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Forested Communities of the Upper Montane in the Central and Southern Sierra Nevada

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Abstract

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Upper montane forests in the central and southern Sierra Nevada of California were classified into 26 plant associations by using information collected from 0.1-acre circular plots. Within this region, the forested environment including the physiographic setting, geology, soils, and vegetation is described in detail. A simulation model is presented for this portion of the Sierra Nevada that refines discussions of climate, and disturbance regimes are described to illustrate the interaction between these features of the environment and vegetation in the study area. In the classification, plant associations are differentiated by floristic composition, environmental setting, and measurements of productivity. Differences in elevation, aspect, topographic setting, and soil properties generally distinguish each plant association described. A detailed description is presented for each plant association, including a discussion of the distribution, environment, vegetation, soils, productivity, coarse woody debris, range, wildlife, and management recommendations. A complete species list and tables for cross referencing specific characteristics of each association are provided.

Retrieval Terms: Vegetation classification, ecological classification, potential natural vegetation, plant association, red fir (*Abies magnifica*), white fir (*Abies concolor*), sugar pine (*Pinus lambertiana*), Jeffrey pine (*Pinus Jeffreyii*), lodgepole pine (*Pinus contorta*), mountain hemlock (*Tsuga mertensiana*), western white pine (*Pinus monticola*), western juniper (*Juniperus occidentalis*), quaking aspen (*Populus tremuloides*).

Useful English/metric conversions for this classification are:

1 inch = 2.54 centimeters	1 centimeter = 0.39 inch
1 foot = 0.30 meters	1 meter = 3.28 feet
1 square foot = 0.09 square meters	1 square meter = 10.76 square feet
1 cubic foot = 0.03 cubic meters	1 cubic meter = 35.31 cubic feet
1 acre = 0.41 hectares	1 hectare = 2.47 acres

The Author

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USDA Forest Service
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The Forest Service, U.S. Department of Agriculture, is responsible for Federal Leadership in forestry.

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**Pacific Southwest
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Introduction

Ecological classifications generally describe several elements of natural resource information such as vegetation, soils, geology, and physiography. They are designed to provide users with site specific information on species composition, environmental setting, productivity, and expected responses to management. Such classifications are not new. Systems such as habitat types (Daubenmire 1952) and community types (Hall 1973) have been used throughout the west since the early 1950’s; however, none of these contain information specific to California ecosystems or Sierra Nevada forested plant communities in particular (Wellner 1987). Several descriptions of California vegetation also include broad-based discussions of plant communities in upper montane forests (Bailey 1995, Eyre 1980, Hickman 1993, Holland 1986, Kuchler 1964, Mayer and Laudenslayer 1988, McNab and Avers 1994, Munz and Keck 1959, Rundle and others 1988, U.S. Department of Agriculture 1981). However, these descriptions generally do not recognize the variety of plant communities that are encountered in the upper montane, and they do not provide detailed discussions of composition, structure, environmental setting, productivity, or management specific to those communities.

Classifications attempt to group similar plant communities and distinguish them from dissimilar ones. The process of classifying is usually arbitrary at some point, because often the distinctions between classified units are not sharp. This is particularly true in natural systems. Thus, classifications remain tentative and subject to change as hypotheses are tested and knowledge obtained. This study is an initial effort to classify upper montane forests in the central and southern Sierra Nevada with the following objectives:

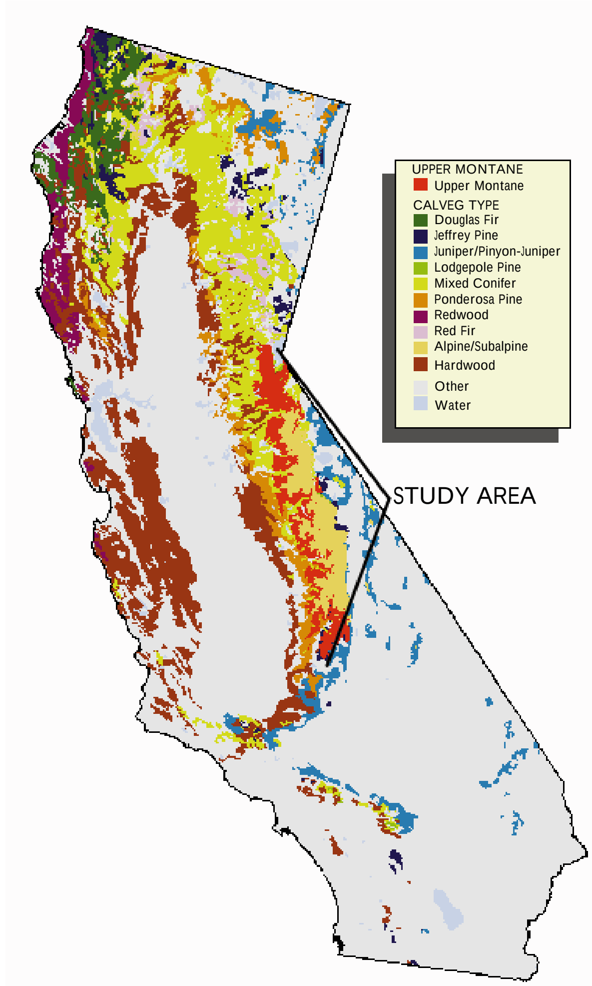
- To identify and describe the major plant communities within the upper montane forests of the central and southern Sierra Nevada.
- To provide an understanding of the relationships between vegetation and environment in these communities.
- To develop a dynamic classification scheme that incorporates current theories about the role of disturbance in succession.
- To provide interpretations of the ecological relationships among and between plant communities that will guide vegetation management of these same communities.
- To provide a framework for describing research results and to serve as a basis for defining future research needs.

This report integrates information about the floristic composition of forested stands with physical site characteristics to provide an ecological classification of upper montane forested ecosystems in the central and southern Sierra Nevada of California and western Nevada.

Study Area

The project area encompassed the upper elevations of the Sierra Nevada between Lake Tahoe in Eldorado County and Lake Isabella in Kern County *(fig. 1)*. It covered both westside and eastside slopes of the range. On the north the boundary followed a line between the American River and McKinney Creek on the west side of Lake Tahoe and Highway 50 at Spooner Summit on the eastside. Latitudes in the north were about 39°7'. The southern boundary was a line that

Figure 1—Upper montane study area in relation to vegetation type distribution in California, based on CALVEG.



crossed Sunday Peak and Little Cannell Meadow on the Sequoia National Forest at latitude 35°45'. Longitudes ranged between 120°25' on the west and 118°9’on the east.

These forests are generally dominated by red fir *(Abies magnifica)*, and this species was used in the classification to distinguish upper montane forests. On the western slopes of the range, the study commenced at elevations where red fir was first encountered. It continued upward until red fir was no longer a component of the stands. Across the crest, it commenced as red fir was again encountered and progressed down the eastern slopes to elevations at which red fir was no longer present. In the north, red fir was first encountered in drainages as low as 5,900 feet on the westside and 7,000 feet on the eastside. In the south, lower elevations ranged between 6,700 feet on the west and 8,000 feet on the east. The alpine and subalpine zones at the Sierra Nevada crest were not covered in the classification, nor were the mixed conifer and ponderosa pine forests at lower elevations on the westside or the Jeffrey pine forests at lower elevations on the eastside.

Seven National Forests, two National Parks, one National Monument and state and private lands were included within the boundaries of the study area. The westside of the Sierra Nevada contained the Eldorado, Stanislaus, Sierra, and Sequoia National Forests, and the Inyo, Lake Tahoe Basin Management Unit, and Toiyabe National Forests were located on the eastside. The National Park System was represented by Yosemite and Sequoia-Kings Canyon National Parks, and Devil’s Postpile National Monument. Portions of Alpine, Amador, Calaveras, Eldorado, Fresno, Inyo, Kern, Madera, Mariposa, Mono, Placer, Tulare, and Tuolumne Counties in California and Douglas County in Nevada were included in the study area. Overall, the classification applies to nearly 3,000,000 acres in the central and southern Sierra Nevada.

Classification Concepts

Potential Natural Community

The basic unit of classification and description is the forested plant association. Plant associations can be viewed as potential natural plant communities that have a definite floristic composition. Generally, they occur within uniform habitat conditions. A potential natural plant community is defined as the plant community that would be established if all successional sequences were completed without human-caused disturbance under existing environmental conditions (U.S. Department of Agriculture, Forest Service 1991). In a practical sense, plant community structures have evolved to a dynamic equilibrium in which individual species are regenerating, competition has stabilized, and a different future plant community is unpredictable in the absence of major disturbance (Driscoll and others 1984). This classification also relates the potential natural plant community to soils and landforms typically occurring in the landscape. The soil element is patterned after the soil taxonomy system developed by the U.S. Department of Agriculture, Soil Conservation Service (1975). Geology and landform elements are those described in standard references, such as the Glossary of selected geomorphic terms for western soil surveys compiled by the U.S. Department of Agriculture, Soil Conservation Service (1984).

The concept of potential natural plant community differs from traditional views of climax vegetation. Climax vegetation has commonly been considered a stable final stage of succession. Plant communities at climax were believed to be determined by regional climate or modification of physical environments by the plant community (Clements 1936) or by other environmental factors such as soil or topography. These plant communities were considered to be in equilibrium with past and future environments, and they were considered self-replacing if disturbed. Succession was seen as deterministic, predictable, and ending with a final, stable climax community. The role of natural disturbances such as fire, flood, or insects and pathogens, or the effect of human activity were not emphasized.

Long-term environmental stability is a key implication of the climax concept; however, climatic records indicate this is not the case. Recent investigations have also shown that succession is not deterministic. Often, several vegetation states can exist at any point on a successional pathway. In many cases a stable, self-replacing equilibrium state (climax) is rarely achieved because of the persistent role of natural disturbance in shaping vegetation patterns and the long-term effects of human activity on plant communities. Thus, the composition and structure of plant communities are currently viewed as contingent. They depend on initial conditions and the sequence of events that occur within and outside them.

The concept of potential natural plant community incorporates both views of succession. The attainment of a relatively stable late-seral community is implied; however, these communities are viewed as expressing a condition of dynamic rather than static equilibrium. At a basic level, plant communities are shaped by climate, soil development, and topographic setting; thus, vegetation is essentially in balance with the biotic and abiotic factors of the site. However, disturbances at a variety of spatial and temporal scales modify vegetation response at individual sites, and succession is not regarded as deterministic. Disturbances can potentially result in several existing vegetation states at any point along a successional path. As a consequence, no stand will ever be identical in all respects to any other. For this reason, the characteristics of potential natural communities cannot be determined from individual stands. They emerge from the characteristics of similar stands distributed in similar settings on the landscape. Succession is also viewed from the perspective of a relatively short time period, not, for example, from a geologic time scale as may be involved in climate change. Thus, the effect of future climatic change or unknown earth shaping disturbances are removed from consideration.

Evolutionary Perspective

From an evolutionary perspective, plant communities are viewed as responding to Darwinian selection at the level of the individual to produce species adaptations to unique environments. Adaptations, in general, may be morphological or physiological, and they equip species to compete and persist in specific habitats. Thus, differences in reproductive rates, differences in competitive abilities through time, response to parasitism, or response to disturbance are viewed as inherited traits that permit a species to inhabit or dominate a particular setting.

Species also coevolve with others. The "principle" of competitive exclusion states that if two species are ecologically identical they cannot simultaneously inhabit the same ecological space. If two species coexist in a saturated environment, an ecological difference may exist between them. Thus, the ecological niche—the sum total of the adaptations of an organism to its particular environment (Pianka 1988)—is the basis of theory about ecological diversification and the development of complex biological communities. These concepts define a species' evolutionary "fitness" in a particular plant community, and they are the bases for using similarity in both species composition and environment to classify samples in this study. Thus, the classification is not based on floristic differences alone, but includes differences in both species and environment as the basis for the classification.

The role of humans in the past is acknowledged, but their future role is not defined. Recently, additional disturbance factors have been added because of human activities. Thus, the introduction of non-native species such as cheatgrass *(Bromus tectorum)* in the 1800's, the introduction of grazing by cattle and sheep in the middle 1800's, the introduction of fire suppression activities in the early 1900's, the introduction of white pine blister rust in the 1930's, and, more recently, changes in air quality as a result of development and industrialization adjacent to the Sierra Nevada, have brought changes in the vegetation that may not be realized for substantial periods of time. Although the concept of potential natural communities does not include future human-caused disturbance, the effects of past human activity must be included.

Changes in community composition and structure related to these newer disturbance elements are essentially unknown at this time. If the effects are only slightly different from historical ones, then differences can be expected to be relatively small, perhaps involving species abundances. On the other hand, if they are more catastrophic or exotic in their effect on vegetation, a significant shift perhaps involving new species complexes may occur (Denslow 1985). For this classification, attempting to project vegetation changes in response to these factors was simply too speculative at this time. In general, the present structure and species composition of the late seral stands sampled was accepted as reflecting the normal variation that occurs in the potential natural plant communities of these sites.

Although vegetation often exists in discrete patches across the landscape, gradual change from one vegetative community to another is a typical pattern in these forests. This change is seen as a response to the environmental and genetic heterogeneity between communities. Many environmental factors affect the normal genetic variation within species to produce gradual rather than abrupt changes in vegetation patterns. These transitions or ecotones reflect the ability of a species to maintain a homeostatic balance across a wide range of environmental conditions. Thus, although the associations classified here are described as discrete entities, they are more properly viewed as lying along a gradient or ecocline with a gradual transition from one community to the next. In some cases an ecotone may be narrow covering a few feet, while in others it may be broad and cover many hundreds of acres.

Classification Hierarchy

Because the classification is not designed to be hierarchical, the plant associations described do not necessarily tier to more broadly or narrowly defined vegetation units described by others. On the other hand, the ability to aggregate or disaggregate vegetation patterns for broad regional or national purposes while maintaining the integrity of the classified units can be useful. Thus, the classification framework described by Driscoll and others (1984) is most appropriate for the plant associations described here. This framework defines a hierarchy of potential natural plant communities from class to formation level, and it describes series and plant associations which occur at lower levels in the hierarchy.

The series concept has not been consistently applied in the literature on classification work (Driscoll and others 1984, Hall 1988, Sawyer and Keeler-Wolf 1995). Series have been characterized both by individual dominant or codominant species of the community, and by the most shade tolerant species regenerating on the site regardless of current dominance. Neither approach is completely compatible with the vegetation patterns of the upper montane forests. For example, western juniper and red fir inhabit fundamentally different environments. Western juniper is adapted to xeric conditions, and it is relatively shade intolerant while red fir is adapted to mesic conditions, and it is more shade tolerant. In stands with both species present, red fir may occur in the understory, and it may provide the most overstory cover in some cases; however, the presence of western juniper indicates that environmental conditions have shifted indicating that it is ecologically advantaged compared to red fir. In this classification, series are defined by overstory species dominance and environment. Dominant or characteristic species of the upper montane are used in conjunction with environmental differences to define series, subseries, and plant association *(appendix A)*. In cases where environmental differences are not clear, dominance of cover and shade tolerance were used.

