponderosa pine was likely more prevalent in the potential natural vegetation in drainages, toward the tops of slopes above canyons, and in pockets of more stable soils. California black oak is commonly associated with ponderosa pine. Burning by American Indians is considered a primary factor in the maintenance of black oak stands (Anderson, 1993). Without such disturbance, it has been suggested that black oak would eventually be crowded out of most suitable sites and would retreat to scattered remnants in mixed conifer forests (McDonald, 1990).

Historically, variable fire intensities and fire patterns in this type of potential natural vegetation encouraged the development of heterogeneity in stand structure and age across the landscape. Currently, fires are infrequent and are generally of high intensity and stand replacing. Landscape patterns at all scales are generally homogeneous where similar environmental conditions prevail. It is estimated that from five to ten fire cycles have been missed in this type. According to the fire return interval departure data, which characterizes a frequent and spatially variable fire regime, 73 percent of this unit has missed five or more fire events, while only five percent is within historic fire frequencies. Fire exclusion in the montane hardwood and montane hardwood-conifer forests has allowed the chaparral zone to encroach into areas formerly occupied by these zones. Consequently, the presence of chaparral in these forests changes the fire regime to one characterized by high severity fires that favor chaparral. The result is an uphill expansion of the chaparral zone at the expense of these vegetation types. Currently conifers are mapped on approximately 40 percent of the type, chaparral on 15 percent, and live oak on 35 percent.

Red Fir

This vegetation type occurs primarily at higher elevations in the Monument. It has a mean elevation ranging from 7,500 to 8,000 feet. The mean annual temperature is about 35 to 50 degrees F. Cold temperatures limit conifer occurrence and growth. The mean annual precipitation, mostly snow, is about 40 to 60 inches. At the higher elevation range near Jordan Peak, the Needles, Mitchell Peak, and Chimney Rock, red fir forms a plant community with Jeffrey pine. Soils, which are often developed in metamorphic parent materials, are rocky, but deep and well drained. This plant community falls in the upper montane vegetation zone, one of the least altered and most contiguous forested vegetation types. Red fir is found mostly on more productive and cooler locations, whereas Jeffrey pine occurs on shallower soils and warmer aspects. At the lower range of elevation, red fir is commonly associated with lodgepole pine. The red fir-lodgepole pine-meadow plant community occurs within a mean elevation of 7,500 feet between Grant Grove and Marvin Pass to Chimney Rock; between Quaking Aspen and Junction Meadow; and on the west side of the Greenhorn Mountains at Tobias Pass. This community occurs frequently in broad canyon bottoms with variable slope steepness. Meadows are a common inclusion. Jeffrey pine can be found on shallow soils. Aspen can be found in very limited locations and amounts in both the northern and southern portions of the Monument.

Mixed Conifer, including Giant Sequoia

The mixed conifer vegetation type, which includes giant sequoia, is found between 5,000 and 7,000 feet in elevation. The mean annual temperature varies from 40 to 55 degrees F. Soils are generally deep, well-drained, and located on gentle to steep slopes. The mean annual precipitation ranges from 30 to 60 inches. Snow is a critical form of this precipitation allowing higher soil moisture through the spring or into the summer months. Tree communities normally consist of at least three different species with white fir, cedar, pines, and black oak common. These conifer species occur in four major plant community types and reflect the variability in soils, climate, past disturbance, slope, and elevation.. These types are: (1) Mixed Conifer (MC)-giant sequoia, (2) MC-ponderosa pine, (3) MC-white fir-sugar pine-giant sequoia, and (4) upper MC-Jeffrey pine-giant sequoia.

Areas with shallower soils often support more open mixed conifer forests with higher percentages of pines and hardwoods. Where soils are deep, giant sequoia groves may comprise up to 18 percent of the area. In these productive areas, white fir is common and found in the main canopy. This occurs more on the northern end of the Monument, such as in the Converse and Evans Complex groves, where the mean elevation is 6,000 feet. On hotter, drier sites at the lower elevation extreme with a mean of 5,000 feet, ponderosa pine is a more common associate of the mixed conifer group. Giant sequoia can be found in the mixture with ponderosa pine in the Deer Creek Grove and in drier portions of Converse Basin. In the southern portion of the Monument from Dillonwood Grove to Sunday Peak and with a mean elevation of 6,600 feet, the mixed conifer community is composed of white fir, sugar pine, and giant sequoia.

Sugar pine may make up a large portion of the species composition where site conditions are more open due to fire, shallow soils, or southerly aspects. Red fir is also present at the upper range in elevation and in cold air drainages. Giant sequoia inclusions can be found on up to five percent of this group. Mixed conifer with Jeffrey pine and giant sequoia occurs within a similar mean elevation between Slate

Mountain and the Kern River, from Indian Rock to Parker Pass. The other major area is located between Jordan Peak and Moses Mountain, along the North Fork of the Middle Fork of the Tule River. A smaller area is located between Dennison Peak and Sequoia and Kings Canyon National Parks. Where Jeffrey pine occurs, soils are shallow and excessively well drained. This favors drought-tolerant Jeffrey pine rather than a more mesic white fir. Sugar pine occurs at lower elevations wherever open stand conditions prevail. Giant sequoia inclusions are found on less than five percent of this subgroup.

Giant Sequoia Ecology

Location and General Habitat

Giant sequoia trees are seldom found in pure stands. They are more often found mixed with sugar pine, ponderosa pine, white fir, incense cedar, and black oak, forming groves at elevations between 5,000 and 7,000 feet in the central and southern Sierra Nevada (Rundel 1971). Annual precipitation in groves varies from about 35 to 55 inches, but varies greatly. Usually, less than about an inch falls between June 1 and September 30, and most of the precipitation is snow between October and April. Snow depths of over six feet are common in midwinter (Rundel 1969). Large giant sequoia trees are found on sites ranging from wet to dry, but are commonly found on moist sites with more gentle slopes and rich soil. Mesic sites that are not too wet for root survival are best for maintaining and growing giant sequoia. In some groves the shape of the topography, along with deep, more fertile soils, indicates there is more water available than expected from precipitation. One study has suggested that more available soil moisture within a grove is associated with subterranean flow from higher elevations (Rundel 1972).

Environmental Threats to Giant Sequoia

The greatest current threat to most sequoia ecosystems is the heavy buildup of surface and ladder fuels which could do serious damage to existing larger trees and the soil resources that support the giant sequoia. Associated with this is the abundant ingrowth of white fir and incense cedar. These species are more tolerant of shade. They reduce the growth of other tree species by using soil moisture and casting shade. They also serve as ladder fuels which could damage or kill the species of greatest concern, due to the additional threat of white pine blister rust.

Many forest trees have insects, diseases, and other factors that shorten their lifespan. The giant sequoia is very resilient to these kinds of environmental threats. Threats to giant sequoia health include altered fire regimes, emergent disease complexes, invasive species, air pollution, and a changing climate (York et al. 2012).

Although cutting large giant sequoia is no longer a threat on National Forest System lands, humans can affect giant sequoia in many ways. Walking or driving over tree roots can affect soils and the roots of sequoia trees (Demetry and Manley 2001). Sequoia roots can reach out over a hundred feet from the base of the tree (Harvey et al. 1980). Roads and buildings can also damage root systems. Road construction can change how much or at what time water enters or leaves the soils where sequoia trees grow (Vale 1975).

Clearing land, burning, or even growing too many trees within a grove may also influence water availability to giant sequoia (Meyer and Safford 2011) and other tree species in mixed conifer forests

(Zald et al. 2008). These changes in water availability and inter-tree competition may reduce the vigor of trees (as indicated by radial growth), even in very large giant sequoias (York et al. 2010). In the absence of prescribed fire and other treatments designed to reduce surface and ladder fuels, giant sequoia groves may be at risk of elevated crown fire potential (Kilgore and Sando 1975). Hence, as these fuels increase beyond threshold values, the risk they pose to larger trees is increased (Stephens et al. 2002). For a full discussion of the susceptibility of vegetation to wildfire, see the Fire and Fuels section next in this chapter. While root rot does not normally kill most sequoias, it weakens the root system and may cause uprooting even in large trees (Piirto et al. 1984). A weakened root system will reduce the ability of a giant sequoia to extract water and nutrients from the soil. However, the effects of root dieseases and insect species on giant sequoia remains poorly understood (Piirto 1992).

Existing Conditions

The following summarizes the status of key ecological conditions, both within the giant sequoia groves and in the surrounding mixed conifer forest. The purpose of this section is to quantify the existing baseline conditions. The Clinton proclamation noted the lack of regeneration of giant sequoia and the risk of the groves to catastrophic fire. It also noted the changes in the forest from past harvesting and the exclusion of fire. Special attention is given in this section to important characteristics of structure, species composition, age class distribution, and fuel loading for the giant sequoia ecosystem. The foundation for these ecological conditions is the report "An Ecological Foundation for Management of National Forest Giant Sequoia Ecosystems" (Piirto & Rogers, 1999). This report describes specific structural and process indicators in the mixed conifer-giant sequoia forest ecosystems in the Giant Sequoia National Monument.

In the Monument, approximately 70 percent of the grove acreage has been continuously protected from both fire and logging. The disruption of the natural fire regime, along with the elimination of any other large-scale disturbances, has led to a cessation of giant sequoia reproduction on this 70 percent of the grove acreage (Stephenson, 1996). The dramatic changes in certain climatic growing conditions for giant sequoia during the last 130 years or so has not been "mirrored" by continual pulses of natural regeneration. Since reproduction is the primary process through which species adapt to changing environmental conditions, it appears that much of the grove acreage has missed "opportunities" to establish new reproduction and allow genetic adaptation to occur.

Twenty-five percent of the grove acreage has been logged but has had little or no prescribed fire. Of this 25 percent, the vast majority was logged near the turn of the 20th century and was concentrated in several groves (Converse Basin, Grant, Indian Basin, and Big Stump) in the northern end of the monument. These harvested groves have revegetated with conifers, and 2nd growth giant sequoias are a significant component of the stand composition. Since the logging however, other opportunities (via disturbance) have been foregone for new generations of giant sequoia to become established.

There is considerable information available about the range of existing conditions in the Monument, particularly those problem areas emphasized in the Presidential proclamation (a lack of giant sequoia reproduction and a risk of catastrophic fire). These include (but are not limited to): stand-level and detailed inventories of the ecological conditions of giant sequoia groves and other vegetation types;

reforestation; stream and riparian conditions; fuel inventories and recent fire history; maps using geographic information systems (GIS) that display vegetation types, land use, ownership, aquatic and wildlife habitat, managed stands and plantations. This robust set of data provides a high degree of certainty regarding the existing conditions in the Monument.

Heterogeneity and Resiliency

Forest ecosystems that are resilient to disturbances, such as insect attacks, extended droughts, diseases, and wildfire, tend to exhibit high structural heterogeneity (North et al. 2009). This ability to withstand and respond to these events is considered the resiliency of the vegetation. This section discusses the key characteristics of vegetation age (seral stages), species composition, and forest structure as a reflection of overall heterogeneity and the resiliency of vegetation.

Seral Stages

Each vegetation type has varying amounts of seral stages. Seral stages represent age groups of the vegetation within the vegetation type. Healthy and resilient vegetation types have a diversity of seral stages. Early seral stages are important in order to provide recruitment for mid and late seral stage vegetation and associated wildlife habitat. These seral stage amounts vary across the Monument landscape and are affected by the sizes and degrees of disturbance by events such as fire or tree cutting. These seral stages are identified and described using the diameter ranges which define each size class of the California Wildlife Habitat Relationships (CWHR) as follows:

Classifications of Seral Stages

Size Class	Diameter	Seral Stage
1: Seedling	Less than 1 inch	Early
2: Sapling	1 to 6 inches	Early
3: Pole	6 to 11 inches	Mid
4: Small	11 to 24 inches	Mid
5: Medium/large	Greater than 24 inches	Late
6: Multi-layered	Size Class 5 trees over a distinct layer of Size Class 4 or 3 trees, with over 60 percent canopy closure	Late

The following tables display major vegetation types by seral stage. The Monument encompasses approximately 328,300 acres of national forest lands. There are approximately 243,100 acres of major vegetation types within the Monument that lie outside the grove boundaries.

Acres of Major Vegetation Types Outside Groves

Vegetation Type	Acres			
	Early Seral	Mid Seral	Late Seral	Total
Blue oak	15	4,569	87	4,671
Chaparral	687	1,020	0	1,707
Mixed conifer	1,079	87,719	28,938	117,735
Montane hardwood	1,616	74,256	4,161	80,032
Red fir	130	30,865	7,975	38,969

Total	3,527	198,428	41,160	243,116

Sequoia groves encompass 27,830 acres in national forest ownership. The groves are heavily dominated by the mixed conifer vegetation type. There are approximately 26,600 acres of major vegetation types in these groves.

Acres of Major Vegetation Types within Groves

Vegetation Type	Acres			
	Early Seral	Mid Seral	Late Seral	Total
Blue Oak	0	0	0	0
Chaparral	50	N/A	0	50
Mixed conifer	221	11,982	10,685	22,887
Montane hardwood	66	2,340	144	2,550
Red fir	0	611	402	1,013
Total	337	15,042	11,231	26,609

Plantations (early seral stages)

During the last 25-30 years, 4 percent (approximately 1,000 acres) of the grove acreage in the Monument has had sufficient disturbance (through logging and subsequent burning for fuel reduction and site preparation) to initiate regeneration of young giant sequoia and associated mixed conifer species and other vegetation. After harvest occurred in these areas, they were re-planted primarily with ponderosa and Jeffrey pine. Lesser amounts of other species were planted, including white fir, rust-resistant and non-rust-resistant sugar pine, incense cedar, red fir, and giant sequoias. Naturally occurring young mixed conifers, as well as oaks, also became re-established to complement the planted trees. Survival and growth of young trees is excellent in almost all areas, and giant sequoia seedlings have become established in close proximity to overstory “monarch” giant sequoias. There is a need to move these existing openings towards desired conditions, particularly in heterogeneity in species composition and diversity of age and size classes. These areas represent early to mid seral stage vegetation, as the average tree diameters are between 6 and 12 inches. When comparing the species mix of the planted trees with the reference conditions likely to have existed prior to 1875, the planted mix is different in that ponderosa and Jeffrey pines were not the overwhelmingly dominant species 100 years ago. In addition, white fir and other shade-tolerant species were less dominant than in the stands that existed just prior to harvest.

Regeneration in Undisturbed Groves

The following graph displays the amount of giant sequoia regeneration in a sampled subset of groves that have not been disturbed by fire or harvesting. The results clearly indicate that giant sequoia trees are almost non-existent in the smaller diameter classes within the groves that have been inventoried. This is not to say that young giant sequoias do not exist, but that their levels are very low. If and when these groves are exposed to wildfire or prescribed fire under existing high fuel loading, many of these young giant sequoias are very likely going to be lost. Given this expected level of mortality from various agents (drought, insects, tree competition, fire), there are not enough young trees to provide recruitment of future monarch trees. Only Deer Creek grove has any significant small trees (approximately 60 trees less than 10 inches in diameter per acre). These results give a grove-wide perspective on the status of younger sequoias. When specific projects are considered for each grove, more intensive information will be needed to validate the site-specific conditions of the groves.

Historic Harvesting in Giant Sequoia Groves

Approximately 20 percent of the grove acreage was logged near the turn of the 20th century and was concentrated in several groves (Converse, Grant, Indian Basin, and Big Stump) in the northern portion of the Monument. These harvested groves have fully and naturally revegetated with conifers, and second-growth giant sequoias are a significant component of the stand composition. The mixed conifer-giant sequoia stands in these historically logged areas are now dominated by mid-seral stage vegetation. Since the logging, however, no other disturbances have occurred to promote the establishment of additional new generations of giant sequoia.

Stand Structure in Sequoia Groves

Giant sequoia groves are a subcomponent of the mixed conifer vegetation type. They occupy a wide variety of site conditions, but often encompass the more productive, moist sites that grow not only the largest giant sequoias, but the largest pines and firs in the mixed conifer group. In most size classes, the average species size distribution follows the common inverse relationship of size and number of trees where the larger the tree, the fewer the number.

Of the groves/grove complexes in the Monument, only 13 have had significant disturbances in the last 120 years that have led to the establishment of substantial new conifer vegetation (early seral stages).

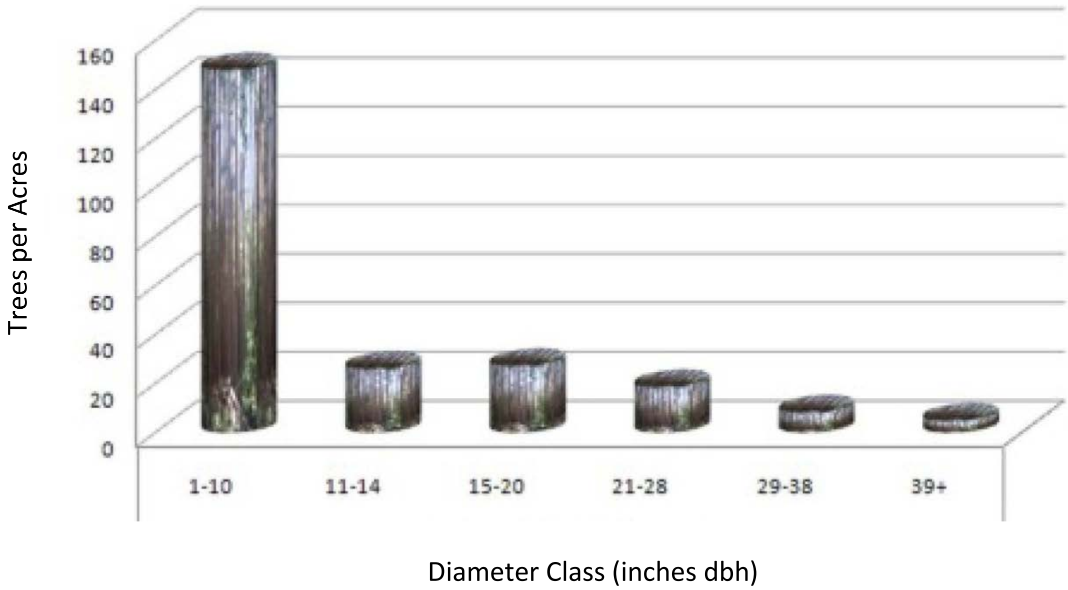
The structure of the regeneration that has become established in the last 120 years is very different from regeneration established prior to that time. The primary disturbance agent in the 1000-year period up until 1875 was a regime of low to moderate intensity, high frequency fires. This fire regime typically created a mosaic of vegetation and gaps, with the gaps typically less than 0.5 acre in size. Larger gaps were more infrequent, although intense wildfires were observed that were possibly several hundred acres in size. The variability in gap size provided a range of growing conditions, which led to a variety of species, from shade-intolerant (pines, giant sequoia, black oak) to shade-tolerant (incense cedar, white fir). The shift in the primary disturbance regime to extensive logging has led to a shift in the structural characteristics of openings. For instance, the Converse Basin Grove was almost completely cutover, and the regrowth is a mostly continuous 120-year old 4,000- acre stand, with little variability. This is an extreme case, however other groves such as the national forest portions of Big Stump, Indian Basin, and Cherry Gap all exhibit similar gap size characteristics that are outside the range of natural variability as described by Piirto and Rogers (1999).

This same situation is displayed in the openings created by logging in the 1980s within and immediately adjacent to some giant sequoia groves on the Sequoia National Forest (now within the Giant Sequoia National Monument). The approximately 1,000 acres of openings average 10 to 15 acres in size, which is often outside the estimated natural range of variability for giant sequoia groves (Bonnickson and Stone 1981, Demetry 1995, Piirto and Rogers 1999) and Sierra Nevada mixed conifer forests (North et al. 2004, Knapp et al. 2012). Many of these canopy openings were re-planted predominantly to pines and lesser amounts of other species such as white fir, sugar pine, and giant sequoia. Although shade-tolerant tree species are becoming more common in giant sequoia groves due to the absence of fire, mechanically-created canopy openings may still retain substantial densities of both planted and naturally regenerated giant sequoia and other shade-intolerant trees (York et al. 2010, Meyer and Safford 2011b).

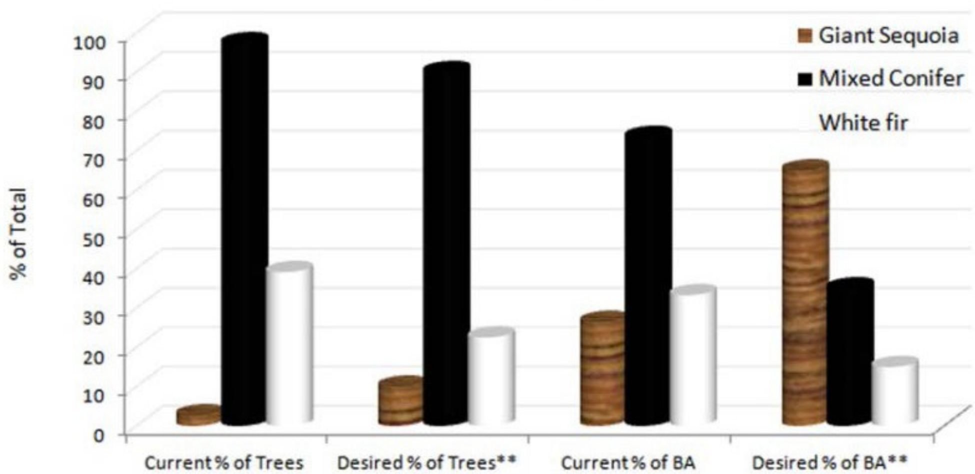
Across all groves, in most tree size classes, the average species size distribution follows the common inverse relationship of size and number of trees, where the larger the tree, the fewer the number, especially in groves where fire has been excluded (York et al. 2012). Trees in the large to intermediate size classes are underrepresented, especially in the 20- to 28-inch size class, as shown in the following table and figure. All of the following figures were based on the 1999 inventory of half the groves in the Monument and the 2009 inventory of the remaining half. This apparent deficiency is due to the lack of disturbance in many of the groves and the lack of recruitment of pines and giant sequoia. The following tables display the very high amounts of shade-tolerant seedling and saplings (almost exclusively white fir and incense cedar) and the sudden “drop-off” in intermediate-sized trees and the existing and desired amounts of mixed conifer species.

