CHAPTER 10

Southern Cascades Bioregion

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In ... the southern portions of ... the Cascades ... where the forests are largely or mainly of yellow pine in open growth, with very little litter or underbrush, destructive fires have been few and small, although throughout these regions there are few trees which are not marked by fire, without, however, doing them any serious damage.

HENRY GANNETT, 1902

Description of the Bioregion

Physical Geography

The Cascade Range extends from British Columbia, Canada, south to northern California where it meets the Sierra Nevada. The Southern Cascades bioregion in California is bounded on the west by the Sacramento Valley and the Klamath Mountains, and on the east by the Modoc Plateau and Great Basin. The bioregion encompasses the Southern Cascades section of Miles and Goudey (1997) and covers approximately 4% (16,740 km^2 [6,460 mi^2]) of the area of California. Mt. Shasta and Mt. Lassen are located in this bioregion.

The Cascades are geologically young and characterized by prominent volcanic peaks (some recently active) that stand above an extensive mainly basaltic plateau. In parts of the central and southern Cascades, volcanics overlie granitic and metamorphic rocks similar to those of the Klamath Mountains and Sierra Nevada (Oakeshott 1971). Soils are derived from volcanic material and are classified as Alfisols, Entisols, Inceptisols, Mollisols, Ultisols, and Vertisols (Miles and Goudey 1997).

Overall, topography in the southern Cascades is gentler than that in the Klamath Mountains or the Sierra Nevada. Elevations range from about 60 m (196 ft) in the southwestern foothills adjacent to the Sacramento Valley to 4,317 m (14,162 ft) at the summit of Mt. Shasta. Other notable topographic features include Mt. Lassen, the Medicine Lake Highlands, Butte Valley, Hat Creek Valley, Burney Falls, Shasta Valley, and the Pit River canyon. Both the Klamath and the Pit rivers originate east of the Cascade crest and breach the range as they flow westward toward the Pacific Ocean (Map 10.1).

Climatic Patterns

The climate in the southern Cascades is mediterranean with wet, cool winters and dry, warm summers. The expression of this climate regime within the southern Cascades is mediated by location along three predominant climatic gradients: (1) a west-to-east gradient in annual precipitation and winter temperature where wetter and warmer conditions prevail on the west side of the range south of Mt. Shasta, (2) a north-to-south gradient where annual precipitation is lower on the west side of the range north of Mt. Shasta due to a rain shadow effect from the Klamath Mountains, and (3) decreasing temperatures and increasing annual precipitation with increasing elevation (Table 10.1).

The driest areas are Butte and Shasta Valleys to the north of Mt. Shasta. Most precipitation falls as snow at higher elevations. The average early April snowpack depth and water content for selected sites in the Cascade Range are shown in Table 10.2.

The west-to-east gradient in precipitation and temperature help to create very different environments at similar elevations on the west side of the crest compared to the east side of the crest, albeit not as dramatically as in the Sierra Nevada. Nevertheless, distinctly different vegetation develops in response to the different climatic regimes. Therefore, the term *westside* is used to refer to environments typical of the west side of the crest and *eastside* for those typical of the east side of the range.

WEATHER SYSTEMS

The southern Cascades are susceptible to the critical fire weather conditions of high winds and low humidity that are caused by weather patterns characteristic of both California and the Pacific Northwest (Hull et al. 1966). Three types of fire weather conditions that occur during the dry period of the year (fire season) are important in the southern Cascades: (1) Pacific High–Post-Frontal (Post-Frontal), (2) Pacific High–Pre-Frontal (Pre-Frontal), and (3) Subtropical High Aloft (Subtropical High).

The Post-Frontal type occurs when high pressure follows the passage of a cold front and causes strong foehn winds

TABLE 10.1

Normal annual, January, and July precipitation and normal maxima and minima January and July temperatures for representative stations (elevation noted) of the southern Cascade Range (WRCC 2002)

	Average Precipitation cm (in)	*Normal Daily Maximum Temperature °C (°F)*	*Normal Daily Minimum Temperature °C (°F)*
Paradise (533 m), West Side			
Annual	139.7 (55.0)		
January	28.2 (11.1)	12.1 (53.7)	3.1 (37.5)
July	0.3 (0.1)	33.1 (91.6)	17.6 (63.6)
Mt. Shasta City (1,204 m), West Side			
Annual	99.1 (39.0)		
January	18.8 (7.4)	5.9 (42.6)	−3.5 (25.7)
July	0.8 (0.3)	29.2 (84.6)	10.1 (50.2)
Mineral (1,486 m), West Side			
Annual	141.0 (55.5)		
January	25.7 (10.1)	4.9 (40.8)	−5.8 (21.5)
July	1.0 (0.2)	27.1 (80.7)	5.9 (42.7)
Burney (956 m), East Side			
Annual	70.6 (27.8)		
January	12.4 (4.9)	6.4 (43.5)	−7.7 (18.1)
July	0.5 (0.2)	30.8 (87.4)	6.2 (43.2)
Mt. Hebron (1,295 m), East Side			
Annual	30.0 (11.8)		
January	3.3 (1.3)	3.9 (39.1)	−9.2 (15.5)
July	1.0 (0.4)	28.3 (83.0)	5.9 (42.6)
Chester (1,379 m), East Side			
Annual	86.1 (33.9)		
January	16.5 (6.5)	5.5 (41.9)	−6.9 (19.6)
July	0.8 (0.3)	29.4 (85.0)	6.7 (44.0)

TABLE 10.2

Average April 1 snowpack data for representative snow courses in the southern Cascade Range ordered from north to south (CCSS 2002)

	Elevation m (ft)	*West/East Side*	*Snow Depth cm (in)*	*Water Content cm (in)*
Medicine Lake	2,042 (6,700)	East	202.7 (79.8)	81.3 (32.0)
Dead Horse Canyon	1,372 (4,500)	East	65.3 (25.7)	29.0 (11.4)
Burney Springs	1,433 (4,700)	East	12.7 (5.0)	5.1 (2.0)
Blacks Mountain	2,042 (6,700)	East	56.9 (22.4)	20.3 (8.0)
Chester Flat	1,402 (4,600)	East	40.6 (16.0)	16.5 (6.5)
Mount Shasta	2,408 (7,900)	West	307.3 (121.0)	106.2 (41.8)
Stouts Meadow	1,646 (5,400)	West	206.5 (81.3)	95.8 (37.7)
Snow Mountain	1,859 (6,100)	West	161.8 (63.7)	81.8 (32.2)
Thousand Lakes	1,981 (6,500)	West	206.2 (81.2)	86.4 (34.0)
Lower Lassen Peak	2,515 (8,250)	West	454.2 (178.8)	202.7 (79.8)
Mill Creek Flat	1,798 (5,900)	West	234.7 (92.4)	98.0 (38.6)

MAP 10.1. Map of the Southern Cascades. The Southern Cascades bioregion occurs between the Sacramento Valley and Klamath Mountains on the west and the Modoc Plateau and Great Basin on the east.

from the north and northeast. The Cone fire in September 2002 that burned 812 ha (2006 ac), mostly in the Blacks Mountain Experimental Forest, is an example of a major fire that burned under Post-Frontal conditions.

The Pre-Frontal type occurs when the southern dry tail of a cold front crosses the area and generates strong southwest or west winds. The strong winds are the key fire weather component in this type because it is common for temperatures to drop and relative humidity to rise. The Lost fire in the Hat Creek Valley that burned more than 9,700 ha (24,000 ac) in September 1987 and the Fountain fire of August 1992 that burned more than 26,000 ha (64,250 ac) on Hatchet Mountain are examples of fires driven by Pre-Frontal conditions.

The Subtropical High type occurs when stagnant high pressure produces high temperatures and low relative humidity for extended periods. In the Cascades, Subtropical High conditions lead to fires controlled mainly by local fuel conditions, diurnal wind flow, and topography. In areas with steep elevation gradients, shifting diurnal winds cause fires to continually change direction. An example was seen in the Bolam fire that burned approximately 390 ha (960 ac) on the north slopes of Mt. Shasta in August 1970. Afternoon upslope winds tended to push this fire toward Military Pass. However, glaciers sitting high on the mountain provided a source of cooling for pulses of downslope winds that occasionally overcame the general afternoon upslope flow. This led to what appeared to be erratic fire behavior as the fire "front" shifted direction in relation to the shifting dominance of the general afternoon upslope winds and the pulses of downslope winds.

LIGHTNING

The Cascade Range averages 18.8 lightning strikes (range 5.5–33.8)/100 km^2/yr (49.5 strikes [range 14.5–89.1]/100 mi^2/yr), which are a common source of ignition. Although lightning is common throughout the range, the density of strikes increases from south to north (van Wagtendonk and Cayan 2007). Occasionally, incursions of subtropical moisture that moves north from the eastern Pacific and the Gulf of California produce widespread thunderstorms that result in numerous fires. Hundreds of lightning fires can be ignited over short periods during these events. The occurrence of widespread, simultaneous, lightning ignitions has contributed to fires that burn for weeks and cover very large areas as in 1977, 1987, 1990, and 1999.

Ecological Zones

South of the latitude of Mt. Shasta, vegetation composition and species dominance in the lower and mid-montane zones is similar to that in the northern Sierra Nevada, but the upper montane and subalpine zones are more similar to the Klamath Mountains and northern Cascades (Parker 1991). When compared to the Sierra Nevada, vegetation composition in the Cascades is more strongly controlled by local topography and substrate and less so by elevation (Parker 1995), likely due to less dramatic elevation differences and youthful geology with young soils. Open woodlands, shrublands, and areas of sparse vegetation occur over wide areas on harsh sites. These conditions are common where young lava flows or other young volcanic materials with shallow, poor soils inhibit vegetative growth regardless of ecological zone. North of Mt. Shasta, in the rain shadow of the Klamath Mountains, the vegetation of the west side of the Cascades resembles vegetation more characteristic of the drier east side of the Cascades. Lower elevations on both sides of the Cascades are dominated by grasslands, shrublands, and woodlands. However, there is considerable variability in the composition and physiognomy of these vegetation types.

SOUTHWESTERN FOOTHILLS

The southwestern foothills of the Cascades, along the northeastern edge of the Sacramento Valley, is a low-elevation, dissected volcanic plateau with vegetation similar to that in the Sierra Nevada foothills (Fig. 10.1). Common alliances in this portion of the bioregion are blue oak *(Quercus douglasii)*, gray pine *(Pinus sabiniana)*, interior live oak *(Quercus wislizenii)*, valley oak *(Quercus lobata)*, buck brush *(Ceanothus cuneatus* var. *cuneatus)*, annual grassland, and vernal pools (Miles and Goudey 1997). Two other important alliances in this zone are ponderosa pine *(Pinus ponderosa)* and California black oak *(Quercus kelloggii)*. This ecological zone corresponds to subsection M261Fa (Tuscan Flows) of Miles and Goudey (1997). Three major creeks (Mill, Antelope, and Deer) flow from the Cascades westward to the Sacramento Valley through this area.

The southwestern foothills area has a complex pattern of vegetation primarily influenced by the depth of the underlying soil (Biswell and Gilman 1961). Blue oak woodland is the most common alliance, and it varies from forest to savanna in terms of tree density (Appendix 3).

NORTHWESTERN FOOTHILLS

The northwestern foothills zone is north of Mt. Shasta and generally corresponds to subsections M261Db and M261Dc of Miles and Goudey (1997). This zone includes the Shasta Valley and adjacent foothills. As this area lies in the rain shadow of the Klamath Mountains and is above 790 m (2,600 ft) in elevation, it is more of an eastside type (Fig. 10.2). Common alliances include big sagebrush *(Artemisia tridentata* vars.*)*, western juniper *(Juniperus occidentalis* ssp. *occidentalis)* woodlands, meadows (mostly sedges [*Carex* spp.]), buck brush, California black oak, and ponderosa pine (Miles and Goudey 1997). Extensive areas are dominated by introduced grasses, especially cheat grass *(Bromus tectorum)*. See Chapter 11 on the Northeastern Plateau for more on vegetation alliances common to this zone.