The Forest Environment

Physiographic Setting

The Sierra Nevada is the single largest mountain range in the contiguous United States (Hill 1975). It extends more than 400 miles along a northwest-southeast trending axis, and it varies in width between 50 and 80 miles with the widest dimensions in the north-central portion of the range. The width decreases both north and south from this region. The height along the crest is impressive. Thirty peaks exceed 12,000 feet, and the range contains Mount Whitney, which at 14,494 feet, towers as the highest peak in the conterminous United States. Along the crest, the highest peaks are found in the central portion of the range *(fig. 2)*. From the north, the elevation of the highest peaks gradually increases until the upper reaches of the Kern River and Mount Whitney are encountered. Heights then drop abruptly toward the southern extension of the range. In the north, near Fredonyer Pass, for example, peaks seldom rise above 8,000 feet, while in the central portion, the highest peaks are commonly above 11,000 feet, and several exceed 14,000 feet. South of Olancha Peak, elevations drop rapidly to below 5,000 feet near Tehachapi at the southern limits of the range.

On the westside, the range rises gradually from elevations near sea level to the crest. At right angles to the crest of the range are three transects: east of Rancho Cordova near the northern portion of the range; east of Clovis in the central portion; and east of Porterville at the southern end of the range *(fig. 3)*. The average slope on the westside is about 2° or 4 percent. This results in an average rise in elevation of about 200 feet per mile. Elevations on the westside increase more abruptly in the south. South of Yosemite Valley, subsidiary ridges whose height approaches that of the main crest are found progressively closer to the Great Valley the farther one proceeds. The western slope in a transect from Porterville to Slate Mountain, for example, is nearly 4° or 7 percent. This results in a rise of nearly 360 feet per mile and typifies the area south of the Kings River. Such a regional change in shape suggests a fundamental difference in the pattern of orogeny. Thus, the northern part of the range is a tilted block; whereas the southern part is similar to a block that has been bodily uplifted (Christensen 1966).

From the crest, the abrupt drop on the eastern side of the Sierra Nevada is well known, and changes in elevation are dramatic. Slopes average 9° or 16 percent. This equates to an elevation gain of nearly 850 feet per mile. The crest drops from over 14,000 feet to elevations below 4,000 feet within 10 miles along a transect across the southern portion of the range near Lone Pine. Even in the north the relief is exceptional. Thus, within 7 miles, slopes drop from over 13,000 feet at Mount Dana to 6,700 feet at Lee Vining, and the drop from Freel Peak to Highway 88 near Lake Tahoe is nearly 6,400 feet within 6 miles.

Figure 2—North to south transect along the crest of the Sierra Nevada showing the heights of the tallest peaks.

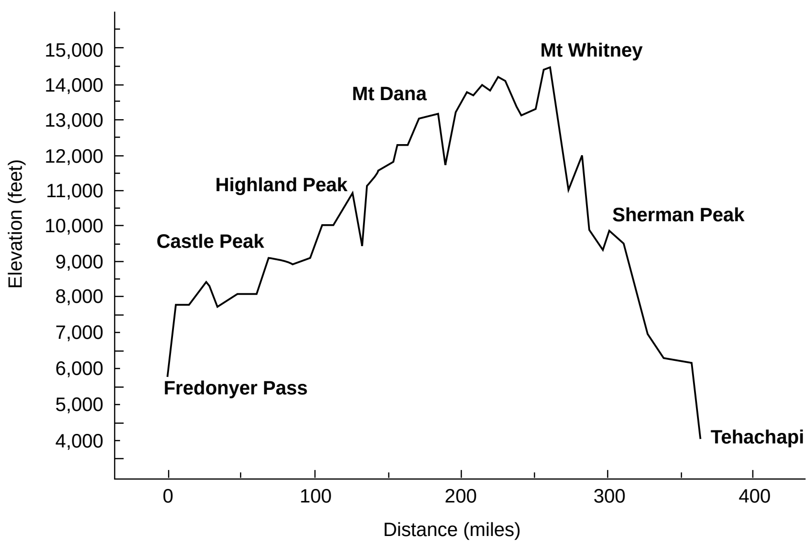
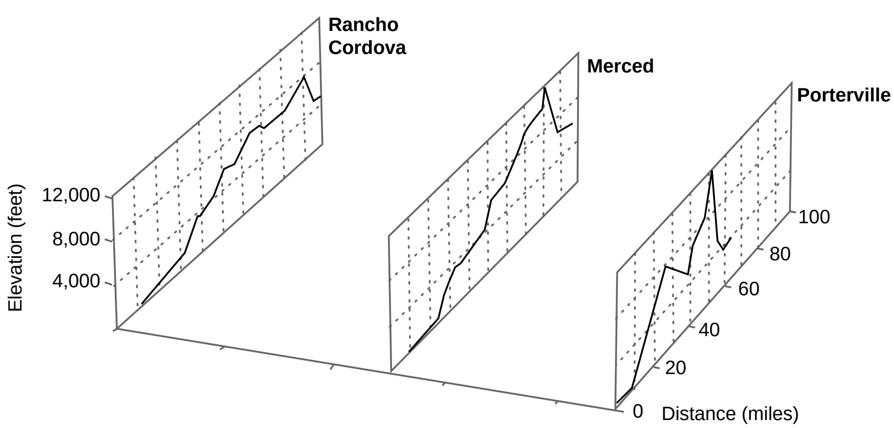


Figure 3—Three transects from west to east across the Sierra Nevada showing change in elevation with distance.



Except for the Kern River, which runs almost due south, major rivers flow generally northeast-southwest at right angles to the axis of the range. These river systems have all cut major canyons into the underlying rocks. The American, Cosumnes, Mokelumne, Stanislaus, Tuolumne, Merced, San Joaquin, Kings, and Kaweah rivers on the westside have all incised canyons several thousand feet deep into the range, and the drop into the Kings River from the top of Spanish Mountain is over 7,000 feet, one of the longest continuous mountain slopes in the United States. River systems on the eastside are less abundant and substantially shorter than those on the west. Nevertheless, rivers such as the Truckee and Walker and lesser drainages such as Robinson, Green, Lundy, Lee Vining, Hilton, and Rock Creek have all incised the range to significant depths. Tributaries to these drainages on both sides of the range feed into them in a dendritic pattern and further dissect the landscape. Thus, on a local scale, relief is substantial and topography complex.

Climate

Generally, climate in the Sierra Nevada is dynamic and always changing. Since the formation of the range, worldwide climate has varied in response to external forces that are based on the dynamics of the solar system and structures of the earth. Currently, the climate of North America is positioned in a warm interglacial period during a glacial age. This glacial age, or Quarternary period on the geologic time scale, has extended from about 2 million years ago to the present.

The current interglacial period appears to be drawing to a close. Commencing with the retreat of the ice sheets that covered large portions of North America until about 20,000 years ago, temperatures in the interglacial steadily rose until near the beginning of the present or Holocene epoch around 10,000 years ago. Since then temperatures have generally fallen, but climatic variation has persisted and resulted in alternate warm and cool periods throughout this time (Moratto 1984, Pielou 1991). Within the past 1,100 years for example, climates have fluctuated between a warm period lasting about 475 years and known as the “Little Climatic Optimum” followed by a cooler period lasting nearly 400 years and known as the “Little Ice Age” (Moratto 1984, Woolfenden 1994). The “Little Ice Age” came to a close only slightly more than 200 years ago at the origins of modern climates.

Modern California climates continue to demonstrate considerable variation. For example, the periods between 1750 and 1820 and 1860 to 1880 have been recorded as being generally very dry (U.S. Department of Agriculture 1941). From the late 1920’s until the late 1930’s, during the “Great Dust Bowl,” and more recently during the late 1970’s, 1980’s and early 1990’s conditions were again dry. Presumably, intervening periods were considered “wet.” Floods recorded in the winters of 1861-62, 1938-39, 1955-56, 1964-65, and 1986-87 in various portions of the state mark years of extreme precipitation (State of California 1979). Thus, over the past 240 years, roughly 110 years of extended drought were offset by 130 years of extended moist or “wet” conditions. Variations in climate are both long-and short-term, and generally, the transitions between changes are not abrupt. Thus, the climate experienced today does not necessarily reflect what has been experienced in the past, and it is unlikely conditions will remain any more stable in the future.

Pollen and macrofossil studies combined with glacial and tree ring chronologies have established vegetation changes in the Sierra Nevada that track the climatic variations over the past 10,000 years (Woolfenden 1994). These climatic changes can have important consequences for vegetation. Most of the tree species in these forests are long-lived, and they have grown under a variety of climatic conditions. Many of the older members of current stands originated and grew during the latter part of the “Little Ice Age,” but they continue to survive and grow in the current climate, which is substantially different from that earlier period. Most individuals in existing plant communities of the upper montane, however, have developed since the "Little Ice Age" under the influence of modern climates. Thus, plant communities in these forests are continually maintaining short-term homeostatic balance while also responding and adapting to long-term climatic variation.

The present climate of California is characterized as Mediterranean with cool, wet winters and warm, dry summers. This basic pattern is the result of a subtropical high pressure system that lies in the mid-Pacific Ocean and deflect slow pressure systems originating in the Gulf of Alaska northward during the summer. In the winter this same high moves south and allows cyclonic storms to cross the northern portions of the state. Even in winter, however, this high and an upper level jet stream often deflect storm tracks to the north. This condition results in a strong north-south moisture gradient in which precipitation decreases substantially from north to south in the range *(fig. 4)*.

The central and southern Sierra Nevada is surrounded on three sides by arid lands. To the west is the great central valley which lies in the rain shadow of the coast ranges. The southern portion of this area, around Bakersfield for example, is true desert with precipitation as low as 6 inches per year and precipitation insufficient to recharge soil water (Major 1988). South from Bishop and east of the range lie the hot deserts of the Mojave, while the cold continental deserts of the Great Basin are found on the east from Bishop northward.

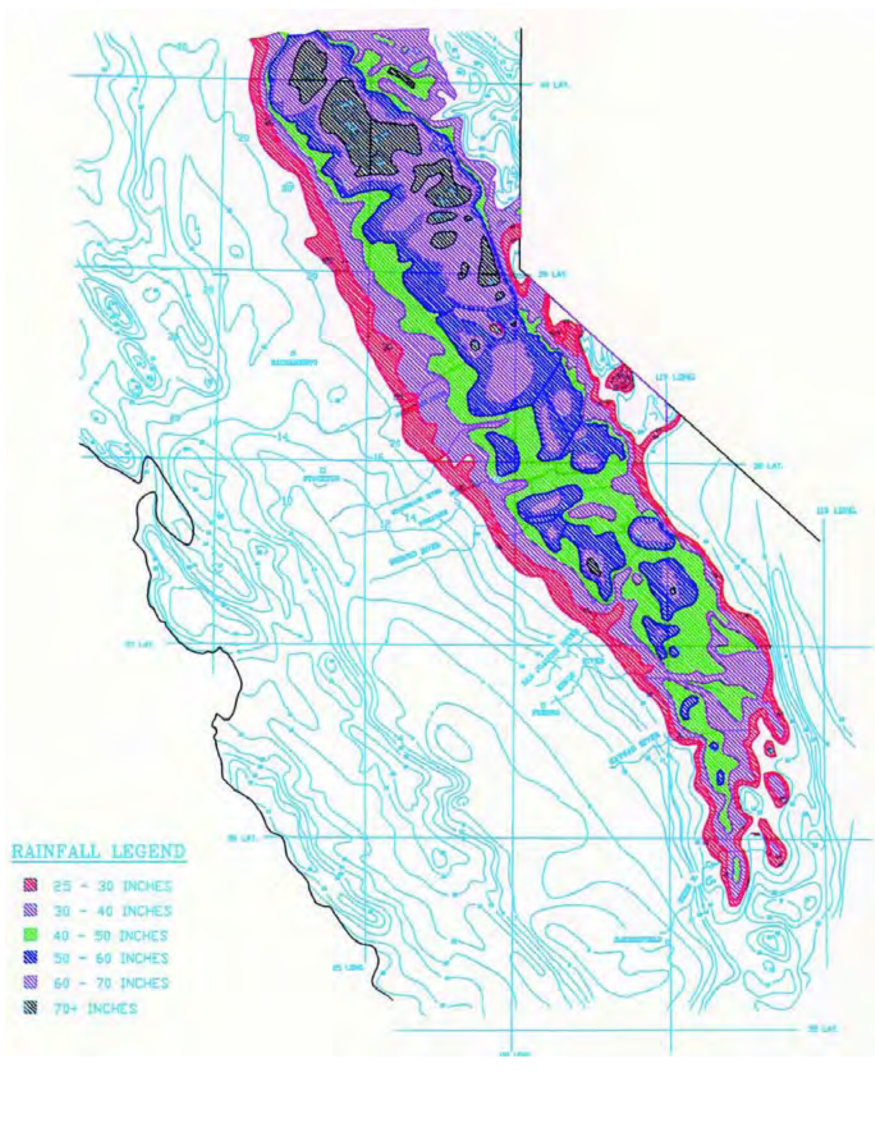


Figure 4—Isohyetal lines of precipitation in the central and southern Sierra Nevada.

Rising from these deserts, the Sierra Nevada exerts a strong orographic effect upon sites located within the range as well as those located east or "downwind" of the range. On the western slopes precipitation generally increases with elevation to the crest where it then decreases at a rapid rate on the east side in the rain shadow of the range. The effect of this rain shadow is extensive. It persists across the Great Basin to the Rocky Mountains. The state of Nevada, directly in the lee of the Sierra Nevada, is the driest state in the nation (U.S. Department of Agriculture 1941). An arid-humid boundary has been established at about 1,230 feet near Auburn in the northern Sierra Nevada, 2,450 feet east of Madera in the south, and 7,870 feet above Mono Lake on the east (Major 1988). Above these elevations precipitation exceeds potential evapo-transpiration and the climate becomes humid.