The lack of recent disturbances, such as fire and harvesting over the last decade or more which create canopy gaps and expose mineral soils, has resulted in many groves lacking significant natural sequoia regeneration less than thirty years old (e.g., Stephenson 1994, Meyer and Safford 2011b, York et al. 2012). The lack of more favorable summer rains or soil moisture during the summer and fall has likely been an additional factor in poor survival and growth of new seedlings (e.g., Stephens et al. 1999, York et al. 2010). Sequoia seedlings planted during this time have survived and established well in the limited openings available for regeneration projects.

Number of Trees per Acre by Diameter Class



Comparison of Existing and Desired Percentages of Giant Sequoia, White Fir, and Other Mixed Conifer Species



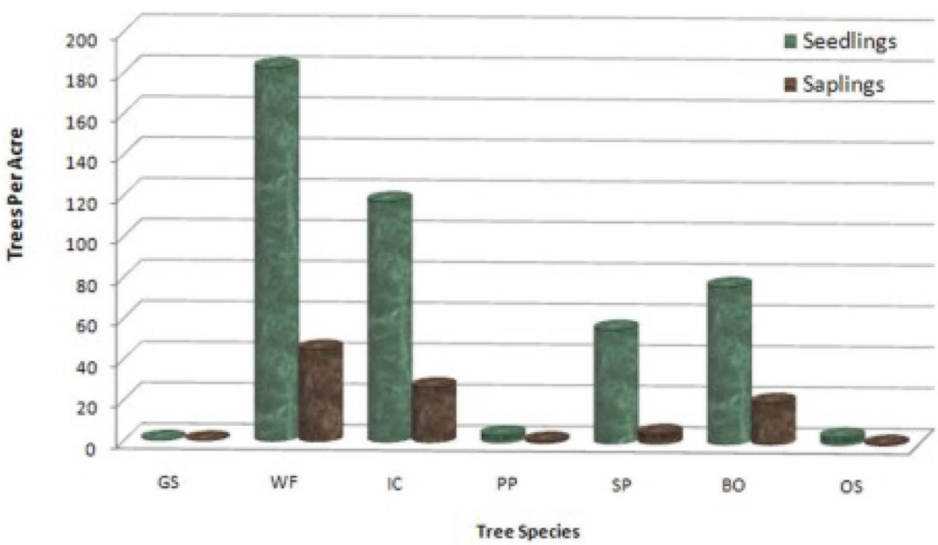
White fir and incense cedar are well-adapted to low understory light conditions with relatively moist soils and are often highly abundant in closed-canopied coniferous stands (Gray et al. 2005, Zald et al. 2008). These two species, which were not as common when the groves burned more frequently, make up about 75 percent of the seedling-sized trees in groves, with black oak and sugar pine being the next most abundant (see Appendix I of this FEIS). Giant sequoia seedlings and saplings may be abundant in occasional openings, but are relatively rare under mature canopies (Demetry and Duriscoe 1996, Meyer and Safford 2011b). Giant sequoia regeneration often depends upon adequately disturbed soils, sufficient soil moisture, and canopy openings for sufficient growth and survival (Harvey et al. 1980).

Tree mortality in groves follows a pattern common in most forests, where most dead trees are smaller and suppressed, but with a greater than expected relative mortality of large-diamer trees (Smith et al. 2005).

Similarly, fewer of the dead, fallen trees are over 24 inches in diameter (see Appendix I of this FEIS). The high mortality of larger white fir, sugar pine, incense cedar, and black oak in some groves is most likely due to overcrowding, drought, and insects. Higher mortality such as this can be expected in many groves given the current drought; future predictions that we may see warmer and drier growing conditions; increasingly higher densities of trees; and older ages of pines, oaks, cedars, and firs.

With a lack of adequately disturbed soils and canopies, giant sequoia only averages about 1 seedling per acre. In 2009, the average number of mixed conifer tree seedlings, including black oak, was 444 trees per acre across 26 groves. A more desirable species mixture would contain 44 giant sequoia seedlings per acre or 10 percent of the total. The following figure displays the amount of early seral stage (seedlings and saplings) mixed conifer species.

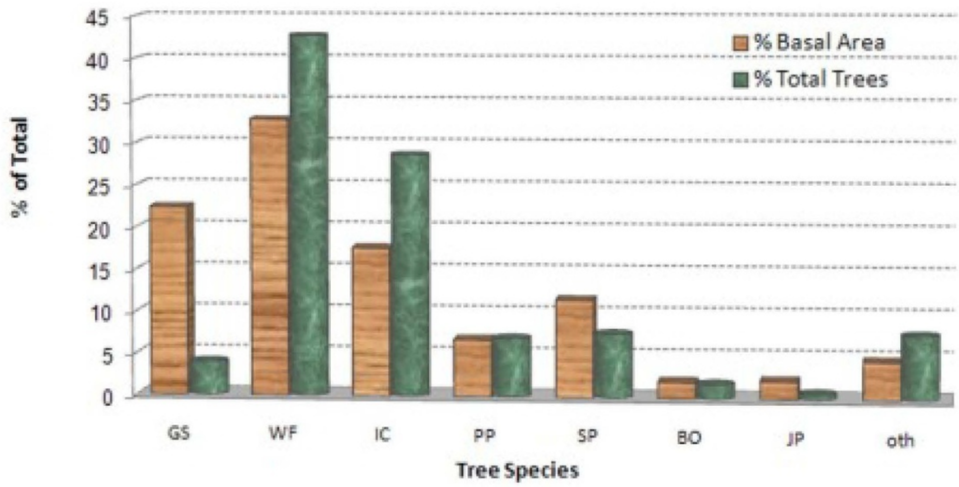
Seedlings and Saplings by Species in Groves



GS=giant sequoia, WF=white fire, IC=incense cedar, PP=ponderosa pine, SP=sugar pine, BO=black oak, OS=other species.

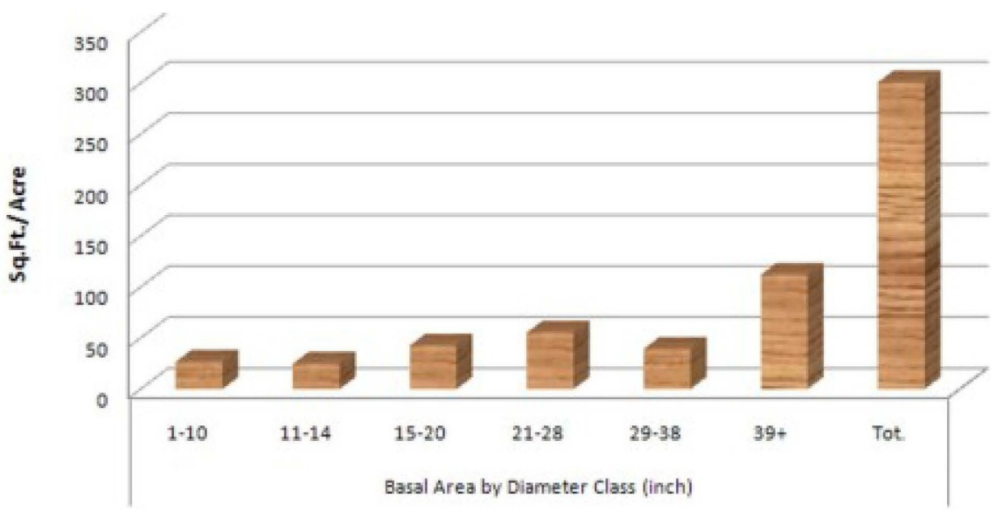
The following figures show additional data for tree species composition and tree density for the giant sequoia groves in the Monument.

Percent of Basal Area and Trees/Acre by Conifer Species in Groves



GS=giant sequoia, WF=white fire, IC=incense cedar, PP=ponderosa pine, SP=sugar pine, BO=black oak, JP=Jeffrey pine, Oth=other species.

Basal Area by Diameter Class in Groves



Gaps

The findings of York et al. (2003, 2004, 2010) are consistent with well-established research on gap size in forest ecosystems across the nation. Small gaps may not provide enough light for shade intolerant species. They found that giant sequoia seedlings compared to other tree seedlings responded best to increases in light. For small gap or group sizes less than 2 acres, the study demonstrated that ample light was lacking in southern portions of the opening for trees that need more light for growth, mainly sequoia and pines. York et al. (2004) found that seedling growth was greatly increased in canopy openings that exceeded between 0.7 and 1.5 acres in size, especially where the opening diameter was 2.6 times the height of the edge trees. The increases in growth rates due to increases in opening sizes were not linear. York at al. (2009) found that growth rates of young giant sequoia seedlings and sugar pine increased rapidly when openings were increased from 0.1 acres to 0.5 acres. The rate of increase was less in openings from 0.5 to 1 acre in size. However, seedlings of both tree species had similar growth rates in the center of gaps that varied between 0.2 and two acres in size. In addition, in an experimental canopy gap study in Redwood Mountain Grove, York et al. (2010) demonstrated that planted giant sequoia seedling growth rates more than doubled as gap size increased from 0.1 acre to 0.6 acre, even though seedling mortality rates did not vary with gap size. These combined experimental studies demonstrate that even relatively small canopy gaps (i.e., 0.4 to 0.7 acre) can significantly increase the growth rates of giant sequoia seedlings and other tree species, such as sugar pine (e.g., York et al. 2004).

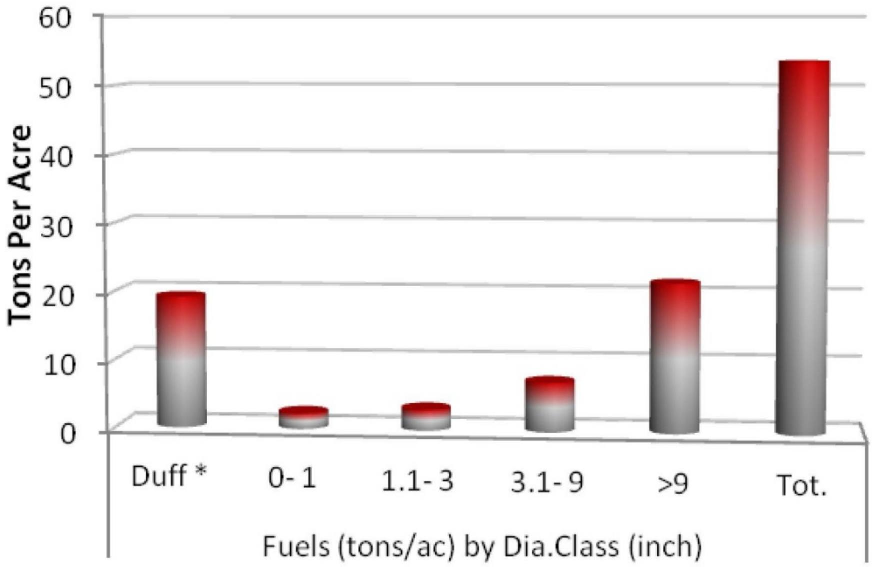
Due to the uncertainty of sugar pine regeneration, due to the effects of white pine blister rust, more attention needs to be placed on the artificial regeneration of more rust-resistant sugar pine to help assure its important role in mixed conifer ecosystems, including giant sequoia groves.

In the Monument, it is anticipated that up to 10 percent of tree planting mixes will include sugar pine, a major species in mixed conifer communities, including giant sequoia groves, that is threatened by the blister rust disease. In order to better manage this species, it will be important to assure ample sunlight in gaps where sugar pine is desired. This will help assure favorable growth and improve resistance to drought, bark beetles, and other factors in addition to the threat that blister rust poses in managing this species. Larger openings in the upper canopy will provide conditions that sequoia and pines need to keep up with or outgrow shrubs, white fir, and incense cedar.

Fuel Loadings

The greatest current risk to most groves is the heavy buildup of surface and ladder fuels which could do serious damage to existing larger trees. Associated with this is the abundant ingrowth of white fir and incense cedar. These more shade tolerant species serve as ladder fuels which could damage or kill the crowns of the largest trees. Tree mortality follows a pattern common in most forests where most dead trees are smaller and suppressed. In 1999 there was an average of 21 standing dead trees per acre over 16 groves. Only 10 percent of these were dominant or larger trees. Similarly, less than 30 percent of the dead, fallen trees were over 24 inches in diameter. The high mortality (42 standing snags per acre) of larger white fir, sugar pine, incense cedar, and black oak in the Mountain Home Grove was most likely due to overcrowding, drought, and insects. Higher mortality such as this can be expected in many groves given the current drought; future projections of warmer climate conditions; increasingly higher densities of trees; and older ages of pines, oaks, cedars, and firs. Higher tree mortality in groves such as Alder Creek (56 snags per acre) and Mountain Home will likely contribute to a higher fuels loading. Alder Creek and Mountain Home groves in 1999 already had total fuel loads of 92 and 75 tons per acre, respectively. Many groves now have an excessive buildup of surface and ladder fuels and a lack of canopy openings needed for abundant regeneration. The average surface fuels, shown in the following figure, and the density of white fir (shown in a later figure), are currently about twice the amount desired for managing fuels and tree species composition in a sequoia grove.

Current Surface Fuel (Averages from 16 groves from 1999)



* 9.4 tons/acre per inch of duff depth = tons per acre of duff

Early seral stages, where surface fuels are reduced and direct light is increased, are generally required to promote and retain regeneration of desirable species like sequoia, ponderosa pine, Jeffrey pine, and possibly sugar pine (York et al. 2004, Zald et al. 2008). Many sequoia groves that experienced decades of fire exclusion have a buildup of surface and ladder fuels (Kilgore and Sando 1975) and a lack of canopy openings that greatly reduce the densities of sequoia regeneration (Harvey et al. 1980).

White fir and incense cedar do not require the early seral stages of seed dispersal, germination, and growth. They can regenerate under many diverse conditions of light, forest floor cover, and soil moisture found in groves. Smaller white fir and incense cedar trees up to 6 inches or more in diameter are easily killed in light to moderate intensity burns. Tree mortality resulting from the effects of fire depends on many factors such as bark thickness (insulation), tree diameter, crown damage, intensity of heat at the base of the stem, duration of the heating event, surface and ground fuel consumption, and weather (Ryan and Reinhardt 1988, Ryan and Amman 1996, Stephens and Finney 2002). Larger diameter trees are generally more resistant to fire injury due to an increase in crown base height and bark thickness (Ryan et al. 1988). Consequently, tree diameter is often a significant factor influencing the probability of mortality in a variety of Sierra Nevada tree species, including giant sequoia, sugar pine, and ponderosa pine (Stephens and Finney 2002). In addition, crown injury is a consistently significan factor predicting post-fire mortality of tree species in conifers throughout the Sierra Nevada (Schwilk et al. 2006, Hood et al. 2010).

Prescribed fires of low to moderate intensity often kill small trees that serve as ladder fuels either by stem or foliar damage. Trees of many sizes may have foliage close to the ground that could be ignited. Stephens and Finney (2002) observed that tree diameter was a significant parameter in all mortality models developed except for giant sequoia and sugar pine. The insignificant diameter factor in the giant sequoia model was presumed to be a result of giant sequoia's ability to resist high amounts of crown damage. Where crown damage was not a major factor, trees 10 inches and larger had a high probability of surviving prescribed fires.

The presence of a wide range of sizes and ages of incense cedar and white fir thus indicate that these shade tolerant species are a part of the natural giant sequoia ecosystems under a sporadic fire regime. Historically, the mean fire return intervals in giant sequoia ecosystems typically ranged between 10 and 20 years (Swetnam et al. 2009, Van de Water and Safford 2011), depending on the topography and scale of analysis. Past human interventions preceding the more recent fire suppression likely resulted in unnaturally frequent burning cycles. Based on this, the recommended management entries for returning low to moderate intensity fire to national forest giant sequoia groves, should be in the range of 5 to 20 years (Piirto and Rogers 2002). Although fire may have occurred in most groves on a similarly frequent basis, it is likely that only portions of a grove burned. Nearly all groves in the Monument have missed several maximum fire return intervals, resulting in negative effects to sequoia ecosystems (e.g., increased insect and disease risk, reduced sequoia regeneration) and increased risk of large high-severity wildfires (York et al. 2012).

Giant Sequoia Regeneration

Many groves currently have scattered trees or groups of small sequoia trees 30 to 100 years old in small openings or other disturbed areas. The lack of recent disturbances, such as fire and vegetation management over the last decade or more which create canopy gaps and expose mineral soils, has resulted in many groves lacking significant natural sequoia regeneration less than thirty years old (e.g., Stephenson 1994, Meyer and Safford 2011b, York et al. 2012). The lack of more favorable summer rains or soil moisture during the summer and fall has likely been an additional factor in poor survival and growth of new seedlings (e.g., Stephens et al. 1999, York et al. 2010). Sequoia seedlings planted during this time have survived and established well in the limited openings available for regeneration projects.

White fir and incense cedar are well-adapted to low understory light conditions with relatively moist soils, and are often highly abundant in closed-canopied coniferous stands (Gray et al. 2005, Zald et al. 2008). These two species, which were not as common when the groves burned more frequently, make up about 75 percent of the seedling-sized trees in groves, with black oak and sugar pine being the next most abundant (see Appendix I of this FEIS).

Giant sequoia seedlings and saplings may be abundant in occasional openings, but are rare under mature canopies. Giant sequoia does not normally regenerate naturally without adequately disturbed soils and openings in canopies. Sugar pine regeneration often requires a combination of adequate soil moisture and litter cover, but seedlings can be found under variable canopy cover conditions (Gray et al. 2005). Sugar pine, ponderosa pine, and Jeffrey pine seedlings can benefit from prescribed fire and mechanical treatments that increase understory light and available soil moisture (York et al. 2004, Moghaddas et al. 2008, Zald et al. 2008).

Early seral stages, where surface fuels are reduced and direct light is increased, are generally required to promote and retain regeneration of desirable species like sequoia, ponderosa pine, Jeffrey pine, and possibly sugar pine (York et al. 2004, Zald et al. 2008). Many sequoia groves that experienced decades of fire exclusion have a buildup of surface and ladder fuels (Kilgore and Sando 1975) and a lack of canopy openings that greatly reduce the densities of sequoia regeneration (Harvey et al. 1980).

Some research has suggested that most groves today lack sufficient young giant sequoias to maintain the present density of mature trees in the future, especially in the absence of recent fire (Stephenson 1994, 1996). However, the few groves that have experienced repeated recent prescribed burning have substantially greater densities of sequoia regeneration than nearby unburned groves (York et al. 2012). Rundel (1971) speculated that giant sequoia regeneration has been declining over a period of 100 to 500 years or more. Given the longevity of the species, the tendency to grow best following canopy-removing disturbances, and the frequency of droughts, it is not likely that sequoia regeneration would follow a smooth pattern of successful seedling establishment. It is likely that sequoia regenerates only during years when the site conditions and soil moisture are optimal (e.g., York et al. 2010). Schubert (1962) recognized that to support the establishment of a young sequoia, moisture and adequate light were critical throughout the growing season.

Although young sequoias must grow large enough to survive the effects of repeated fires, sequoia regeneration may benefit from repeated prescribed burning. In Sequoia and Kings Canyon National Parks, giant sequoia regeneration increased following single-entry prescribed burns, and increased again following second-entry burns (York et al. 2011). In a related study, giant sequoia regeneration was detected following second-entry burns, but not first-entry burns (Webster and Halpern 2010). These results emphasize that repeated prescribed burning in sequoia groves can have beneficial effects on giant sequoia regeneration. Patches of giant sequoia regeneration in clusters of a few trees or small even-aged patches frequently occur in canopy gaps of up to an acre (Demetry and Duriscoe 1996, Stephenson 1996). Even-aged cohorts greater than approximately an acre are relatively uncommon, but may be found as a result of past stand-replacing wildfire or mechanical harvest (Bonnickson and Stone 1982, Stephenson 1996).

Another major concern in most sequoia ecosystems is the heavy buildup of surface and ladder fuels which could do serious damage to existing larger trees and the soil resources that support the giant sequoia in the event of a wildfire. Associated with this is the abundant in-growth of white fir and incense cedar (Bonnickson and Stone 1982). These species are more tolerant of shade (Schubert 1965, Laake 1990). They reduce the growth of other tree species by competing for light and soil moisture. They also serve as ladder fuels which could damage or kill the crowns of the largest trees (Stephens et al. 2009). Sugar pine may be the species of greatest concern, due to the additional threat of white pine blister rust (Schwandt et al. 2010).

Regeneration of giant sequoia requires adequate soil moisture to allow young seedling roots to grow and reach soil depths that will maintain the seedling during the long, warm summer and fall (Harvey et al. 1980, Harvey and Shellhammer 1991). After seedling roots are established young sequoias will grow rapidly depending on the amount of soil moisture and light reaching its foliage.