LOW ELEVATION EASTSIDE

Lower elevations of the east side of the Cascades occur primarily along the Pit River corridor and the lower reaches

FIGURE 10.1. Southwestern Foothills occur on a dissected volcanic plateau. The thin, rocky soils often support blue oak and gray pine as shown here in Bidwell Park, Chico. (Photo by Carl N. Skinner.)

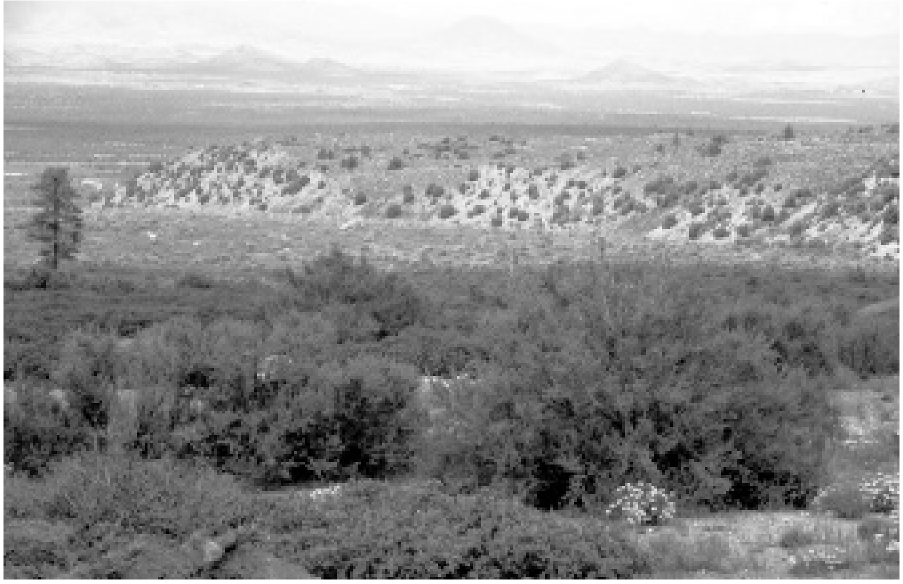


FIGURE 10.2. Northwestern Foothills. Shrublands on north slopes of Mt. Shasta looking northwest into the Shasta Valley. Shrubs in photo are mostly greenleaf manzanita, tobacco brush, and bitterbrush. (Photo by Carl N. Skinner.)

of Hat Creek. This zone corresponds roughly to the lower portions of Miles and Goudey's (1997) subsection M261Dj (Hat Creek Rim). The low elevation of the Pit River gorge may have allowed it to serve as a corridor for plant species characteristic of westside habitats to migrate into eastside environments. For example, between Burney and Fall River, gray pine, California black oak, Oregon white oak *(Quercus garryana)*, and buck brush, usually associated with westside environments, co-occur with western juniper and bitterbrush *(Purshia tridentate)* (Fig. 10.3). See Chapter 11 on the Northeastern Plateau for more on vegetation alliances common to this zone.

The Pit River corridor near Burney Falls also has disjunct stands of mountain misery *(Chamaebatia foliolosa)* that grow in association with ponderosa pine, California black oak, Douglas-fir *(Pseudotsuga menziesii* var. *menziesii)*, Oregon white oak, and other conifers. For more information on mountain misery, which commonly occurs throughout the montane zone in the Sierra Nevada south of the Feather River canyon, see Chapter 12.

MID-MONTANE WESTSIDE/EASTSIDE

Conifer forests dominate the mid-montane zone on both sides of the range and they are intermixed with woodlands and shrublands. Few natural meadows or grasslands occur on the west side of the range. Species composition varies from

FIGURE 10.3. Lower Montane Eastside. Gray pine mixed with western juniper on rim of Pit River Canyon near Fall River Mills depicting the mixing of vegetation usually found on the west side of the range with that more characteristic of the east side of the Cascades. (Photo by Carl Skinner, USDA Forest Service.)

FIGURE 10.4. Mid-Montane Westside. Mixed stand of Douglas-fir, ponderosa pine, sugar pine, incense-cedar, California black oak, white fir, and mountain dogwood in the Flatwoods near Big Bend. Stand was mechanically thinned for fire hazard reduction ten years prior to the photograph. (Photo by Derrick B. Skinner.)

west to east over the crest but less so than in the Sierra Nevada because the crest is lower in elevation and mountain passes are relatively low (Griffin 1967). Nevertheless, the mid-montane zone of the southern Cascades is quite different on the east compared to the west side of the crest because of the rain shadow effect and differences in temperature. Consequently, our discussion is split between westside and eastside alliances. The mid-montane westside corresponds to subsections M261Dg and M261Di of Miles and Goudey (1997). The mid-montane eastside corresponds to subsections M261Da and M261Dj of Miles and Goudey (1997).

Mixed-species conifer forests dominate the mid-montane zone on the west side of the Cascade Range (Fig. 10.4). Any of six conifer species (ponderosa pine, Douglas-fir, incense-cedar *[Calocedrus decurrens]*, sugar pine *[Pinus lambertiana]*, Jeffrey pine *[Pinus jeffreyi]*, and white fir *[Abies concolor]*) may co-occur and share dominance (Barbour 1988, Parker 1995, Beaty and Taylor 2001). A subcanopy of the deciduous hardwoods California black oak, bigleaf maple *(Acer macrophyllum)*, and mountain dogwood *(Cornus nutallii)* and the evergreen canyon live oak *(Quercus chrysolepis)* may occur beneath the conifer canopy. Stand composition is influenced by elevation, slope aspect, soil moisture conditions, and substrate (Griffin 1967).

FIGURE 10.5. Upper Montane. Shrub fields intermixed with patches of conifers on Snow Mountain (named for the large patch of snow in the center of the photo that lasts through the summer except in very dry years). Dominant shrubs are tobacco brush, greenleaf manzanita, bitter cherry, and bush chinquapin. (Photo by Carl N. Skinner.)

Mixed white fir–red fir *(Abies magnifica* var. *shastensis)* forests occur above the elevation of the mixed conifer zone in the Cascades (Parker 1995). The forest cover is often interrupted by stands of montane chaparral. The most common shrubs of the Cascade Range montane chaparral are greenleaf manzanita *(Arctostaphylos patula)*, *Ceanothus* spp., and shrub oaks. Montane chaparral appears to occupy sites that are unable to support trees due to shallow soils; exposed slopes where cold, high winds and ice damage are common; or sites that have experienced severe fire (Wilken 1967; Weatherspoon 1988; Bolsinger 1989; Beaty and Taylor 2001).

Extensive areas east of the Cascade crest are dominated by ponderosa pine, Jeffrey pine, or a combination of both. Other conifers, such as white fir and incense cedar, may be locally important but do not usually attain dominance, especially on the drier sites (Rundel et al. 1977). Western juniper and curl-leaf mountain-mahogany *(Cercocarpus ledifolius)* may be associates on drier and rockier sites. Widely scattered, small stands of quaking aspen occur throughout this zone east of the Cascade crest around seeps, on meadow edges, and on young exposed basalt.

UPPER MONTANE

Upper-montane-zone conifer forests and shrublands have similar species composition on both sides of the crest. However, species dominance varies widely and is influenced by total annual precipitation, topography, and substrate. The more common conifers in this zone are Jeffrey pine, ponderosa pine, white fir, red fir, lodgepole pine *(Pinus contorta* ssp. *murrayana)*, and western white pine *(Pinus monticola)*. Common shrubs include bush chinquapin *(Chrysolepsis sempervirens)*, greenleaf manzanita, pinemat manzanita *(Arctostaphylos nevadensis)*, mountain whitethorn *(Ceanothus cordulatus)*, tobacco brush *(Ceanothus velutinus* var. *velutinus)* (commonly called snowbrush in this bioregion), huckleberry oak *(Quercus vaccinifolia)*, Parry's rabbitbrush *(Chrysothamnus parryi)*, rubber rabbitbrush *(Chrysothamnus nauseosus)*, and big sagebrush. As in the mid-montane zone, forest cover can be interrupted by stands of montane shrubs on harsh sites or where there has been a history of severe fires (Fig. 10.5). The drier portions of this zone are found on the eastern edge of the bioregion and correspond to subsections M261Dd and M261Dh of Miles and Goudey (1997). See Chapter 11 for more on herbaceous and shrub vegetation alliances common to the eastern part of this zone.

Large, seasonally wet, montane meadows are characteristic of the upper-montane zone east of the crest. The remainder of the zone corresponds to the portions of subsections M261Df, M261Di, and M261Dm of Miles and Goudey (1997) that are at elevations lower than the subalpine zone.

SUBALPINE

Subalpine and alpine vegetation is generally limited to the highest peaks in the southern Cascades such as Mt. Shasta, Mt. Lassen, and Crater Peak. Common alliances are mountain hemlock *(Tsuga mertensiana)*, whitebark pine *(Pinus albicaulis)*, and red fir. These areas are the higher elevations of subsections M261Df, M261Di, and M261Dm of Miles and Goudey (1997) (Fig. 10.6).

Overview of Historic Fire Occurrence

There are generally two periods with distinctly different fire regimes in the Cascades. First was a Native American period, before 1905, when fires were generally frequent. This period includes both the pre-historic and the European-settlement periods. The Native American period was followed by the fire-suppression period ensuing with the establishment of the national forest reserves in 1905 when fire occurrence decreases dramatically (Skinner and Chang 1996; Taylor

FIGURE 10.6. Subalpine woodland of mountain hemlock near Reading Peak in Lassen Volcanic National Park. (Photo by Carl N. Skinner.)

1990, 1993, 2000; Beaty and Taylor 2001; Bekker and Taylor 2001; Norman 2002; Norman and Taylor 2002, 2005).

Prehistoric Period

As discussed in Chapter 17, native people of the southern Cascade Range used fire to promote production of food and basketry materials, to help gather grasshoppers and other insects, to improve hunting conditions, and for ceremonial purposes (Lewis 1990, 1993). Though the use of fire by native people appears to have been widespread, the extent of its influence on vegetation at broad scales is unknown.

The mediterranean climate, the commonality of lightning ignitions, and the widespread use of fire by native people in the Cascades promoted frequent surface fires of mostly low to moderate intensity with frequency decreasing with elevation. Pronounced local variations in fire frequency also occur due to interruptions in fuel connectivity caused by volcanics (e.g., lava flows, scoria depositions, debris flows; Taylor 2000).

Historic Period

Parts of the bioregion began to experience a decrease in fire occurrence as early as the late nineteenth century (Norman and Taylor 2005). The decrease was pronounced near meadows and coincided well with a documented period of heavy sheep grazing (Taylor 1990b, Norman and Taylor 2005). Most areas did not experience a fire frequency decline until the beginnings of organized fire suppression. The earliest accounts of wildland fire suppression are from 1887 for fires burning along the railroad lines near what is now the city of Mt. Shasta (Morford 1984). The first recorded organized fire protection in wildland areas was by the Central Pacific Railroad in 1898, which supported mounted patrols to suppress fires in the McCloud flats east of Mt. Shasta (Morford 1984).