Precipitation

Precipitation falls primarily as rain at elevations below 6,000 feet. The rate of increase is about 7.1 inches per thousand feet of elevation gain on the westside in the north, 6.1 inches in the south, and 7.3 inches on the eastside (National Oceanic and Atmospheric Administration 1982). Rainfall apparently peaks from 5,000 to 6,000 feet and declines at higher elevations *(fig. 5)*. However, at these elevations the form of precipitation begins to change to snow (State of California, Department of Water Resources 1991), and measurements in areas where both rain and snow occur are difficult to determine. Differences in measurement techniques probably result in records that show a decline in precipitation at elevations above 6,000 feet. Stations established to measure rainfall amounts do not often adequately measure precipitation in the form of snow, and snow course measurements do not generally account for precipitation falling as rain, particularly in the summer and fall before a snowpack is established. Few stations account for precipitation falling in either form, and even fewer have a substantial history. In these transition elevations, a true estimate for precipitation is probably a composite of both types of record. At elevations of 7,000 to 9,500 feet, which might be considered typical for the upper montane, estimates show that between 65 and 90 percent of precipitation falls as snow (Major 1988, State of California 1979).

The snowpack builds through the winter and generally attains maximum depth and water content around the end of March (State of California, Department of Water Resources 1991). Values are recorded on April 1 of each year, and this date is used as the basis for comparisons. The average April 1 snow depth for elevations between 7,000 and 9,500 feet are quite different by subregion. Thus, snowpack depth in the northern portion of the study area on the westside is about 84 inches on April 1, while in the south it is 25 percent less at 63 inches. Maximums

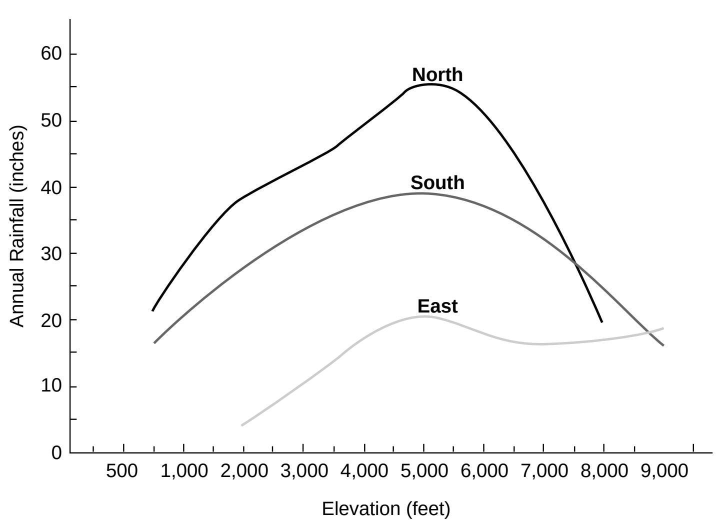


Figure 5—Annual rainfall by elevation for three subregions in the central and southern Sierra Nevada.

for the northern and southern portion of the study area are 247 and 219 inches, respectively. On the eastside the snowpack averages over 71 inches, but there is a substantial difference between station records in the northeast compared to those in the southeast. The average on the eastside in the north is about 74 inches while it is only 28 inches in the south. The maximum snowpack depth recorded in the central and southern portion of the Sierra Nevada for the 50-year period 1941 to 1990 at all stations was 267 inches (22.25 feet), and this occurred on the eastside.

As elevation increases above 6,000 to 7,000 feet, the April 1 water content increases until about 8,000 feet in the north and east and 9,000 feet in the south *(fig. 6)*. The rate of change per thousand feet is about 6.4 inches on the westside in the north, 3.8 inches in the south, and 5.2 inches on the eastside. Above these elevations water content apparently declines. A large part of this reduction may result from redistribution of newly fallen snow by wind and higher levels of evaporation and melting since vegetation becomes sparse at higher elevations (Major 1988).

Regional variation in the water content of the snowpack is high in the central and southern Sierra (State of California, Department of Water Resources 1993) *(fig. 7)*. The outstanding feature of southern and eastside stations is the high percentage of sites and years that receive less than 20 inches of water from the April first snowpack. Northern stations on the westside show a more uniform distribution of water content over time. Thus, not only do southern and eastern sites receive less total snowpack, they experience lower water content more often. Years with high April 1 water content in the snowpack occur less often in the south and east than in the north.

The location of the red fir dominated upper montane forests is highly correlated with the snowpack. Over 90 percent of all red fir dominated sample sites were located between 7,000 and 9,500 feet. These are the zones of maximum April 1 snow depth and water content. On the west side, Barbour has found good correlation between elevations of the white fir-red fir ecotone and the altitude of the freezing level during major storms at latitudes near 39° (Barbour and others 1991). This same study also showed a sharp increase in April 1 water content within the ecotone at latitudes between 38 and 40°, and it indicated that snow depth could be a predictor of water content. Within the ecotone, the relative density of red fir increased with snow depth and April 1 water content. Field observations indicate the same relationship at somewhat higher elevations on the westside in the south and on the eastside. The average April 1 water content in the snowpack at elevations between 7,000 and 9,600 feet is 34.3 inches in the north In the south it is 24.7 inches, and on the eastside it is 28.1 inches.

An important constituent of summertime weather in the Sierra Nevada is convective buildup (National Oceanic and Atmospheric Administration 1982). Moist air rising from the central valley in the afternoons, or warm moist air masses originating in the Gulf of California and Pacific coast of Mexico condense at high elevations over the crest to form large cumulonimbus clouds. Often these clouds are accompanied by lightning, intense localized rainfall, and substantial drops in temperature. Summertime snowstorms have been recorded in these upper montane forests. The peak season for such convective activity is June through September although September also includes precipitation accompanying the first storms of fall from the Gulf of Alaska and coast of Mexico. Average monthly summer precipitation levels in inches at representative elevations by subregion of the upper montane include:

Elevation	***North***	***South***	***East***
7,000 ft.	0.66	0.48	0.56
8,300 ft.	0.75	0.56	0.66
9,500 ft.	0.84	0.63	0.75

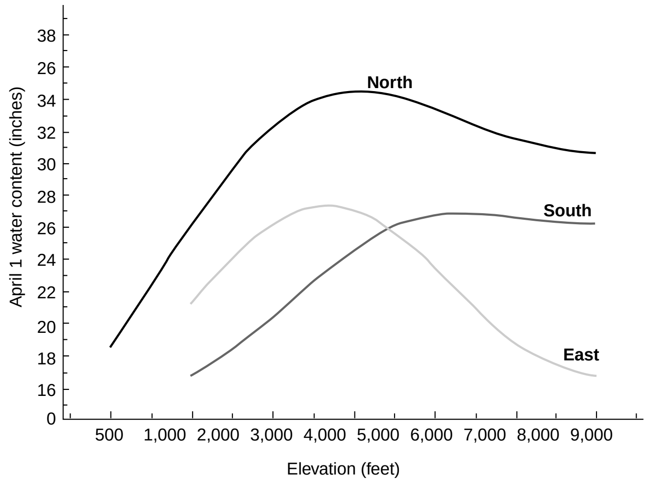


Figure 6—April 1 water content of the snowpack by elevation in three subregions of the central and southern Sierra Nevada.

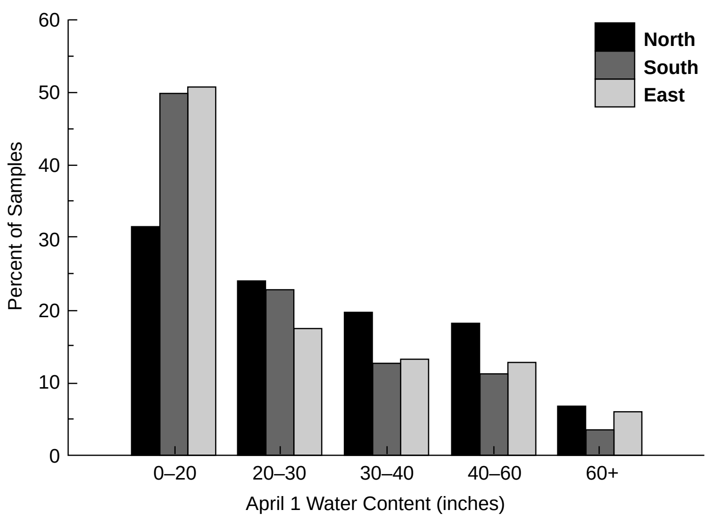


Figure 7—Regional variation in the April 1 water content of the central and southern Sierra Nevada snowpack between elevations of 7,500 and 9,000 feet.

Averages, however, are misleading. Most of the storms originating from convective activity are infrequent at a specific location. They are often of high intensity but relatively short duration. Thus, a single 2-inch precipitation event occurring over a few hours within a 10-year period averages 0.2 inches per year for the period. Because many of these storms are of high intensity, substantial surface runoff occurs that is not available for long-term use by plants. The overall effect on vegetation may therefore not be substantial. Probably as important in regulating plant activity are the periods of lowered temperatures and higher humidities that accompany these storms. A rainfall event may or may not occur at a particular site, but generally cloudiness and cooler temperatures occur over a larger area when convective storms are present, and these conditions may persist for several days.

Temperature

Temperatures decrease as elevation increases in each of the major geographic subregions of the study area (National Oceanic and Atmospheric Administration

1982). A rapid drop in temperature with elevation on the eastside as compared to the westside in both winter and summer is apparent, and the rate of change is greater in the summer in all areas *(fig. 8)*. Average temperatures for January, July, and yearlong at representative elevations in the upper montane were determined from regression values *(table 1)*.

Table 1—Average temperatures (°F) by subregion at representative elevations in the upper montane.

Subregion	Elevation (Feet)		
	7,000	*8,000*	*9,000*
North			
January	32.8	30.9	28.9
July	64.0	61.8	59.7
Yearlong	46.0	43.7	41.4
South			
January	34.1	32.2	30.3
July	62.5	59.6	56.6
Yearlong	45.7	43.0	40.2
Eastside			
January	26.4	23.4	20.3
July	59.3	54.6	49.9
Yearlong	41.5	37.5	33.5

Average lapse rates (change in temperature per 1,000 feet of elevation change) in degrees Fahrenheit for July (summer) and January (winter) *(fig. 8)* include:

	North	***South***	***East***
January	1.9	1.9	3.0
July	2.1	3.0	4.7

On a 40° day at 4,000 feet in January, ambient air temperatures at 8,000 feet might lie near 32° on the westside. Such a day on the eastside might be expected to result in ambient air temperatures at 8,000 feet of 28°. A 100° day during July near sea level in the central valley would be expected to be near 83° in the north and 76° in the south at 8,000 feet on the westside. A similar day on the eastside in Bishop would see a temperature of 81° at 8,000 feet.

Geology

The Sierra Nevada range is a block of uplifted granitic rocks that has been tilted to the west. In detail, however, the geologic structure of the range is more complex than this. It results from important events that occurred throughout the history of the range, and it defines the character of these mountains as they are viewed today. In the foothills and at scattered locations at higher elevations as well as along the crest are metamorphic rocks that predate the range. In the north, volcanic mud and ash flows have covered the granitic batholith over extensive areas. In addition, the higher elevations have been extensively glaciated during the Wisconsonian glaciation of North America. Volcanoes, such as those near Mammoth Mountain, have erupted in recent history, and erosion and faulting are continual.

Origins of the range date from the Paleozoic era more than 225 million years ago when sediments were deposited in a shallow sea that covered most of the range. These deposits were intruded, folded, and metamorphosed as the range took shape. Uplifting and subsequent erosion have resulted in two major areas of

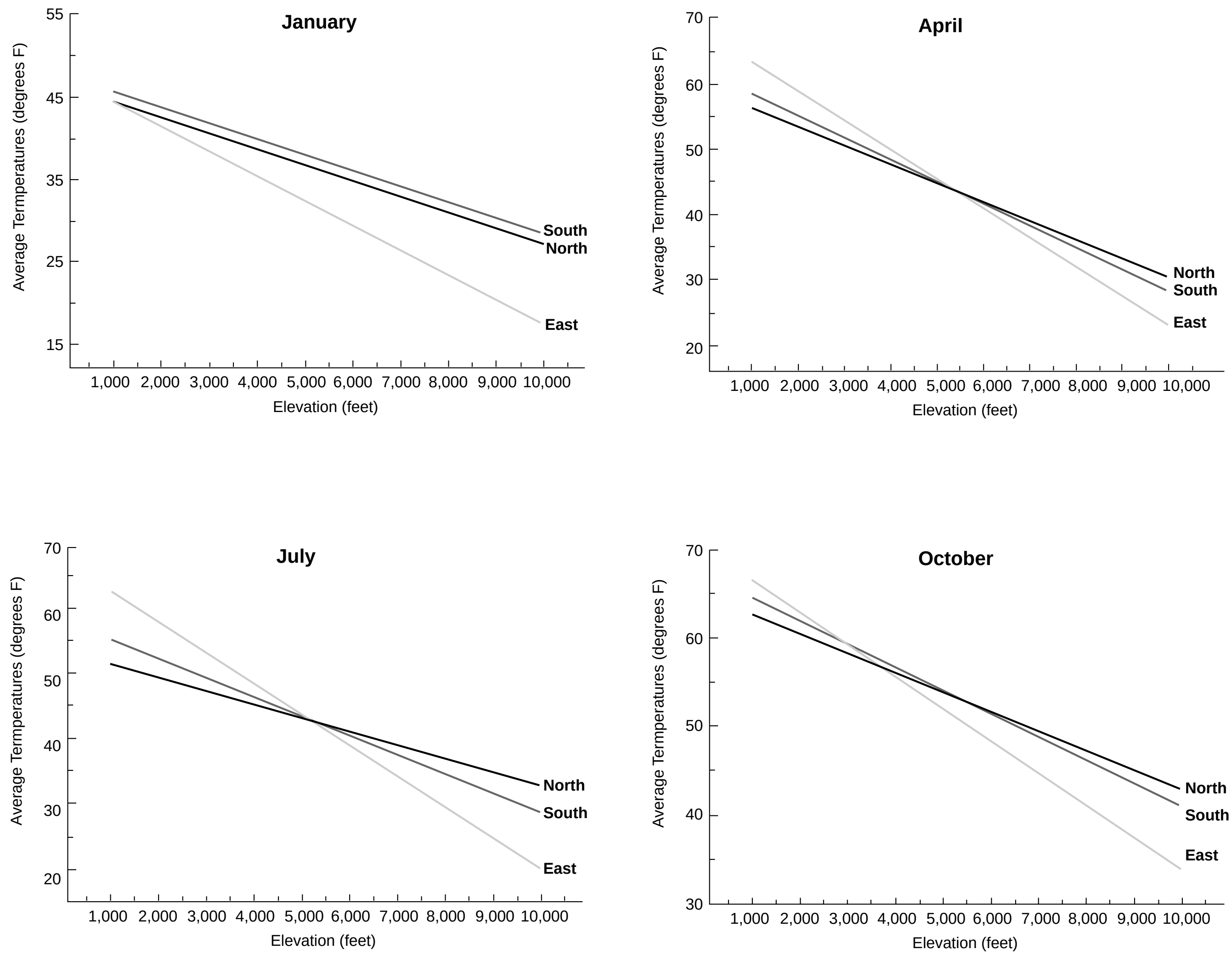


Figure 8—Change in temperature with elevation by subregion and time of year for the central and southern Sierra Nevada.