Giant sequoia has been considered shade intolerant throughout the various stages of its life (Harvey et al. 1980). Young giant sequoia seedlings, however, can tolerate low light conditions and may even require shade to reduce excessive avaporative water loss until more extensive root systems are established (Stark 1968, York et al. 2010). Survival of sequoia seedlings in the first year appears to be very sensitive to the amount of direct sunlight reaching the seedling. This may also be related to the timing of growth of roots and amount of duration of heat during the growing season. While it is clear that established giant sequoia grows best in direct sunlight, first year seedlings may not (Harvey et al. 1980). Field observations indicate that exposure to sunlight in extremely hot weather where the canopy opening is greater than 70 percent may reduce the growth and survival of first year sequoia seedlings. After the initial establishment, sequoia trees grow better in full sunlight. Under continued shade, they will grow slowly and can remain alive as a small tree (5 to 15 feet tall) for 30 to 100 years or more. As with many trees that show an intermediate tolerance to shade in the juvenile stages, giant sequoia will die after several years under a very dense canopy (Hanna pers. comm.). It will still require field testing to determine why survival of sequoia seedlings in the shade in the first year may be much better than survival in full sunlight. This may become more important to study if we continue to experience warmer, longer, and drier summers.

Picture 1 A 40-year-old giant sequoia 7 feet tall and 2 inches in diameter at the base suppressed and killed by overcrowding and 100 percent canopy cover in Alder Grove.

White fir and incense cedar regeneration is highly adapted to shade-tolerant conditions, but can also grow successfully in open canopy conditions typical of high intensity burned or harvested areas (Zald et al. 2008, Meyer and Safford 2011b). In these conditions, there can be sufficient sunlight and available moisture for seed dispersal, germination, and growth. White fir and incense cedar can regenerate under many diverse conditions of light, forest floor cover, and soil moisture found in groves (Meyer and

Safford 2011b). The ability of these species to regenerate and persist under a wide variety of conditions is reflected in the high amounts in the giant sequoia groves and in the mixed conifer vegetation type. The presence of a wide range of sizes and ages of cedar and fir thus indicate that these shade tolerant species are a part of the natural giant sequoia ecosystems under a sporadic fire regime. Fire return intervals in giant sequoia ecosystems frequently ranged between four and 16 years and typically burned as low- to moderate-intensity surface fires (Stephenson 1996). Smaller patches (frequently less than one acre) of high-intensity fire were also characteristic of fire regimes within giant sequoia groves (Stephenson 1996). Based on this, using mechanical or fire treatments for returning low- to moderate-intensity fire to national forest giant sequoia groves, could promote understory treatments with occasional canopy gaps to attain restoration objectives, such as the promotion of sequoia regeneration (Piirto and Rogers 2002). However, in the long term, timing of treatments will need to account for changes in climate and shifting reference conditions (Stephens et al. 2010).

Although fire may have occurred in most groves on a similarly frequent basis, it is likely that only portions of a grove burned. Sequoia ecosystems are highly variable in moisture and topography and have adapted to fire return intervals that are irregular in both location and length of time.

Giant Sequoia Grove Inventory

Giant sequoia groves are a subcomponent of the mixed conifer vegetation type. They occupy a wide variety of site conditions, but often encompass the more productive, moist sites that grow not only the largest giant sequoias, but the largest pines and firs in the mixed conifer group. In most size classes, the average species-size distribution follows the common inverse relationship of size and number of trees where the larger the tree, the fewer the number. Intermediate sized trees are underrepresented; however, with only 26 trees per acre in the 11- to 14-inch size class, as shown in the following table and figure.[1] This apparent deficiency may be due to the lack of disturbance in the last 50 years and the lack of recruitment of pines and giant sequoia.

Tree Density–Number of Conifer and Hardwood Trees per Acre (TPA) by Diameter Class

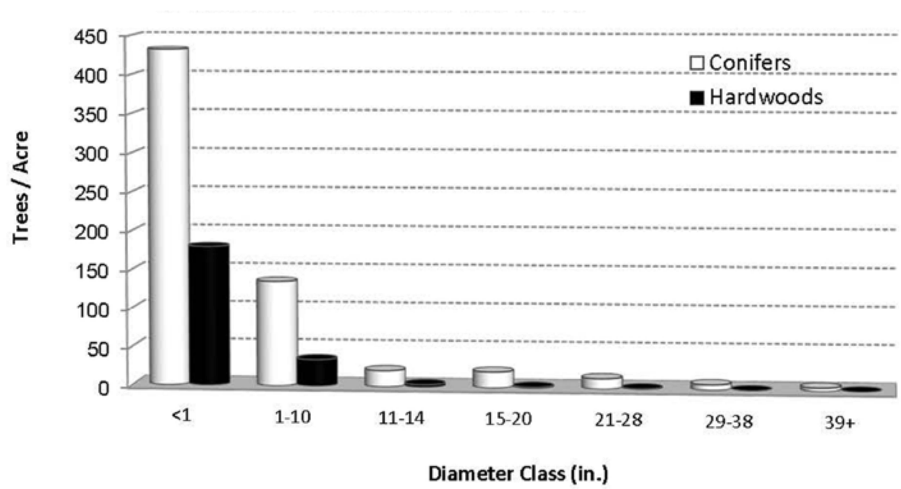
	Conifer TPA by Dia.Class (inch)								Hardwood TPA by Dia.Class (inch)							
Grove	<1	1-10	11-14	15-20	21-28	29-38	39+	Tot.	<1	1-10	11-14	15-20	21-28	29-38	39+	Tot.
Alder Creek	.	218	33	32	24	9	5	.	.	.	.	.	.	.	.	.
Big Stump	.	41	17	17	21	13	8	.	.	.	.	.	.	.	.	.
Black Mountain	.	223	31	38	30	20	14	.	.	.	.	.	.	.	.	.
Cherry Gap	.	127	11	5	0	1	0	.	.	216	3	1	0	0	0	220

[1] All of the following tables and figures were based on the 1999 inventory of half the groves in the Monument and the 2009 inventory of the remaining half. The regeneration data is from a 2009 inventory of all groves in the Monument. The rest of the data from 2009 have not been examined to date.

Grove	Conifer TPA by Dia.Class (inch)								Hardwood TPA by Dia.Class (inch)							
	<1	1-10	11-14	15-20	21-28	29-38	39+	Tot.	<1	1-10	11-14	15-20	21-28	29-38	39+	Tot.
Converse Basin	.	209	18	20	14	6	3	.	11	12	3	0	0	0	0	26
Deer Creek	.	160	35	25	22	8	2	.	.	.	.	.	.	.	.	.
Grant Grove	.	93	25	26	21	7	6	.	.	.	.	.	.	.	.	.
Indian Basin	.	59	17	27	25	9	3	.	.	.	.	.	.	.	.	.
Landslide	.	190	30	14	13	5	5	.	.	.	.	.	.	.	.	.
Long Meadow	.	60	20	9	5	2	6	.	.	.	.	.	.	.	.	.
Mountain Home	.	173	48	72	38	15	5	.	.	.	.	.	.	.	.	.
Packsaddle	.	87	16	16	10	4	3	.	.	.	.	.	.	.	.	.
Peyrone	.	192	41	56	26	9	5	.	.	.	.	.	.	.	.	.
Red Hill	.	190	21	35	18	6	6	.	.	.	.	.	.	.	.	.
Redwood Mtn	.	189	33	25	19	8	2	.	.	.	.	.	.	.	.	.
Starvation	.	156	17	16	9	7	3	.	.	.	.	.	.	.	.	.
Abbot	595	169	10	19	12	6	4	914	25	13	0	0	0	0	0	38
Agnew	28	106	37	37	11	5	2	225	6	0	0	0	0	0	0	6
Bearskin	690	179	12	11	11	6	3	911	30	0	3	2	0	0	0	35
Belknap	710	237	20	20	12	7	5	1009	399	49	4	3	1	0	0	456
Burro Creek	496	108	16	21	13	7	7	667	191	46	0	0	0	0	0	236
Cunningham	788	69	28	15	7	6	3	915	406	0	0	0	0	0	0	406
Deer Meadow	180	111	16	16	7	3	3	334	125	19	5	2	0	0	0	150
Dillonwood	436	114	22	13	8	14	4	613	359	0	3	4	1	1	1	368
Evans	263	143	8	8	5	5	3	435	59	10	1	1	0	0	0	70
Freeman	546	172	12	14	9	6	6	765	188	8	1	0	0	0	0	197
Maggie Mtn	38	29	0	8	2	3	5	84	388	0	10	0	0	0	0	397
Middle Tule	90	46	13	13	8	11	8	189	60	29	0	0	0	0	0	89

Grove	Conifer TPA by Dia.Class (inch)								Hardwood TPA by Dia.Class (inch)							
	<1	1-10	11-14	15-20	21-28	29-38	39+	Tot.	<1	1-10	11-14	15-20	21-28	29-38	39+	Tot.
Monarch	277	123	17	5	12	2	2	437	105	111	9	5	13	0	0	230
Silver Creek	504	105	32	23	9	6	1	682	238	64	8	9	4	0	0	322
South Peyrone	354	61	15	9	13	9	5	466	100	4	0	2	0	0	0	105
Upper Tule	483	42	0	11	4	10	14	563	0	0	0	0	0	0	0	0
Wishon	877	291	23	6	9	5	3	1213	550	74	16	5	4	2	0	650
Average	433	135	21	21	14	7	5	635	180	34	3	2	1	0	0	211

Number of Conifer and Hardwood Trees per Acre by Diameter Class (Average of All Groves)



Many groves now have an excessive buildup of surface and ladder fuels and a lack of openings needed for abundant regeneration. The average surface fuels, shown in the table and figure below, and the density of white fir, also shown in the third and fourth following table/figure, are currently about twice the amount desired for managing fuels and tree species composition in a sequoia grove. The presence of a wide range of sizes and ages of incense cedar and white fir indicate that these shade tolerant species are a part of the natural giant sequoia ecosystems under a sporadic fire regime with return intervals that may have ranged from a few years to several hundred depending on the location and size.

Current Surface Fuels and Standing Dead Trees (Snags)

Grove	Current Conditions (Mean Values)								Desired Conditions (Mean Values)							
	Tons/ac. by Dia.Class (inch)						Snags		Tons/ac. by Dia.Class (inch)						Snags	
	Duff *	0-1	1.1-3	3.1-9	>9	Tot.	BA ft^2/a	TPA	Duff	0-1	1.1-3	3.1-9	>9	Tot.	BA ft^2/a	TPA
Alder Creek	28	6	8	15	35	92	.	.	10	2	2	2	15	31	20	8
Big Stump	17	2	2	2	31	54	.	.	10	2	2	2	15	31	20	8
Black Mountain	30	3	4	5	49	92	.	.	10	2	2	2	15	31	20	8
Cherry Gap	18	3	4	5	5	34	3	1	10	2	2	2	15	31	20	8
Converse Basin	22	3	5	5	20	53	20	6	10	2	2	2	15	31	20	8
Deer Creek	25	4	6	4	8	48	10	3	10	2	2	2	15	31	20	8
Grant Grove	27	2	2	4	24	59	.	.	10	2	2	2	15	31	20	8
Indian Basin	12	2	3	4	8	29	.	.	10	2	2	2	15	31	20	8
Landslide	17	4	6	8	15	51	32	8	10	2	2	2	15	31	20	8
Long Meadow	17	3	3	2	20	45	22	5	10	2	2	2	15	31	20	8
Mountain Home	26	5	7	10	27	75	.	.	10	2	2	2	15	31	20	8
Packsaddle	34	3	3	3	18	61	.	.	10	2	2	2	15	31	20	8
Peyrone	33	2	3	5	16	59	.	.	10	2	2	2	15	31	20	8
Red Hill	36	2	2	4	13	57	.	.	10	2	2	2	15	31	20	8
Redwood Mtn	19	2	3	4	17	45	.	.	10	2	2	2	15	31	20	8
Starvation	50	3	4	4	42	103	.	.	10	2	2	2	15	31	20	8
	Tons/ac. by Dia.Class (inch)						Snags		Tons/ac. by Dia.Class (inch)						Snags	
	Duff *	0-1	1.1-3	3.1-12	>12	Tot.	BA ft^2/a	TPA	Duff	0-1	1.1-3	3.1-12	>12	Tot.	BA ft^2/a	TPA
Abbot	7	2	1	9	.	.	14	6	10	2	2	2	15	31	20	8
Agnew	7	2	3	11	.	.	37	12	10	2	2	2	15	31	20	8
Bearskin	7	2	2	12	.	.	17	5	10	2	2	2	15	31	20	8
Belknap	32	2	2	10	.	.	40	9	10	2	2	2	15	31	20	8
Burro Creek	16	2	2	9	.	.	97	12	10	2	2	2	15	31	20	8
Cunningham	10	1	2	11	.	.	54	15	10	2	2	2	15	31	20	8
Deer Meadow	3	2	2	9	.	.	38	11	10	2	2	2	15	31	20	8
Dillonwood	15	2	2	11	.	.	32	7	10	2	2	2	15	31	20	8
Evans	31	1	2	7	.	.	38	9	10	2	2	2	15	31	20	8
Freeman	14	2	2	9	.	.	71	8	10	2	2	2	15	31	20	8
Maggie Mtn	11	1	2	7	.	.	14	5	10	2	2	2	15	31	20	8
Middle Tule	10	2	2	9	.	.	32	6	10	2	2	2	15	31	20	8
Monarch	2	1	2	7	.	.	42	14	10	2	2	2	15	31	20	8
Silver Creek	24	2	2	11	.	.	37	11	10	2	2	2	15	31	20	8
South Peyrone	10	1	2	9	.	.	98	14	10	2	2	2	15	31	20	8
Upper Tule	10	2	2	8	.	.	38	3	10	2	2	2	15	31	20	8
Wishon	11	2	2	10	.	.	26	6	10	2	2	2	15	31	20	8
Average 2009	13	2	2	9	.	.	43	9	10	2	2	2	15	31	20	8
Average 1999	26	3	4	5	22	60	17	5	10	2	2	2	15	31	20	8
Average all	19	2	3	7	22	54	30	7	10	2	2	2	15	31	20	8

Grove	Current Conditions (Mean Values)								Desired Conditions (Mean Values)							
	Tons/ac. by Dia.Class (inch)						Snags		Tons/ac. by Dia.Class (inch)						Snags	
	Duff *	0-1	1.1-3	3.1-9	>9	Tot.	BA ft^2/a	TPA	Duff	0-1	1.1-3	3.1-9	>9	Tot.	BA ft^2/a	TPA

* 9.4 tons per acre per inch of duff depth = tons per acre Duff.

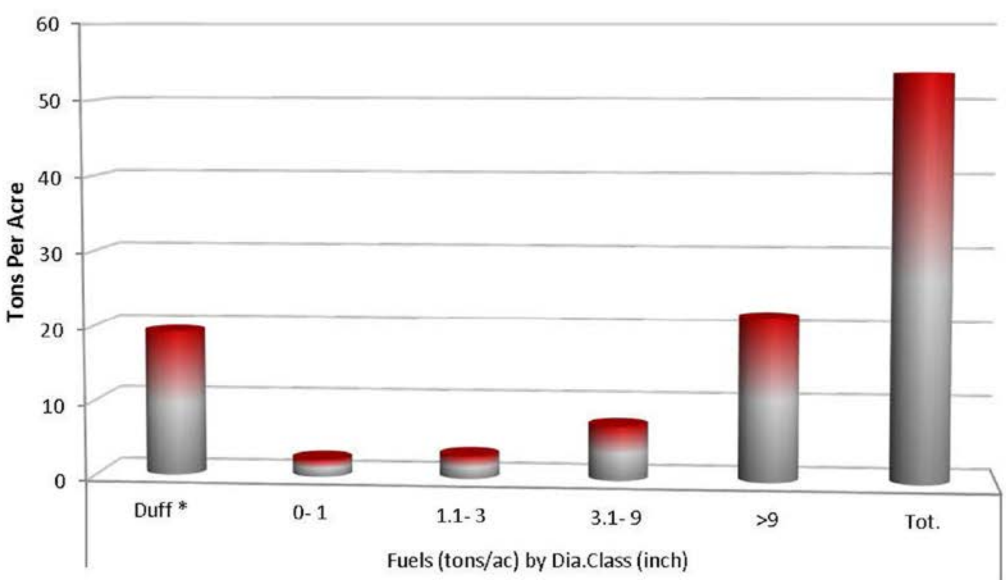
**In column 3, the 2009 vegetation database cutoff was at 12 inches rather than 9 inches.

**Averages for material over 9 inches will be based on the 1999 inventory.

***Desired Conditions are averages. These will range by individual fuel types within groves.

****The first 16 groves were inventoried in 1999 and the last 17 groves were inventoried in 2009.

Current Surface Fuels (Averages of 16 Groves from 1999)



Current and Desired Species Composition and Basal Area (BA)

	Current % of Trees				Desired % of Trees**				Current % of BA				Desired % of BA**			
Grove	GS*	MC*	WF*		GS	MC	WF		GS	MC	WF		GS	MC	WF*	
Alder Creek	1.0	99	71		10	90	22.5		32	68	42		65	35	15	

	Current % of Trees				Desired % of Trees**				Current % of BA				Desired % of BA**			
Grove	GS*	MC*	WF*		GS	MC	WF		GS	MC	WF		GS	MC	WF*	
Big Stump	5.0	95	36		10	90	22.5		15	85	36		65	35	15	
Black Mountain	4.0	96	52		10	90	22.5		20	80	47		65	35	15	
Cherry Gap	1.0	99	0		10	90	22.5		4	96	0		65	35	15	
Converse Basin	19.0	81	50		10	90	22.5		25	75	32		65	35	15	
Deer Creek	1.0	100	37		10	90	22.5		23	77	28		65	35	15	
Grant Grove	2.0	98	31		10	90	22.5		10	90	27		65	35	15	
Indian Basin	9.0	91	25		10	90	22.5		20	80	22		65	35	15	
Landslide	6.0	94	38		10	90	22.5		31	69	42		65	35	15	
Long Meadow	3.0	98	41		10	90	22.5		46	54	14		65	35	15	
Mountain Home	0.3	100	42		10	90	22.5		5	95	44		65	35	15	
Packsaddle	1.0	99	61		10	90	22.5		40	60	45		65	35	15	
Peyrone	1.0	99	48		10	90	22.5		6	94	46		65	35	15	
Red Hill	3.0	97	72		10	90	22.5		59	41	23		65	35	15	
Redwood Mtn	3.0	97	36		10	90	22.5		20	80	32		65	35	15	
Starvation	4.0	96	44		10	90	22.5		2	98	45		65	35	15	
Abbot	0.1	100	41.7		10	90	22.5		3	97	12		65	35	15	
Agnew	0.2	100	86.4		10	90	22.5		23	77	69		65	35	15	
Bearskin	11.5	89	53.8		10	90	22.5		18	82	34		65	35	15	
Belknap	0.3	100	26.9		10	90	22.5		40	60	27		65	35	15	
Burro Creek	2.7	97	29.7		10	90	22.5		58	42	27		65	35	15	
Cunningham	0.2	100	14.1		10	90	22.5		26	74	31		65	35	15	
Deer Meadow	0.7	99	48.1		10	90	22.5		49	51	33		65	35	15	
Dillonwood	3.1	97	25.1		10	90	22.5		25	75	39		65	35	15	
Evans	0.9	99	55.6		10	90	22.5		37	63	29		65	35	15	
Freeman	0.3	100	46.8		10	90	22.5		49	51	29		65	35	15	

	Current % of Trees				Desired % of Trees**				Current % of BA				Desired % of BA**			
Grove	GS*	MC*	WF*		GS	MC	WF		GS	MC	WF		GS	MC	WF*	
Maggie Mtn	0.3	100	11.8		10	90	22.5		46	54	29		65	35	15	
Middle Tule	3.6	96	9.4		10	90	22.5		41	59	46		65	35	15	
Monarch	0.2	100	39.1		10	90	22.5		18	82	23		65	35	15	
Silver Creek	0.8	99	31.7		10	90	22.5		13	87	33		65	35	15	
South Peyrone	0.2	100	33.2		10	90	22.5		27	73	49		65	35	15	
Upper Tule	1.7	98	26.3		10	90	22.5		44	56	38		65	35	15	
Wishon	0.0	100	28		10	90	22.5		1	99	24		65	35	15	
Average	3	97	39		10	90	23		26	74	33		65	35	15	

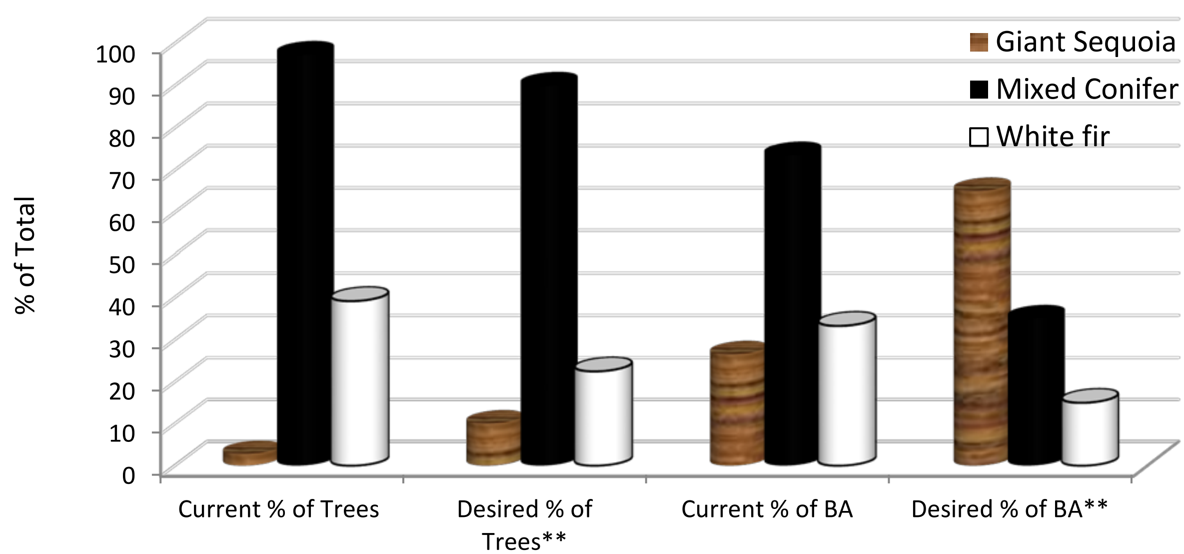
* GS = giant sequoia; MC = all mixed conifer except GS, and includes black oak; WF = white fir, which is a component of MC.