Current Period

The total area burned by fires was greatly reduced in the twentieth century compared with pre-historic levels, due to highly effective fire suppression in the relatively gentle terrain. The gentle terrain also allowed early logging of the large fire-resistant trees which, combined with the effects of fire suppression, has left forests heavily stocked with young trees. Forests in parks and wilderness areas that were not logged have also developed high densities of young trees due to fire suppression (Dolph et al. 1995, Taylor 2000). Thus, where surface fires were frequent and extensive (e.g., foothill through mid-montane) and mostly low to moderate intensity, fires are now either kept small or they escape initial fire suppression efforts and become large, mostly high-intensity fires. Examples of these large, severe fires include the Pondosa (1977; 6,000 ha [about 15,000 ac]), Lost (1987; 9,700 ha [24,000 ac]), Campbell (1990; more than 48,500 ha [120,000 ac]), Fountain (1992; about 26,000 ha [64,250 ac]), and Gunn (1999, more than 24,000 ha [59,000 ac]). All of these fires except the Fountain fire were started by lightning.

Further indication that the reduction in fire occurrence that has occurred during last century is largely due to fire suppression is that the nature of climate variation over the last approximately 150 years has been such that one would have expected fire occurrence to have increased rather than decline (Swetnam 1993, Stine 1996, Chang 1999). The climate has generally warmed since the mid-1800s and precipitation, although variable, was relatively high in the late 1800s and early 1900s and declined at the time when fire-suppression policies were initially implemented (Graumlich 1987, Hughes and Brown 1992, Earle 1993, Stine 1996). The longer fire season associated with a warming climate (Flannigan and Van Wagner 1991, Chang 1999, Swetnam and Baisan 2003) and the accumulation of burnable fuel biomass as a result of increased precipitation (Chang 1999, Swetnam and Baisan 2003) would likely have contributed to more frequent, widespread fires. Yet, just the opposite has taken place.

The southwestern Cascade foothills were assessed for biotic integrity (Moyle and Randall 1996) and fire risk (McKelvey and Busse 1996) by the Sierra Nevada Ecosystem Project (SNEP). This area has a high fire risk based on area burned through the twentieth century compared with other areas included in the SNEP assessment (McKelvey and Busse 1996). The southwestern foothills portion of the Cascades has the greatest proportion of area burned over the period 1910–1993 of all major watersheds included in the SNEP assessment area (SNEP 2003). However, Moyle and Randall (1996) found the biological integrity of the three major tributaries (Mill, Antelope, and Deer Creeks) to be unusually high compared to the rest of the SNEP assessment area with much of the native fish and amphibian faunas intact " ... and the biotic communities ... still largely governed by natural processes" despite the frequent occurrence of large fires in the twentieth century. Thus, the relatively frequent, large twentieth-century fires did not have a detrimental effect on aquatic communities at least in this part of the Cascades. Notably, two more large fires have burned in the watershed since the SNEP assessment—the Barkley occurred in 1994 and burned more than 10,000 ha (24,700 ac), whereas in 1999 the Gunn fire burned more than 24,000 ha (60,000 ac).

Major Ecological Zones

Fire Patterns

To adequately convey the importance of widespread fire regime characteristics, we must break with the protocol of the other bioregional chapters and discuss the fire regimes more generally, without assigning them necessarily to a specific ecological zone. To assign them to a specific ecological zone could potentially convey a misleading impression to the reader that these characteristics are specific to a particular ecological zone.

SEASONALITY

The position of fire scars identified in tree-ring fire-scar studies demonstrates that most fire scars occur in latewood or at the ring boundary (Fig. 10.7). This indicates that fires burned mostly in mid-summer through fall, which is typical of forests under the influence of long, dry summers characteristic of mediterranean climates (Skinner 2002). Both dead and live fuels reach their lowest moisture levels at that time and ignite and burn easily. However, there is temporal and spatial variation in the seasonal timing of fires suggesting a complex set of interactions among slope aspect, elevation, climate variation, and the seasonal occurrence of fire (Taylor 2000, Beaty and Taylor 2001, Bekker and Taylor 2001, Norman 2002, Norman and Taylor 2002, Norman and Taylor 2003). Fires occurred earlier in the season on drier pine-dominated sites (i.e., south- and west-facing aspects) at lower elevation compared to more mesic sites (i.e., north- and east-facing aspects) and high-elevation sites (Taylor 2000; Bekker and Taylor 2001). Seasonality has also varied over time. In pine-dominated forests east of the Cascade crest, fire scars were more common in earlywood during a cool, wet period between 1790 and 1820 than in decades before or after (Norman and Taylor 2003). Fires that burned in years with normal or above normal precipitation burned mainly in the late summer and fall.

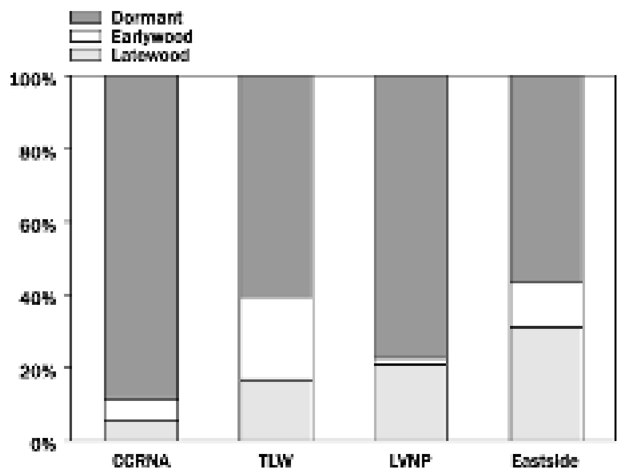


FIGURE 10.7. Distribution of intra-ring locations for fire scars from fire history studies in the Cascade Range of California. Study areas were Cub Creek Research Natural Area (CCRNA; Beaty and Taylor 2001), Thousand Lakes Wilderness Area (TLW; Bekker and Taylor 2001), Lassen Volcanic National Park (LVNP; Taylor 2000), and Eastside pine and mixed conifer sites (Eastside; Norman and Taylor 2003).

TOPOGRAPHY

As in the Klamath Mountains, dendroecological records of historical fire regimes that include the pre–fire-suppression period demonstrate that variability in fire-return intervals and fire severity are strongly influenced by topography, especially slope aspect, elevation, and slope position. Statistically significant differences in fire-return intervals have been identified within the same forest type on different slope aspects, and fire-return interval lengths increase with elevation between the montane and upper-montane zone (Taylor 2000, Beaty and Taylor 2001, Bekker and Taylor 2001). Fire-return interval lengths have also been found to vary with slope position. Upper slopes had shorter median fire return intervals than middle and lower slopes (Norman and Taylor 2002). Fire-return intervals also vary with other terrain characteristics. Forests interspersed with lava flows, scoria fields, or other features with little or no vegetation cover that impede fire spread have longer fire return intervals than areas with continuous forest cover (Taylor 2000). Riparian zones affected landscape patterns of fire occurrence by acting as barriers to the spread of some fires as in the Klamath Mountains (Beaty and Taylor 2001, Norman and Taylor 2002) (Sidebar 10.1).

FIRE SEVERITY

Patterns of fire severity during the pre–fire-suppression period were associated with topographic position, at least in deeply incised terrain. In the Cub Creek Research Natural Area, Beaty

SIDEBAR 10.1. FIRE-RETURN INTERVAL INTERPRETATION: A CAUTIONARY NOTE

Fire-return intervals in most fire-scar studies from the Cascade Range have been estimated primarily from fire scars removed in wedges from trees with exposed wounds *(cat faces)* (Taylor and Halpern 1991, Taylor 2000, Beaty and Taylor 2001, Bekker and Taylor 2001, Taylor and Solem 2001). In only a few cases were stumps available to see full cross-sections of the trees (Taylor 1993, Norman and Taylor 2002, Norman 2002). Relying only on trees with open wounds may bias estimates of fire-return intervals. Wounds induced by low-intensity surface fires often heal over completely, especially on true firs *(Abies* spp.*)* and Douglas-fir, leaving no external evidence of past fires (Taylor 1993, Stuart and Salazar 2000, Taylor and Skinner 2003). Cross-sections of stumps often yield abundant evidence of past fires, although the trees have no external evidence of having been scarred by fire (Fig. 10.1.1).

For example, Taylor and Skinner (2003) found that 86% of Douglas-fir trees (stumps) with internal fire records had no external evidence of being damaged by fire. Importantly, true firs and Douglas-fir trees with open wounds often exhibit extensive rot when compared to trees with healed wounds. This may further reduce the ability to detect a full fire scar record using only trees with open wounds.

For example, Taylor and Halpern (1991) relied primarily on fire scars from cat faces of live trees in two mixed red fir–white fir stands and supplemented this sample with a few cross-sections from cut stumps next to the stands. Later, full cross-sections were sampled from cut stumps by Taylor (1993) on two 3-ha (7.5-ac) plots adjacent to the stands originally sampled by Taylor and Halpern (1991). The two new plots were located within an area that had been logged as a shelter wood, leaving abundant exposed stump surfaces to detect otherwise hidden fire scars. Mean fire-return intervals using full cross-sections from the two new plots ranged from 18.6 to 26.3 years, whereas those using the original cat-face samples were longer at 41 to 42 years. The values obtained from the new cross-sections are similar to mean

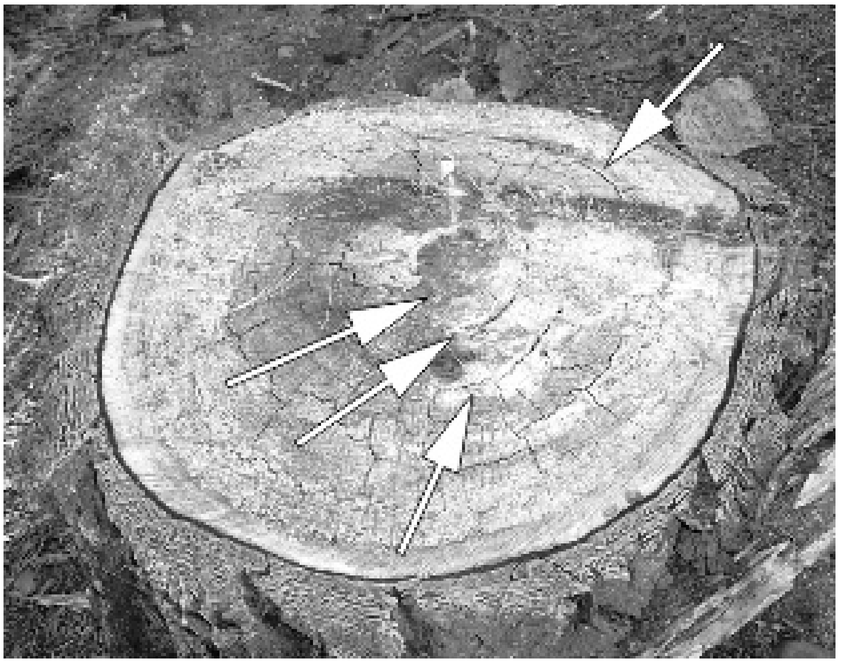


FIGURE 10.1.1. Photo of Douglas-fir stump with hidden fire scars (indicated by arrows). These scars would not be evident without seeing the full cross-section of the stump. (Photo by Carl N. Skinner, USDA Forest Service.)

fire-return intervals identified by Skinner (2003) also using full cross-sections in a red fir stand in the Klamath Mountains.

Due to variation in climate and differences in fuel beds, there are likely real differences in fire-return interval between slope aspects and along elevation gradients. However, as species composition changes from pine-dominated (with many well-preserved fire scars in open wounds) to true fir– or Douglas-fir–dominated stands (where rapid healing hides most scars and open wounds have a tendency to rot), differences detected using only cat-faced trees may be exaggerated compared to estimates from full stem cross-sections.