Paleozoic and Mesozoic metamorphic rocks present in the current landscape. One set of these rocks is found in a belt along the western foothills; the other lies as roof pendants in a scattered band along the crest. Most of these formations lie outside the study area; however, scattered throughout the upper montane forests are isolated outcrops that survived erosion and date from these periods. Within the study area, more of these rocks were encountered in the southern portions of the range than the north.

Sedimentary deposition of the Paleozoic era was followed by downfolding and development of a large syncline along the axis of the range during the Mesozoic era of 225 to 80 million years ago. This syncline was intruded by the Sierra Nevada granitic batholith and subsequently uplifted. The granite was intruded as hundreds of discrete plutons, apparently in several pulses (Bateman and Warhaftig 1966, Oakeshott 1971). These plutons show differences in mineralogy and textures that can be recognized at the surface and result from variations in the orogenic processes that formed the range. They are generally distributed in belts with the western rocks somewhat older than those on the crest or eastside, and they vary in size from 1 square mile to over 500 square miles. Quartz monzonite and granodiorite are the most abundant rocks in the batholith (Bateman and Wahrhaftig 1966).

Volcanic eruptions during the Tertiary period covered substantial areas north of the Middle Fork of the Tuolumne River. The earliest deposits were rhyolitic tuffs, and ash flows of the Valley Springs formation that date from 30 to 20 million years ago and range up to 800 feet thick. These were followed in sequence by the andesitic mudflows (lahars) and latites of the Relief Peak and Stanislaus formations that were deposited between 19 to 9 million years ago and range up to 3,000 feet in thickness. The final deposit in the sequence was the Mehrten or Disaster Peak formation composed of andesites, rhyolites, and basalt ranging in age from 9 to 5 million years ago. This formation is about 1,000 feet thick (Slemmons 1966). The combination of these formations cap the ridges and upland areas of the northern portion of the study area except in areas where the granitic batholith rose above the volcanic flows when they were formed or was exposed by erosion later.

Tilting and further uplift of the range to present heights occurred in the Pliocene epoch of 10 to 5 million years ago. The amount of uplift appears to be quite variable. In the north it is estimated at about 6,000 feet, while in the south it appears to be as high as 14,000 to 19,000 feet (Bateman and Warhaftig 1966). Faulting, which appears to have accompanied the deformation, also began along the eastside around 10 million years ago. In response to the uplift and tilting, rivers incised their drainages to depths of 2,000 to 4,000 feet. From this uplift and subsequent erosion the range obtained the deep canyons of the westside and the dramatic relief of the eastern escarpment. Most of this downcutting was completed before the end of the Pliocene about 2 million years ago (Bateman and Warhaftig 1966).

Pleistocene glaciation began in the Sierra Nevada about 3 million years ago at the same time it was occurring throughout the northern portions of the continent and other high mountain ranges of the world. At the height of glaciation the range bore an icecap nearly 270 miles long and 20 to 30 miles wide (Warhaftig and Birman 1965). It extended from near the Middle Fork of the Feather River to areas between Mount Whitney and Olancha Peak. While the icecap was large in extent, it did not cover continuous areas, and many peaks, ridges, and aretes were left uncovered as refugia. On the eastside glaciers extended to the adjacent lowlands, and attained depths of over 1,000 feet. On the westside the ice descended to elevations as low as 3,000 to 4,000 feet, but it attained much greater depths. For example, a depth of 4,000 feet has been estimated for the glaciers of the Grand Canyon of the Tuolumne, and the Merced glacier appears to have attained a depth of 6,000 feet (Bateman and Warhaftig 1966). This great icepack gradually diminished during the subsequent interglacial period until it disappeared around 20,000 years ago.

Glaciation provided a major force that shaped the current landscape of the Sierra Nevada. Although most of the large drainages appear to have attained their present depths before the Pleistocene epoch, glaciers carved many of these drainages into the characteristic “U-shaped” profiles observed in canyons throughout the range. Other drainages retained their “V-shaped” pattern but were downcut further. Broad areas were scraped free of weathering rock and developing soil. Deep basins, often filled with alluvium such as Yosemite Valley, were formed in drainage bottoms. Trenches were etched and many times filled with debris along joints that occurred in the granitic batholith. Moraines were formed, and this material was deposited along the sides and bottoms of canyons as the glaciers retreated. In other places glacial till not deposited from moraines was left scattered on the landscape. Finally, as the glaciers moved they carried deposits from higher elevations to lower or across surfaces developing from different parent materials. As a result, morainal ridges and glacial till were often found to be mixtures of volcanic, metamorphic, and granitic rock types. This was particularly common in the northern part of the study area.

More recently, during the Pleistocene and Holocene epochs, volcanic activity has occurred on the eastside and in the southern portion of the range. Much of this within the upper montane is located near Mammoth Mountain and Mono Lake. Basaltic andesites, quartz-latite, and rhyolitic tuff range in age from 370,000 to as recent as 6,000 years, and possible dates as recent as 500 to 850 years ago have been obtained from the Inyo Craters (Bateman and Warhaftig 1966). In several areas these flows are overlain with pumice erupted from a line of craters extending south from the Mono Craters to the Red Cones. This pumice mantle extends as far as Kaiser Pass near Huntington Lake, and it often covers soils that were developing at the time of eruption. Further south, along the headwaters of the South Fork of the Kern River, are several basaltic cinder cones and flows, including the latite domes of Monache Mountain and Mount Templeton that appear to date from mid-Pleistocene.

Soils

Soils in the upper montane are weakly developed. Erosion from steep slopes, the relatively short period of time since Pleistocene glaciation, and a Mediterranean climate have limited the degree of soil development. These soils are typically medium to coarse textured, and they often do not contain a zone of clay accumulation or B horizon.

Soil Classification

Soils are classified into orders, suborders, great groups, subgroups, families, and series on the basis of properties that distinguish genetic processes. Differentiating criteria at higher levels of the taxonomy, such as soil order, are broad and general in importance; whereas those at lower levels are more specific. Taxonomically, upper montane soils are characterized by four orders: Entisols, Inceptisols, Alfisols, and Mollisols. Entisols are those soil groups that show no signs of profile development while Inceptisols are those with some development. Alfisols and Mollisols are developed soils. Alfisols contain an argillic or clay horizon while Mollisols have a dark, thick topsoil with high levels of organic matter. Most samples in this study were Inceptisols. Entisols were also encountered in substantial numbers, but Alfisols and Mollisols were uncommon *(fig. 9)*.

The results of this study showed that Entisols occurred in higher proportions on the eastside than elsewhere in the study area. Nearly 50 percent of the eastside samples were Entisols. Many of these came from the cindery deposits near Mammoth Mountain and from flow rocks on the eastside, but the highest proportion of these sites overall came from the granitic rocks of the Sierran batholith. Entisols also occurred in high numbers in the southern portion of the westside. This appears to coincide with the steeper topography and drier climate of this region.

Within the four dominant orders, Umbrepts and Ochrepts were predominant suborders in the Inceptisols *(fig. 10)*. Umbrepts are dark, reddish brown, acidic soils that are freely drained and organic matter-rich. They typically occur in areas with a Mediterranean climate. Ochrepts are light brown colored soils that are freely drained and occur in a wide moisture and temperature range. They often occur on steep slopes. Psamments, which are sandy soils with low available water holding capacity (AWC; see *Glossary*), and orthents, which occur on erosional surfaces and generally do not have diagnostic horizons, were common in the Entisols. Xeralfs were the major suborder on sites with Alfisols. These are reddish soils of Mediterranean climate that experience extended periods of summer dryness. They often have an abrupt boundary between the A and B horizon. Xerolls occurred more often in the few Mollisols. They, too, occur in areas with a Mediterranean climate and are dry for extended periods in the summer.

In this study the most commonly encountered features differentiating soil families were particle size class, mineralogy, and temperature class. As much as 50 percent of the samples were classified as skeletal in particle size class

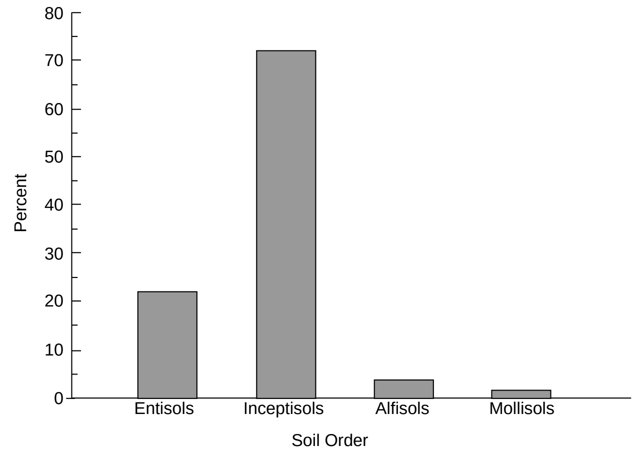


Figure 9—Percent of soil samples by soil order in the central and southern Sierra Nevada.

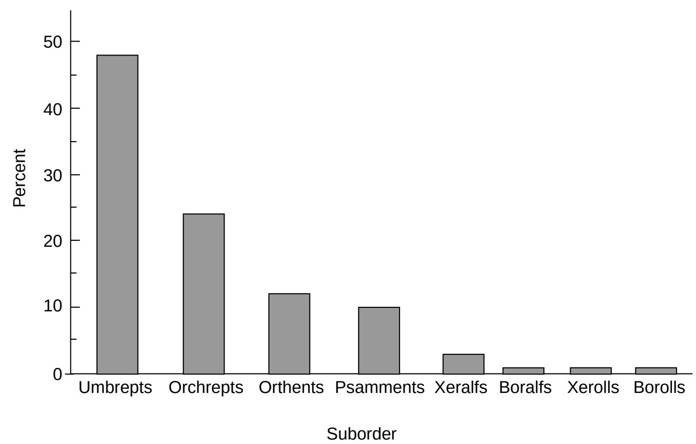


Figure 10—Percent of soil samples by soil suborder in the central and southern Sierra Nevada.

indicating the high proportion of sites with greater than 35 percent of the volume in rock fragments. Of the remaining samples nearly 30 percent had a loamy particle size class, and over 10 percent were sandy. Ashy, medial, cindery, and contrasting particle size classes were also encountered. Almost all sites were in the mixed mineralogy class. Soil temperatures were mostly in the frigid and cryic regimes. Over 80 percent of the sites were classified as frigid implying that mean annual soil temperatures at 20-inches depth were estimated to be below 47° F (8° C) but with summer temperatures warmer than cryic soils. A substantial number of sites (14 percent) were classified in the cryic regime with mean annual temperatures between 32 and 47° F (0 to 9° C). Less than 5 percent of the samples were classified in the mesic temperature regime.

Soil colors were predominantly yellow-red (YR). Essentially all of the topsoils occurred in hues of 7.5 YR, 10 YR, or 2.5 Y. Over 90 percent of the topsoils were 10 YR in hue alone. These were yellow-red to yellow soils when moist. Few occurrences of redder soils were encountered in surface horizons. Topsoils were also strongly mollic in value and chroma. Over 90 percent were very dark brown, mollic colors. Subsoils showed similar patterns. Ninety-eight percent of the subsoils were 7.5 YR, 10 YR, 2.5 Y and 5 Y in hue. These were also yellow-red to yellow in color when moist. Subsoils varied more in value and chroma than topsoils. They were almost evenly distributed between high value and low value showing wide ranges in light versus dark colored soils. Chroma was also variable and showed uniform distributions between soils that were strongly colored and those that were not.

Parent Materials

Parent materials originated from six different rock types: granitic, volcanic flows, lahars, tephra and ash deposits, and metamorphic sources. A small portion came from sources in which rock types had been mixed either through glacial activity or gravity. A very few sites were derived from sedimentary rocks. Granitic sources far surpassed all other parent materials. The two largest soil orders, Inceptisols and Entisols, were found mainly on these granitic rocks as might be expected. Among the extrusive volcanic type parent materials, Inceptisols and Alfisols were found almost exclusively on the lahars; whereas Entisols were found more commonly on volcanic flows, tephra, and ash deposits. Soils derived from metamorphic rocks and mixed rocks were most commonly Inceptisols.

Soil Development

As elevation increased, soil classification changed at the order level and additional differences in soil characteristics were found. Together these features seemed to reflect climate change with increased elevation. The relationship was not direct because soil formation generally depends upon other factors such as parent material, topography, vegetation, and time, and their influence was not usually equal for a given soil. However, as elevation increased, the proportion of Entisols increased while the proportion of Inceptisols correspondingly decreased *(fig. 11)*. Surface horizons also became more ochric, or pale colored, and subsurface horizons became lighter (higher values in the Munsell color chart) and less gray (higher chromas). AWC tended to decrease, and textures in both the surface and subsurface horizons became sandier and more coarse textured as elevation increased. These observations reflect results found in other mountainous regions of the world (Birkeland 1974, Wilde 1958).

Topographic setting often plays an important role in soil formation. The results showed that aspect was an important topographic feature of the study area that is correlated with the occurrence of plant communities. Other studies have indicated that aspect is a significant factor in soil development, assuming that higher temperatures accelerate soil reactions and therefore soil formation (Birkeland 1974). However, a strong correlation between aspect and soil temperature was not observed in the study area. In these forests, soil temperatures are correlated primarily with tree cover and less so with aspect or

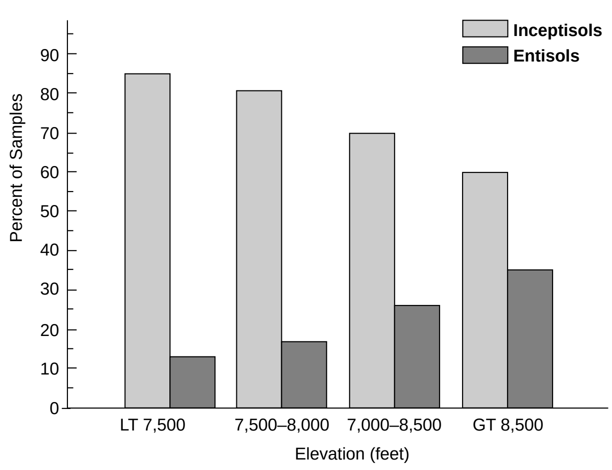


Figure 11—Percent of Inceptisols and Entisols on granitic and volcanic parent materials in relation to elevation.

elevation. Many sites on south aspects in the upper montane have dense stands of trees. In such stands soil temperatures were generally cool; whereas open sites, regardless of aspect, were generally warmer. AWC, soil taxonomy, and topsoil depth were also found to be uncorrelated with aspect when parent materials were held constant.