** Larger giant sequoia trees will increase BA of that species. More pine and less fir is desired in most groves.

***Desired % of trees or basal area are general averages that will vary by grove and tree size.

****The first 16 groves were inventoried in 1999 and the last 17 groves were inventoried in 2009.

Comparison of Current to Desired Species Composition and Density



Many groves currently have small sequoia trees scattered in small openings or other disturbed areas that may be 35 to 100 years old. The lack of recent disturbances over the last decade or more which exposes mineral soils and allows light to reach the ground, has resulted in many groves lacking natural sequoia regeneration less than twenty years old. The lack of more favorable rains or soil moisture during the summer and fall has likely been an additional factor in poor survival and growth of new seedlings. Sequoia planted during this time have survived and established well in the limited openings available for regeneration projects. White fir and incense cedar, which are well-adapted to extremes in soil moisture, temperature, and light conditions, are often abundant. These two species make up about 75 percent of the seedling sized trees in groves with black oak and sugar pine being the next most abundant, as shown in the following table. Giant sequoia seedlings and saplings may be abundant in occasional openings, but are rare under mature canopies. With a lack of adequately disturbed soils and canopies, giant sequoia only averages about 1 seedling per acre over all groves combined. In 2009, the average number of mixed conifer tree seedlings, including black oak, was 444 trees per acre across 26 groves. A more desirable species mixture would contain 44 giant sequoia seedlings per acre or 10 percent of the total. Given the longevity of the species, the tendency to grow best in disturbances, and frequent droughts, it is not likely that sequoia regeneration would follow a smooth pattern of frequent, successful seedling establishment. It is likely that sequoia regenerates only during certain years when the site conditions and soil moisture are optimal. It is also likely that one or more decades are required between burning to enable a young sequoia to withstand the heat. Sporadic regeneration of the species in small groups or large even-aged cohorts is more an ecological trait than a concern in the groves of the Monument.

Tree Species Composition–Total Number of Seedling and Sapling Sized Trees per Acre

	Tree Seedlings/Acre by Species*										Tree Saplings/Acre by Species*									
Grove	GS	WF	RF	IC	PP	JP	SP	BO	oth	Tot.	GS	WF	RF	IC	PP	JP	SP	BO	oth	Tot.
Alder Creek	0	186	.	229	7	.	14	0	0	436	.	.	.		.		.	.	.	.
Big Stump	0	305	.	133	3	.	85	0	25	550	.	.	.	.	.		.	.	.	.
Black Mountain	3	0	.	0	0	.	0	0	0	3	.	.	.	.	.		.	.	.	.
Cherry Gap	0	30	.	20	0	.	0	0	0	50	.	.	.	.	.		.	.	.	.
Converse Basin	3	355	.	85	2	.	10	0	0	455	.	.	.	.	.		.	.	.	.
Deer Creek	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	.
Grant Grove	0	365	.	205	0	.	105	0	0	675	.	.	.	.	.		.	.	.	.
Indian Basin	0	300	.	58	22	.	28	0	0	408	.	.	.	.	.		.	.	.	.
Landslide	0	210	.	60	15	.	55	0	0	340	.	.	.	.	.		.	.	.	.
Long Meadow	3	0	.	0	0	.	0	0	0	3	.	.	.	.	.		.	.	.	.
Mountain Home	0	119	.	214	0	.	33	0	3	369	.	.	.	.	.		.	.	.	.

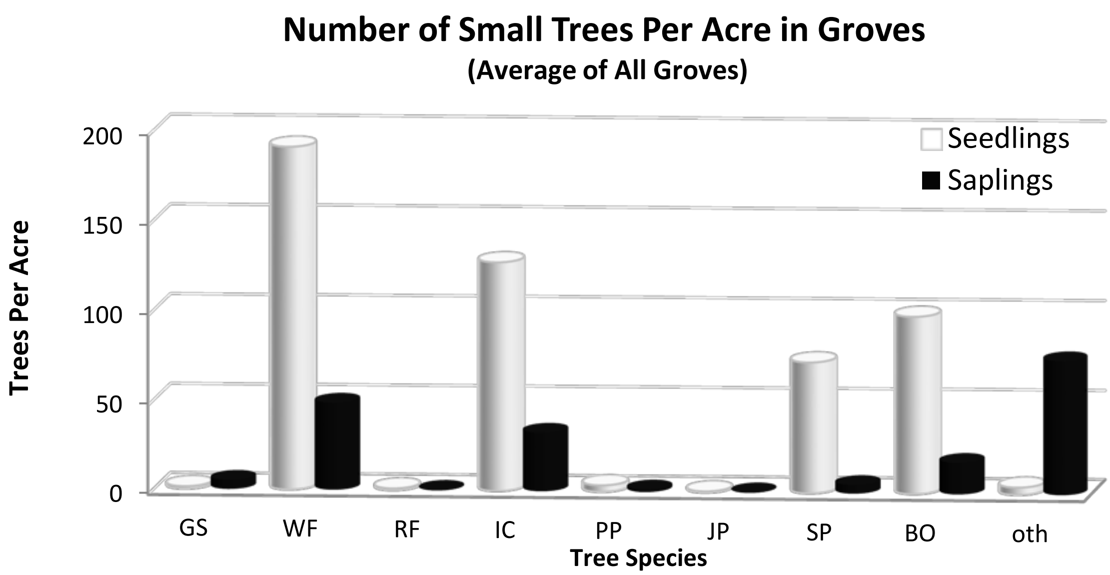
Packsaddle	0	140	.	58	0	.	38	18	0	253	.	.	.	.	.		.	.	.	.
Peyrone	0	113	.	90	7	.	7	0	0	217	.	.	.	.	.		.	.	.	.
Red Hill	1	0	.	0	0	.	0	0	0	1	.	.	.	.	.		.	.	.	.
Redwood Mtn	2	661	.	708	25	.	107	0	2	1506	.	.	.	.	.		.	.	.	.
Starvation	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.		.	.	.	.
Abbot	0	356		275	0		63	25	0	719	0	31		88	0		6	13	138	275
Agnew	0	6		6	17		0	6	0	33	0	28		0	0		0	0	28	56
Bearskin	20	443	0	150	0	0	77	30	0	720	80	33	0	37	3	0	3	0	0	157
Belknap	0	268	4	223	1	0	198	378	13	1085	1	79	1	101	4	0	3	43	0	232
Burro Creek	5	182	0	264	0	0	46	186	5	687	0	41	0	18	0	0	0	0	46	105
Cunningham	0	100	0	194	0	0	469	406	0	1169	0	50	0	44	0	0	0	0	0	94
Deer Meadow	0	131		29	3		7	125	4	299	0	42		16	0		2	11	79	150
Dillonwood	5	132		232	5		64	355	0	791	5	73		23	0		0	0	100	200
Evans	1	174	1	58	2	3	24	59	0	322	1	82	1	31	1	1	12	8	0	137
Freeman	0	299		74	4		135	181	0	693	0	95		40	11		10	15	170	340
Maggie Mtn	0	19		0	0		0	344	0	363	0	19		0	0		6	44	69	138
Middle Tule	0	58		20	0		10	60	0	148	0	38		3	0		0	25	65	130
Monarch	0	191		41	0		36	105	9	382	0	41		18	5		23	32	118	236
Silver Creek	0	242		150	0		104	233	0	729	0	25		54	0		4	42	125	250
South Peyrone	0	107		29	0		207	21	0	364	0	14		11	0		0	4	29	57
Upper Tule	0	92		0	0		250	0	0	342	0	33		0	0		0	0	33	67
Wishon	0	347		357	0		103	543	67	1417	0	107		77	0		13	67	277	540
Average	1	191	1.0	128	4	0.7	73	99	4	501	5	49	0.3	33	1	0.3	5	18	75	186

* Values based on fixed plot sampling. Tree seedlings are less than 1 inch diameter breast height (dbh); saplings are 1 to 4.9 inches dbh.

* GS=giant sequoia, WF=white fir, IC=incense cedar, PP=ponderosa pine, SP=sugar pine, BO=black oak, JP=Jefferey pine,

oth=other trees including canyon live oak and other hardwoods. Other trees in Cherry gap are mostly willow.

**The first 16 groves were inventoried in 1999 and the last 17 groves were inventoried in 2009.



GS=giant sequoia, WF=white fir, RF=red fir, IC=incense cedar, PP=ponderosa pine, JP=Jeffrey pine, SP=sugar pine, BO=black oak, oth=other trees,

The greatest scientific concern in most groves is not sequoia regeneration, but the heavy buildup of surface and ladder fuels which could do serious damage to existing larger trees. Associated with this is the abundant ingrowth of white fir and incense cedar. These more shade tolerant species reduce the growth of other tree species by using soil moisture, crowding the growing space, and casting shade. They also serve as ladder fuels which could damage or kill the crowns of the largest trees. Tree mortality follows a pattern common in most forests where most dead trees are smaller and suppressed. The current inventory shows an average of 15 standing dead trees per acre over all groves. About 20 percent of these are dominant or larger trees. Similarly, less than 30 percent of the dead, fallen trees are over 24 inches in diameter, as shown in the following table. The high mortality (42 standing snags per acre) of larger white fir, sugar pine, incense cedar, and black oak in the Mountain Home Grove is most likely due to overcrowding, drought, and insects. Higher mortality such as this can be expected in many groves given the current drought, future predictions that we may see warmer and drier growing conditions, increasingly higher densities of trees, and older pines, oaks, cedars, and firs. Higher tree mortality in groves such as Alder Creek (56 snags per acre) and Mountain Home will likely contribute to a higher fuels loading. Alder Creek and Mountain Home groves in 1999 already had total fuel loads of 92 and 75 tons per acre, respectively. The desired amount of fuel loading for these groves is 31 tons per acre.

Standing Dead Conifer Trees (Snags) by Forest Canopy Position and Fallen Conifer Trees (Logs) by Diameter Class

	No.of Snags/acre by Canopy Position					No.of Logs/acre by Dia.Class (inch)				
Grove	Dom	Co-Dom	Inter	Sup	Tot.	10-15.9	16-23.9	24+	Tot.	
Alder Creek	3	3	5	44	56	24	20	15	59	

Grove	No.of Snags/acre by Canopy Position					No.of Logs/acre by Dia.Class (inch)				
	Dom	Co-Dom	Inter	Sup	Tot.	10-15.9	16-23.9	24+	Tot.	
Big Stump	1	4	6	1	12	8	8	6	22	
Black Mountain	3	3	6	23	35	15	8	16	39	
Cherry Gap	.	.	.	.	1	9	10	3	22	
Converse Basin	1	2	3	0	6	6	7	9	22	
Deer Creek	0	1	1	1	3	2	2	2	6	
Grant Grove	1	3	4	1	10	10	5	5	20	
Indian Basin	0	3	9	2	14	19	9	5	33	
Landslide	.	.	.	.	8	7	9	10	26	
Long Meadow	1	1	1	1	4	3	2	6	11	
Mountain Home	18	3	5	16	42	26	18	13	57	
Packsaddle	1	2	3	0	7	8	4	7	19	
Peyrone	2	3	14	6	25	14	10	9	33	
Red Hill	2	3	11	48	64	13	8	6	27	
Redwood Mtn	1	3	11	15	29	21	6	6	33	
Starvation	1	3	8	1	12	9	9	8	26	
Abbot	0	3	3	0	6	.	.	.	.	
Agnew	0	4	5	3	12	.	.	.	.	
Bearskin	0	2	2	1	5	.	.	.	.	
Belknap	0	2	8	0	10	.	.	.	.	
Burro Creek	2	3	3	4	12	.	.	.	.	
Cunningham	2	2	1	10	15	.	.	.	.	
Deer Meadow	0	1	10	0	11	.	.	.	.	
Dillonwood	1	5	2	0	8	.	.	.	.	
Evans	0	0	5	4	9	.	.	.	.	
Freeman	0	1	4	4	9	.	.	.	.	
Maggie Mtn	0	1	4	1	5	.	.	.	.	
Middle Tule	0	3	2	1	6	.	.	.	.	
Monarch	0	2	11	1	14	.	.	.	.	
Silver Creek	2	2	7	1	11	.	.	.	.	
South Peyrone	0	2	9	4	15	.	.	.	.	
Upper Tule	1	0	0	2	3	.	.	.	.	
Wishon	1	0	2	3	6	.	.	.	.	
Average	1	2	5	6	15	12	8	8	28	

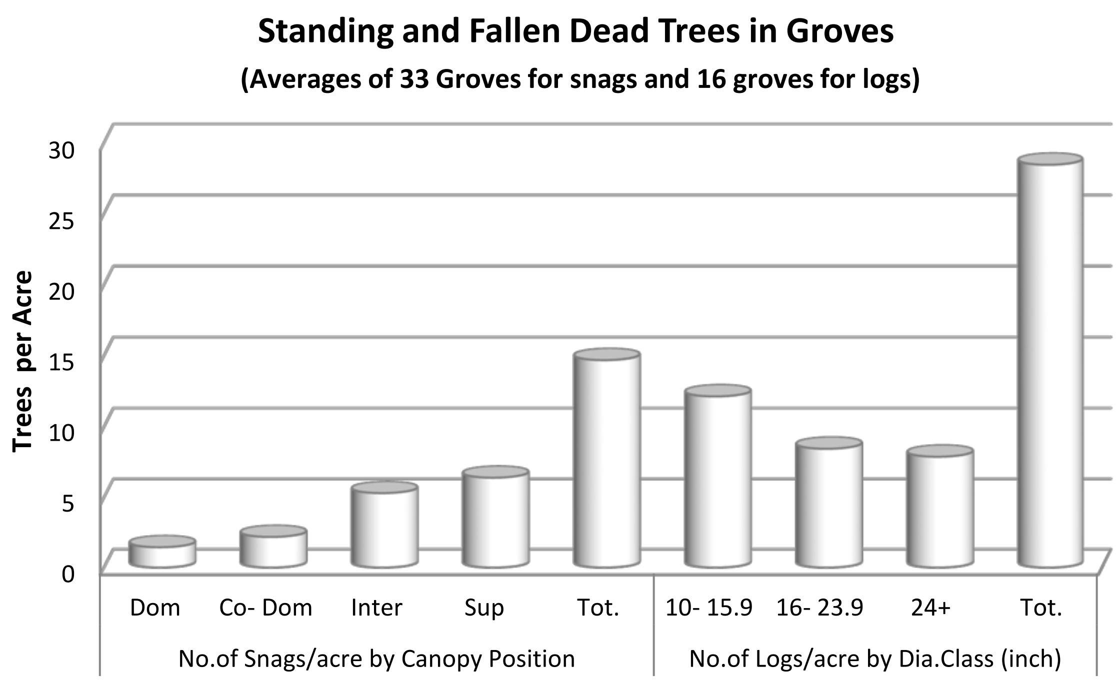
*Canopy position - Dom=dominant, Codom=codominant, Inter=intermediate, Sup=suppressed.

**Log data for 2009 Inventory will be available in individual grove reports

*** High Mortality of larger WF, SP, IC, and BO in the Mtn Home Grove is due to overcrowding, drought, and insects.

****The first 16 groves were inventoried in 1999 and the last 17 groves were inventoried in 2009.

*****Logs by diameter class for 2009 Inventory will be available in individual grove reports



The following tables and figures show more data for tree species composition, tree density, and canopy cover and height for the giant sequoia groves in the Monument.

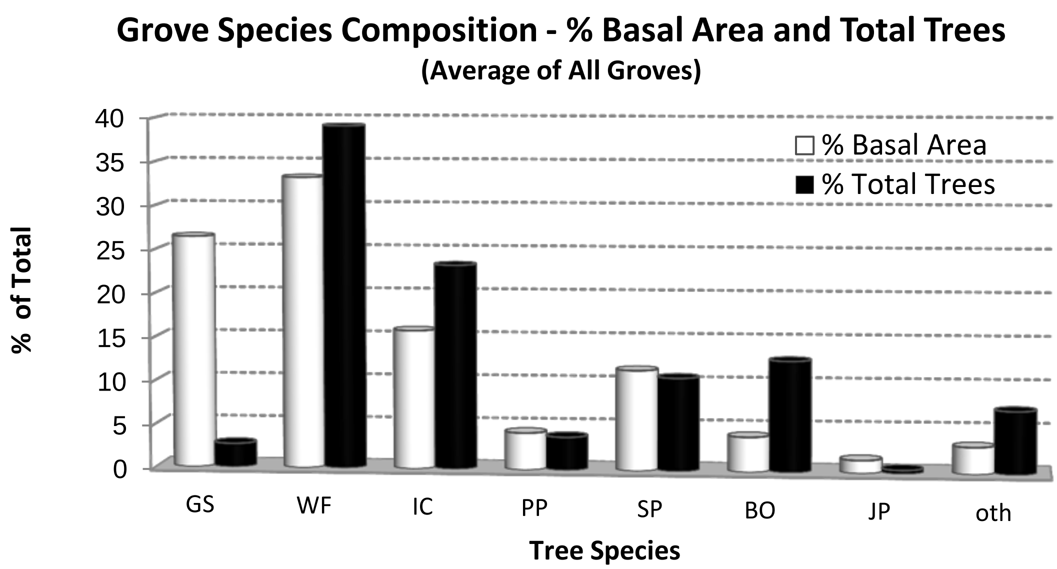
Tree Species Composition as a Proportion of Basal Area and Total Number of Trees

Grove*	Tree Sp.* Composition % Basal Area								Tree Sp.* Composition % Tot.Trees							
	GS	WF	IC	PP	SP	BO	JP	oth	GS	WF	IC	PP	SP	BO	JP	oth
Alder Creek	32	42	13	0	6	0	0	7	1.0	71	14	0	5	0	0	9
Big Stump	15	36	15	5	29	0	0	0	5.0	36	39	3	17	0	0	0
Black Mountain	20	47	10	1	17	0	0	5	4.0	52	17	4	12	0	0	11
Cherry Gap	4	0	1	34	0	18	35	8	1.0	0	4	23	0	8	10	54
Converse Basin	25	32	10	10	17	5	0	1	19.0	50	14	6	5	5	1	0
Deer Creek	23	28	33	1	8	6	0	1	1.0	37	45	1	7	10	0	0
Grant Grove	10	27	27	5	29	2	0	0	2.0	31	47	5	12	3	0	0
Indian Basin	20	22	22	29	7	0	0	0	9.0	25	43	14	8	0	0	1
Landslide	31	42	18	1	5	0	0	3	6.0	38	28	6	7	0	0	15
Long Meadow	46	14	6	6	5	1	0	22	3.0	41	18	32	5	2	0	0
Mountain Home	5	44	19	2	23	0	0	7	0.3	42	29	1	19	0	0	9

Packsaddle	40	45	7	1	7	0	0	0	1.0	61	32	1	5	0	0	0
Peyrone	6	46	17	1	13	0	0	17	1.0	48	20	1	7	0	0	23
Red Hill	59	23	6	2	9	0	0	1	3.0	72	13	7	4	0	0	1
Redwood Mtn	20	32	32	10	5	0	0	1	3.0	36	53	4	4	0	0	0
Starvation	2	45	46	1	6	0	0	0	4.0	44	43	4	5	0	0	0
Abbot	3	12	37	0	42	0	5	0	0.1	42	45	0	9	4	0	0
Agnew	23	69	0	3	5	0	0	0	0.2	86	2	8	0	2	0	0
Bearskin	18	34	16	0	30	3	0	0	11.5	54	21	0	10	4	0	0
Belknap	40	27	18	3	7	5	0	1	0.3	27	27	1	14	30	0	1
Burro Creek	58	27	9	1	5	0	0	0	2.7	30	35	0	6	21	0	6
Cunningham	26	31	13	4	27	0	0	0	0.2	14	18	0	37	31	0	0
Deer Meadow	49	33	10	1	1	4	1	0	0.7	48	14	1	2	31	1	2
Dillonwood	25	39	15	2	10	9	0	0	3.1	25	27	1	7	37	0	0
Evans	37	29	13	3	13	1	4	0	0.9	56	19	1	8	14	1	0
Freeman	49	29	6	4	8	0	1	3	0.3	47	13	2	16	20	0	2
Maggie Mtn	46	29	0	0	16	6	3	0	0.3	12	0	0	2	33	0	53
Middle Tule	41	46	5	0	5	1	0	3	3.6	9	17	0	10	59	0	1
Monarch	18	23	16	6	10	27	0	0	0.2	39	14	1	10	34	0	1
Silver Creek	13	33	28	2	5	20	0	0	0.8	32	24	0	11	32	0	1
South Peyrone	27	49	17	0	5	1	0	1	0.2	33	8	0	37	5	0	17
Upper Tule	44	38	0	0	0	0	0	19	1.7	26	0	0	44	0	0	28
Wishon	1	24	38	4	6	23	0	4	0.0	28	27	0	7	35	0	4
Average	26	33	16	4	11	4	2	3	3	39	23	4	11	13	0	7

* GS=giant sequoia, WF=white fir, IC=incense cedar, PP=ponderosa pine, SP=sugar pine, BO=black oak, JP=Jefferey pine, oth=other trees including canyon live oak and other hardwoods. Other trees in Cherry gap are mostly willow.