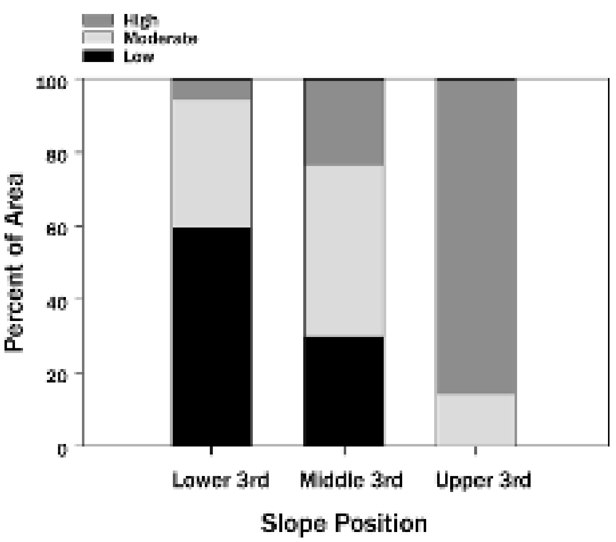


FIGURE 10.8. Topographic distribution of severity patterns in the Cub Creek Research Natural Area (Beaty and Taylor 2001).

and Taylor (2001) found that the upper thirds of slopes and ridgetops, especially on south- and west-facing aspects, experienced the highest proportion of high-severity burns. Lower thirds of slopes and north- and east-facing aspects experienced the smallest proportion of high-severity burns and the highest proportion of low-severity burns. Middle slope positions were intermediate (Fig. 10.8). This pattern is strongly pronounced in the Klamath Mountains and is discussed in detail in Chapter 9.

Southwestern Foothills

FIRE RESPONSES OF IMPORTANT SPECIES

Blue oak woodland is the most common alliance in this subregion and it varies from forest to savanna in terms of tree density (Sawyer and Keeler-Wolf [in review]). Most dominant shrubs and hardwood trees in the foothills sprout following fire (Table 10.3). These include scrub oak *(Quercus berberidifolia)*, interior live oak, birch-leaf mountain-mahogany *(Cercocarpus betuloides* var. *betuloides)*, yerba santa *(Eriodictyon californicum)*, bearbrush *(Garrya fremontii)* (commonly called Fremont silk tassel in this bioregion), flannelbush *(Fremontodendron californicum)*, and California bay *(Umbellularia californica)*. A different regeneration strategy, germination after fire from a soil seedbank, is characteristic of three dominant shrubs: buck brush, whiteleaf manzanita *(Arctostaphylos viscida)*, and common manzanita *(Arctostaphylos manzanita)* (Biswell and Gilman 1961). California nutmeg *(Torreya californica)*, a sprouting conifer, is commonly found in the steep canyons, especially on north-facing slopes (Griffin and Critchfield 1972).

Additional important species in this zone are gray pine, ponderosa pine, California black oak, and California juniper *(Juniperus californica)*. Each of these species survives surface fires of low to moderate intensity. Among these species, ponderosa pine is most fire resistant; California black oak, least fire resistant. Moreover, both gray pine and California black oak have characteristics that promote regeneration after more severe fire. When top-killed, California black oak sprouts vigorously from the root crown and gray pine is semi-serotinous. Gray pine's heavy cones protect the seeds from heat and cones open slowly over several years. California junipers have dense crowns that inhibit herbaceous understory growth so fires mostly scorch the edges of individual crowns. However, California juniper is not resistant to fire and is killed by moderate-intensity surface fires.

FIRE REGIME–PLANT COMMUNITY INTERACTIONS

Chapter 12 discusses fire regimes of the Sierra Nevada foothills which are likely to be similar to those of this ecological zone (Table 10.4) (see Sidebar 10.2).

TABLE 10.3

Fire response types for important species in the southwestern foothills zone of the South Cascades bioregion

	Type of Fire Response			
Lifeform	Sprouting	Seeding	Individual	*Species*
Conifer	None	Stimulated (seed dispersal)	Resistant/killed	Gray pine
	Fire stimulated	None	Resistant/top-killed/survive	California nutmeg
	None	None	Resistant/killed	Ponderosa pine
Hardwood	Fire stimulated	None	Resistant/top-killed/survive	California black oak, blue oak
	Fire stimulated	None	Top-killed/survive	Interior live oak, valley oak, California bay, bigleaf maple, Pacific dogwood, foothill ash, Fremont cottonwood
Shrub	None	Stimulated (germination)	Killed	Buck brush
	Fire stimulated	None	Top-killed/survive	California buckeye, Lemmon's ceanothus, flannel bush, birch-leaf mountain-mahogany, toyon, yerba santa, poison oak

TABLE 10.4

Fire regime characteristics for southwestern foothills ecological zone

Vegetation type	Southwestern foothills–woodlands	Southwestern foothills–conifers	Southwestern foothills–shrubs
Temporal			
Seasonality	Summer–fall	Summer–fall	Summer–fall
Fire-return interval	Short	Short	Medium
Spatial			
Size	Medium–large	Medium–large	Medium–large
Complexity	Moderate	Moderate	Multiple
Magnitude			
Intensity	Low–moderate	Low–moderate	Multiple
Severity	Low–moderate	Low–moderate	Moderate–high
Fire type	Surface	Surface	Crown

NOTE: Fire regime terms used in this table are defined in Chapter 4.

SIDEBAR 10.2. BEAVER CREEK PINERY

In the transition from the southwestern foothills to mid-montane forest are topographic features that support open stands of ponderosa pine and California black oak. These forests are best developed on broad, flat ridgetops. Examples are the Graham and the Beaver Creek Pinery in the Deer Creek watershed (Fig. 10.2.1). Though it survived the 1990 Campbell fire largely intact, the Graham Pinery suffered significant pine mortality in the Barkley fire of 1994. The Beaver Creek Pinery (BCP), which is approximately 250 ha (615 ac), was also burned by both fires with only patchy tree mortality.

FIGURE 10.2.1. Lower-Montane Westside. The Beaver Creek Pinery sits on this flat ridgetop in the Ishi Wilderness Area. (Photo by Carl Skinner, USDA Forest Service.)

FIGURE 10.2.2. Typical stand structure in the Beaver Creek Pinery. Note the two people standing in front of a large ponderosa pine at lower, right of center. (Photo by Carl Skinner, USDA Forest Service.)

FIGURE 10.2.3. Stand treated with mechanical thinning (whole tree harvest) followed by prescribed fire at the Blacks Mountain Experimental Forest. (Photo by Carl Skinner, USDA Forest Service.)

FIGURE 10.2.4. Stand treated with only mechanical thinning (whole tree harvest) at the Blacks Mountain Experimental Forest. (Photo by Carl Skinner, USDA Forest Service.)

Fire scars indicate the BCP burned frequently in the twentieth century. Thus, it is thought that the BCP may broadly represent stand conditions that were similar to pre–fire suppression westside ponderosa pine forests (Taylor 2002) (Fig. 10.2.2). The fire scar record (n = 36 cross-dated samples) from the BCP indicates that it burned five times during the twentieth century. However, there was a 66-year period without fire scars between 1924 and 1990. The pre–fire-suppression composite mean fire-return interval for fires that scarred 50% or more of the samples was 6 years, indicating that fires that burned throughout the BCP were frequent prior to fire suppression. There has been a four-fold increase in the mean fire-return interval to 24.5 years since the onset of the fire-suppression period. Most fire scars occurred in latewood and late-earlywood indicating that they burned during the growing season (Taylor 2002). Frequent fires seem to have promoted a fine-grained patchy stand structure with tree clumps of 100 m^2 (1,076 ft^2) to 1,500 m^2 (16,146 ft^2; Taylor 2002), similar to that described for other ponderosa pine forests that experienced frequent pre-settlement fires (e.g., Cooper 1961, Morrow 1986, White 1985).

Interestingly, diameter distributions for unlogged stands on the east side of the Cascade Range dominated by ponderosa and Jeffrey pine in the Blacks Mountain Experimental Forest (BMEF) in 1938 were similar to current diameter distributions of ponderosa pine forests in the BCP (Oliver 2001). Stands of this type at BMEF have been treated with a combination of thinning followed by prescribed fire and thinning without prescribed fire (Oliver 2000). Stands treated with both thinning and prescribed fire have developed diameter distributions very similar to those of 1938 at BMEF and found currently in the BCP (Fig. 10.2.3). However, where thinning alone was used, diameter distributions remained quite different because small-diameter trees were not subsequently thinned by prescribed fire (Oliver 2001) (Fig. 10.2.4).

TABLE 10.5

Fire regime characteristics for mid-montane westside and eastside ecological zones

Vegetation type	Mid-montane conifers—west side	Mid-montane shrubs—west side	Mid-montane conifers—east side	Knobcone pine	Mid-montane shrubs—east side
Temporal					
Seasonality	Summer–fall	Summer–fall	Summer–fall	Summer–fall	Summer–fall
Fire-return interval	Short	Medium–long	Short	Truncated Medium	Medium–long
Spatial					
Size	Small–medium	Medium–large	Small–large	Medium	Small–large
Complexity	Moderate	Low–moderate	Moderate	Low–moderate	Low–high
Magnitude					
Intensity	Low–moderate	Moderate–high	Low–moderate	Multiple	Low–high
Severity	Multiple	Moderate–high	Multiple	Moderate–high	Moderate–high
Fire type	Surface	Passive	Surface	Passive	Crown

NOTE: Fire regime terms used in this table are defined in Chapter 4.

TABLE 10.6
Fire response types for important species in the mid-montane westside zone of the South Cascades bioregion

	Type of Fire Response			
Lifeform	Sprouting	Seeding	Individual	*Species*
Conifer	None	Fire stimulated (establishment)	Resistant/killed	Ponderosa pine, Douglas-fir, Jeffrey pine
	None	None	Resistant/killed	Incense-cedar, sugar pine, white fir, western juniper
	None	Fire stimulated (seed dispersal)	Killed	Knobcone pine, Modoc cypress
	None	None	Killed	Pacific yew
Hardwood	Fire stimulated	None	Resistant/top-killed/ survive	California black oak
	Fire stimulated	None	Top-killed/survive	Bigleaf maple, canyon live oak, white alder, Oregon ash, quaking aspen
Shrub	Fire stimulated	Stimulated (germination)	Top-killed/killed	Greenleaf manzanita
	None	Stimulated (establishment)	Killed	Curl-leaf mountain-mahogany
	Fire stimulated	Stimulated	Top-killed/survive	Deerbrush, tobacco brush, mahala mat
	None	Stimulated (germination)	Killed	Buck brush
	Fire stimulated	None	Top-killed/survive	Birch-leaf mountain-mahogany, Lemmon's ceanothus, shrub tanoak, vine maple, mountain maple, bush chinquapin

Northwestern Foothills

Chapter 11 discusses fire regimes of the Northeastern Plateau which are likely similar to those of this area since many species and alliances are common to both areas.

Mid-Montane Westside

Most information available on fire ecology and fire history in the mid-montane zone is for woody plants in conifer-dominated landscapes (Table 10.5).

FIRE RESPONSES OF IMPORTANT SPECIES

All of the more common conifer species (ponderosa pine, Douglas-fir, incense cedar, sugar pine, Jeffrey pine, and white fir) survive frequent surface fires of low to moderate intensity when mature (Table 10.6). The primary difference is how early in life they become resistant to these fires. All of the common deciduous hardwoods, California black oak, big-leaf maple, and mountain dogwood, and the evergreen canyon live oak are able to survive low-intensity surface fires, and they sprout vigorously when top-killed by fire. Stand composition is influenced by elevation, slope aspect, soil moisture conditions, and substrate (Griffin 1967). With few exceptions, the more common shrubs such as greenleaf manzanita, *Ceanothus* species, and shrub oaks sprout vigorously after being top-killed. One exception is whiteleaf manzanita, which is easily top-killed by even low-intensity fires and relies on soil seed banks to germinate following fires. Manzanitas and *Ceanothus* spp. generally germinate from seed following fires. One exception is Lemmon's ceanothus which relies entirely on sprouting after being top-killed.