Topographic position, such as ridge top or toeslope, was correlated with soil development. Thus, surface horizon colors became more ochric or pale colored on upper slopes while soil depth and AWC increased on lower slope positions. Textures in both surface and subsurface horizons were sandier and more coarse textured on ridges and upper slope positions and loamier on lower slopes and benches. Taxonomically, soils were more skeletal in ridgetop and upper slope positions indicating a higher proportion of coarse fragments encountered in the profiles.

Soils and Vegetation

The relationship of soil classification to plant association is difficult to assess because of the dependence of each on several other factors as well as the interaction between soils and vegetation. In most cases in this study, when plant association was compared with soil classification at the family or series level, correlation was low. Practically every association occurred on soils of at least three different great groups and many more families *(appendix B)*. However, when vegetation at a broader level such as plant series or subseries *(appendix A)* was compared with soil order or suborder, some patterns did emerge. Thus, while all plant associations in the upper montane occurred on Inceptisols, some plant communities at the subseries level were found more frequently on Entisols. These were the lodgepole pine and Jeffrey pine series, and the red fir-western white pine subseries. A second group also occurred in significantly higher proportions on Alfisols and Mollisols. These were some of the lodgepole pine, mountain hemlock, and quaking aspen series, and the white fir-sugar pine-red fir and red fir/mountain mule ears subseries.

Although the relationship between soil taxonomy and vegetation classification was often not clear, several soil properties were found to exhibit correlations with vegetation in these communities. Most important were soil depth, thickness of the topsoil, coarse fragment content, AWC, summertime soil temperature at 20 inches, soil texture, and pH. Plant communities generally occur on a continuum with a range of values for each of these soil characteristics. Rarely do they occur on soils with a limited range of values. Broad relationships were found, however, between vegetation composition and each of these soil properties, and comparisons can be made between plant communities at a series or subseries level.

Nearly two-thirds of all samples had soil depths greater than 35 inches; however, the mountain hemlock, Jeffrey pine, and western juniper series had high occurrences on soils of less than 35 inches. The western juniper series in particular contained the shallowest depths overall with a significant number of stands occurring on sites with less than 20 inches of soil. The red fir/mountain mule ear plant association fell into two major groups: those with soil depths less than 25 inches, and those with depths greater than 35 inches. Floristically, however, stands in this association were similar. These differences in depth reflected variation across the landscape and implied that factors other than soil depth may be regulating stand composition and structure in this association. The deepest soils were encountered in the quaking aspen series and the red fir-white fir, red fir-lodgepole pine, and red fir subseries. The Bolander's locoweed association also occurred on sites with deep soils.

Topsoil depths averaged over 9 inches on all sites; however, a fairly large number of stands had topsoils of less than 7 inches. The mountain hemlock series, the red fir-western white pine, and a high proportion of the red fir subseries were in this group—all forested sites occurring at higher elevations.

The deepest topsoils were found in the quaking aspen and western juniper series and the Bolander's locoweed association. Most of these communities had high forb and grass cover and (except for quaking aspen) low tree densities. These results correlated with the observations on soils in forest-prairie transitions wherein forested sites had relatively shallow surface horizons and grass and forb dominated sites had deeper topsoils (Birkeland 1974).

Coarse fragment content in topsoils were substantially less than in subsoils on most sites. Coarse fragments increased from about 20 to nearly 40 percent with depth in average stands. Soils in the red fir-white fir and red fir-lodgepole pine subseries and the quaking aspen series had large numbers of samples with less than 35 percent coarse fragment contents throughout the profile. At the opposite end of the spectrum, the western juniper, Jeffrey pine, and mountain hemlock series had relatively high occurrences on sites with coarse fragments exceeding 35 percent throughout the profile. The western juniper subseries in particular had more than 35 percent coarse fragments in nearly one-third of the topsoil and two-thirds of the subsoil samples.

AWC ranged up to 6.9 inches for the 40-inch profile with an average of about 3 inches. The quaking aspen series and the red fir-white fir and red fir-lodgepole pine subseries typically were found on soils with the highest water holding capacity, while low values were commonly encountered in the mountain hemlock, Jeffrey Pine, and western juniper series and the red fir-western white pine subseries.

Plant associations with naturally lower stocking levels under undisturbed conditions tended to have the warmest soils. High numbers of samples with warm soils occurred in the Jeffrey pine and western juniper series and the Bolander's locoweed association. Summertime temperatures on these sites generally exceeded 50° F. Except for the Bolander's locoweed association, these are also the plant communities that often occur on south facing aspects. The coldest soils were found in the mountain hemlock series, as might be expected from their generally dense tree cover, north aspects, and steep slopes. The red fir and red fir-white fir subseries also contained cooler soils. Soil temperatures were typically less than 49° F in these stands.

Soil textures were typically sandy loams and loams throughout the profiles. In general, soils in the upper montane can be considered moderately-coarse to moderately-fine textured. Soils in the red fir series contained high proportions of sandy loams while significantly higher numbers of loams were encountered in the lodgepole pine series. A substantial number of sites also occurred in coarse textured sands. The red fir-western white pine subseries and the Jeffrey Pine series, for example, have a significantly higher proportion of sites on these coarse textured soils. Soils in these stands were often modified further with high gravel content throughout the profile. The quaking aspen series, on the other hand, had higher levels of sandy clay loams and clay loams in the profiles, which were considered moderately fine textured soils. Few sites with clay textures were encountered in these forests.

Soil pH was basically acid in both topsoil and subsoil. Averages overall were about 5.8. The quaking aspen and western juniper series, and the white fir-sugar pine subseries had the highest average pH in surface horizons at 6.0 to 6.2, with ranges up to 7.1. Conversely, the lowest pH was encountered in the mountain hemlock series with an average of 5.3, and individual sites in this association were recorded as low as 4.3. The Bolander's locoweed plant association also had consistently low pH values. The higher pH under quaking aspen was probably because many hardwood stands have more basic soil reactions (Birkeland 1974, Wilde 1958), but the results did not explain the higher pH levels under stands in the western juniper and white fir-sugar pine subseries, although the shrub component on these sites could be a contributing factor. The western juniper subseries usually has a consistently high shrub component, and many stands in the white fir-sugar pine subseries also have substantial shrub understories; however, other stands with high shrub levels do not show a similar response.

Vegetation

Overview

From elevations below 1,000 feet to those above 14,000 feet, the Sierra Nevada is broadly zoned into vegetation bands within which characteristic plant communities occur. At the lowest elevations on the westside are annual grassland steppes mixed with blue oak *(Quercus douglasii)* occurring in savannah-like woodlands. At slightly higher elevations a sclerophyllous evergreen shrub and tree component commonly referred to as chaparral emerges, while at still higher elevations the beginnings of a coniferous forest dominated by ponderosa pine *(Pinus ponderosa)* is found. These communities are followed by forests of mixed coniferous species known as the Sierra Nevada mixed conifer type (Eyre 1980) and dominated by mixes of ponderosa pine, sugar pine *(Pinus lambertiana)*, white fir *(Abies concolor)*, and incense cedar *(Calocedrus decurrens)*. Above, the upper montane forests are found. They are generally characterized by the presence of red fir and lodgepole pine *(Pinus contorta)*. They are followed at still higher elevations by the coniferous forests and woodlands of the subalpine zone typified in most cases by pure stands of lodgepole pine and whitebark pine *(Pinus albicaulis)* in the north or lodgepole pine and foxtail pine *(Pinus balfouriana)* in the south. At the highest elevations of the range an alpine zone of low forb and grass communities predominates. As the summits are crested and the descent down the steep eastern side of the range proceeds, the patterns of the westside repeat except at elevations below the upper montane: a Jeffrey pine *(Pinus Jeffreyii)* dominated forest emerges, followed at still lower elevations by pinyon pine *(Pinus monophylla)* woodlands mixed with sagebrush *(Artemesia tridentata)* shrublands at the edge of the Great Basin.

One species provides a common thread throughout the upper montane forest of the Sierra Nevada: red fir. This species, more than any other, distinguishes the upper montane from the mixed conifer forests at lower elevations and the subalpine forests above (Barbour and Major 1988, Rundle and others 1977). However, not all forested or woodland stands in the upper montane are dominated by red fir, and many do not even contain red fir. Eyre (1980) for example, documents at least 10 vegetation types that contain red fir as an associated species. Nevertheless, in most stands red fir is present, or it lies within adjacent stands at similar elevations.

Red fir is present in the central and southern Sierra Nevada as two varieties: California red fir *(Abies magnifica* var. *magnifica)* and Shasta red fir *(Abies magnifica* var. *shastensis)*. During the study a line of demarcation could not be precisely determined between the two; however, a latitudinal division occurs near the Middle Fork of the Kings River at latitude 36°50'. South of the Middle Fork, stands contain Shasta red fir. Just to the north, near Wishon Reservoir, scattered individual Shasta red fir have been found, but further north, as far as the limits of the study area along the Middle Fork of the American and Rubicon Rivers, stands appear to contain only California red fir. Whether stands on the Monarch Divide between the Middle and South Fork of the Kings River contain Shasta red fir is unknown at this time.

Red fir is seldom encountered south of Mammoth Mountain on the eastern escarpment until the Kern Plateau is reached. Canyons south of Mammoth Mountain such as Convict Creek and Hilton Creek contain extremely small stands, and one small stand growing in association with foxtail pine occurs near Onion Valley west of Independence, but no others were found in this portion of the range. A smaller break in the northern distribution on the eastside apparently lies between Reversed Peak near June Lakes and Green Creek southwest of Bridgeport.

Other species also demonstrate strong latitudinal or longitudinal gradients or occupy unique settings within the study area. Mountain hemlock *(Tsuga mertensiana)*, for example, lies predominantly north of the South Fork of the Kings

River. Stands lie as far south as Mount Silliman at latitude 36°3' (Parsons 1972). However, north of Yosemite near latitude 38°, stands begin to become a common feature in the upper montane forests. Sugar pine and incense cedar are two species that essentially do not occur in eastside stands. Huckleberry oak *(Quercus vaccinifolia)* is found primarily north of the Kaiser Pass area on the San Joaquin River on the westside, and north of Sonora Pass on the eastside. This species occurs primarily on granitic parent materials as does Sierra chinquapin *(Castanopsis sempervirens)*. Snowbrush *(Ceanothus velutinus)* and sticky-leaved rabbit brush *(Chrysothamnus viscidiflorus)* are located only on the eastside. Mountain mule ears *(Wyethia mollis)* is an herb that forms distinctive communities on the volcanic soils of the Merhten formation from north of Yosemite National Park through the northern limits of the study area. Gray's lovage *(Ligusticum Grayii)*, a common forb in some lodgepole pine communities, is rare in the southern portion of the westside, and it is essentially absent on the eastside south of Ebbetts Pass.

Quaking aspen *(Populus tremuloides)* is one of the most widely distributed species in North America (Jones 1985, U.S. Department of Agriculture 1965). It occurs on moist habitats throughout the upper montane, but stands are often widely scattered on the westside, particularly in the south. Westside stands are typically quite small. Many are less than one acre and most are less than 5 acres. Often small aspen patches finger through larger communities to form a mosaic across a hillside. Barry (1971) has found sharp ecotones between communities in this arrangement. Eastside locations south of Mammoth Mountain Lake are also widely separated, but north of Mono Lake, and particularly north of Conway Summit on Highway 395, stands become more common and larger than those on the westside. Fairly large stands reminiscent of those in the Rocky Mountains are present in the northeastern part of the study area around Hope Valley near Carson Pass. Many aspen stands in the Sierra are being invaded by conifers. In some cases, these invasions appear to be the result of the combined effects of long-term fire suppression and grazing. In other cases, causes do not appear to be so directly related.

Quaking aspen stands may also contain some of the oldest organisms in the Sierra Nevada. Sexual reproduction is rare in the west, and most stands reproduce vegetatively by suckering. Individual clones resulting from this process can persist for thousands of years, and it has been suggested that most current clones in the Great Basin are at least 8,000 years old (Jones and DeByle 1985).

At lower elevations on the westside, white fir, sugar pine, and incense cedar generally grow in association with red fir, and in scattered instances, such as at the Freeman Creek and Tuolumne Groves, Giant Sequoia grows in association with red fir. Western white pine *(Pinus monticola)*, mountain hemlock, and lodgepole pine are common associates at higher elevations. At the upper boundary with the subalpine zone, whitebark pine and, in the south, limber pine *(Pinus flexilis)* and foxtail pine begin to appear in stands. They can be used as indicators of the transition to subalpine. Jeffrey pine and western juniper *(Juniperus occidentalis)* form communities with red fir on shallow sandy soilsover a wide range in elevation. Lodgepole pine and quaking aspen occupy moist sites on lower slope positions and benches.

For all samples in the study area elevation ranges include:

	Elevation (ft)	
Latitude (degrees)	***Westside***	***Eastside***
38+	5,780-9,160	5,860-9,100
37-38	6,160-9,200	7,800-9,520
37-	6,680-9,460	8,120-9,640

Dense, essentially pure red fir stands (stands with tree cover exceeding 50 percent) occupy an elevational band of about 2,000 feet throughout the range although actual elevations vary by subregion. Elevations encountered by these stands in the north, for example, were between 6,660 and 9,120 feet while in the south, they occurred between 7,240 and 9,240 feet. Eastside stands lie between 7,180 and 9,200 feet.

Community Structure

Individual stand physiognomy is variable in the upper montane because of substantial variation in height, diameter, and density of species dominating or characteristic of each association. Tree height falls naturally into three categories. Species such as red fir, white fir, sugar pine and Jeffrey pine can be quite tall. These species commonly averaged taller than 130 feet, and the tallest individuals exceeded 200 feet. Lodgepole pine, western white pine, and mountain hemlock by comparison, are mid-height trees that usually average around 90 feet with the tallest individuals exceeding 125 feet. Western juniper and quaking aspen are the shortest species with heights averaging between 50 and 70 feet. The tallest western juniper was measured at 72 feet, and the tallest quaking aspen measured 121 feet.

Diameters generally follow these same patterns. Larger red fir, white fir, sugar pine, and Jeffrey pine will usually have diameters at breast height that exceed 40 inches. The largest red fir was measured at 74 inches diameter. Larger individuals of western white pine and mountain hemlock can be as large as 45 to 50 inches with averages around 32 inches. Lodgepole pine is generally taller than western white pine and mountain hemlock, but diameters are generally smaller. Lodgepole averages 27 inches in larger individuals, although the largest diameter measured was 44 inches. Western juniper is a short tree with quite large diameters. Averages for large individuals are around 48 inches, but the largest tree measured was substantially larger at 92 inches. Quaking aspen, on the other hand, is much smaller with the larger members of a stand averaging near 16 inches. The largest individual was measured at 27 inches.