**The first 16 groves were inventoried in 1999 and the last 17 groves were inventoried in 2009.

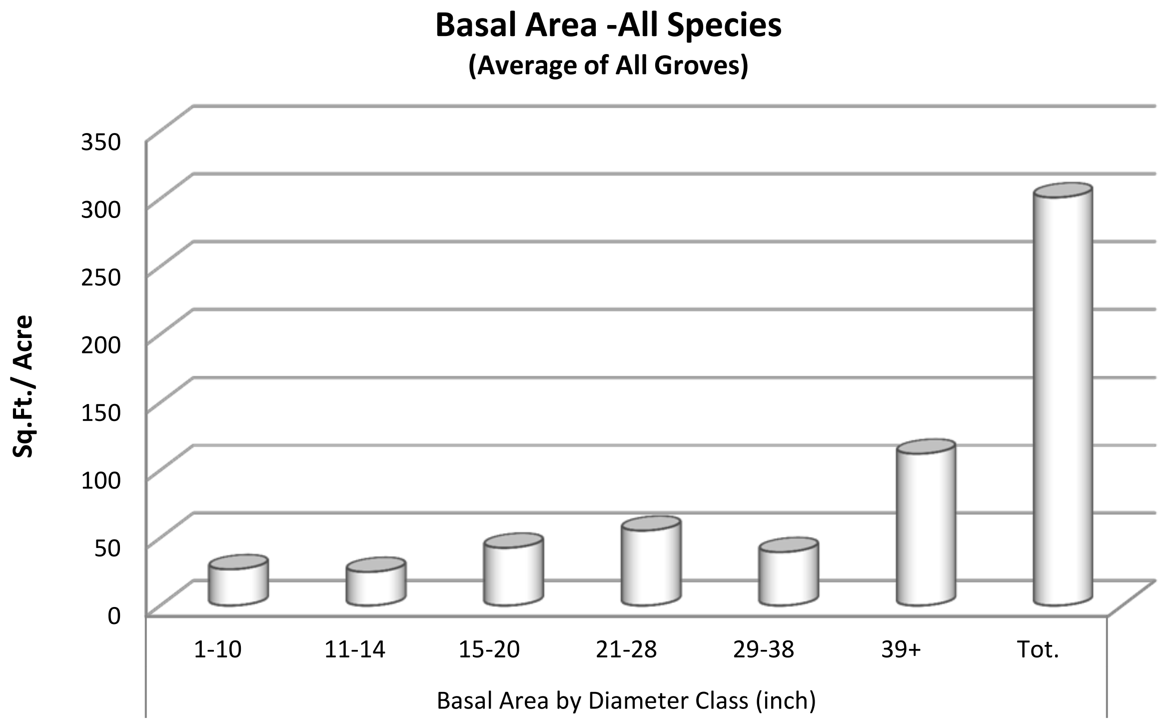


GS=giant sequoia, WF=white fir, IC=incense cedar, PP=ponderosa pine, SP=sugar pine, BO=black oak, JP=Jefferey pine,

Tree Density (Combined Species)–Basal Area (BA) per Acre by Diameter Class

Grove	BA (ft^2/ac) by Diameter Class (inch)							
	1-10	11-14	15-20	21-28	29-38	39+	Tot.	
Alder Creek	47	31	55	77	3	145	358	
Big Stump	9	16	30	70	76	102	303	
Black Mountain	45	31	52	64	58	142	392	
Cherry Gap	42	14	10	0	5	0	71	
Converse Basin	29	19	35	45	39	43	210	
Deer Creek	14	33	45	71	45	89	297	
Grant Grove	16	24	45	63	37	57	242	
Indian Basin	10	16	46	83	54	37	246	
Landslide	23	31	26	46	41	152	319	
Long Meadow	11	19	14	17	14	301	376	
Mountain Home	35	46	90	95	67	67	400	
Packsaddle	16	15	28	33	23	120	235	

Grove	BA (ft^2/ac) by Diameter Class (inch)							
	1-10	11-14	15-20	21-28	29-38	39+	Tot.	
Peyrone	42	40	77	69	45	71	344	
Red Hill	32	18	61	55	37	389	592	
Redwood Mtn	27	28	41	64	46	47	254	
Starvation	29	16	26	33	40	31	175	
Abbot	19	10	35	40	37	39	180	
Agnew	34	36	62	36	27	97	291	
Bearskin	12	13	21	37	36	49	169	
Belknap	33	22	38	39	42	128	302	
Burro Creek	17	15	33	44	45	223	376	
Cunningham	2	25	25	25	40	46	163	
Deer Meadow	24	18	29	22	15	123	231	
Dillonwood	13	3	29	29	91	70	254	
Evans	11	8	14	18	29	87	165	
Freeman	17	12	24	29	39	207	329	
Maggie Mtn	5	10	15	5	16	111	162	
Middle Tule	8	12	24	28	70	186	327	
Monarch	46	22	15	44	11	42	180	
Silver Creek	31	37	57	43	36	17	220	
South Peyrone	10	14	20	43	55	121	263	
Upper Tule	2	0	20	13	61	236	333	
Wishon	43	35	19	43	41	43	224	
Average	23	21	35	43	40	110	272	



Forest Vegetation Canopy Cover (cc) and Height (ht) by Vegetation Group

Grove	Conifer		Hardwd		Shrub		Forb		Grass		Tot.Tree		Tot.Oth	
	cc %	Ht (ft)	cc %	Ht (ft)	cc %	Ht (ft)	cc %	Ht (ft)	cc %*	Ht (ft)	cc %		cc %	
Alder Creek	78	103	34	46	15	6	16	1	1	1	113		32	
Big Stump	71	111	16	57	19	3	5	1	2	1	87		26	
Black Mountain	64	104	11	33	27	5	9	1	1	1	75		37	
Cherry Gap	29	46	42	31	42	5	12	1	12	1	71		66	
Converse Basin	67	79	27	38	56	3	8	1	1	1	94		65	
Deer Creek	75	95	22	60	1	1	25	.	1	.	97		27	
Grant Grove	59	89	6	53	33	2	7	1	1	1	65		41	
Indian Basin	62	96	0	.	14	3	14	1	3	1	62		31	
Landslide	68	97	1	19	13	3	4	1	2	1	69		19	
Long Meadow	71	182	7	49	40	2	10	.	5	.	78		55	

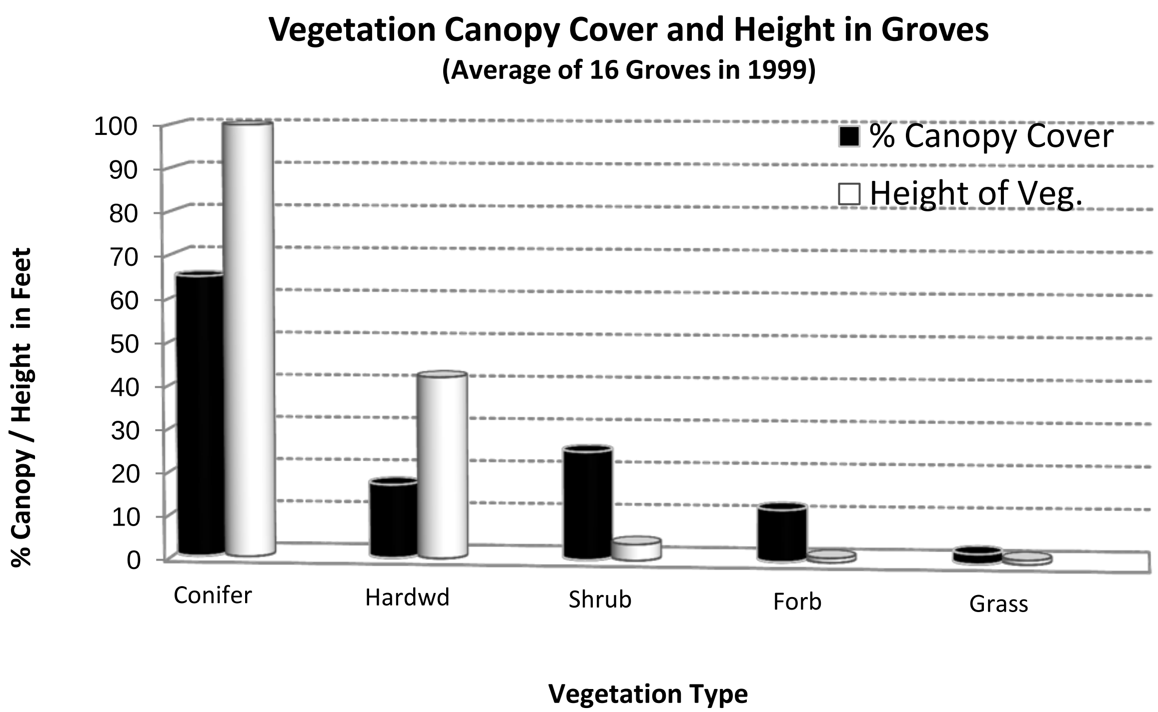
Grove	Conifer		Hardwd		Shrub		Forb		Grass		Tot.Tree		Tot.Oth	
	cc %	Ht (ft)	cc %	Ht (ft)	cc %	Ht (ft)	cc %	Ht (ft)	cc %*	Ht (ft)	cc %		cc %	
Mountain Home	63	92	24	34	18	4	18	1	1	1	87		37	
Packsaddle	55	110	10	50	30	4	17	1	1	1	65		48	
Peyrone	55	86	36	33	20	5	5	1	1	1	91		26	
Red Hill	95	149	5	32	20	3	5	1	1	1	100		26	
Redwood Mtn	66	84	20	49	35	5	3	1	1	1	86		39	
Starvation	54	82	15	45	13	5	39	1	3	1	69		55	
Abbot	45	30	3	3	.	.	.	.	.	.	48		.	
Agnew	55	59	0	1	.	.	.	.	.	.	55		.	
Bearskin	38	8	6	4	.	.	.	.	.	.	44		.	
Belknap	42	28	24	3	.	.	.	.	.	.	66		.	
Burro Creek	55	22	2	6	.	.	.	.	.	.	57		.	
Cunningham	37	39	0	1	.	.	.	.	.		37		.	
Deer Meadow	35	28	15	3	.	.	.	.	.	.	50		.	
Dillonwood	37	15	19	2	.	.	.	.	.	.	56		.	
Evans	34	23	4	2	.	.	.	.	.	.	38		.	
Freeman	50	36	3	1	.	.	.	.	.	.	53		.	
Maggie Mtn	24	40	14	1	.	.	.	.	.	.	38		.	
Middle Tule	44	43	6	3	.	.	.	.	.	.	50		.	
Monarch	15	34	55	9	.	.	.	.	.	.	70		.	
Silver Creek	23	30	44	6	.	.	.	.	.	.	67		.	
South Peyrone	42	34	3	3	.	.	.	.	.	.	45		.	
Upper Tule	45	22	0	0	.	.	.	.	.	.	45		.	
Wishon	24	53	48	3	.	.	.	.	.	.	72		.	
Average	51	65	16	21	25	4	12	1	2	1	67		39	

* For grass cover (%) and height (ft), the value 1 = 0 to 1. Tot.Oth = total shrub, forb, and grass.

**The first 16 groves were inventoried in 1999 and the last 17 groves were inventoried in 2009.

***Tree heights for 2009 Inventory are average height of all size classes.

****Shrub, grass, and forb cover and heights will be available in individual grove reports.



Legal and Regulatory Compliance

- National Forest Management Act of 1976
- National Forest Resource Management: Forest Service Manual (FSM) 2000—Chapter 2020—Ecological Restoration and Resilience
- Silvicultural Practices Handbook (FSH 2409.17), Silvicultural Examination and Prescription Handbook (FSH 2409.26d)
- Timber Management: FSM 2400—Silvicultural Practices Chapter

Management Direction

Strategies

Strategies Specific to Giant Sequoias, by Alternative

Strategy	Alt. B	Alt. C	Alt. D	Alt. E	Alt. F
1. As part of the fuel load reduction plan for each giant sequoia grove,[2] emphasize the protection of:					
• Large giant sequoia trees	X	X	X	X	X
• Large trees of other species, including pines, red firs, incense cedars, and black oaks.	X	X		X	X
(MSA, pp.9-11, b. Grove Management)					
2. Protect naturally-occurring isolated giant sequoias located outside of grove administrative boundaries and near areas of human use from vegetation management activities, giving special consideration to the root systems. When practical, preserve them within wildlife clumps or within areas reserved to meet seral stage diversity requirements.	X	X	X	X	X
3. Provide additional protection to the named giant sequoias—Boole, President Bush, and Chicago Stump—from fuels reduction activities, wildfires, and from human disturbance that can damage tree health, such as peeling bark and trampling on roots. Protect these specific trees by pulling fuels away from the base of the trees or removing ladder fuels that could promote a crown fire in them.	X	X	X	X	X
4. Give the designation of "grove" to any detached naturally-occurring group (10 or more giant sequoia trees, with at least 4 trees with a dbh of 3 feet or larger) located outside an existing grove's administrative boundary. If previously unknown giant sequoia trees of any size and number are discovered outside a grove's administrative boundary, modify the boundary according to the standards and guidelines (1990 MSA, pp. 21-22, xii)-xiii)).	X	X	X	X	X
Give this new grove a 300-foot restricted mechanical entry zone within the grove influence zone (GIZ) (1990 MSA, p. 21, xii)).				X	
Develop a zone of influence (ZOI) within which key ecological processes, structures, and functions should be evaluated to ensure that the giant sequoia groves are preserved, protected, and restored (North et al. 2000).	X				X
5. With the exception of areas recommended for preservation, consider Converse Basin Grove to be available for vegetation management (tree cutting and/or removal), where clearly needed for ecological restoration and maintenance or public safety, and to promote regeneration of giant sequoias (MSA, pp. 26-27).				X	

Strategies for Climate Change/Carbon Sequestration, by Alternative

[2] Using the grove administrative boundary.

Strategy	Alt. B	Alt. C	Alt. D	Alt. E	Alt. F
6. Design forest management techniques to forestall impacts to high value resources, such as retention of named giant sequoia trees.	X	X	X	X	X
7. Improve the potential for forest ecosystems to return to desired conditions following natural disturbances, such as through the use of prescribed fire, managed wildfire, or mechanical treatments to reduce ladder fuels or tree densities.	X	X	X	X	X
8. Restore essential ecological processes and patterns (for example, structural heterogeneity) to reduce impacts of current stressors.	X	X	X	X	X
9. Provide mitigation measures for minimizing short-term greenhouse gas emissions and promoting long-term sequestration of carbon resulting from site-specific project activities.	X	X	X	X	X

Strategies for Ecological Restoration, by Alternative

Strategy	Alt. B	Alt. C	Alt. D	Alt. E	Alt. F
10. Accomplish ecological restoration, in part, through the reduction of fuels by decreasing down woody material, ladder fuels, and brush.	X	X	X	X	X
11. Promote heterogeneity in plantations and young stands by encouraging more diversity in species composition and age. Reduce stand density in young stands and encourage shade-intolerant species such as giant sequoia, pine, and oak.	X	X	X	X	X
12. Improve stand resilience and health by varying spacing of trees both inside and outside of giant sequoia groves.	X	X	X	X	X
13. Encourage natural regeneration of tree species, including giant sequoia. In areas where natural regeneration is not likely, use planting as determined in site-specific project analysis.	X	X		X	X

Strategy	Alt. B	Alt. C	Alt. D	Alt. E	Alt. F
14. To regenerate tree species, including giant sequoia, rely only on natural regeneration.			X		
15. Promote resiliency in Monument ecosystems by using the following tools, in order of priority:					
• Prescribed fire, mechanical treatment, managed wildfire (when available)	X				
• Prescribed fire and managed wildfire (when available), mechanical treatment		X			
• Managed wildfire (when available), prescribed fire, mechanical treatment			X		
• Mechanical treatment, prescribed fire, managed wildfire (when available)				X	
• Combination of tools determined by site-specific analysis					X

Strategies for Pest Management, by Alternative

Strategy	Alt. B	Alt. C	Alt. D	Alt. E	Alt. F

16. Continue using integrated pest management, allowing carefully controlled, limited use of pesticides to rapidly control pests and encourage a natural environment.	X	X		X	X
17. Continue to use integrated pest management in limited circumstances, without the use of pesticides.			X		

Objectives

Objectives for Giant Sequoias, by Alternative

Objective	Alt. B	Alt. C	Alt. D	Alt. E	Alt. F
1. Within 20 years, complete a grove-specific fuel load reduction plan for each giant sequoia grove in the Monument (MSA, pp.9-11, b. Grove Management).	X	X	X	X	X
2. Within 20 years, accomplish ecological restoration projects in the WUI defense zone in the giant sequoia groves.	X	X	X	X	X
3. Within 20 years, accomplish ecological restoration projects in 25 percent of the giant sequoia groves outside of the WUI defense zone.	X	X		X	X
4. Within 20 years, accomplish ecological restoration projects in 15 percent of the giant sequoia groves outside of the WUI defense zone.			X		
5. For Converse Basin Grove, within 5 years: (a) allocate approximately 600 acres for preservation management with a buffer; and (b) allocate 10 percent of the remaining 2,400 acres (approximately 240 acres) in the grove for preservation and regeneration of giant sequoias to replace trees cut at the turn of the century. This 10 percent should include areas where there has been significant regrowth of giant sequoias (that is, areas where 70- to 100-year-old giant sequoias are abundant). No designated preservation units should be less than 40 acres (USDA Forest Service 2007a, pp. 26-27).				X	

Objective	Alt. B	Alt. C	Alt. D	Alt. E	Alt. F
6. Manage all major vegetation types in the first two decades to accomplish at least 50 percent of the acres desired for ecological restoration. This would involve changes to accomplish an early seral stage, fuels reduction, and increased growing space inside and outside of groves.		X	X		

Objectives for Mixed Conifer, by Alternative

Objective	Alt. B	Alt. C	Alt. D	Alt. E	Alt. F

7. Manage vegetation to: • Change approximately 2 percent of the mixed conifer types to an early seral phase in giant sequoia groves per decade. • Change approximately 1 percent of the mixed conifer types to an early seral phase outside of groves per decade. • Change approximately 10 percent of the mixed conifer types to reduce fuels and increase tree growing space in groves per decade. • Change approximately 6 percent of the mixed conifer types to reduce fuels and increase tree growing space outside of groves per decade.	X			X	X

Objective for Blue Oak–Interior Live Oak, by Alternative

Objective	Alt. B	Alt. C	Alt. D	Alt. E	Alt. F
8. For the life of the plan, keep the total acreage of the blue oak vegetation type stable.	X	X	X	X	X

Objectives for Chaparral–Live Oak, by Alternative

Objective	Alt. B	Alt. C	Alt. D	Alt. E	Alt. F
9. Manage vegetation to change approximately 6 percent of the chaparral vegetation types to an early seral phase outside of groves per decade.	X			X	X

Objectives for Montane Hardwood–Conifer, by Alternative

Objective	Alt. B	Alt. C	Alt. D	Alt. E	Alt. F
10. Manage vegetation to: • Change approximately 24 percent of the montane hardwood-conifer vegetation types to an early seral phase in giant sequoia groves per decade. • Change approximately 2 percent of the montane hardwood-conifer types to an early seral phase outside of groves per decade. • Change approximately 12 percent of the montane hardwood-conifer types to reduce fuels and increase tree growing space in groves per decade. • Change approximately 9 percent of the montane hardwood-conifer types to reduce fuels and increase tree growing space outside of groves per decade.	X			X	X

Objectives for Red Fir, by Alternative

Objective	Alt. B	Alt. C	Alt. D	Alt. E	Alt. F
11. Manage vegetation to: • Change approximately 3 percent of the red fir vegetation types to an early seral phase in giant sequoia groves per decade. • Change approximately 1 percent of the red fir types to an early seral phase outside of groves per decade. • Change approximately 1 percent of the red fir types to reduce fuels and increase tree growing space in groves per decade. • Change approximately 1 percent of the red fir types to reduce fuels and increase tree growing space outside of groves per decade.	X			X	X

Standards and Guidelines

Standard/Guideline	Alternative				
	B	C	D	E	F
Vegetation, including Giant Sequoias					
Monument-wide [3]					
1. For all projects that include a proposal for tree removal from within the Monument, except for personal use fuelwood, conduct an evaluation to document the clear need for removing trees for ecological restoration and maintenance or public safety.	X	X	X	X	X
2. When implementing vegetation and fuels treatments, retain all conifer trees with a dbh of 20 inches or greater in westside forest types. Retain montane hardwoods with a dbh of 12 inches or larger in westside forest types. Occasional mortality of larger trees is expected to occur; however, design prescribed fire prescriptions and techniques to minimize the loss of large trees and large down material.	X				
3. When implementing vegetation and fuels treatments, retain all live conifer trees with a dbh of 12 inches or greater in westside forest types. Retain montane hardwoods with a dbh of 12 inches or larger in westside forest types. Occasional mortality of larger trees is expected to occur; however, design prescribed fire prescriptions and techniques to minimize the loss of large trees and large down material.			X		
4. Incidental removal of trees that present safety hazards may deviate from vegetation management standards and guidelines.	X	X	X	X	X
5. Fall and remove hazard trees along Maintenance Level 3, 4, and 5 roads and within or immediately adjacent (tree falling distance) to administrative sites. Review by an appropriate resource specialist is required prior to falling hazard trees along Maintenance Level 1 and 2 roads. Retain felled trees, where needed, to meet down woody material standards.	X	X			X
6. Plant all regeneration areas requiring reforestation except where natural seeding is prescribed. Regeneration by natural seeding will be applied primarily in the true fir type (MSA, Exhibit N, p. 3, C.1.).	X	X		X	X

[3] These standards and guidelines apply across all land allocations/management areas in the Monument.