FIRE REGIME–PLANT COMMUNITY INTERACTIONS

Fire regimes in mixed-species mid-montane forests have been documented in the Cub Creek Research Natural Area (CCRNA) in the Deer Creek drainage and vary with forest species composition and environment (i.e., slope aspect, slope position, elevation), which co-vary on the western slope of the Cascades (Beaty and Taylor 2001). Median composite and point fire-return intervals on pine-dominated south-facing slopes (9 years, 19 years) were shorter than those on fir-dominated north-facing slopes (34 years, 54 years); other slope aspects had intermediate values. Variation in fire-rotation lengths paralleled that for fire return intervals, and they were longest on north-facing slopes (42.5 years) and shortest on south-facing slopes (17.4 years). Fire extent in the 1,590-ha (3,900-ac) study area also varied by year and by slope aspect. The average extent of a burn was 106 ha (range, 7–379 ha). Most fires burned only one or two slopes but five burned across three or more slopes. Average fire sizes were largest on north-facing (80 ha, range 37–120 ha) and south-facing (75 ha, range 21–105 ha) slopes and smaller on other slope aspects. Most of these burns (90%) occurred after trees had stopped growth for the year (dormant) (see Sidebar 10.2). Topographic variation in fire severity in the Cub Creek watershed, which is deeply incised, was particularly pronounced as interpreted from the spatial distribution of forest structural types throughout the watershed (Fig. 10.8). Multi-aged and multi-sized forests were concentrated on lower slopes and valley bottoms whereas more even-aged and even-sized stands that develop after high-severity burns mainly occupied upper slopes and ridgetops. Similar landscape structural patterns have been described in the steep, complex terrain of the Klamath Mountains (Taylor and Skinner 1998). This suggests that topography may be an important control on fire severity and forest structure at landscape scales. Upper- and mid-slope positions often experience higher fire intensities due to pre-heating of fuels, higher effective wind speeds, and lower canopy cover (Rothermel 1983, Weatherspoon and Skinner 1995, Taylor and Skinner 1998; Chapter 3 this volume).

Fire frequency in CCRNA also varied by time period. Mean composite fire-return intervals were similar in the Native American (6.6 years) and settlement (7.7 years) periods but longer (30.7 years) in the fire suppression period. Only two fires burned in the study area after 1905. The dramatic increase in fire rotation length from 28 to 407 years after 1905 underscores the decline in the role of fire in these ecosystems that begins coincident with the implementation of fire suppression. There was no evidence in CCRNA, or in other mid-montane forests on the west slope of the Cascades (Norman and Taylor 2002), of a fire frequency decline during the settlement period like that reported for mid-montane forests in the southern Sierra Nevada (Caprio and Swetnam 1995). Thus, there appears to be considerable regional variation in when fire frequency changed in California montane forests, and this may be reflected in the type and magnitude of vegetation changes that are associated with altered fire regimes.

The mixed-species conifer forests on the west side of the Cascades have changed since the onset of the fire-suppression period (Beaty 1998, Norman and Taylor 2002). Forest density has increased, and there has been a shift in species composition toward increasing density of fire-sensitive white fir. Moreover, many areas that were montane chaparral early in the twentieth century have been invaded by trees, especially white fir, and are now closed forests. Thus, it is likely that fire suppression was an important factor in vegetation changes that have reduced the structural diversity of both forest stands and forested landscapes in the mid-montane zone.

Mid-Montane Eastside

FIRE RESPONSES OF IMPORTANT SPECIES

Most of the more-common conifer species (Jeffrey pine, ponderosa pine, incense cedar, and white fir) survive frequent surface fires of low to moderate intensity when mature (Table 10.7). As on the west side of the range, the primary difference is how early in life they become resistant to these fires. Western juniper is more easily killed by fires that the other conifers would survive and it invades open sites from refugia during longer fire-free periods. Three conifers in this zone—knobcone pine *(Pinus attenuate)*, MacNab cypress *(Cupressus macnabiana)*, and Modoc cypress *(Cupressus bakeri)*—have serotinous cones. These species rely on occasional severe crown fires to induce regeneration.

The more common hardwoods of this zone are Oregon white oak, curl-leaf mountain-mahogany, quaking aspen *(Populus tremuloides)*, and California black oak. Oregon white oak is resistant to low- to moderate-intensity surface fires and is able to sprout vigorously if top-killed by fire. Curl-leaf mountain-mahogany is killed by even low-intensity surface fires. It reinvades burned sites from rocky outcrops and other fire refugia during periods of reduced fire activity. The fire ecology of quaking aspen has not been well studied in this zone. However, quaking aspen is fire sensitive but sprouts vigorously after it has been top-killed by fire.

Mahala mat *(Ceanothus prostrates)* is a common understory shrub in the mid- to upper montane forests of the range on both sides of the crest. It germinates from stored seed banks following fires.

FIRE REGIME–PLANT COMMUNITY INTERACTIONS

Of the three species of serotinous cone conifers, Modoc cypress and MacNab cypress occur in small, widely scattered groves on rocky, shallow soils (Griffin and Critchfield 1972).

The most widespread of the serotinous-cone species is knobcone pine. Knobcone pine has not been well studied in the Cascade Range. More information on the fire ecology of knobcone pine can be found in Chapters 9 and 12. Although primarily a westside species through most of its range, knobcone pine is found on both sides of the Cascades. The most extensive stands occur on the south- and east-facing slopes of Mt. Shasta. On the

TABLE 10.7

Fire response types for important species in the low elevation eastside zone of the South Cascades bioregion

	Type of Fire Response			
Lifeform	Sprouting	Seeding	Individual	*Species*
Conifer	None	Stimulated (seed dispersal)	Resistant/killed	Gray pine
	None	None	Resistant/killed	Ponderosa pine, western juniper
Hardwood	Fire stimulated	None	Top-killed/killed	California black oak
	Fire stimulated	Stimulated (establishment)	Survive/top-killed	Oregon white oak
Shrub	None	Stimulated (germination)	Killed	Buck brush
	Fire stimulated when young	None	Top-killed/sometimes survive when young	Bitterbrush
	Fire stimulated	Stimulated (germination)	Top-killed/survive	Mahala mat
	Fire stimulated	None	Top-killed/survive	Mountain misery

east side of the Cascades, knobcone pine extends to the lava beds north of Fall River Valley and into the Northeast Plateau along the base of the Big Valley Mountains. The widespread distribution of this serotinous cone species suggests that severe fires were an important component of mid-montane fire regimes at least in some locations. Knobcone pines are short lived and usually begin dying after 50 or more years without fire (Vogl et al. 1977). Thus, after decades of fire suppression and the associated low fire occurrence, many stands are experiencing widespread mortality (e.g., Imper 1991). Severe crown fires are advantageous to mature, standing trees because these fires move quickly through the stands and melt heavy resin coating the cones. This promotes seed dispersal onto mineral soil soon after the passage of the fire. Conversely, as time since fire increases and stands die, the dead, fallen trees accumulate as dry fuel leaving the seedlings and cones susceptible to intense fires that consume cones and kill seeds and seedlings. Consequently, contemporary stands may lose the ability to regenerate and this species may experience a range contraction in the Cascades.

The low-growth habit of mahala mat situates green, relatively moist leaves on and near soil and litter surfaces. This low-growing shrub often does not burn well except under extreme burning conditions. Unburned patches of the shrub on the forest floor provide refuge for small, fire-susceptible seedlings and saplings of conifers and other shrubs (e.g., white fir, bitterbrush, curl-leaf mountain-mahogany) that establish in them. By giving protection to young woody plants, mahala mat may have played an important role in long-term stand dynamics and vegetative diversity of Cascadian forests.

The historical fire regimes of yellow pine-dominated alliances (Jeffrey pine and ponderosa pine), especially in the area transitioning from mid-montane to upper-montane environments in the southern portion of the bioregion, have been described by Taylor (2000) and Norman (2002). Fires were frequent in yellow pine forests until late in the nineteenth century or the onset of the fire-suppression period (Table 10.5).

Norman (2002) identified pre–fire suppression fire regimes and stand structure across an approximately 800-km^2 landscape between Eagle Lake and Butte Creek. Both open pine forest sites (OPF) and closed pine forest sites (CPF) were studied. Median fire-return intervals composited for 1- to 3-ha sites were 12 years (range 6–17) for OPF sites and 14.4 years (range 7–22) for CPF sites. Notably, widespread fires, detected on multiple sites across the large study area, had a median return interval of 20.5 years (range 7–49). These results are similar to mixed pine forests in the nearby Blacks Mountain Experimental Forest.

These conifer forests have changed, often considerably, coincident with the period of fire suppression (Norman 2002). Forest density has increased, and there has been a shift in species composition toward increasing density of pines and more fire-sensitive white fir. Moreover, many areas that were montane meadows early in the twentieth century have been invaded by trees, especially Jeffrey and lodgepole pine, and are becoming forests (Norman and Taylor 2005). Thus, fire suppression, interacting with climatic variation and more

TABLE 10.8
Fire-response types for important species in the upper-montane zone of the South Cascades bioregion

	Type of Fire Response			
Lifeform	Sprouting	Seeding	Individual	*Species*
Conifer	None	None	Resistant/killed	Jeffrey pine, ponderosa pine, white fir, red fir, western white pine
	None	None	Killed	Lodgepole pine
Hardwood	Fire stimulated	None	Top-killed/survive	Quaking aspen, willows, black cottonwood
Shrub	Fire stimulated	Stimulated (seed production)	Top-killed/survive	Bush chinquapin, mountain whitethorn,
	Fire stimulated	Stimulated (germination)	Top-killed/survive	Greenleaf manzanita, tobacco brush
	None	Stimulated	Killed	Pinemat manzanita
	Fire stimulated	None	Top-killed/survive	Huckleberry oak, rubber rabbitbrush
	None	None	Killed	Big sagebrush

locally with other land uses such as grazing and logging, has contributed to vegetation changes that have reduced the structural diversity of both forest stands and forested landscapes.

Small stands of quaking aspen are scattered throughout the montane and upper-montane zone east of the Cascade crest. Though quaking aspen is not well studied in the Cascades, years of observation suggest several important relationships between quaking aspen and fire. In quaking aspen stands with few conifers, the high fuel moisture of the herbaceous understory and generally low fuel loads reduce fire intensity as fire enters stands. This occurs even under more severe burning conditions. Severe passive crown fires in adjacent conifer stands have been observed to change to low-intensity surface fires when they enter quaking aspen stands. However, if the quaking aspen stand has been heavily invaded by conifers, the fires continue to burn severely. Conifers are capable of replacing quaking aspen, and fires were probably a key process that maintained quaking aspen stands before the fire suppression period. Since the onset of fire suppression, many quaking aspen stands have been invaded and overtopped by conifers. Where heavy conifer invasion has gone on long enough to have significantly reduced the vigor of quaking aspen clones, the clones may have difficulty sprouting following severe fires. In some areas, quaking aspen has already been replaced by conifers and contemporary quaking aspen stands probably cover less area than before the fire suppression period.

Young basalt flows with little or no soil cover large areas such as in the Hat Creek Valley. These low-productivity sites limit fuel accumulations, and fires are unable to burn well except under severe weather conditions. These sites also seem to serve as fire refugia for many fire-sensitive species, including curl-leaf mountain-mahogany, western juniper, bitterbrush, and quaking aspen.