Stand densities are quite variable depending on plant community. The red fir plant association is dominated by red fir. It has one of the highest average stand density indexes at 517 (Reinecke 1933), and several stands exceeded 1,000 in this study. Tree cover averaged 77 percent. The red fir/pinemat manzanita plant association, on the other hand, is also dominated by red fir, but has an average stand density index of only 290 and tree cover averages 50 percent. A further example of a plant association dominated by another species is western juniper with a stand density index of 225 and tree cover that averages 33 percent. Essentially this community is an open woodland, whereas red fir communities are closed canopy forests.

Individual trees of each species can be quite old. Western juniper, western white pine, and Jeffrey pine appear to be among the oldest of the upper montane species. In fact, one individual western juniper was measured at older than 1,500 years with an estimated age of more than 2,200 years. The oldest western white pine was over 720 years, and the oldest Jeffrey pine measured was in excess of 650 years. Red fir, white fir, mountain hemlock, and lodgepole pine are also long-lived species with ages exceeding 400 years. The oldest of this group was a red fir measured at 586 years. Lodgepole pine is commonly seen as a relatively short-lived species; however, the average age of trees measured was about 220 years, and the oldest was measured at 443 years. The shortest lived of the upper montane species appear to be sugar pine and quaking aspen. The oldest sugar pine was only 248 years. Although quaking aspen clones may be quite old, individual trees commonly do not exceed 130 years (Jones and Schier 1985). The oldest quaking aspen measured in this study was 135 years.

Understory cover values are often a reflection of environmental conditions within an association more than tree cover. Generally, shrub cover decreases as tree cover increases in late seral stands, but this is not always the case, and shrub cover within an association often does not correlate well with tree density in these forests. For example, the Jeffrey pine/huckleberry oak plant association has an average shrub cover of 55 percent, and stands typically have low tree density. Conversely, the red fir association averages 2 percent shrub cover, and stands are typically quite dense. These two associations lie at opposite ends of the spectrum. When compared, there is a strong correlation with cover and density between these two associations; however, within each, shrub cover is poorly correlated with tree density. This results from environments within each that are unique. With forbs and grasses this relationship is also tenuous. Many densely forested communities in the upper montane have high forb and grass components. Quaking aspen and some lodgepole pine stands are examples of such communities with high tree cover and well developed forb and grass understories.

Species diversity is relatively uniform among all regions of the study area although the northern portions had higher values for the Hill diversity indices than the southern (Ludwig and Reynolds 1985). This could be expected with the north-south, east-west distributions of many of the species. Thus, distributions of species such as mountain hemlock, huckleberry oak, or Gray's lovage in the north, and the strong correlations between mountain mule ears and the volcanic soils of the north or the occurrence of snowbrush in the northeast, provide additional species in many northern stands that result in higher levels of diversity as compared to the south. This seems to agree with what can be seen on the ground, as stands in the northwestern and northeastern portions of the study area appear more diverse in all layers.

An average of 11 species were encountered in these stands, but typically, a few species comprised most of the cover. Thus, the average number of abundant species on most sites was only three. This is not surprising in these high elevation forests, for often the species with highest cover are represented by just a few tree species. Many understories are open with few additional species, and these have low cover values.

In addition to variation in individual stand physiognomy, the plant associations are arranged across the landscape in patchy, spatially complex patterns. This results primarily from variation in geology, aspect, soil development, topography, drainage patterns, and relief among others, but it leads to stands that are relatively small. A high proportion are less than 25 acres in size, and few are larger than 100 acres (Potter and others 1992a). Rundle and others (1977) describe stands ranging in size from a fraction of an acre to several acres, and Richards (1959) has found more than 50 percent of the Sierra Nevada montane forests to be covered with rock outcrops, meadows, shrub patches, and lakes. Thus, the upper montane forests of the Sierra Nevada are a mosaic of relatively small stands composed of discrete plant associations intermingled with non-forested areas.

Disturbance Elements

Disturbances such as avalanche, wind, lightning, insects, pathogens, and fire have long been significant features of upper montane forests. More recently, humans as well have made substantial impacts on the processes and functions of these same plant communities. Disturbances operate on scales of a single organism to entire ecosystems over time frames that vary from a matter of minutes to decades. An avalanche may occur at a given location annually, or it may occur once during a period of a century or longer. The entire event may last less than a minute. At each occurrence, however, several plant communities can be affected. Few of these disturbances have been quantified, and their effect on plant community composition and structure during long time periods is largely speculative. This study did not examine these factors in detail; however, descriptions of the more important disturbance elements of the upper montane are presented, as well as documentation of the current knowledge regarding each of these, and logical inferences of the effects on vegetation patterns.

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 ecosystem. An avalanche chute that effectively eliminates a stand of conifers can become a refuge for shrubs, herbs, and grasses that otherwise would not be able to compete in dense forests, and this can add to the overall species and structural diversity of the area. 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. Mortality and damage from insects provides habitat for wildlife and secondary consumers, and it can provide a critical link in the recycling of nutrients. 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.

Avalanche, Wind, and Lightning

Avalanche, wind, and lightning are important disturbance elements; however, they are often quite localized in effect. These forests are the major zone of snowfall and snow accumulation in the state, and avalanches are not an uncommon event. Muir (1894) noted that "avalanche chutes are of common occurrence in all the upper forests." Field observation indicates this is the case. Avalanches can trigger on any slope over 30 percent in the zone of snow accumulation, but they seem to occur more often on slopes exceeding 40 percent. Most avalanches occur in "chutes" or gullies that have been in place for a long time. They are quite obvious on the landscape, and they are maintained by frequent avalanche activity.

Avalanche can also occur on slopes that show no evidence of past activity. Often in such situations older forests are damaged. Muir (1894), for example, notes the complete removal of an older lodgepole pine stand by avalanche, and stands containing many large older trees that have been destroyed by avalanche are not uncommon throughout the central and southern Sierra Nevada. Commonly, these stands lie on lower slope positions below uniform, open slopes that reach into a zone of snow accumulation above and have few anchoring structures such as rocks, ledges, or trees. Sometimes these slopes are surprisingly short in length. Evidence of past avalanches can be seen in steep canyons at higher elevations throughout the study area. They commonly affect stands across an entire drainage floor depending on their strength. Tree regeneration layers usually remain intact, and shrub, herb, and grass layers are undisturbed. These avalanches seem to occur over large areas in particularly heavy snow years, such as 1986, and they are probably linked to weather patterns preceding and during the specific event.

Wind damage is highly variable in the upper montane. Long time periods pass with little damage, then a major event will occur, and extensive damage results. John Muir records such an event in December of 1874 (Muir 1894). He notes trees breaking off every few minutes throughout one entire night. In the northern Sierra Nevada wind speeds of 70 to 78 miles per hour were recorded for the Columbus Day storm of October 12, 1962 that also caused major damage in red fir and white fir stands. Intervening years showed little damage from wind (Gordon 1973a). This storm was felt the entire length of the Sierra Nevada. For example, a localized patch of windthrow in a red fir stand on the Sequoia National Forest was dated to that storm during field investigations for this study. Taylor and Halpern (1991) examined radial growth patterns within two red and white fir stands in the southern Cascades, and they found releases in the early 1970's and 1980's that were attributed to windstorms.

In general, however, damage from wind is light. The only study of the effect of wind damage on upper montane forests in the Sierra Nevada illustrates several points (Gordon 1973a). Over a 6-year period damage affected only 9 percent of the stand volume, and most of this occurred in two wind storms. The study also found most of the damage resulted from uprooting and breaking of individual trees rather than groups, and intermediate crown class trees were more affected than any other tree class. As might be expected, the amount of rot and wind damage were strongly correlated. On the other hand, tall dominants that have been exposed to winds for long time periods, withstood high winds very well. Finally, effects were often very localized and not related to the direction of prevailing winds. These results seem to correlate with observations throughout the Sierra Nevada and indicate that in the upper montane, disturbance from wind is correlated with small gap formation within most stands.

Lightning kills or damages single trees. It assumes importance in the upper montane because of the high frequency of lightning strikes. Aside from its role in fire occurrence, lightning also develops gaps within tree canopies. Often trees seem to explode and split into pieces that are scattered over wide areas. Muir (1894) noted trees 200 feet high and 50 to 60 inches in diameter that "were split into long rails and slivers from top to bottom and scattered to all points of the compass." These individuals are often simply killed. White fir and red fir appear to be particularly suseptible to shattering. In other cases a large groove is created down the length of the tree, and the tree survives although it is disposed to attack by insects and pathogens. Finally, lightning often kills the tops of trees. This predisposes the tree to attack by insects or pathogens, but just as importantly in the case of true fir, such damage often limits future cone production.

Insects and Pathogens

Insect and pathogen populations are generally active throughout the growing season across all portions of the forest. Populations increase or decrease depending on a variety of factors, but commonly they respond to short-term environmental conditions such as droughts, changes in vegetation, or interactions between themselves. The effects on a particular plant community are also variable depending on the plant species, stand structure, stocking levels, and stage of growth. Many of the insect and pathogens of the upper montane are relatively species specific. Under low level or background conditions individual trees and small groups are generally affected, and the effects appear fairly inconspicuous; however, little is known about the ecological impacts of insect activity during non-outbreak periods (Mattson and Addy 1975, Moeck and others 1981, Williams and others 1992). During a population build up and development of "epidemic" conditions the same effects may be observed but simply on a larger, more obvious scale. In both cases removal of individuals and groups affects species composition and stand structure of the remaining stand that can affect future species composition and structure.

Bark beetles in the order Coleoptera are major contributors to mortality within the tree component. Several of these affect pine species common in these forests. The Jeffrey pine beetle *(Dendroctonus jeffreyii)* affects only Jeffrey pine. The mountain pine beetle *(Dendroctonus ponderosae)* affects lodgepole pine, sugar pine, and western white pine. These two species have the potential to kill large numbers of trees when conditions allow populations to build. Engraver beetles in the genus Ips are often associated with bark beetle attack, but occasionally can kill small-diameter trees and top-kill larger pine as well. The emarginate ips *(Ips emarginatus)*, and the pine engraver (*Ips pini*) can attack and kill all of the pine species found in the upper montane. Red fir and white fir can be killed on a fairly large scale by the fir engraver *(Scolytus ventralis)* (Furniss and Carolin 1977).

Several moths of the order Lepidoptera are defoliators that contribute to mortality and growth loss. The Douglas fir tussock moth *(Orgyia pseudotsugata)* attacks white fir in California, and of the defoliating insects in the upper montane, it has probably the highest potential to cause top-kill, mortality, and short-term growth loss in stands containing white fir. The western spruce budworm *(Choristoneura occidentalis)* is one of the most extensive defoliators in Western North America, and it occurs principally on white fir. Currently, it has not been reported from the central and southern Sierra Nevada. The Pandora moth *(Coloradia pandora)* affects all of the pine species in the upper montane, but the most recent outbreaks have involved Jeffrey pine. This species favors habitats with loose upper layers of duff and soil such as the pumice soils near Mammoth Mountain where recent outbreaks have occurred. The lodgepole pine needle miner *(Coleotechnites milleri)* primarily affects lodgepole pine, but it can also attack western white pine and mountain hemlock. To date, this species has been observed primarily within a localized area around Tuolumne Meadows in Yosemite National Park. Mortality can occur as a result of repeated defoliations by the needle miner, but most often defoliated trees are attacked and killed by mountain pine beetle.

Pathogens causing substantial damage to trees in these forests include three main categories: mistletoes, root diseases, and rusts. True mistletoe *(Phoradendron* spp.) occurs on several conifer species in the upper montane such as white fir, western juniper, and incense cedar, but in most cases the effects are not substantial. By far the most damaging losses are from dwarf mistletoes *(Arceuthobium* spp.*)*. Most dwarf mistletoe is host specific and occurs on one or at most a few species. For example, *Arceuthobium abietinum (*f.sp. *concoloris)* occurs only on white fir while *Arceuthobium abietinum (*f.sp. *magnificae)* occurs only on red fir. Together, these two species are widely distributed, and they constitute one of the most serious forest disease problems in the management of true fir (Scharpf 1993). The species of dwarf mistletoe that cause major damage on tree species in the upper montane include:

Dwarf Mistletoe Species	***Host Tree Species***
*Arceuthobium abietinum (*f.sp. *concoloris)*	White fir
*Arceuthobium abietinum (*f.sp. *magnificae)*	Red fir
Arceuthobium americanum	Lodgepole pine
Arceuthobium californicum	Sugar pine
Arceuthobium campylopodum	Jeffrey pine
Arceuthobium tsugense subsp. *mertensianae*	Mountain hemlock, western white pine

In true fir stands, the cytospora canker *(Cytospora abietis)* is commonly associated with dwarf mistletoe infections. Branches infected with dwarf mistletoe are commonly attacked and killed by this cytospera.

Root disease is becoming more important in western forests. This is largely because of past practices that have increased the incidence and severity of these pathogens. Of the indigenous species infecting trees in the upper montane, annosus root disease *(Heterobasidion annosum)* is clearly the major contributor to mortality. Worldwide, this has become one of the major disease problems in managed stands, and it is abundant in the true fir forests in California. The fungus spreads through root contact or spore dispersal to cut or damaged stems of adjacent trees. Although many centers die out quickly, the disease has been recorded as surviving as long as 50 years in a single stump; so that future generations of trees can be infected. There are two host specific forms: one that infects mostly pines and incense cedar, and one that infects true fir, hemlock, and giant sequoia. In pine stands the disease can kill host trees rapidly. In fir stands it causes a butt rot, but it generally does not kill the host directly. On the eastside it apparently can cause outright mortality on fir (Scharpf 1993), and it does increase the susceptibility of host trees to insect attack and windthrow.

White pine blister rust *(Cronartium ribicola)* is an introduced fungus that has become the major contributor to tree mortality among the five-needled pines. It is host specific to this group of pine, and it is known to attack all of the white pine and all species in the genus ribes, which is its alternate host, in the upper montane. Although it has caused substantial damage to younger sugar pine trees at lower elevations of the study area, the disease has not been observed to cause significant damage to larger sugar pine trees or to higher elevation species such as western white pine and whitebark pine. Because this species has been introduced to the central and southern Sierra Nevada probably within the past 30 years, the long-term outcome of its presence in these forests is unknown. Obviously, there has been little time for host and disease to coevolve in similar environmental settings and for a more or less stable condition to develop. In the short run, it now appears as if a substantial change in species composition could be taking place at least in younger age classes at lower elevations. The ecological importance of these changes has not been studied extensively.