7. Regenerate conifer by natural seeding where feasible.			X		
8. Both natural and artificial regeneration shall be used as appropriate (MSA, Exhibit N, p. 1, A.2.b.).	X		X	X	X
9. Save viable existing reproduction where feasible and incorporate into silvicultural prescriptions for new stands (MSA, Exhibit N, p. 3, C.2.).	X	X	X	X	X
10. Utilize current state-of-the-art regeneration techniques including controlling pests, such as gophers, and controlling competing vegetation (MSA, Exhibit N, p. 3, C.3.).	X	X	X	X	X
11. Make dead and down woody material available for firewood gathering.	X	X		X	X
12. Make dead and down material available for firewood throughout the forest. Make some green material available for firewood (MSA, Exhibit N, p. 3, D.2.).				X	
13. In order to maintain forest diversity, particularly within the mixed conifer forest type, reforestation and timber stand improvement prescriptions shall generally emulate desired species composition. Variation from this guideline will be the exception and will be discussed in an environmental document (MSA, Exhibit N, p. 3, E.1.).	X	X	X	X	X
14. Design vegetation treatments to provide for edge corridors of cover and enhancement of special habitat features such as meadows for wildlife (MSA, Exhibit N, p. 4, E.3.).	X	X	X	X	X
Giant Sequoia Groves [4]					
15. Protect and manage giant sequoias to perpetuate the species and preserve old growth specimen trees.	X	X	X	X	X
16. Any naturally-occurring giant sequoia (1 foot or larger dbh) which is located within 500 feet of at least 3 other giant sequoias (each 1 foot or larger dbh), shall always be included within the hypothetical perimeter line [of the grove] (1990 MSA, p. 13, (2) (e) i)).	X	X	X		X
17. Refine the lower boundary of the zone of influence (ZOI) as necessary for groves adjacent to, included in, or in any way affected by proposed site-specific projects, to protect the giant sequoia groves and their associated ecosystems. Survey stream channels where downstream riparian ecotype is unknown, assign the downstream ecotype(s), identify the nearest stable stream channel below the grove, and refine the ZOI based on this new information (North et al 2002).	X				X
18. Several adjacent groves are to be managed as if they were one large grove, the hypothetical perimeter line, as defined, shall be a single line around the outermost giant sequoia trees in the complex of groves, taken as a whole (MSA, p. 14, (2) (e) iii).)	X	X	X	X	X

[4] Using the grove allocation boundary defined for each alternative: Alternatives A and E—GIZ; Alternatives C and D—administrative boundary; Alternatives B and F—ZOI.

19. Restrict mechanical entry and vegetation management within grove administrative boundaries. The following mechanical/motorized uses will be permitted within the grove boundary line: a) use of existing roads, b) management in accordance with approved fuel load reduction plans, where clearly needed for ecological restoration and maintenance or public safety, c) use of light equipment to build and/or maintain trails, d) use of equipment to fight wildfires (use of heavy equipment off of existing roads will require Forest Supervisor approval), and e) use of battery-operated wheelchairs (MSA, pp. 7-8, 2.a.(1)). In Indian Basin Grove, there will be no felling of trees except for safety reasons in and near the Princess Campground area south and east of Highway 180 (MSA, p. 18, v)).	X	X		X	X
20. Restrict mechanical entry and prohibit the felling of trees within grove administrative boundaries. The following mechanical/motorized uses will be permitted within the grove boundary line: a) use of existing roads, b) management in accordance with approved fuel load reduction plans, where clearly needed for ecological restoration and maintenance or public safety, c) use of light equipment to build and/or maintain trails, d) use of equipment to fight wildfires (use of heavy equipment off of existing roads will require Forest Supervisor approval), and e) use of battery-operated wheelchairs (MSA, pp. 7-8, 2.a.(1)).			X		
21. Protect the named sequoias (such as the Boole Tree) from wildfires and fuels reduction activities. Protect these trees by pulling fuels away from the base of the tree or removing ladder fuels that can promote a crown fire in the named sequoia.	X	X	X	X	X
22. Continue to treat the Belknap/McIntyre/Wheel Meadow Grove Complex as one large grove. The Grove Boundary Team may consider a no tree felling, restricted mechanical entry zone that would extend north and east to Highway 190. The other boundaries of the grove shall include a 500-foot no tree felling, restricted mechanical entry zone outside of the hypothetical perimeter line of outermost giant sequoias of the grove within the final grove boundary line and an additional 500-foot grove zone of influence (MSA, pp. 16-17, (j) ii))..				X	
23. The Greater Evans Grove Complex shall be integrated into this complex and managed as one large grove in drawing the hypothetical perimeter line of outermost giant sequoias in the grove: Lockwood Grove, Evans Grove, Kennedy Grove, Burton Grove, Little Boulder Grove, and Boulder Grove. There shall be a 500-foot no tree felling, no mechanical entry zone outside of the hypothetical perimeter line of the outermost giant sequoias in the grove within the final grove boundary line and an added 500-foot grove zone of influence (MSA, p. 17, (j) iii)).				X	
24. The Freeman Creek Grove and Watershed: There shall be no tree felling or removal and no motorized vehicle use by the public anywhere in the Freeman Creek Grove Management Area. The Sequoia National Forest shall manage this area as a botanical area (MSA, p. 17, (j) iv)).				X	

25. All land areas outside of the Botanic Area but within the Freeman Creek Watershed, west of Lloyd Meadow Road, shall be managed by the Regulation Class II, single tree or small group selection uneven-aged management prescription. There shall be no green timber sales scheduled in the watershed west of the Botanic Area in this planning period. Existing plantations may be managed; provided, however that no management prescription outside and upslope of Giant Sequoias shall adversely impact the hydrology of the sequoias (MSA, p. 18, (b), Exhibit F).				X	
26. The Freeman Creek Trail from North Road to the Lloyd Meadow Road shall be designated as Sensitivity Level One (MSA, p. 18, (c)).				X	
27. The following groves shall have a 500-foot no tree felling or removal, restricted mechanical entry zone outside of the hypothetical perimeter line of the outermost giant sequoias in the groves within the grove boundary lines, plus an additional 500-foot grove zone of influence: Bearskin Grove, Big Stump Grove, Deer Creek Grove, Grant Grove, Landslide Grove, Long Meadow Grove, Packsaddle Grove, Peyrone Grove, Red Hill Grove, Redwood Mountain Grove, Starvation Creek Grove (MSA, p. 19, vi)).				X	
28. The following groves shall receive a 300-foot no tree felling or removal, restricted mechanical entry zone outside of the hypothetical perimeter line of the outermost giant sequoias in the grove within the grove boundary line, plus an additional 300-foot grove influence zone: Powderhorn Grove, Alder Creek Grove, Abbott Creek Grove, Cherry Gap Grove,Mountain Home Grove, and Cunningham Grove (MSA, p. 19, vii)).				X	
29. The Grove Boundary Team may reasonably adjust final boundaries of groves and/or grove influence zone, subject to final approval by the Forest Supervisor, either to expand or contract these zones, for a specific grove, so long as there is a rational basis for the adjustment (such as topographic features) and all participating team members agree to the adjustment (MSA, p. 22, (k)).				X	
30. With the exception of Converse Basin, these grove and grove zone of influence boundary line standards and guidelines are solely for the purpose of protecting the groves and the adjacent areas, and are not intended as a “release” or a management prescription for other areas of the forest, which shall be managed or protected as otherwise provided in the forest plan and in this agreement (MSA, pp. 22-23, (l)).				X	
31. Except as otherwise provided in the MSA, each grove, with final administrative grove boundaries determined as described herein, shall remain outside the suitable land base (MSA, p. 24, (5)).				X	
32. Within the Grove Influence Zone (GIZ), only Regulation Class II, single tree, small group uneven-aged management silvicultural prescriptions will be permitted both before and after final administrative Grove Influence Zone boundaries are identified; provided, however, that if a more protective management designation also applies to the area, or portions of the area (such as streamside management zones, SOHAs, etc.), the more protective designation shall govern what, if any, vegetation management is allowed in the Grove Influence Zone (MSA, p. 25, (1)).				X	
33. The Sequoia National Forest shall consider Regulation Class 2 helicopter single tree removal for tree removal operations outside and upslope of, and in close proximity to, a Grove (MSA, p. 26, (3)).				X	

34. The Sequoia National Forest shall manage the Freeman Creek Grove Management Area as a Botanic Area (MSA, p. 26, e. (1)).	X			X	X
35. Permit only the following mechanical/motorized use inside the grove administrative boundary line: • Expansion of the parking areas for trailheads (MSA, pp. 7-8, 2. a. (1))	X	X	X	X	X
36. For purposes of the MSA, the following mechanical/motorized uses only will be permitted inside an interim or final Grove boundary line: • Expansion of parking areas for trailheads; • Use of existing roads; • Use of light equipment to build and/or maintain trails; • Use of battery operated wheelchairs. (MSA, pp. 7-8, 2. a. (1))				X	
37. If any tree felling or removal is planned within 1,000 feet of any...final grove boundary, a special written notice shall be sent to the appellants. This notice shall include a topographical map that specifically: (a) locates the boundary of the proposed cutting unit, (b) locates the Forest Service...final grove boundary, (c) predicts the distance between the two, and (d) specifies a date and time, no sooner than 30 days, unless otherwise agreed upon, for the interested parties to accompany the Forest Service in the field to review the plan on the ground, with the objective to resolve differences prior to the preparation of an EA or EIS (MSA, p.23, (3)).				X	
38. In all situations where logging or road construction is planned outside of, but upslope of a grove, a special written notice shall be sent to all appellants during initial development of project alternatives. This notice shall explain fully the action proposed and shall include a topographical map which specifically: (a) locates the boundary of the proposed cutting unit or road to be built, (b) locates the grove boundary, (c) predicts the distance between the two, and (d) specifies a date and time, no sooner than 30 days, unless otherwise agreed upon, for the interested parties to accompany the Forest Service in the field to review the plan on the ground, with the objective to resolve differences prior to the preparation of an EA or EIS. The decision document for any such activity shall include a specific finding that the grove will not be harmed (MSA, pp. 25-26, (2)).				X	

39. All giant sequoias 3 feet or larger dbh in Converse Basin shall be preserved, regardless of any other permitted logging activity. Small giant sequoias may be cut along with other species (MSA, p. 27, e. (2)).				X	
40. Naturally-occurring giant sequoia trees (under 3 feet dbh) located inside of the Grove Influence Zone shall be protected from all logging operations, including specifically the root system. Every reasonable effort shall be made to protect naturally occurring giant sequoia trees (under 3 feet dbh) located outside of the Grove Influence Zone from road construction, cable logging, and other logging activities (MSA, pp. 20-21, xi)).				X	
Sugar Pine					
41. Silvicultural prescriptions are to consider means of maintaining the widest possible base of sugar pine genes. Generally, this means protecting as many sugar pine trees as possible while meeting land management plan objectives (MSA, Exhibit N, p. 4, G. 1.).	X	X	X	X	X
42. Continue to plant a modest mix (5-10 percent) of sugar pine along with other mixed conifer species. This may mean collecting seed from non-tested trees in order to maintain a sugar pine seedbank. With resistant stock this percentage could be increased (MSA, Exhibit N, p. 4, G. 2.).	X	X		X	X
43. Intensify the effort to collect sample cones from candidate resistant trees. This is a high priority (MSA, Exhibit N, p. 4, G. 3.).	X	X	X	X	X
44. Continue to protect trees that are known to carry resistance. Collect seed from these trees for our seedbank (MSA, Exhibit N, p. 4, G. 4.).	X	X	X	X	X
Young Stands, Including Plantations					
45. In young stands of trees, apply the necessary silvicultural and fuels reduction treatments to: (a) accelerate the development of old forest characteristics, (b) increase stand heterogeneity, (c) promote hardwoods, and (d) reduce risk of loss to wildland fire. Use mechanical fuels treatments to remove the material necessary to achieve the following outcomes if the treated plantation was to burn under 90th percentile fire weather conditions: (a) wildland fire would burn with average flame lengths of 2 to 4 feet, (b) the rate of fire spread would be less than 50 percent of the pre-treatment rate of spread, and (c) fireline production rates would be doubled. Achieve these outcomes by reducing surface and ladder fuels and adjacent crown fuels. Treatments should be effective for more than 5 years.	X	X			X

46. In plantations (timber strata classifications 0x, 1x, 2x, and 3x), apply the necessary silvicultural and fuels reduction treatments to: (a) accelerate the development of old forest characteristics, (b) increase stand heterogeneity, (c) promote hardwoods, and (d) reduce risk of loss to wildland fire. Use mechanical fuels treatments to remove the material necessary to achieve the following outcomes if the treated plantation was to burn under 90th percentile fire weather conditions: (a) wildland fire would burn with average flame lengths of 6 feet or less, (b) the rate of fire spread would be less than 50 percent of the pre-treatment rate of spread, and (c) fireline production rates would be doubled. Achieve these outcomes by reducing surface and ladder fuels and adjacent crown fuels. Treatments should be effective for more than 5 years.				X	
Hardwood Ecosystems					
47. During or prior to landscape analysis, spatially determine distributions of existing and potential natural hardwood ecosystems (Forest Service Handbook 2090.11). Identify hardwood restoration and enhancement projects.	X	X	X	X	X
48. During or prior to landscape analysis, spatially determine distributions of existing and potential natural hardwood ecosystems (Forest Service Handbook 2090.11). Assume pre-1850 disturbance levels for potential natural community distribution. Work with province ecologists or other qualified personnel to map and/or model hardwood ecosystems at a landscape scale (approximately 30,000 to 50,000 acres). Include the following steps in the analysis: (1) compare distributions of potential natural hardwood ecosystems with existing hardwood ecosystems; (2) identify locations where existing hardwood ecosystems are outside the natural range of variability for potential natural hardwood ecosystem distribution; and (3) identify hardwood restoration and enhancement projects.				X	
49. Manage hardwood ecosystems for a diversity of hardwood tree size classes such that seedlings, saplings, and pole-sized trees are sufficiently abundant to replace large trees that die and maintain mast production.	X	X	X		X
50. Where possible, create openings around existing California black oaks and canyon live oaks to stimulate natural regeneration.	X	X	X		X
51. Retain the mix of mast-producing species where they exist within a stand.	X	X	X		X
52. Retain all blue oak and valley oak trees except where: (a) stand restoration strategies call for tree removal; (b) trees are lost to fire; or (c) tree removal is needed for public health and safety.	X	X	X	X	X
53. When planning prescribed fire or mechanical treatments in hardwood ecosystems: (a) consider the risk of noxious weed spread and (b) minimize impacts to hardwood ecosystem structure and biodiversity.	X	X	X	X	X
54. When planning prescribed fire in hardwood ecosystems, consider the risk of noxious weed spread and public health and safety.		X	X	X	
55. In mixed conifer - hardwood stands, leave at least 20 square feet per acre basal area of oaks where this currently exist (MSA 1990, p.30, 3.a.).				X	
56. Where it currently exists in pure hardwood stands, maintain a minimum average of 50 square feet per acre basal area. Leave heavy mast-producing trees in any harvest of oaks (MSA 1990, pp.30-31, 3.b.).				X	
57. Where it currently exists, leave a minimum of 30 square feet per acre basal area of oaks in mixed conifer hardwood stands identified as key deer areas (MSA 1990, p.31, 3.c.).				X	
58. In mixed conifer -hardwood or hardwood stands, favor retention of oak trees exhibiting active use as cavity nesting sites or granaries (MSA 1990, p. 31, 3.e.).				X	

Environmental Consequences

The effects analysis for vegetation focuses on the potential effects of the alternatives on the vegetation itself, as well as the growth environment of trees including growing space, soils, and moisture. This section also discusses the potential effects on Monument ecosystems in terms of ecological restoration, resiliency, heterogeneity, giant sequoia regeneration, and carbon sequestration. The ecological effects of the alternatives are spatially bounded by the outermost perimeter of the Monument. The effects are primarily analyzed for the first two decades of projected treatments for each of the alternatives. Beyond two decades, the analysis of effects becomes more speculative given the unpredictable nature of the environmental and management factors, such as climate change and budget levels.

Assumptions and Methodology

Ecological Restoration

The Forest Service definition for ecological restoration is found in the Forest Service Manual, Chapter 2020, Ecological Restoration and Resilience (FSM 2000, August 30, 2011). It defines restoration as:

> The process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed. Ecological restoration focuses on establishing the composition, structure, pattern, and ecological processes necessary to facilitate terrestrial and aquatic ecosystem sustainability, resilience, and health under current and future conditions.

The Pacific Southwest Region Ecosystem Restoration goal states, in part, that:

> Our goal for the Pacific Southwest Region is to retain and restore ecological resilience of the National Forest lands to achieve sustainable ecosystems that provide a broad range of services to humans and other organisms.

The Clinton proclamation also identifies a role for forest restoration. It states, in part, that:

> These forests need restoration to counteract the effects of a century of fire suppression and logging. Fire suppression has caused forests to become denser in many areas, with increased dominance of shade-tolerant species. Woody debris has accumulated, causing an unprecedented buildup of surface fuels (Clinton 2000).

Modern restoration approaches use historical information as a guide, not as a precise set of specifications. Inferences gleaned from historical forest structure and composition can advise current project designs, but must be adjusted to confront current conditions and a different future climate.

Use of Science

The scientific approach used to disclose effects was based on quantitative, tested, and applied forest science. The research findings of other scientific investigators served as tools that helped guide predictions and explain why a certain response might be expected. These references are found as citations throughout the section. A wide variety of references were carefully reviewed to assure proper research methodology was used and to understand how they relate to the Monument. Some of the more recent studies were examined and are discussed in detail in this analysis. The Sequoia National Forest resource database was used as a tool in this analysis, as the best forest-level information available. In addition, this analysis considered the advisories of the Scientific Advisory Board, as follows.

Scientific Advisory Board (SAB) Advisories

Advisory III. Desired Conditions

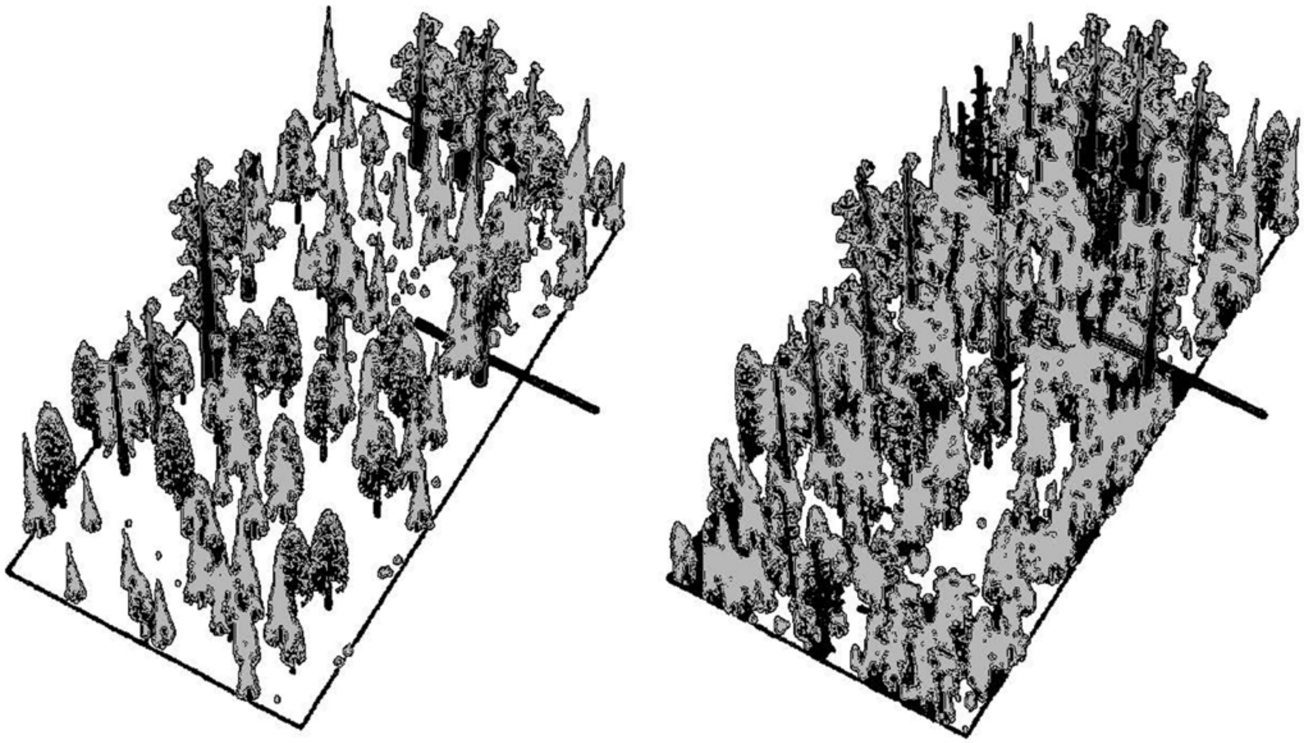
> The overriding desired condition for vegetation is one that exhibits both stability and resilience, while best maintaining native biodiversity. That is, the overriding goal for vegetation is the ability to resist stressors (stability) and to recover from stresses once they occur (resilience). The presidential proclamation itself speaks of “restoring natural forest resilience” in the Monument (The Scientific Advisory Board 2003, Advisory III).