Many yellow pine-dominated forests and woodlands today have a relatively continuous understory of bitterbrush, such as seen in stands surrounding Butte Valley and other areas. Bitterbrush in the Cascades is fire sensitive and easily killed by even low-intensity fires. It does not sprout well unless young and vigorous. Where it is mature and robust it is highly flammable, burns with high intensity, and fires usually kill the plants outright. Given these traits, it is unlikely the contemporary widespread continuity of bitterbrush, especially the mature robust shrubs, was typical of these environments under pre-historic fire regimes. Fires were too frequent. It is likely bitterbrush took advantage of refugia provided by basalt flows and mahala mat to maintain itself in this generally fire-prone ecosystem.

Upper Montane

FIRE RESPONSES OF IMPORTANT SPECIES

Fire ecology information is available for montane shrubs and four common tree-dominated alliances in the southern Cascade Range: white fire, red fir, lodgepole pine, and Jeffrey pine (Table 10.8). Of the more common conifer species found in the upper montane of the Cascades, Jeffrey pine is most fire resistant, followed by white fir, red fir, western white pine, and lodgepole pine, respectively (Agee 1993).

TABLE 10.9

Fire regime characteristics for upper-montane ecological zone

Vegetation type	Yellow pine-dominated	True fir-dominated	Lodgepole pine	Upper-montane shrubs
Temporal				
Seasonality	Summer–fall	Late summer–fall	Late summer–fall	Late summer–fall
Fire-return intervals	Short	Short–long	Medium–long	Medium–long
Spatial				
Size	Small–large	Small–medium	Small–medium	Medium
Complexity	Moderate–high	Moderate–high	Low–high	Low–high
Magnitude				
Intensity	Low–moderate	Low–high	Low–high	Moderate–high
Severity	Low–moderate	Low–high	Moderate–high	Moderate–high
Fire type	Surface	Surface	Surface	Crown

NOTE: Fire regime terms used in this table are defined in Chapter 4.

Shrub species dominance varies with substrate, soils, and other conditions. However, nearly all dominant, woody species in upper-montane shrub fields sprout following fires, including bush chinquapin, huckleberry oak, and bitter cherry *(Prunus emarginata)*. Important species that both sprout and germinate from seed from long-lived soil seed banks include tobacco brush, greenleaf manzanita, mountain whitethorn, deer brush, and pinemat manzanita.

FIRE REGIME–PLANT COMMUNITY INTERACTIONS

The influence of commercial thinning and prescribed burning on the germination and establishment of tobacco brush and manzanita (greenleaf and pinemat) have been studied in young-mature, even-aged white fir and red fir stands that had regenerated in a shrub field near Jenny Springs on the Lassen National Forest just outside of the Swain Mountain Experimental Forest (Weatherspoon 1985, 1988). Though no live shrubs and few shrub skeletons were present in plots before treatments were applied, more than 15 million tobacco brush seeds/ha (6 million/ac) were found in the top 10 cm (4 in) of soil. Mechanical treatments included: (1) unthinned controls, (2) moderate thinning, and (3) heavy thinning. Prescribed burning treatments were: (1) unburned controls in each level of thinning; (2) under burn half of the plots in spring before thinning; and (3) under burn all plots except controls after thinning, half in spring and half in fall (Weatherspoon 1985).

After treatments, the density of tobacco brush and manzanita seedlings was higher on burned than on unburned, and on thinned than on unthinned plots and varied with the amount of fuel consumed (Weatherspoon 1985). Apparently, most seedlings died that germinated in shaded, unthinned plots. Fuel consumption was generally greater in fall burns compared to spring burns. Seedling density was lowest in unburned areas, somewhat greater in shallow burns (litter consumed), highest in areas of moderate depth of burn (fermentation layer consumed), and lower again in deeply burned areas (humus layer consumed). Seed stores were not reduced by shallow burns, but 94% of the seeds were killed to 10 cm (3.9 in) soil depth, and 100% were killed to 4 cm (1.6 in) depth where humus was consumed (Weatherspoon 1988). Overall, seedling density varied with fuel consumption, suggesting that highly consumptive pre-thinning burns may be effective at reducing stored seed reserves (Weatherspoon 1985).

The Jenny Springs study suggests that recurring, consumptive fires under dry, late summer conditions probably served to reduce seed stores of montane shrub species more rapidly than would otherwise have occurred. Thus, stands of trees that have been in place for longer periods (centuries) and experienced many fires would be expected to have less seed stored in the soil than young stands that have recently emerged from a shrub field or stands that experienced fewer fires. A high-intensity fire occurring as the stand was emerging from a shrub field when seed stores are high, or in an older stand that had experienced relatively few fires may kill many seeds—but the more open environment may increase survivorship of the seedlings. Conversely, older stands that had been burned many times over the years by low- to moderate-intensity fires would likely have considerably fewer seeds stored in the seed bank. A high-intensity fire may not induce as great a flush of seedlings due to the long-term depletion of the seed bank. Where shrubs such as huckleberry oak and bush chinquapin that do not develop seed banks were extirpated from a site by conifer competition, they would have to re-invade similarly to conifers following a high-intensity, stand-replacing fire.

Truffle abundance was also evaluated 10 years after thinning and 9 years after burning in the Jenny Springs study area (Waters et al. 1994). Interestingly, no difference in the frequency or biomass of truffles was found between thinning treatments with or without the use of prescribed fire (Waters et al. 1994). However, the composition of the truffle species assemblage differed between the thinned and unthinned environments.

There are few data on the fire history of montane shrub fields because the severe nature of brushfield fires consumes most evidence needed to reconstruct fire histories (Skinner and Chang 1996). However, fire scar data collected by Nagel and Taylor (2005) in the central Sierra Nevada from trees along the edges and scattered within stands of montane chaparral had a median point fire-return interval of 28 years (range 6–77) (Table 10.9). In contrast, surrounding forests had a median point fire return interval of 14 years. This suggests that fire-return intervals in montane chaparral may be longer and more variable than in surrounding conifer forests. Fuel structure, conditions needed for burning, and rates of fuel recovery in montane chaparral are different than in adjacent conifer forests and are probably responsible for the longer and more variable fire-return intervals. The absence of fire, primarily due to fire suppression, has also led to widespread conversion of montane shrublands to forest in the northern Sierra Nevada and southern Cascades (Bock and Bock 1977, Conard and Radosevich 1982, Beaty and Taylor 2001, Bekker and Taylor 2001, Nagel and Taylor 2005).

White fir-dominated stands in the Cascades are common in the transition area from mid-montane to upper-montane environments, especially on mesic sites. Stands are usually mixed with either Jeffrey pine or red fir at lower and higher elevations, respectively. Fire regimes generally vary between those characteristic of these other two species depending on which is more important. Figure 10.9 shows how conditions have changed in stands where white fir is a major component during the twentieth century in Lassen Volcanic National Park.

Stands where red fir is dominant or co-dominant are common, especially on mesic sites, in the upper-montane zone of the southern Cascades (Laacke 1990, Parker 1991). Where the upper-montane transitions to subalpine environments, red fir is found most frequently on xeric sites (Taylor 1990). Common red fir associates include white fir, western white pine, Jeffrey pine, lodgepole pine, and mountain hemlock (Laacke 1990).

Pinemat manzanita is a common, prostrate understory shrub in upper montane forests and woodlands. Its low growth habit situates green, relatively moist leaves on and near soil and litter surfaces. Thus, pinemat manzanita burns well only under extreme burning conditions, and burns are usually patchy. Unburned islands of pinemat manzanita serve as fire refugia for small, fire-susceptible conifer seedlings and saplings. Consequently, by giving protection to the small conifers, pinemat manzanita may play an important role in long-term stand dynamics of upper-montane forests, similar to that described for mahala mat in mid- and upper-montane forests.

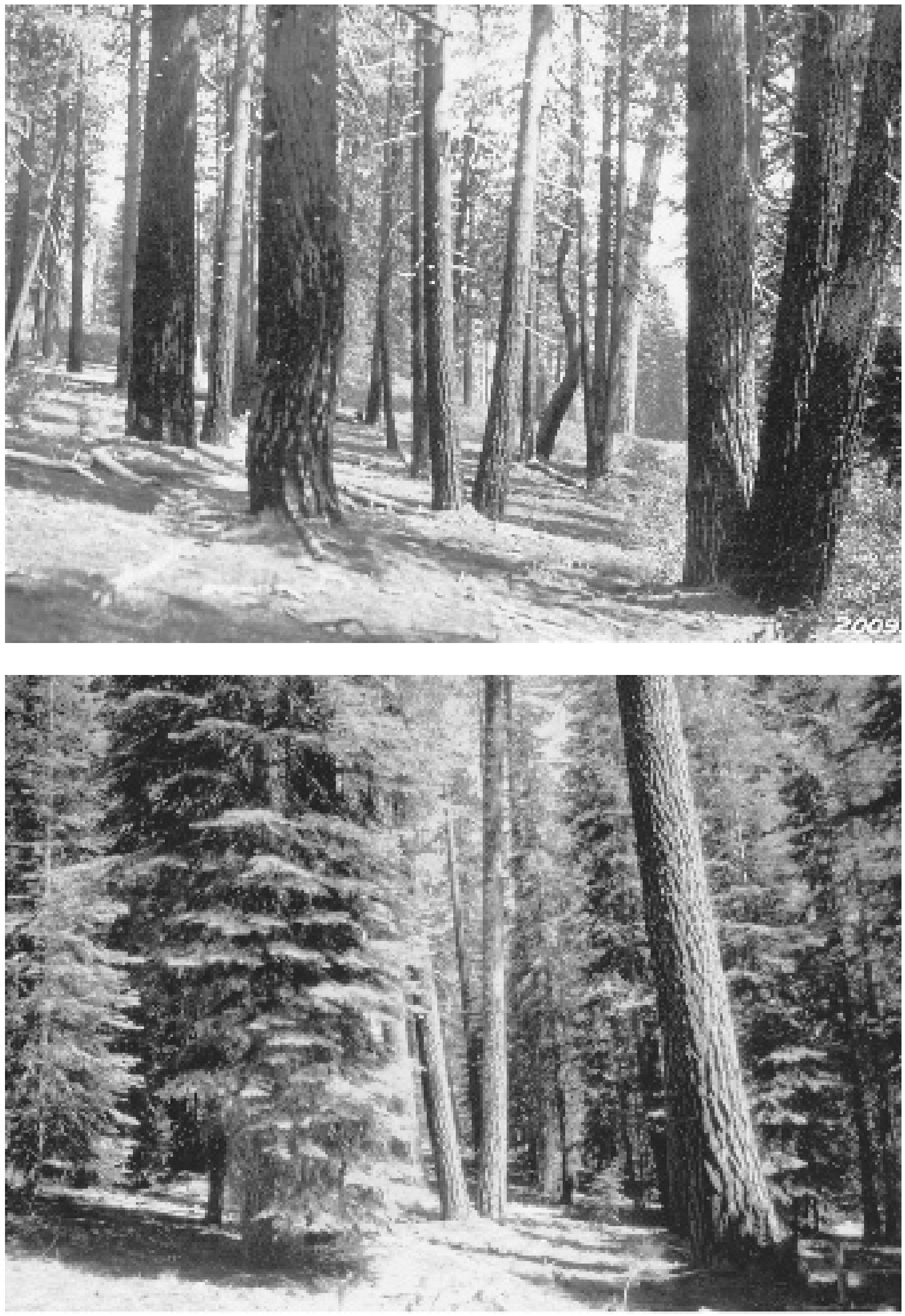
Fire occurrence in red fir forests has diminished considerably since the onset of the fire suppression period in the early twentieth century (Taylor 1993, McKelvey et al. 1996, Taylor 2000). Along with the ever-increasing time between fires, there has been an increase in forest density, similar to forest changes that are occurring in lower- and mid-montane forests (Taylor 2000). Figure 10.10 is representative of the ongoing changes in stand conditions that are representative of upper-elevation red fir forests in the southern Cascades since the early 1920s.