Fire

The species composition and structure of the upper montane reflects the ecological adaptation of both species and communities to the fire regime of these forests. Thus, the fire regime of this particular region contains an underlying evolutionary significance (Mutch 1970). The fire regime in any area can be described in terms of the frequency of fires, their size, and their severity (type and intensity). The red fir and lodgepole pine forests of the southern Cascades and Sierra Nevada have been characterized as lying in a moderate severity fire regime (Agee 1990). Forests in this regime tend to have longer (25 to 100 year) fire return intervals, and fires have a wide range of effects. Evidence for fires is abundant in the upper montane. About 40 percent of all samples sites in this study showed signs of the presence of fire through fire scars, burned stumps, or charcoal on the surface or in soil profiles. Yet, relatively little is known about fire regimes in this portion of the Sierra Nevada. Gradually, evidence is being obtained, so that current knowledge of lightning patterns, fire frequency, fire size, and fire severity can be summarized.

Lightning Patterns—Lightning is a common feature in summer afternoons during most years, and fire ignitions from this source are higher in the upper montane than at lower elevations. Van Wagtendonk (1993a) documents a higher proportion of lightning strikes in relation to area of upper montane in Yosemite National Park over a 5 year period. The maximum number of strikes were observed between 9,000 and 10,000 feet in lodgepole pine and subalpine forests. Fire starts from lightning are also higher in the upper montane than at lower elevations. For example, in Sequoia National Park red fir forests cover 13 percent of the park lands, but 21 percent of all lightning fires occurred in this vegetation type (Taylor, pers. comm.). Similarly, in Yosemite National Park approximately 70 percent of all lightning fires occurred between 6,000 and 9,000 feet elevation, and the maximum number of fires occurred in the red fir type (van Wagtendonk 1993a). Vankat (1985) noted that fires in the upper montane have been most common in elevations between 6,600 and 9,800 feet. On the six National Forests within the study area about 60 percent of all lightning fires occurred above 6,500 feet on the westside and 7,500 feet on the eastside. Significant differences have been found in the distribution of these upper elevation fires by subregion. Fires occur at upper elevations on the eastside and southern portion of the study area more commonly than in the north. In the north, for example, only 46 percent of the fires occurred at elevations above 6,500 feet; whereas, in southern forests on the westside, 64 percent occurred at higher elevations, and on the eastside 60 percent started at elevations higher than 7,500 feet (Bailey, pers. comm.).

Fire Frequency—The actual number of fires starting per million acres per year is quite variable. One study in the Emigrant Basin Wilderness Area, which covers about 112,000 acres, averaged nearly three fires per year between 1951 and 1973 (Greenlee 1973). Another study in the Natural Fire Management Zone of Sequoia-Kings Canyon National Park averaged six fires per year between 1950 and 1973 (no acreage reported), and a 14,700 acre drainage in the same area averaged three per year (U.S. Department of Interior 1975). Kilgore (1971) reported 13 fires less than one-fourth acre in size over 20 years within a 5,000 acre area of Sequoia-Kings Canyon National Park. Van Wagtendonk (1986) recorded 17 fires per year on 355,540 acres over a 53-year period. National Forest records indicated 6,865 fires in upper montane elevations over a 22-year period on an estimated 2 million acres of the study area (Bailey, pers. comm.). Most of these fires were small and many occurred that were not reported (Greenlee 1973, Vankat 1985). Comparatively, the results of these reports can be summarized as:

Study	*No. Fires/Million Acres/Year*
Kilgore (1971)	130.0
Greenlee (1973)	26.8
U.S. Dept. of Interior (1975)	204.1
van Wagtendonk (1986)	44.0
Bailey (pers. comm.)	156.0

Fire return intervals have been approximated from five studies. These estimates are based on fire frequency or the interval between fires at a single point or small piece of ground. In the southern cascades a fire return has been estimated at 40 years in low elevation red fir (Agee 1990). Taylor and Halpern (1991) also estimated a 41-year average with a range of 5 to 65 years based on 17 trees in 2 stands in the southern cascades. Further study in the same area by Taylor (1993), however, indicated average fire return intervals of about 13 years for small fires with a range of from 1 to 57 years and 26 years with a range of from 5 to 47 years for larger fires. Intervals appear to lengthen in the central and southern Sierra Nevada. On the basis of a sample of 16 trees adjacent to three stands in the southern Sierra Nevada, Pitcher (1987) estimated an average return interval of 65 years with a range of 5 to 126 years. On the basis of 117 trees within 68 stands in the central and southern Sierra, an interval of 53 years with a minimum of 7 years and a maximum of 141 years was estimated.[1] These differences seem consistent with fuel patterns in the two areas. In the north, topography is more gentle and vegetation is more continuous; whereas, in the south, the landscape is more fragmented, natural fuelbreaks are more common, and the vegetation less continuous.

These estimates contain inherent difficulties. First, not all trees are scarred in a fire. This is particularly true in the upper montane; for example, Kilgore and Taylor (1979) estimated only 20 percent of the trees were scarred in lower elevation red fir types, and only 15 percent of the trees in any one stand that were scarred.[1] Second, scarring may not record all fires in a stand. Low intensity fires may cause little to no scarring while intense fires may kill all the trees in an area and leave no scars. This is particularly true on very young trees or on older trees that carry long records. Because of thick bark, other trees may not scar for several fires until the cambium is killed and the bark peels away. Then several fires may be recorded, but after the bark regrows and insulates the cambium from further damage or the tree dies, records become lost once again. Thus, individual trees are often not accurate gauges of fire frequency, and estimates based on them must be considered "first approximations" at this point. Nevertheless, the pattern does seem to contrast with those at lower elevations where intervals average between 8 to 10 years and range between 2 to 25 years (Kilgore and Taylor 1979, van Wagtendonk 1985).

[1] Unpublished data on file at Supervisor's Office, Stanislaus National Forest, Calif.

Fire Size—Fire size in the upper montane ranges widely; however, the overwhelming majority of fires appear to be small. Thus, of 39 lightning-caused fires reported in the Emigrant Basin Wilderness Area between 1951 and 1973, nearly 80 percent were less than ¼ acre, and none were larger than 10 acres (Greenlee 1973). Of the 6,865 fires on the 6 National Forests in the study area between 1970 and 1992, 85 percent were smaller than 0.25 acre and 99 percent were smaller than 10 acres (Bailey, pers. comm.) In Sequoia-Kings Canyon National Park between 1968 and 1973, 80 percent of the fires were smaller than ¼ acre, 87 percent were smaller than 10 acres, and only 13 percent were larger than 10 acres (U.S. Department of Interior 1975). Similar results were noted by van Wagtendonk (1993a) in Yosemite National Park where 56 percent of the fires occurring at higher elevations between 1972 and 1993 were less than 0.25 acre, and 82 percent were smaller than 10 acres *(fig. 12)*. Kilgore (1971) reports a fire in the upper montane that was suppressed at ¼ acre in 1968, but he indicates the fire would have had little impact and probably would have gone out at a small acreage even if it had not been suppressed. He reports another that burned 2 months and covered less than 2 acres. Reporting on prescribed natural fire areas in Sequoia-Kings Canyon National Park, Kilgore and Briggs (1972) note that out of 53 fires in a 4-year period all but 4 burned less than 10 acres. Most of these fires were less than 1 acre and went out in a few days.

Fires reported on National Forest lands occurred under fire suppression policies. Whether they were actually suppressed at reported acreages or suppressed at all is unknown; access is difficult in much of the upper montane, and many of these fires had grown to near their maximum size by the time suppression efforts were initiated. Those reported for Sequoia-Kings Canyon and Yosemite National Parks occurred in prescribed natural fire areas where generally no suppression effort is initiated, and they appear to substantiate this view of fire size at higher elevations.

Moderate size fires are also an important feature of the upper montane. In fact, the largest amount of acreage burned at higher elevations in Yosemite National Park between 1972 and 1993 was from fires that were between 10 and 1,000 acres in size (van Wagtendonk 1993b) *(fig. 13)*. For example, in the red fir type, 7,774 acres were burned in fires larger than 1,000 acres; whereas fires between 10 and 1,000 acres burned 13,136 acres, and only 307 acres were burned in fires that were less than 10 acres. The average size fire larger than 10 acres was estimated at 258 acres in the red fir type and about 168 acres in the lodgepole pine type (van Wagtendonk 1993a). Of two fires in red fir forests within Sequoia-Kings Canyon National Park, one grew to 452 acres over the course of a month before going out. Another burned for 3 months and eventually reached 115 acres before going out against natural barriers (Kilgore and Briggs 1972).

Fires larger than 1,000 acres are not rare. In a single drainage of Sequoia-Kings Canyon National Park 3 fires in lower elevation upper montane stands burned about 7,300 acres in consecutive years (U.S. Department of Interior 1975). In 1977 another series of lightning fires in the same general area consumed more than 10,000 acres. These fires started in July and burned into September (DeBenedetti and Parsons 1979). Three recent fires in Yosemite burned areas in the upper montane that ranged in size from 1,126 to 1,357 acres. They were part of larger fires that burned in lower elevation forests as well (van Wagtendonk, pers. comm.).

Often moderate and large fires appear to occur at the interface with the lower montane (mixed conifer) forests where fires may start at lower elevations, move into the upper montane, and cover substantial acreages before eventually dying out. A dramatic example of this occurs on south facing aspects in practically all of the major river canyons that dissect the Sierra. The steep sidewalls of these canyons are shrub dominated, but typically above a major break in slope they become dominated by conifers. If elevations are high enough, the species

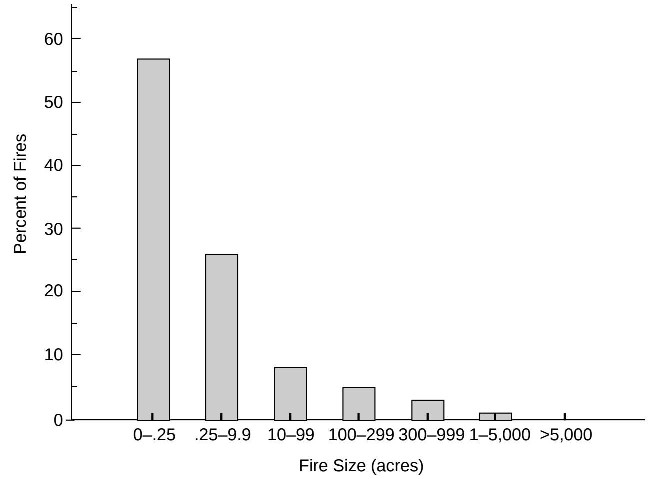


Figure 12—Percent of fires by size class in red fir and lodgepole pine vegetation types in prescribed natural fire zones in Yosemite National Park between 1972 and 1993.

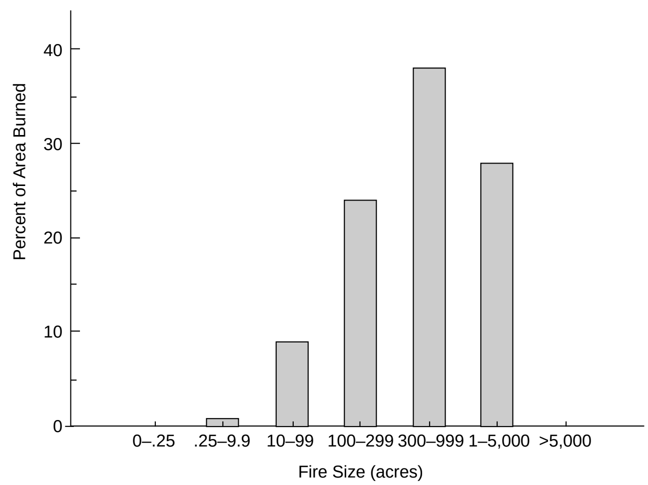


Figure 13—Percent of total area burned by fire size class in red fir and lodgepole pine vegetation types in Yosemite National Park between 1972 and 1993.

composition is dominated by upper montane taxa. Because the shrub fields gradually succeed to conifers, it is surmised that fire plays a major role in maintaining them as shrub dominated communities. At the break in slope and above, fire climate changes and fire intensity and severity is reduced.

Depending on fire weather and fuel conditions, fires moving from lower slopes may burn for extended periods and can cover large acreages at higher elevations. Recent National Forest fire history supports this view. Thus, the Stormy and Clover fires on the Sequoia National Forest, the Rock Creek fire on the Sierra National Forest, the Dardanelle fire on the Stanislaus National Forest, the Wright's fire on the Eldorado National Forest, the Rainbow fire on the Inyo National Forest, and the Acorn fire on the Toiyabe National Forest were all large fires that originated at lower elevations under extreme fire weather, and they were suppressed as they reached the upper montane forests.

Fire Effects—Large stand-replacing fires are not common, but fires often burn with varying intensities and severity within stands and between stands in the upper montane. Thus, within a single stand areas with little damage to vegetation may be interspersed with areas in which all vegetation is killed, or one stand may be severely burned while another is burned lightly. The effects vary depending on combinations of several different environmental factors such as temperature, wind, and humidity, but they are also highly dependent on the species composition, stand structure, and topographic setting of individual plant associations.

Burning season, aspect, and topographic setting are important components of fire occurrence and effect in these higher elevation forests as elsewhere. Most lightning fires are concentrated in the middle to late summer in upper montane forests. Greenlee (1973) notes that most fires in the Emigrant Basin Wilderness occurred after July, and Vankat (1985) records 85 percent of all lightning fires in Sequoia National Park in one study occurring between July and September. Lightning caused fires also appear to occur with higher frequency on ridges and upper slopes and on south to west aspects in these forests. Thus, Greenlee (1973) observes that more than 70 percent of the fires in the Emigrant Basin Wilderness within a 23-year period lie on south to west aspects. Similarly, over a 63-year period Vankat (1985) records the highest number of fires in Sequoia National Park lying on SE, S, SW, W, and NW aspects. Nearly 30 percent of these same fires occurred on ridge top positions. Fires in Yosemite National Park follow the same pattern with 55 percent of the lightning fires occurring on SE, S, SW, W, and NW aspects; furthermore, fires on south and west facing slopes became larger because 89 percent of the fires larger than 50 acres occurred there. The hotter and drier conditions of these sites appear to account for these differences (van Wagtendonk 1986).