The current growing conditions for vegetation ecosystems have been altered from that which existed prior to 1875. For example, current atmospheric CO2 concentration is the highest it has been in at least 420,000 years (Scientific Advisory Board 2003, Advisory III). Global temperature is rising, and the 1990s was probably the warmest decade in the last 1,000 years (Mann et al. 1998; IPCC, 2001). In the Sierra Nevada, current temperatures are also rising, and are among the warmest of the last millennium (Graumlich 1993). Rising temperatures, especially the average annual minima, are also apparent in the southern Sierra Nevada in the past century (Meyer and Safford 2011; see Appendix C).

Mixed conifer forests are subject to recurring interactions from a wide range of environmental events (“stressors” to ecosystems) such as insects, diseases, and drought. One possible strategy to ensure that these forests are resilient to these agents is to restore forest structural conditions and ecological processes characteristic of fire-adapted forests, including some general conditions that existed prior to 1875. For instance, under lower stocking conditions, there is less inter-tree competition for available sunlight, soil moisture, nutrients, and growing space. This reduced competition allows trees to 1) be more stable and resistant to severe alteration by stressors and 2) be more resilient as they respond to stressors. Currently, much of the forested landscape is much denser and has much more surface fuel than in pre- 1875 conditions which reduces the forest’s resilience to catastrophic wildfire and other stressors. However, restoration of strict forest structural characteristics to pre-1875 conditions will not guarantee sustainability of our forests in the future with changing climate (Stephens et al. 2010). Instead, understanding the ecological processes that have shaped forests (for example, fire) may provide important clues as to the critical features of resilient forest ecosystems (North et al. 2009). For instance, research suggests that heterogeneity in spatial patterns of forest structure and fuels (including live tree, snag, fuel, coarse woody aspect of fire-resilient forests (Stephens et al. 2010). Increasing the proportion of fire-adapted pines (e.g., ponderosa pine, Jeffrey pine) and reductions in tree densities (especially in the smaller size classes) are additional characteristics of resilient forests that may be more resilient to future changes in climate (North et al. 2009, Stephens et al. 2010, Peterson et al. 2011).

The work of Dr. Tom Bonnicksen in Redwood Mountain Grove also provides insight into the change in stand conditions over the last 100 or more years. The following figure shows the current stand conditions on the right. Note the lack of openings and the generally dense smaller trees. The figure on the left is Dr. Bonnicksen's rendition of the structure of the same stand approximately 100 years ago. Note the scattered openings in the stand and the lower tree densities.

Computer-Generated Picture of a 2.5-Acre Portion of Redwood Mountain Grove



On the right is the forest structure based upon actual stand data as of 1983. On the left is an estimate of how the grove might have looked under pre-1875 environmental conditions.

Based on this advisory, the overriding desired condition for vegetation is to promote forest resilience and regional native biodiversity by restoring key ecological processes, reducing tree densities, promoting spatial heterogeneity, and favoring fire-adapted species (such as pines, oaks, and giant sequoias). The effects analysis for vegetation compares the alternatives by how each alternative would protect the giant sequoias, and promote stand resilience and heterogeneity.

Advisory IV. Restoration of the Natural Fire Regime

> Develop a decision tree to help determine which methods of forest restoration and maintenance should apply at different locations.

A decision tree has been developed and included in this FEIS in Appendix A.

Advisory V. Prioritizing Areas of Land

Areas within the Monument must be prioritized for management action. There is value in using an explicit, quantitative scheme to identify areas most in need of management action, such as restoring pre-1875 fire regimes and forest structure (Caprio et al. 1997; Keifer et al. 2000). Such a scheme would probably consider (but not necessarily be limited to) some weighted combination of:

1. **Hazard** of catastrophic stress, such as stress by severe wildfire. Factors to consider would likely include (but not necessarily be limited to) fuel load, ignition probability, stand density, fire ladder, adjacent vegetation types, and current vegetation mosaic.
2. **Risk** to values and objects of interest. Factors to consider would likely include (but not necessarily be limited to) water quality, erosion, sensitive species, public safety, ceremonial and traditional uses, and identification as objects of scientific or historical interest.
3. **Ecological Need:** Factors to consider would likely include (but not necessarily be limited to) number of fire cycles missed, biodiversity, and deviation from pre-1875 vegetative structure, composition, and function.
4. **Feasibility:** Factors to consider might include (but not necessarily be limited to) economic, site access, legislated land designations, and social acceptance.

It is unreasonable to expect that a thorough, fine-grained prioritization of management areas will be included in the first Monument management plan. However, at a minimum, the plan should include the determination to set priorities plus the factors to be considered for prioritizing areas, or better yet, a quantitative scheme to be used in the prioritization.

Areas are prioritized for treatment in the Monument based on protection of the objects of interest, public safety, and ecological restoration. These areas are prioritized differently by alternative as shown in the Fire and Fuels Strategies for Ecological Restoration (Chapter 2; Alternatives Considered in Detail; Desired Conditions, Strategies, and Objectives; Fire and Fuels Strategies, Strategies for Ecological Restoration). The decision tree used for each site-specific project proposed in the Monument considers the above four factors, assessing risk and effectiveness (Chapter 2, Alternatives Considered in Detail, Readers Guide to Alternative Descriptions, Ecological Restoration, Decision Tree).

Advisory XI. Sequoias

Adherence to the Sierra Nevada Framework guidelines may not enable gap development through mechanical means as no tree greater than 20 inches can be removed.

Failure to regenerate giant sequoia could adversely affect the long-term sustainability of the giant sequoia ecosystem (The Scientific Advisory Board 2003, Advisory XI).

The effects analysis for Vegetation compares the alternatives in terms of stand resilience and the need to provide openings (gaps) and other disturbances for giant sequoia regeneration. Numerous studies are referenced in describing what changes are needed to help accomplish desired conditions. Gap size is discussed in terms of adjacent tree heights and the likely effects on regeneration of desirable tree species. Gap size is also discussed in relation to recent studies by York et al (York 2009) (see the Giant Sequoia Regeneration sections that follow).

Advisory XIII. Local Market

> Seek ways of building trust that mechanical thinning, when necessary, is ecologically motivated and not economically motivated, and that economic feasibility is critical to forest restoration efforts.

This effects analysis for vegetation stresses the importance of ecological restoration as defined by the Forest Service and the Pacific Southwest Region, and the role of restoration identified in the Clinton proclamation (see Ecological Restoration section above). Strategies specific to ecological restoration are included for both Vegetation and Fire and Fuels (see Desired Conditions, Strategies, and Objectives section of Chapter 2). In addition, a section on ecological restoration has been added to Chapter 2 that includes definitions, types of treatments being considered, and clearly needed criteria (see the Ecological Restoration section of Chapter 2). The Socioeconomics sections of Chapters 3 and 4 discuss and analyze the effects of Monument management on local economies and markets.

Advisory XX. Definition of Treatment

> Include a glossary with the Draft Environmental Impact Statement and other documents as needed (The Scientific Advisory Board 2003, Advisory XX).

Definitions of the types of treatments or tools proposed for use in the Monument are included in 1). The order of priority for these tools: managed wildfire, prescribed fire, and mechanical treatment, are shown for each alternative in its alternative description, as well as in the Vegetation Strategies for Ecological Restoration (Chapter 2; Alternatives Considered in Detail; Desired Conditions, Strategies, and Objectives; Vegetation Strategies; Strategies for Ecological Restoration).

Advisory XXIV. Trade-offs

> In a single, stand-alone section of the EIS, thoroughly compare and contrast the ecological trade-offs between prescribed fire and mechanical thinning (including hand treatments).
>
> With reference to this stand-alone section, make evident which ecological trade-offs between prescribed fire and mechanical thinning were considered important in weighing the alternatives. Deemphasize those that are of little or no ecological consequence, such as precision in gap formation, and emphasize those that might have important ecological consequences, such as invasive species, native species, soils, and pathogens, while considering uncertainty (see above). Reevaluate the Alternatives in this light (The Scientific Advisory Board 2003, Advisory XXIV.).

The trade-offs section below discusses the potential ecological trade-offs between prescribed fire and mechanical treatments.

Assumptions for All Alternatives

Key Modeling Assumptions

The SPECTRUM model was used to help quantify these effects. Spectrum is a computer-based analytical tool for building natural resource management models. The results were used by the interdisciplinary team to help identify the potential effects that are expected from each alternative and to help distinguish differences in effects between the alternatives. This section describes the assumptions used to estimate the number of acres that would be treated per year. The number of acres treated per year is based on the projected budget and standards and guidelines for each alternative. The estimated acres of treatments were used as approximations for comparing the alternatives. For more information related to the modeling effort used for this effects analysis, see the Modeling Overview in Appendix H of this FEIS.

- Wildfire would continue to burn portions of the Monument, with the projected annual rate based upon historical data.

- Mechanical treatments for restoration purposes (promoting resiliency and heterogeneity) will be followed by prescribed fire.

- Most treatments in the first two to three decades would implement strategies to protect the objects of interest and communities from unwanted fire, a priority consistent with the Framework and supported by many members of the public, both locally and nationally.

- Initial treatments to protect the objects of interest and communities would be completed in approximately 20 years. As the initial treatments are completed, the emphasis would shift to restoration and maintenance treatments (re-treatment of areas already treated to maintain desired fuel conditions and to restore a frequent fire return interval).

- While the modeling was done for 15 decades to evaluate long-term trends, the model effectively simulates treatments for only the first two to three decades.

- The Monument budget for vegetation management was assumed to be two million dollars per year.

- The modeling assumes that the assessment of potential treatments meeting the clearly needed criteria can only be made at the site-specific project level, considering the specific context of the purpose and need for action. The modeling assesses the capacity of each alternative to provide areas potentially suitable for a “Clear Need” evaluation while meeting the intent and theme of the alternative.

Effects Assumptions

- Reducing inter-tree competition will result in increased resilience of forest trees to stresses associated with multi-year drought and a warming, potentially drier, climate.

- While it is sometimes said that fire 'thins' forests, it is not the same as thinning accomplished by mechanical methods. Both result in the death of trees, however, selective mechanical cutting allows for precision that cannot be achieved otherwise. Per acre tree numbers are reduced in both cases, however the resultant spatial arrangement obtained with mechanical methods can favor selected trees in ways that fire is unable to.

- Fire is the only feasible method to significantly reduce surface fuel levels.

- The use of fire, alone, or in combination with mechanical treatments, can promote understory plant development.

- Mechanical treatments are unlikely to completely mimic the ecological processes that are associated with historical fire effects.

Trade-offs

It is assumed that there are advantages and disadvantages ("trade-offs") to be considered in the decision to use either fire or mechanical treatments in conducting ecological restoration activities. These trade-offs are based on different site factors and conditions. In order to meet project objectives, fire may be a desirable tool on one site and mechanical may be desired on another (or a combination of the two methods). The intensity of prescribed fire is more challenging to control on a tree-by-tree basis as compared to mechanical methods, where vegetation can be carefully selected by operators. Prescribed fire behavior is responsive to a wide variety of conditions that are not easily predicted or controlled. These conditions include: changing weather conditions and variations in fuel conditions within burning areas. There is inherent risk in using prescribed fire given the many variables that dictate the intensity of the fire. A prescribed fire with planned low intensities can revert to high intensities, resulting in an unintended loss of tree species, soil protection, greatly increased erosion, nutrients, and site productivity (Gill and Allen 2008, Kaufmann et al. 2005, Stephens and Fule 2005), not to mention risk to life and property.

Managed fire can reduce smaller trees and surface accumulations of woody debris. Light to moderate burning will reduce smaller shade tolerant species that may otherwise provide a vertical ladder for crown fires, take up moisture and nutrients, or block sunlight for regeneration of other species. Severe burn intensities often result in killing individual or groups of larger trees. Burns that kill scattered individual larger trees will create small canopy gaps that may serve to provide growing space or areas for regeneration and growth of other species. Burns that kill large groups of trees may result in stand replacement. These more severe burns are most likely to expose soils to erosion and a loss of productivity including deterioration of moisture holding properties and a loss of nutrients in an ecosystem as a result of volatilization, leaching, or runoff. Weakened trees not killed by more severe fire will be more susceptible to bark beetle attack. Erosion, insect and disease effects, accumulations of vegetation debris, and decomposition are natural ecological processes.

Stephens et al. (2009) on page 315 noted, "Mechanical plus fire treatments were effective in reducing fire severity in the Cone Fire (Skinner et al. 2004, Ritchie et al. 2007), the Rodeo Chediski Fire (Strom 2005), and the Biscuit fires (Raymond and Peterson 2005) as well as other wildfires (Omi and Martinson 2004) in the western United States. In addition, fire-only treatments were effective at reducing fire severity on the Hayman Fire (Graham 2003), the Rodeo-Chediski Fire (Finney et al. 2005), and other fires (Biswell 1989)…" Fuels have built up in the Monument and will continue to do so until treatments are allowed or nature reacts with wildfire. As fuel loads increase, burning will be more difficult. Stephens et al. (2009) warned, "… effectiveness of prescribed burn treatments will likely decline more rapidly over time as surface fuels accumulate (Finney et al. 2005, Skinner 2005)."

The weight of existing scientific evidence indicates that mechanical (hand cutting or self-propelled) followed by prescribed burning treatment is generally the first restoration choice where excessive fuels and small shade tolerant trees have accumulated in Western forests, and that special circumstances will be needed to justify burning or thinning only. The 15 different investigators familiar with fuels and forest management in the study by Schwilk et al (2009) recognized substantial "downsides" to burning on page 300. No "downsides" were singled out for mechanical treatments since these treatments generally accomplish surface and ladder fuels reduction. They stated, "The burning-only treatment also led to large numbers of snags (saplings and trees) that will fall over the next several years to decades, increasing the amount of fuel loading once again (Skinner 2005, Stephens and Moghaddas 2005b)…. Multiple sequential burns may be required before the fuel loading and the rate of accumulation of fuels are maintained at lower levels (Keifer et al. 2006)." Schwilk et al. (2009) on page 300, with a similar conclusion on page 301, "At the western sites, the combined mechanical plus burning treatment generally produced stand structures with fewer ladder fuels (saplings) and lower rates of fuel accumulation (i.e., fewer snags that remain to fall and less twig and litter fall from live trees due to reduced basal area), leading to more rapid development of conditions resilient to wildfire (Stephens et al. 2009)." Schwilk et al. (2009) summarized, "Without burning to treat the surface fuels, many of these mechanically thinned stands might resist crown fire initiation and spread, but could still be lost as a result of excessive heating and crown scorch in a wildfire (Agee and Skinner 2005, Ritchie et al. 2007)." Similarly, Stephens et al (2009), with 8 of the same authors as found in the report by Schwilk et al. (2009) recognized on page 316, " although mechanically treating stands may enhance suppression capabilities by reducing crown fire potential, fire effects in these stands may be severe (Figs. 4–6), primarily due to high residual surface fuel loads..."

When considering mechanical methods that employ heavy equipment, there are trade-offs to be considered with regard to road accessibility, effects to soil, steep slopes, and costs. These factors need to be evaluated at the project level to determine the benefits and adverse effects as compared to using prescribed fire alone or in conjunction with mechanical methods.

In practice, mechanical treatments will often be followed by prescribed fire to further treat fuels accumulations. Burning may be delayed by a few years or more in stands of younger trees that are more susceptible to crown scorch or main stem injury. Slash may also be piled and burned to reduce risk to desirable trees. In some instances, fire could provide safe and adequate treatment of fuels without mechanical treatments. Mechanical treatments may also replace fire under certain conditions.

Mechanical treatments with or without fire have resulted in successful natural regeneration of giant sequoia. A hot fire is often necessary for maximum natural sequoia regeneration, but resource trade-offs must be considered (see Effects of Alternatives on Giant Sequoia Regeneration section below).

More acres of prescribed fires than mechanical treatment are projected in Alternatives B, and C. Wildfire is predicted to occur on more acres than prescribed burning or mechanical treatments. With concerns about a warmer climate, increased emphasis on carbon sequestration, and increased concerns about the restrictions and effects of smoke management, it is essential to consider many alternative methods to reduce the increasing surface and ladder fuels that are building up in the Monument. It is important to note that mechanical treatments would often include a follow-up treatment to further reduce surface and/ or ladder fuels. Mechanical treatments would be designed to prepare certain sites for safe use of fire and it is anticipated that many stands can be managed with fire only after the mechanical treatments have helped to restore lower fuel loadings.

Fire and/or mechanical treatments are commonly used to achieve ecological restoration goals. While frequently used in combination, they are often portrayed as mutually exclusive in the debate between process versus structural restorationists.

Preliminary results from the Fire and Fire Surrogate Study were that "Mechanical treatments followed by burning produced the strongest result at most sites, with more resilient forest structures..., lower surface fuel loads, and reduced rate of accumulation of surface fuels. If burning alone were the only management option, additional burns might over time reduce tree densities and fuel loading, but the mechanical plus burning treatments achieved this condition more rapidly (Schwilk 2009).

The authors concluded that "Overall, the desired response of the ecological variables presented in this paper to fuel treatments involving burning and/or mechanical treatments was generally maximized by the combined mechanical plus burning treatments. These treatments produced desired changes in stand structure, while reducing surface fuel loading and rate of fuel accumulation in the near-term, and also increasing native understory herbaceous species diversity. Because mechanical plus burning treatments also appeared to favor alien herbaceous species invasion, this negative may need to be balanced against the positive attributes where alien species present particular management issues (Schwilk 2009)."

While the combination of mechanical and prescribed fire treatments can be effective, Schwilk et al, notes that "It is unlikely that the varied ecological roles of wildland fire can ever be entirely replaced by mechanical thinning. However, in today's fuel-rich environments, even prescribed fire may lead to ecological outcomes that differ from historical wildfires. Mechanical harvesting may help to create conditions that allow subsequent prescribed burning (and perhaps wildland fire) to accomplish fire-related objectives more precisely and rapidly than burning alone, but mechanical treatments may not be able to mimic ecological effects of fire such as soil heating."

Collins et al. (2011) concluded, “Based on our results it appears that if restoration of historical forest structure is an objective and fire alone is the tool then initial fires need to be intense enough to kill trees in the lower and intermediate canopy strata. While fires of lesser intensity likely will reduce surface fuels and understory trees which is important in reducing potential tree mortality from fire (Agee and Skinner 2005, Stephens et al. 2009a) and possibly maintaining desired forest conditions once achieved initially, they may not be sufficient alone to achieve historical forest structure given the substantial tree establishment that occurred during the fire exclusion period (Collins and Stephens 2007).”

Restoration treatments in the Monument will likely be followed by slash disposal either by burning, removal, or by redistribution. Schwilk et al. (2009) on page 300, with a similar conclusion on page 301, “At the western sites, the combined mechanical plus burning treatment generally produced stand structures with fewer ladder fuels (saplings) and lower rates of fuel accumulation (i.e., fewer snags that remain to fall and less twig and litter fall from live trees due to reduced basal area), leading to more rapid development of conditions resilient to wildfire (Stephens et al. 2009).” Schwilk et al. (2009) summarized, “Without burning to treat the surface fuels, many of these mechanically thinned stands might resist crown fire initiation and spread, but could still be lost as a result of excessive heating and crown scorch in a wildfire (Agee and Skinner 2005, Ritchie et al. 2007).” Similarly, Stephens et al (2009), with 8 of the same authors as found in the report by Schwilk et al. (2009) recognized on page 316, “ although mechanically treating stands may enhance suppression capabilities by reducing crown fire potential, fire effects in these stands may be severe (Figs. 4–6), primarily due to high residual surface fuel loads...”

Resiliency

The Society of American Foresters defines resilience as ‘the capacity of a (plant) community or ecosystem to maintain or regain normal function and development following disturbance.” Multiple disturbance agents will influence the vegetation within the Monument. Large wildfires and periodic multi-year droughts, with associated bark beetle infestations, have been the most easily recognized, although more subtle effects are brought about by windthrow, root disease, and limited fire spread lightning strikes. Actions can be taken to provide for resilience including modifications to species composition, tree density, and arrangement.

- Reducing stand density, increasing tree resilience by providing access to increased levels of soil moisture and growing space, is an effective method to reduce bark beetle-related mortality (Fettig et al., 2007) Slower growing trees appear to be more susceptible to successful attack by the western pine beetle (Craighead, 1925). In general, the subordinate crown class trees, including the intermediate and suppressed classes, are growing more slowly than the codominant and dominant crown class and would be expected to be more susceptible. Beyond crown class, crown ratio can also indicate individual tree resilience. Sartwell (1971) illustrated a strong relationship between trees with crown rations of 30 percent or less and bark beetle-related mortality.