Fire regimes in red fir–dominated landscapes are characterized by mixed-severity burns (Agee 1993) that occur mainly in the late summer or fall after trees have stopped growth for the year (Taylor 2000). Mean fire-return intervals for points (individual trees) in forests dominated by red fir range from 25–110 years with the median being 70 years (Taylor and Halpern 1991, Taylor 1993, Taylor 2000). This is similar to a mean value (i.e., 65 years) reported for high-elevation red fir–western white pine forests in the southern Sierra Nevada (Pitcher 1987). However, most studies in red fir forests have used fire scars extracted from open wounds and did not have access to stumps. Open wounds on trees in these environments tend to rot. Access to stumps would allow the discovery of hidden scars in trees that successfully healed following the wound. Without access to stumps, frequency of fire occurrence may be underestimated (Sidebar 10.1).

Stands dominated by lodgepole pine in the Cascades are more similar to those of central Oregon (e.g., Stuart et al. 1989; Parker 1991, 1995; Agee 1993) than they are to lodgepole pine stands in the Sierra Nevada (e.g., Parker 1986; Potter 1998). In the Cascades, lodgepole pine dominates topographic settings conducive to cold-air ponding, high water tables, or sites with infertile, coarse volcanic material (Parker 1991, 1995; Agee 1994; Bekker and Taylor 2001; Taylor and Solem 2001). Red fir and white fir are often important associates, especially on more upland sites (Parker 1991, 1995), where the firs may eventually replace lodgepole pine after long periods without fire (Bekker and Taylor 2001, Taylor and Solem 2001).

Lodgepole pines are considered fire sensitive because they have thin bark and are easily damaged or killed by moderate-intensity surface fires (Agee 1993, Cope 1993). In the southern Cascades, average point fire-return intervals were 63 years (range 59–67 years) in the Caribou Wilderness (Taylor and Solem 2001) and 47 years (range 38–54 years) in the Thousand Lakes Wilderness (Bekker and Taylor 2001). These are more comparable to upper-montane, red fir forests than montane forests dominated by yellow pines. Fire-return intervals in the southern Cascades are shorter than those reported for lodgepole pine in central Oregon (Agee 1993). However, lodgepole stands north and east of Mt. Shasta may be more similar to those of central Oregon because they too are most extensive on pumice and andesite flats.

A mixed-severity fire regime consisting of small, low-severity fires and larger fires with significant portions of stand-replacing, high-severity effects appears to have been common in lodgepole pine forests (Fig. 10.11). These recurring mixed-severity fires, interacting with beetles and wind



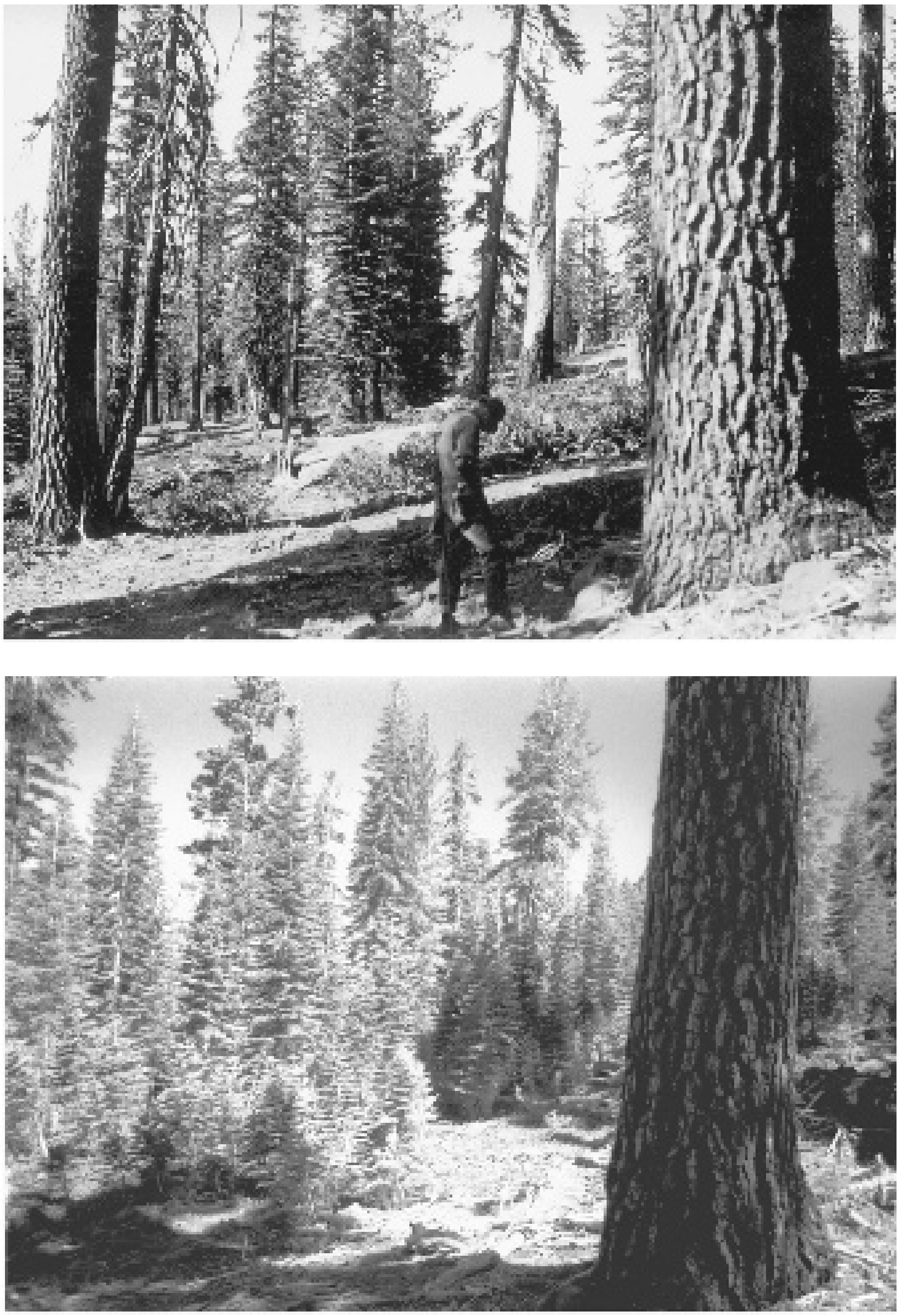
A

B

FIGURE 10.9. Paired photos showing representative changes in structure of white fir/Jeffrey pine forests in Lassen Volcanic National Park. Photo A taken in 1925. Photo B taken at same location in 1993. (Photo A by A. E. Weislander; photo B by Alan Taylor, from Taylor 2000, used with permission of Blackwell Publishing.)

events, created variable multi-aged forests at both plot and landscape scales (Bekker and Taylor 2001, Taylor and Solem 2001). Average extent of pre–fire-suppression fires in lodgepole pine forests were 150 ha (370 acres) in the Caribou Wilderness (Taylor and Solem 2001) and 405 ha (1,000 acres) in the Thousand Lakes Wilderness (Bekker and Taylor 2001).

Fire rotations in lodgepole pine forests vary by time period. During the Native American period, fire rotations in the Caribou Wilderness were 76 years and lengthened to 177 years during the settlement period (1850–1910) (Taylor and Solem 2001). During the settlement period, fire rotation for lodgepole pine forests in the Thousand Lakes Wilderness was shorter at 46 years (Bekker and Taylor 2001). The fire rotation period has lengthened considerably in both study areas since the onset of fire suppression. In the Caribou Wilderness, the fire rotation has increased to 577 years (Taylor and Solem 2001) and no fires were detected in fire scars in lodgepole pine forests in the Thousand Lakes Wilderness since the beginning of fire suppression (Bekker and Taylor 2001).



A

B

FIGURE 10.10. (A) October 1925, on the west side of Prospect Peak. The scene shows a red fir–western white pine stand with few seedlings and saplings on the forest floor. There are also patches of tobacco brush and bush chinquapin in the understory but little herbaceous cover. Fire scars on a nearby sample tree indicate the stand last burned in 1883. (B) July 1993. Trees in the stand have increased in height and diameter and new seedlings and saplings have established in the understory since 1925. The tree in the foreground (left) of the 1925 scene died and fell; seedlings and saplings have established in this opening. Ground fuels (needles, twigs, branches, boles) have also increased on the forest floor. (Photo A by A. E. Weislander; photo B by Alan Taylor, from Taylor 2000, used with permission of Blackwell Publishing.)

Stand density in eastside yellow pine forests has increased during the twentieth century (Dolph et al. 1995), and the onset of the increase corresponds with the beginning of the fire suppression period (Taylor 2000, Norman 2002). Repeat photography of eastside pine forests in Lassen Volcanic National Park that have never been logged (Weislander 1935) illustrates changes in forest conditions between the 1920s and 1993. As discussed previously, these changes are unlikely to be due to climate change. They are due mainly to the dramatic reduction of area burned as a result of fire suppression and are typical of changes observed in eastside pine forests throughout the park (Fig. 10.12).

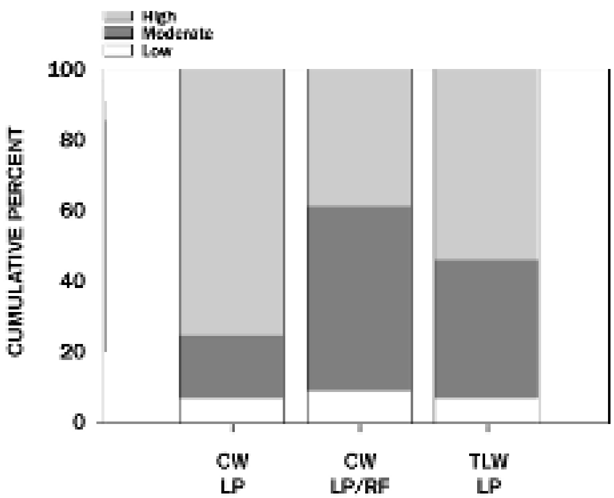


FIGURE 10.11. Distribution of fire severity classes in lodgepole pine of the Caribou Wilderness Area (CW; Taylor and Solem 2001) and the Thousand Lakes Wilderness Area (TLW; Bekker and Taylor 2001).

Jeffrey-pine-dominated forests occupy the lower elevations on south-, east-, and west-facing slopes in eastside environments. In eastern Lassen Volcanic National Park (LVNP), median point fire-return interval (individual tree scale) (n = 36) for this type of forest was 16 years and ranged from 13 years on east-facing slopes to 32 years and 31 years on south- and west-facing slopes, respectively. Longer fire-return intervals on slopes that dry earlier each year (i.e., south, west), and hence are more fire prone, were unexpected. Lava flows and scoria fields, however, were present on the south- and west-facing slopes and apparently reduced import of fire from adjacent areas lengthening fire-return intervals (Taylor 2000). This effect underscores the importance of local topographic conditions as a control on fire regimes. The fire scar record for lower-elevation mixed-pine forests had a grand median fire return interval of 14 years (Norman 2002), similar to pine forests in eastern LVNP, but the range of median values on LVNP was wider (Taylor 2000).

Changes in stand density and species composition in the twentieth century have been documented in unlogged stands in the Blacks Mountain Experimental Forest (BMEF; Dolph et al. 1995). The density of small-diameter trees (<38 cm [15 in]) in BMEF stands increased fourfold or more between 1938 and 1991, whereas the density of large-diameter trees (>70 cm [27.5 in]) declined by 3.5 per hectare (1.4/ac) (Dolph et al. 1995). It has been hypothesized that the loss of larger trees has been at least partly due to increased competition from the smaller trees that have established since the onset of fire suppression. Increased competition for moisture and nutrients may have created stressful conditions for the larger trees making them more susceptible to fatal insect attack, especially during dry periods. Intense competition between small- and intermediate-size trees also reduces growth of intermediate-sized trees and their recruitment into larger size-classes as existing larger trees die (Dolph et al. 1995, Minnich et al. 1995).

Subalpine

Lightning is frequent in the subalpine zone of the Cascade Range (van Wagtendonk and Cayan 2007). Yet, there is little evidence that fire plays a significant role in this zone. Trees in this zone are generally very sensitive to even low-intensity fires. Though lightning is frequent, the few fires that ignite rarely spread beyond individuals or small groups of trees. This is the result of climatic conditions and sparse fuels that are not conducive to fire spread. Historic fire regimes were likely similar to that described for the adjacent Sierra Nevada bioregion (see Chapter 12).

Management Issues

Managers in the Cascade Range face several fire-related challenges (e.g., smoke management, fuel accumulations, increasing stand density, wildland-urban interface) but none are unique. However, three issues—wildlife habitat, wildland-urban interface, and changing stand structures—stand out in this bioregion.

Wildlife Habitat

There is a need to better understand the role frequent low- and moderate-intensity fires once had on wildlife habitat through their influence on the development of the forest mosaics at watershed and landscape scales. Especially important is an improved understanding of the influence of fire on development of old forest ecosystems and patterns of large, dead woody material in the relatively gentle terrain of the Cascade Range. The topography of the Cascades, which is more conducive to extensive fires (Norman and Taylor 2003) than that of the Klamath Mountains (Taylor and Skinner 2003), suggests that relationships with these habitat factors may be different than those described for the Klamath Mountains or other bioregions. Describing these patterns would have important implications for management of such species as spotted owls *(Strix occidentalis occidentalis)* (Weatherspoon et al. 1992), fur-bearers, and northern goshawks *(Accipiter gentilis)*. An improved understanding will help managers to better assess risks associated with different management alternatives that inadequately consider fire as a process in fire-prone ecosystems (e.g., Attiwill 1994, Mutch and Cook 1996, Arno et al. 1997, Cissel et al. 1999, Arno and Allison-Bunnell, 2002).

Wildland-Urban Interface

A large proportion of the bioregion is classified as mixed interface (CDF 2002b) because dwellings are widely dispersed in small, scattered communities that are embedded in wildland vegetation. This pattern has resulted in the loss of hundreds of homes to wildfires in just the last three decades (CDF 2002a). The Fountain fire alone burned more than 300 homes in 1992 (CDF 2002a). The wildland–urban interface fire problem will continue to grow as development inexorably expands throughout the bioregion.

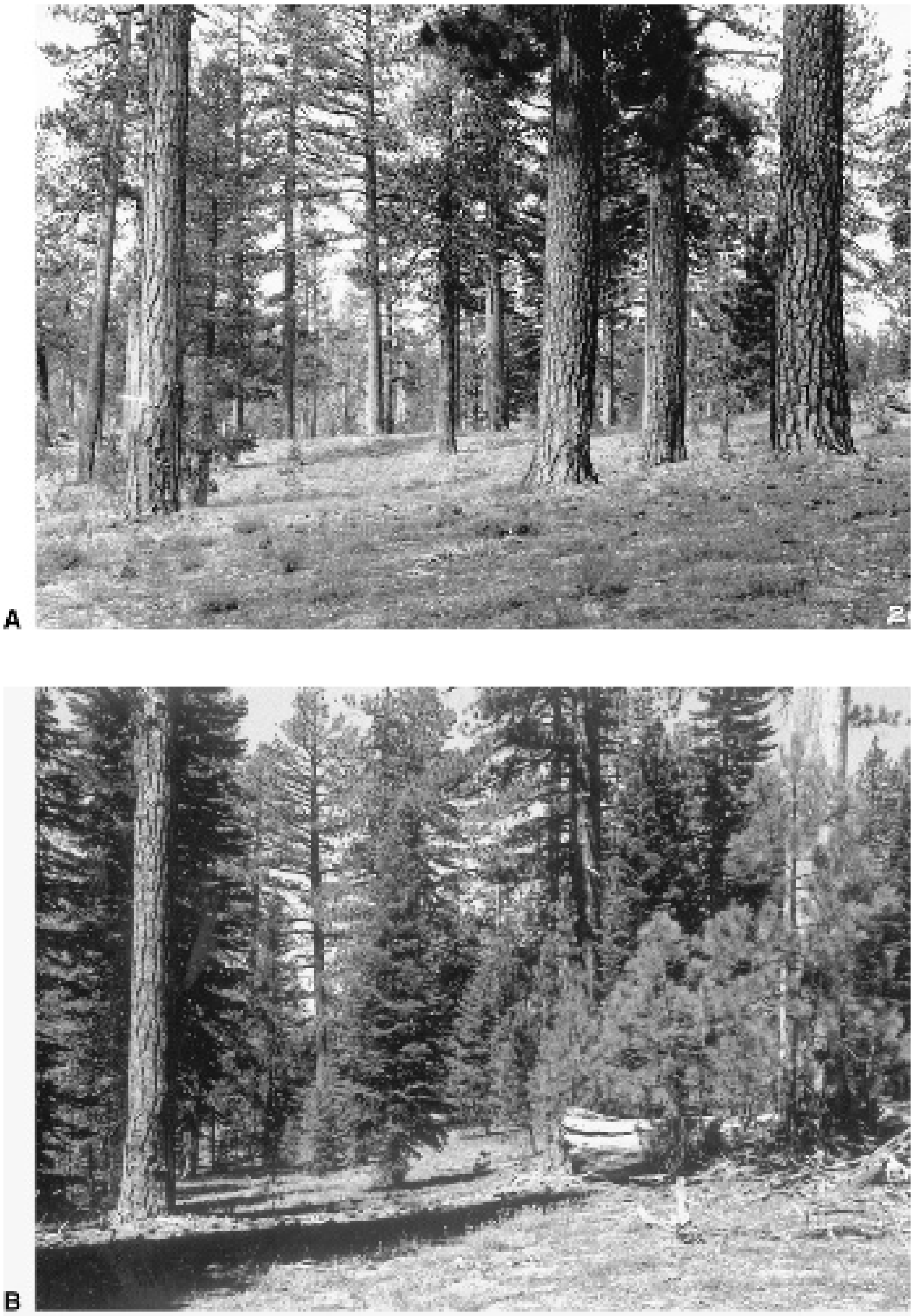


FIGURE 10.12. (A) October 1925, on the south side of Prospect Peak. The scene shows a mixed Jeffrey pine–white fir stands with few seedlings, saplings, or small-diameter stems in the forest understory. A small patch of tobacco brush is present in the foreground (right) but there is little herbaceous cover. Note the charred bark on the large-diameter stems. Fire scars on a nearby sample tree indicate the stand last burned in 1892. (B) June 1993. A dense stand of mostly white fir now dominates the forest understory and ground fuels (needles, twigs, branches) have accumulated on the forest floor. Stand density in this scene is now 820 trees (more than 4.0 cm dbh) ha^{-1}. This site was revisited in 1994. All large-diameter Jeffrey pines in the stand had died due to bark beetles. (Photo A by A. E. Weislander; photo B by Alan Taylor in 1994, from Taylor 2000, used with permission of Blackwell Publishing.)

Changing Stand Structures

Nearly a century of minimal fire occurrence due mostly to fire exclusion in forests that once experienced frequent fires has greatly altered compositional and structural diversity in forest stands and forested landscapes. The reduction in frequency and extent of fire has resulted in an increase in stand density, a shift from fire-tolerant to fire-intolerant species, and has reduced structural heterogeneity in both forest stands and forested landscapes in many parts of the western United States (Agee 1993, Arno and Allison-Bunnell 2002). Forests in the Cascade Range of California have also experienced these changes (Dolph et al. 1995, Taylor 2000), and these changes appear to be contributing to the increase in area burned by severe wildfires in this region, especially in lower- and mid-elevation forests (McKelvey et al. 1996, Weatherspoon and Skinner 1996, Stephens 1998). A similar shift to more severe fires may also begin to occur in less fire-prone, higher-elevation forests as stand density and time since last fire increase with continuing fire suppression (Taylor 2000).

Future Directions

Ecological Effects of Fuels Treatments and Altering Stand Structures

The changing stand and fuel conditions in fire-prone, lower-elevation forests have led many to conclude that widespread treatment of forest fuels is necessary to restore ecological integrity and to reduce the high risk of destructive, uncharacteristically severe fires (e.g., Hardy and Arno 1996, Terhune 2002). Treatments that are being discussed for widespread application include selective tree removal, mechanical manipulations of fuels, and prescribed fire, but the effectiveness of these treatments and their ecological effects are poorly known (Weatherspoon and Skinner 2002). Resource managers need much better information about the ecological consequences of creating different stand structures with mechanical thinning or fire as they develop plans to reduce fire hazard (Zack et al.1999, Oliver 2000, Weatherspoon and Skinner 2002).

To address this need, three large, stand-manipulation studies have been initiated in the Cascade Range of California by the U.S. Forest Service, Pacific Southwest Research Station's Redding Silviculture Laboratory. The three large studies are: (1) the Blacks Mountain Ecological Research Project (BMERP; Oliver 2000), (2) the Little Horse Peak Research Project (GAMA [Goosenest Adaptive Management Area]; Zack et al. 1999; Ritchie 2005), and (3) the Southern Cascades Fire/Fire Surrogates Site which is part of the National Fire and Fire Surrogates Study (FFS; McIver et al. 2001). These studies are interdisciplinary, complimentary, and are designed to assess both the short- and long-term ecological effects of altering stand structures by using mechanical thinning, prescribed fire, or both. With the completion of the FFS treatments in November 2002, all initial treatments for each study are in place.

Fire-Climate Interactions

The southern Cascade Range sits in an intermediate position along a latitudinal gradient in regional to hemispheric-scale climate variation and fire regimes in this area may be especially sensitive to changes in the strength of these climatic teleconnections (e.g., El Niño Southern Oscillation [ENSO], Pacific/North American pattern [PNA], Pacific Decadal Oscillation [PDO]). For example, wet conditions in northern Mexico and southern California and dry conditions in Washington are associated with a warm ENSO, whereas an opposite wet (north)-dry (south) pattern is typical of a cold ENSO. However, in the intermediate geographic position occupied by the southern Cascade Range, both wet (e.g., 1997) or dry (e.g., 1977) years can be associated with a similar ENSO signal. Focused work on fire–climate interactions in this transitional area is needed to better understand variation in fire–climate relationships. Moreover, this understanding can be used to develop tools for predicting the nature of upcoming fire seasons. Prediction of problematic fire seasons months to years in advance will enhance allocation of resources to suppression and fire readiness, in the case of severe seasons, and to fuels treatment using prescribed fire in favorable seasons. Early results indicate that extensive fires in eastside pine forests were associated with droughts influenced by associations of the PDO and ENSO in distinctive phases (Norman and Taylor 2003).

Summary

Annual summer drought, ample winter precipitation, and abundant lightning combined to make fire frequent and generally low or moderate in severity in most of the southern Cascade Range during the Native American period. Fire exclusion, grazing, and logging have dramatically changed fire regimes and forest structure in Cascade ecosystems over the last century. Of all management activities, it is likely that fire suppression has been the most pervasive because it alone has been ubiquitously applied. There is considerable discussion about the need to reduce fire hazard by manipulating fuels and stand structure either mechanically or with the use of prescribed fire. However, accomplishing fire hazard reduction is often problematic due to competing social/political objectives for Cascade forests (e.g., wood production, preservation for wildlife, maintenance of air quality). Regardless of how these controversies are resolved, the ecosystems of the Cascade Range will continue to change in response to historic and contemporary management activities in expected and unexpected ways.

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