- Larger trees, in stands regarded as representative of old-growth forests developed in nearly a century of fire exclusion, are also susceptible to bark beetle-related mortality (Guarin and

Taylor, 2005). Similarly, Lutz et al. (2009) described increased old-growth forest mortality rates throughout western North America.

- With regard to resilience in the context of wildfire, removal of smaller conifer trees that can act as ‘ladder fuel’ decreases the potential extent of stand-replacement, providing for higher levels of overstory tree survivorship. Some hardwoods would be top-killed in a wildfire, but may resprout from their surviving root system and reestablish as dominant trees (Tappeiner and McDonald 1980, Fites-Kaufmann et al. 2006).

- The degree of thinning with prescribed fire is less predictable than it is with mechanical treatment. Monitoring data from the adjacent Sequoia and Kings Canyon National Parks indicates a 61 percent reduction in tree density in the mixed conifer-giant sequoia forest after prescribed fire treatment (USDI, 2001). A similar effect would be expected under all action alternatives if mechanical treatments are used, as site conditions in the Monument are similar to those in this national park.

- Fuel loading would be reduced. According to fire management personnel at Sequoia and Kings Canyon National Parks, post-burn fuel loading levels in mixed conifer forests are reduced by approximately 40 to 50 percent, depending on the species composition of the mixed conifer forest. Treatments would also lead to a reduced risk of uncharacteristically severe fire.

- The density of shade-tolerant species, such as white fir and incense cedar, would be reduced. Conversely, shade-intolerant species would increase, as more openings are created by fire and/or mechanically, and pines, hardwoods, giant sequoias and other shade intolerant species become established.

Heterogeneity

Stephenson (1999) described heterogeneity as a logical product of past periodic fire events that were often small and patchy. Craighead (1925) associated patches of pine to be the result of group-killing by the western pine beetle. Bonnicksen and Stone (1982) concluded that this heterogeneity may not be easy to accomplish with just fire since fuel accumulations have been widespread and uniform. Given the wide range of conditions (e.g., slope, access), it is likely that a combination of mechanical treatments and prescribed fire will most effectively accomplish structural heterogeneity desired conditions, while more safely reintroducing fire and encouraging small patches of giant sequoia and other shade intolerant species to regenerate.

- Promoting heterogeneity in vegetation is a key part of the desired conditions and objectives for vegetation. Increased heterogeneity is achieved by moving towards desired conditions for species composition, greater structural diversity in the form of openings within the forest matrix, and increased diversity of vegetation seral stages. Greater heterogeneity will improve the resiliency of ecosystems to withstand and adapt to changes in their environment. Increasing the resiliency of vegetation to environmental stresses is a key part of the desired condition and objectives. Activities that create openings for regeneration, reductions in ground and ladder fuels, growing space and nutrition for featured trees, and access for management and recreation are likely to lead to sustainable ecosystems that are resilient. Managing the growing space of vegetation for the most suitable structure and composition of vegetation would improve resiliency and would help maintain these ecosystems during times of drought or other natural stress events such as insect attacks or diseases. Treatments emphasizing resiliency, including fuels reduction, would play a major role in restoring these forest ecosystems to the desired conditions.

- Heterogeneity will improve by increasing structural and species diversity, reducing the risk of damage from wildfire, and re-introducing fire. The extent and intensity of these effects will vary by alternatives. There is an element of uncertainty as to the scope and amount of these effects because of the difficulty in predicting fire behavior and variations in fuel loading and burning conditions. In addition, alternatives that do not provide for mechanical treatments in conjunction with prescribed fire, or which limit the size of tree that can be removed (i.e., diameter limits), would affect the ability to quickly alter stand structure.

Giant Sequoia Regeneration

- In areas where fire intensity or soil disturbance is high, soil will be exposed, providing favorable conditions for the establishment and growth of early seral stages of giant sequoias, other conifers, and other vegetation (brush, forbs, etc) (York et al. 2004, Meyer and Safford 2011b).

- Patches of new vegetation will become established, and shade-intolerant species such as giant sequoias, pines, and certain hardwoods will often increase in response to prescribed fire or thinning treatments that create canopy openings (Zald et al. 2008, York et al. 2004). There may be sprouting from the stumps of fire-top-killed oaks (primarily black oak) leading to new age classes of hardwoods (McDonald 1969, Fites-Kaufmann et al. 2006). The re-introduction of fire is expected to begin a shift in species composition in favor of shade-intolerant species as openings are created in the canopy of conifer forest types. These effects have been described in project documentation from the Sequoia National Park (USDI 2001). Specifically, giant sequoia regeneration is expected to increase.

  The creation of openings will lead to the establishment of young mixed conifer vegetation that will include giant sequoias and pines (York et al. 2010, Meyer and Safford 2011b). In openings close to seed-bearing giant sequoias, giant sequoia seedlings will become established, along with other naturally-occurring species (Demetry and Duriscoe 1996). Long-term survival and growth of shade-intolerant species will be more reliable in openings larger than ¼ acre, due to the more open conditions toward the middle of openings (away from the edge effect of adjacent large trees) (York et al. 2003). It is likely that initial prescribed burning treatments for protection or restoration purposes will lead to a change in composition in both the smaller and larger diameter classes (Sequoia National Park 2002, Kiefer et al 2001). Giant sequoia regeneration may also increase substantially following second-entry burns (Webster and Halpern 2010).

- It will be important to assure ample sunlight in openings where ponderosa pine and other shade-intolerant species are desired (York et al. 2010). This will help assure favorable growth and may improve long-term resistance to drought, bark beetles, and root pathogens. Larger openings in the upper canopy will often provide conditions that promote giant sequoia and pine regeneration (York et al. 2004).

- It has long been known that fire can prepare a site, stimulate natural regeneration, and promote growth of giant sequoia (Stephenson 1996). This is a function of many factors, such as the amount of soil moisture throughout the warmest season (York et al. 2003, Shellhammer and Shellhammer 2006). The exposure of mineral soil and the opening of the canopy, attributed to harvesting, has been associated with successful sequoia regeneration (Kilgore and Biswell 1971, Harvey et al. 1980). Years of below average precipitation may reduce the chances for these conditions to occur, regardless of the method of treatment (Stephens et al. 1999, York et al. 2010). The poor success of giant sequoia regeneration over recent decades may be related to a reduction in favorable soil surface and light environments and poor seedfall timing. In addition, the intensity of fire, early snowmelt, and increased summer heat on exposed sites may further reduce regeneration success (Harvey et al. 1980). The most likely limiting factor, however, is a combination of light and soil moisture availability (Stark 1968, York et al. 2003). While giant sequoia seedlings exhibit a certain degree of tolerance towards shade and drought (Stark 1968) and can establish in relatively small canopy openings (York et al. 2010), it also displays that the juvenile vegetation shading will reduce sequoia seedling growth after the first year or two of establishment (York et al. 2010). Where low-severity fire is the only disturbance in the last twenty years, patches of sequoia regeneration are rare in groves (Mutch and Swetnam 1995, Meyer and Safford 2011b).

Survival of one-year-old planted sequoia seedlings in open, burned areas with 50 percent survival in August 2009 due to dry upper soils and exposure to heat.

Survival of identical sequoia seedlings in moist soils with 70 percent shade from vegetation was 100 percent in August 2009.

- Sequoia seedlings recently planted in the current drought showed low to moderate survival in the first year in burned openings on mesic sites. The first photo above shows a healthy seedling in an area with productive sandy loam soil. The soil moisture was 1.7 percent (volumetric) in late August and survival was 50 percent. A similar site one mile away with 1.6 percent soil moisture had 13 percent survival. The second photo above is from a more mesic site with more vegetation and an average shading of 70 percent. These seedlings, from an identical seed source, had 100 percent survival and displayed the best growth even when overtopped by other vegetation. The soil moisture in August 2009 was 14 percent (volumetric).

- Trials with seedlings, from the same lot, also examined the effects of exposure to heat. Seedlings grown in hot, direct sunlight stopped growing in June 2009 even when soils were moist. Seedlings growing in 70 percent shade, with the same amount of soil moisture grew more and had better survival. Based on field observations, future programs to promote sequoia regeneration will need to consider the interactions between temperature and moisture that might be expected with a warming climate (Hanna pers. comm.). Based on these observations, the best approach for a large program to promote new giant sequoias will be to plant in years with higher moisture and cooler temperatures.

- Although first year survival may be better with shade, established sequoia trees grow faster in full sunlight. The pole-sized sequoias in the photo below were planted in larger openings in Long Meadow Grove and have grown rapidly in full sunlight. Sequoias that have established and remain in the canopy of other vegetation will grow much slower. A giant sequoia sapling (1-4-inch diameter tree) may survive for decades in the shade of other trees or shrubs. In many cases, it will eventually die from shading.

- Canopy gap size directly influences the growth and density of giant sequoia and other conifer regeneration (York et al. 2004, Meyer and Safford 2011b). Growth rates of giant sequoia regeneration increases with greater light availability associated with increased gap size (0.1 to 1 acre) and greater distance from gap edge (York et al. 2010).

Although first year survival may be better with shade, established sequoia trees grow faster in full sunlight such as these planted sequoias in larger openings in Long Meadow Grove.

Direct Effects

There are no direct effects on vegetation from the alternatives in this programmatic plan because no site-specific projects are proposed.

Indirect Effects

Protection of the Objects of Interest

In all alternatives, a combination of mechanical and fire treatments would help protect the giant sequoias and surrounding forest ecosystems from drought, insects, disease, and unwanted fire.

All alternatives allow a managed control of tree density and fuel burning which would help protect forests from drought, insects, and fire. Alternatives E and F have the fewest restrictions on vegetation management designed to meet the purpose and need. Alternatives C and D have the most restrictions on mechanical vegetation management.

Resiliency

Alternatives C and D are not likely to result in as much stand density reduction for forest health and protection from severe wildfire. These alternatives rely mainly on fire and would have a reduced chance to positively affect resiliency.

Alternatives A, B, E, and F promote a combination of the use of fire and mechanical treatments for resiliency.

Alternative F is more likely to improve forest resilience, as it permits the most flexibility in treatment methods. The ability to remove larger trees where necessary for forest health and resiliency would result in reduced competition between trees and faster growth in remaining trees.

Vegetation Types

All of the alternatives move vegetation toward the desired conditions for vegetation (see Chapter 2, Vegetation Desired Conditions). The SPECTRUM model projects the estimated changes in the amount of early, mid, and late seral stages that could result from vegetation management over the next 20 years for mixed conifer forest, giant sequoias, montane hardwood-conifer, and red fir vegetation types.

In the mixed conifer forest, early seral stage vegetation is estimated to increase 450 to 650 percent in all alternatives. Mid seral stage of this vegetation type is expected to decrease in all alternatives, ranging from a reduction of 35 percent in Alternative E to a 50 percent decrease in Alternative A. The amount of late seral stage is estimated to increase in all alternatives, ranging from a 17 percent addition in Alternative A to approximately 35 percent in Alternatives B, E, and F.

In giant sequoias, early seral stage vegetation estimates are very low. This is discussed further in the following section on giant sequoia regeneration. Mid seral stage of giant sequoias is expected to decrease in all alternatives, ranging from a reduction of approximately 40 percent in Alternatives C and D to about 55 percent in Alternative A. The amount of late seral stage is estimated to increase in all alternatives, ranging from a five percent addition in Alternative C and D to between seven and eight percent in Alternatives A,B, E, and F.

In montane hardwood-conifer, early seral stage vegetation is projected to increase two to four percent in Alternatives A, B and F; four to six percent in Alternatives B and E; and approximately 15 percent in Alternatives C and D. Mid seral stage of this vegetation type is expected to decrease in all alternatives, ranging from a reduction between seven to 10 percent in Alternatives A, B, E, and F to a 15 percent decrease in Alternatives C and D. The amount of late seral stage is projected to increase in all alternatives, ranging from a 10 percent addition in Alternatives C and D to approximately 15 percent in Alternatives A, B, E, and F.

In red fir, early seral stage vegetation is projected to increase 80 percent in Alternatives A, B, E and F, and approximately 200 percent in Alternatives C and D. Mid seral stage of this vegetation type is expected to decrease in all alternatives by approximately 20 percent. The amount of late seral stage is projected to increase in all alternatives between two and three percent.

Heterogeneity

All alternatives would increase diversity of age classes and species composition through the use of fire and/or mechanical treatments. In alternatives with smaller diameter limits, such as Alternative C, it could take longer to reach the desired conditions for heterogeneity.

Alternative D is expected to result in the most early seral habitat as a result of more uncharacteristically severe wildfires.

Alternatives E and F allow more flexibility in managing species composition, structural diversity, and fuels. This would be expected to protect stands from uncharacteristically severe wildfire and promote heterogeneity.

For potential changes in the amount of early, mid, and late seral stages by vegetation type, see the previous Resiliency section.

Giant Sequoia Regeneration

The combination of mechanical treatments and burning allow maximum flexibility in selecting which ladder fuels to remove and which associated tree species to feature. The 2009 treatment at Mountain Home State Forest in the first photo below illustrates how the larger giant sequoia was protected while ladder fuels were removed and white fir and cedar were thinned. The second photo shows a similar mechanical treatment that opened up the stand for recreation visibility, reduced surface fuels, removed ladder fuels, and promoted heterogeneity (species diversity and openings). Mineral soil exposure encouraged regeneration of mixed conifers, including giant sequoia.

Re-establishing fire regimes within fire-excluded giant sequoia groves can be an important step in restoring these ecosystems and promoting resilience (North et al. 2009, Stephens et al. 2010). Low-intensity fire and understory thinning can be used to reduce surface and ladder fuels and better protect dominant trees in the coniferous forest (Stephens et al. 2009), including giant sequoia groves (Kilgore and Sando 1975). Medium or small patches of high-intensity fire, possibly in combination with mechanical treatments, can create larger openings and promote conditions favorable for giant sequoia regeneration (Meyer and Safford 2011b).

Alternative D does not allow artificial planting. Regeneration would be limited to instances where weather and disturbances coincide to provide favorable conditions for germination and growth. Alternatives A, B, C, E, and F, in addition to natural regeneration, allow artificial planting of nursery grown seedlings. Seedlings would be planted in favorable sites at the best time of year. This would produce better regeneration success in terms of seedling establishment and survival. Alternative F, which is projected to provide for a larger number of mechanically treated acres, would result in more acres of favorable forest canopy and mineral soil conditions for giant sequoia regeneration.

Thinning followed by pile burning in 2009 at Mountain Home State Forest.

Fifteen years after thinning followed by burning at Mountain Home State Forest.

Sometimes natural regeneration will establish in small patches or with a few trees scattered across a stand within a grove (Harvey et al. 1980). The photos below illustrate the kind of effects that may be required to obtain abundant natural regeneration in giant sequoia groves. The first photo, taken in the Redwood Mountain Grove, illustrates the common absence of giant sequoia regeneration in areas with reduced surface and ladder fuels, small gaps, and frequent light to moderate burning. The second photo shows an adjacent area with an abundance of giant sequoia regeneration that was burned by a severe wildfire in 1987. Most of the larger giant sequoias survived the high severity burn, but some were killed.

Projections of giant sequoia regeneration by the SPECTRUM model were not considered to be reasonable due to the known limitations of the model. In order to estimate the amount of giant sequoia regeneration, several factors were considered. Giant sequoias require some canopy opening to successfully regenerate. The types of vegetation management likely to create openings suitable for giant sequoia regeneration are those that would remove trees from the canopy. This could occur with relatively hot prescribed fire, wildfire, or mechanical treatments. In the first 20 years, these types of activities are most likely to occur in the WUI defense zone. Even with these types of treatments, it is unlikely that many openings suitable for giant sequoia regeneration would occur in a treated area. It is estimated that approximately 10 percent of defense zone treatments would provide adequate openings. The amount of these activities which might take place in giant sequoia groves varies by alternative. Based on these assumptions, it is estimated that the acres of giant sequoia regeneration would be approximately 300 acres in Alternative A, 200 acres in Alternative B, 100 acres in Alternative C, 0 acres in Alternative D, 400 acres in Alternative E, and 500 acres in Alternative F.

Frequent light to moderate intensity burning with no sequoia regeneration (Redwood Mountain Grove).

Stand replacement wildfire promotes natural sequoia regeneration (Redwood Mountain Grove).

Wildfires burning in giant sequoia groves are also capable of creating openings suitable for regeneration. Because the amount, intensity, and location of wildfires make estimates of regeneration from wildfire highly speculative, no estimates of giant sequoia regeneration resulting from wildfire are provided. Based on the management direction in Alternatives C and D, it is expected that those two alternatives have the greatest potential to create suitable openings for giant sequoia regeneration with wildfire.

Cumulative Effects

The geographic extent of analysis is the Monument and the temporal extent is the next two decades.

Resiliency

The ability to increase resilience within the Monument is scaled, in part, by the projection of acres treated with effective methods. The likelihood of multi-year drought within the next two decades, combined with the potential for the even higher evapotranspirational demands of a warming climate, may reduce the projected benefits associated with increased treatment acres. In addition, wildfires may erase treatment benefits in areas where treatment acres fail to provide benefits over a significant portion of the area.

Prescribed fire prescriptions that kill some of the larger trees will contribute to the resilience of the remaining larger trees. The outcome, however, will likely result in tree arrangements that are not always as effective as would be obtained by mechanical treatments. This distinction would be of particular importance in situations when specific tree arrangements and/or species compositions are desired. The effects of a warming climate may reduce the beneficial effects of decreased tree numbers per acre. Remaining high density tree arrangements are likely to be more common locations for bark beetle-related mortality during multi-year drought periods.

Uncertainty related to the post-prescribed fire effects on tree arrangements complicates the projection of resiliency accomplishments. Modeling estimates project annual prescribed burning to be approximately 7,000 to 10,000 acres for Alternative A, 1,200 to 1,500 acres for Alternative B, 600 to 700 acres for Alternative C, 50 to 100 acres for Alternative D, 900 to 1,100 acres for Alternative E, and 1,000 to 1,200 acres for Alternative F.

Alternatives that also include mechanical and hand treatments would provide for site-specific increases in resiliency. Modeling estimates project annual mechanical or hand treatments to be approximately 1,300 to 1,600 acres for Alternative A, 1,100 to 1,200 acres for Alternative B, 300 to 600 acres for Alternative C, 100 to 250 acres for Alternative D, 1,100 to 1,300 for Alternative E and 1,500 to 2,000 acres for Alternative F. While site-specific, literally tree-specific, resilience objectives would be met, uncertainties described above also apply. In particular, evapotranspirational demands may outstrip even the most highly-tailored tree arrangements.

Alternative D, given the relatively small number of treatment acres, would likely be inconsequential compared to the other alternatives.

Heterogeneity

The cumulative effects related to heterogeneity would mimic, in general, those described for resilience. Alternative D is an exception, in relation to species composition, as natural regeneration is not likely to provide the same amount of pine species, or the number of rust-resistant sugar pine as the other alternatives.

Alternative D, treating less acres, is anticipated to be more affected by wildfire than treatments. Heterogeneity increases would be driven by fire type. If wildfire results in widespread stand-replacement (crown fire), the trend toward increased heterogeneity would be less than the trend resulting from surface and mixed-severity fires.

Giant Sequoia Regeneration

With the exception of Alternative D, where tree planting is not projected, increases in giant sequoia regeneration are likely to increase in scale with treatment acres. Alternative D could also lead to increased giant sequoia regeneration depending on the location and intensity of wildfires in the groves. However, although Alternative D is likely to allow more naturally-ignited high intensity fires to burn, the actual frequency and location of these fires is dependent upon weather conditions and lightning strikes. There is no guarantee that any of these fires would occur in groves. In contrast, in the other action alternatives, the use of prescribed fire and mechanical treatments, combined with managed wildfire (unplanned ignitions), makes it more likely that fire would be reintroduced in portions of groves to aid regeneration in a shorter timeframe. Tree mortality, regardless of cause, in combination with prescribed fire, should lead to increased potential for both planted and natural regeneration. The effects of a warming climate may reduce this outcome, as compared to the recent historical outcomes related to the creation of openings and suitable soil exposures.

Standards and Guidelines and Monitoring

Effects on vegetation affect the giant sequoias, mixed conifer, and other vegetation types and their ecosystems in the Monument, including the following objects of interest identified in the proclamation (Clinton 2000):

> The naturally-occurring giant sequoia groves and their associated ecosystems, individual giant trees, rare and endemic plant species such as the Springville clarkia, and other species listed as threatened or endangered by the Endangered Species Act or sensitive by the Forest Service.
>
> The ecosystems and outstanding landscapes that surround the giant sequoia groves.

The standards and guidelines for vegetation displayed in Appendix A focus on regeneration, the giant sequoia groves, sugar pine, plantations, hardwood ecosystems, and integrated pest management and are designed to protect the objects of interest and their ecosystems, both inside and outside of the groves.

The monitoring plan developed for the Monument, as described in Part 3—Design Criteria of the Monument Plan, contains implementation, effectiveness, validation, and status and trend monitoring for ecosystem analysis and vegetation. Plan monitoring is conducted to evaluate plan implementation and its effectiveness in meeting management strategies and objectives, in particular protecting the objects of interest and restoring ecosystems. Vegetation monitoring focuses on giant sequoia groves, forest outside of groves, and canopy gap analysis. Monitoring in the groves concentrates on trends in large trees, grove structure and composition, regeneration, and fuel loading to help determine management effectiveness and detect change. Outside of the groves field examinations would have a similar focus. Canopy gap analysis throughout the Monument would help determine if pine and giant sequoia regeneration is meeting desired conditions.

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