Fire intensity in these forests reflects plant community structure and species composition. John Muir, for example, noted that on calm days of fall in lodgepole pine forests, fires crept quietly along the ground until a larger lodgepole pine tree was encountered then the entire tree often burned. This pattern repeated itself at irregular intervals for “weeks at a time” (Muir 1894). Five studies have documented differences in fire intensity and severity in upper montane forests. Pitcher (1987) described variable impacts from fires in three stands of red fir mixed with western white pine. No evidence was found for extensive crown fires, but individual trees and groups of trees of about 0.5 ha were killed. Kilgore (1971) noted that fire in red fir dominated stands had little effect on the species composition and stand structure. He observed that little crowning took place in these fires, and although many red fir seedlings and saplings were killed, few older red fir were affected. Mature lodgepole pine were killed, but lodgepole pine regeneration was stimulated. Kilgore and Briggs (1972) observed a 452-acre fire burning in Jeffrey pine over a shrub layer of manzanita. They estimated that 80 percent of the manzanita layer burned, but few pines more than 10 feet were killed. This fire was extinguished when it reached a moist draw with quaking aspen, a rocky ridge, a rocky escarpment, and sparsely vegetated bluffs. They also observed a 115-acre fire spreading slowly in red and white fir with scattered Jeffrey pine and little understory. This fire was limited in size by a wet draw, a grassy glade, and fuel discontinuities. Many small trees, snags, and older trees with open catfaces or decayed interiors were consumed completely, but few instances were observed in which the fire burned in the crowns. Agee (1990) noted that variable effects resulting from fire behavior in natural fires burned in 1978 and 1986 seemed to be characteristic of red fir forests. Although much of the burned areas he observed had moderate severity, areas of high and low intensity were also noted.

In a study of lower elevation upper montane forests in Sequoia-Kings Canyon National Park, vegetation patterns were grouped into three categories: open (30 percent cover), closed (60-90 percent cover), and brush habitats (50 percent cover) (U.S. Department of Interior 1975). Fire effects were highly variable depending on type of habitat. Fires in open habitats burned with low intensity and severity. Those in closed stands were more variable and unpredictable with areas of intense heat and severe damage (especially in areas of fuel buildup) alternating with areas of low intensity and little damage. Brush habitats experienced the highest intensity and damage to conifers particularly on slopes. In addition to climate, these responses were attributed to differences in cover, species composition, stand structure, distribution and buildup of fuels, and topographic setting of each of the habitats. Microclimate was fundamentally different in each habitat, and burning in general was patchy and related to fuel continuity. These observations correlate well with the observations of Mutch (1970) who hypothesized that plant species and communities possess specific burning properties related to fire adaptations.

Recent prescribed burning programs in the upper montane have confirmed those observations. For example, fire effects in an August burn on the Stanislaus National Forest were reflective of plant association. Within a Jeffrey pine/ huckleberry oak association on a south facing slope, over 75 percent of the shrub layer and most of the smaller conifer seedlings and saplings were consumed. Scattered large dominants were lightly damaged. Within dense stands of the red fir and white fir-sugar pine-red fir associations, understory trees and shrubs were largely consumed in some cases but bypassed in others depending on factors such as slope position, fuel accumulations, and fire intensity in adjacent stands. Surprisingly, little effect occurred in stands with pinemat manzanita understories. Gaps in which all trees were killed and ranging in size as large as about 1 acre were created in dense stands of the red fir association. Finally, fire effects in the lodgepole pine/Gray's lovage association were minor. After reaching the stand, flame heights lowered and intensity diminished. A month later, the fire was creeping in litter and fine fuels, but little damage was observed on trees or most understory species in this stand.

Small-scale fire effects appear to dominate these forests. Evidence for this view is supported by several sources. First, higher elevations experience shorter burning seasons and cooler temperatures. In addition, fires in the upper montane are often accompanied by rain and higher humidities, and they occur in a fragmented landscape. For example, Potter and others (1992a) found stand sizes to be significantly distributed toward stands with smaller acreage in the upper montane. Most fires are therefore small. When fires do reach large size, burning patterns are patchy, and many relatively small scale disturbances of varying intensity are created within a stand. Spatial relationships within stands appear to support this view. For example, many have related the patchy distribution of different size trees in red fir stands to gap phase regeneration in response to disturbance (Barbour and Woodward 1985, Gordon 1978c, Hallin 1957, Oosting and Billings 1943, Parker 1992). Taylor and Halpern (1991) found regeneration, saplings, and small trees clumped at scales similar to canopy openings in support of this idea. Finally, distributions of tree size classes in most of the plant associations presented in this study are similar to an irregular structure or the reverse "J" shape structure of uneven-aged stands, indicating that gaps have been filled with regeneration over time, and there is a lack of large scale stand replacement.

In summary, current knowledge of upper montane fire regimes indicate that more lightning strikes occur than at lower elevations, and these strikes cause more fires than at lower elevations. Most of these fires are less than 10 acres; however, most of the acreage burned occurs in fires of moderate size between 10 and 1,000 acres. Occasional large fires do occur. The intensity and effect of fire in the upper montane varies with overall burning conditions, but they heavily depend on the topographic setting and the composition and structure of individual plant associations burned.

Native-American Influence on Fire Patterns

Humans have influenced the fire regime of these forests for at least the last 10,000 years and perhaps longer (Moratto 1984). Most of the forest stands we see today originated after 1200 A.D., a time when relatively large, stable Native-American populations occupied sites along major streams and tributaries at lower elevations (Woolfenden 1994). But, the impact of this long-term occupancy on vegetation patterns is largely unknown at this time.

Relatively little is known about the details of manipulation of vegetation by Native-American populations at lower elevations in the Sierra Nevada, and even less is known about higher elevations (Anderson 1993, Lewis 1973). Most descriptions of Native-American burning are from low elevation areas. Lewis (1973), for example, notes that little information is available on higher elevation communities such as red fir and lodgepole pine, and he observes that "since plant and animal resources are reduced as altitude increases and growing seasons shorten we may expect that Indians [sic] affected those environments to lesser degrees." Bonnickson (1975) also believes that fires at higher elevations are the result of escapes from lower elevations. Climatic changes alone have fluctuated between cool/wet and warm/dry periods several times over the past several thousand years (Moratto 1984, Pielou 1991, Woolfenden 1994), and this obscures the effects of Native-American burning patterns even further. Thus, it is difficult to piece together the specific vegetation patterns that might have emerged from the interaction of native burning over such a long time period. Most insights must be gained from circumstantial evidence and inference.

Native-American populations were present and wide-ranging at all elevations in the Sierra including the upper montane. Because of the heavy snowpack and short growing season, most use at higher elevations was undoubtedly seasonal, but abundant evidence of occupation by all Sierra tribes in the upper montane exists. National Forest archeological surveys consistently show the presence of native populations throughout the range, and evidence for use of the upper montane forests is more widespread than expected. Populations were concentrated away from low elevation permanent village sites to a belt between 4,000 and 9,000 feet during the summer (Anderson 1993), and well-used trading routes across the Sierra were established (Anderson 1993, Reynolds 1959). Both John Muir and Joseph LeConte describe contacts made with small groups of Native-Americans near Mono Pass in the 1870's on an obviously well-established trade route (LeConte 1930, Muir 1894).

Generally, even at higher elevations, if favorable sites for occupation are located, then evidence of occupation is also found (Balen, pers. comm.). Bedrock grinding sites are not uncommon in the upper montane, and they were probably used for typical acorn processing. John Muir (1911), for example, notes the heavy loads of acorns carried by Native-Americans 60 to 70 miles across Mono pass. But most likely higher elevation grasses and bulbs were also used as a readily available food source while the higher elevation sites were occupied (Anderson 1993, Lewis 1973). During sampling for the classification, obsidian flakes and arrowheads were found at several widely scattered sites in the sample area indicating movement throughout the upper montane.

Some compelling reasons have been posited to support the idea that Native-Americans made extensive use of higher elevation sites. First, deer migrate upward into feeding and fawning areas in the upper montane in early summer. By summer's end herds are commonly found at elevations above 6,000 feet. Second, additional plant materials become available along an elevational gradient as summer progresses. Flowering often persists into late summer at higher elevations; whereas at lower elevations, plants have long dried up. Third, the most extensive meadow systems in the Sierra Nevada lie at elevations above 6,000 feet, and they are prime sources of many food materials. Fourth, high elevation sites placed Native-Americans in close contact with trading partners on the other side of the mountains. Finally, the coolness of higher elevations is an attractive alternative to the heat of a California summer at lower elevations.

Thus, because this evidence shows that Native-Americans were attracted to higher elevations, then they also likely used techniques learned at lower elevations to shape vegetation for their use at higher elevations. Such techniques would undoubtedly have included the use of fire. However, the details of this burning at higher elevations is unclear, such as their frequency, size, and timing, and to what extent such fires supplemented the patterns established by lightning fires.

Many studies have described how native populations used fire as a tool to control vegetation. Evidence shows that almost every tribe in the western United States used fire to modify its environment, and the magnitude of such burning in the Sierra Nevada may have been substantial (Kilgore and Taylor 1979, Lewis 1973). Burning was used to drive game and improve hunting and access; encourage resprouting, establishment, and production of plants used for food and tools; aid food gathering; control insects and pathogens harmful to food supplies; maintain plant community diversity and allow prediction of resource availability; and to prevent fuel buildup that could lead to disastrous fires around villages, water sources, and cultivated areas (Anderson 1993, Lewis 1973). Thus, fire was used in an integrated, highly skilled, and ecologically significant way to shape specific plant communities within the Sierran landscape as a whole (Anderson 1993, Lewis 1973, McCarthy 1993, Vankat 1977).

Although the use of fire may have been widespread in general, the actual application often appears to have been directed at very specific plant or animal communities that could have been quite small in size. Small bands and families frequented traditional sites where plant or animal resources could be gathered on a predictable basis for many generations (Anderson 1993). For example, many of the species collected for food are found primarily in meadow situations at higher elevations (Anderson 1990, 1993). Vegetation management in these habitats probably involved tilling by hand, coppicing, and the use of fire. The use of fire to encourage production of mule ear seeds *(Wyethia* spp.*)* has been described at lower elevations in the Sierra Nevada (Anderson 1993), and it can logically be inferred that such techniques would also have been used at higher elevations in the unique communities of mountain mule ears *(Wyethia mollis)*. Often burning was done to create openings that would increase both plant and animal resources (Burcham 1974, Lewis 1973). In other cases burning appears to have been done on a very local scale around areas of long-term residency (Burcham 1974), and the spottiness and higher frequency of such local burning probably affected vegetation patterns on a much finer scale than would have been obtained with natural fire (Lewis 1973).

On the other hand, burning was also applied over larger areas to enhance hunting opportunities or to encourage development of understory plants within a general area. If this is accurate then fire use could have covered substantial areas and created patterns similar to large natural fires. Lewis (1973) notes in a report on burning for acorn gathering, that no underbrush remained in the valleys or on the hillsides and that one side of a valley was burned, and then, a year later, the other side. Reynolds (1959) found that natural ignition alone was inadequate to explain the vegetation patterns that existed at contact. He showed that Native-Americans supplemented the frequency of natural fires greatly. Kilgore and Taylor (1979) concluded that natural ignitions alone were not adequate to account for the historic fire frequency in mixed conifer forests. McCarthy (1993) reports that in the south central Sierra Nevada large acreages were burned over to kill the brush and that in the early days of European settlement the forest floor was clear and a horse could be ridden anywhere through the woods. John Muir (1894) also comments on the open patchy nature of the early Sierra Nevada forests.

In summary, it appears Native-American burning was applied to Sierra Nevada forests in a highly sophisticated way over thousands of years. Because evidence shows they inhabited the upper montane forests on a seasonal basis, we can infer that such occupancy involved the use of practices learned elsewhere, including the use of fire. The details of such use are relatively unknown, and the influence on higher elevation forests is also not known, but the use of fire was probably planned to accomplish specific results and fire frequencies and vegetation patterns observed today must include consideration of these practices along with those described for naturally occurring lightning fires.

Influence of European Settlement on Fire Patterns

Reconstructing fire patterns is difficult from the time of Native-American contact with European settlers in the 1850's until the beginning of fire suppression around 1900 because few reliable records are available. Even after fire suppression policies were started, record keeping was poor—particularly at higher elevations. Only in the most recent periods since about the 1930's have reliable records been available, and few of these detail the effects of fire on specific plant communities.

After European settlers became established in the mid-1800's, they began using the Sierra Nevada for a variety of purposes. Grazing, in particular, was common throughout the range, and herders used fire for many of the same reasons that native populations did (Kilgore and Taylor 1979). Muir (1894) comments that "running fires are set everywhere (by sheepherders)," and "the entire forest belt is thus swept and devastated from one extremity of the range to the other." Contemporary newspaper accounts document fires as large as 30,000 acres that were set by sheepherders, and many felt that the greatest percentage of the large destructive fires in the Sierra Nevada were caused by sheepherders "during the thirty years preceding the establishment of the Forest Reserves" (West 1935). Fires were usually set in the fall as the herds were removed from the range. This practice was adopted to improve access and encourage sprouting and establishment of favored species the following year.

The details of the use of fire, its influence on forest composition and structure, and how such burning combined with simultaneous grazing interfaced with the decline of Native-American burning or supplemented lightning fires is unknown at this time. By analyzing fire scars, Kilgore and Taylor (1979) estimated that the fire record for the period between European settlement and about 1875 was similar to the previous 165 years. This work supports the view of Vankat (1977), who concluded that much of the burning done by sheepherders was a continuation of burning by Native-American populations.

Fire suppression policies by government agencies became widespread in the early 1900's. These policies became effective at lower elevations soon after their inception, but because of the problems of access, the effect was not as immediate at higher elevations. Kilgore (1971) notes, for example, that early fire suppression efforts were directed towards the lower elevation mixed conifer types, and he estimates the ecological importance of fire suppression efforts before 1940 was questionable at higher elevations. Kilgore and Taylor (1979) and DeBenedetti and Parsons (1979) found that fire suppression became effective at higher elevations in the mid 1920's in Sequoia National Park, and Taylor (1990) estimates effective fire suppression around 1926 in upper montane forests in the southern Cascades. Currently, throughout most of the National Forest and private lands in the study area, fire suppression policies remain in effect; however, on most National Park lands a prescribed natural fire policy is now being used at least at higher elevations.

Studies have indicated that the impact of fire suppression policies has resulted in an increase of the amount of shade tolerant species. The loss of quaking aspen stands to shade tolerant conifers in many parts of North America, including the upper montane, has been attributed to fire suppression (Kauffman 1990). Kilgore and Taylor (1979) relate the increase of white fir understory in the sequoia-mixed conifer forest type to the absence of fire. Vankat and Major (1978) relate increased tree density at lower elevations in the upper montane to fire suppression, but at higher elevations increased tree density appears to be the result of reduced grazing pressure. For example, mixed, white fir and giant sequoia stands showed increases in white fir density and cover since the initiation of fire suppression. Red fir stands also showed an increase in red fir density and cover, and, where it is associated with lodgepole pine, a decrease in lodgepole pine cover and density. These results agree with other studies that have examined changes in these forests since fire suppression policies were enacted (Biswell 1989, Gruell, pers. comm., Heinselman 1981, Kilgore 1971, Kilgore 1973, Kilgore 1981, Rundel and others 1977, Van Wagtendonk 1974, Weatherspoon and others 1992). On the other hand, in lodgepole pine communities at higher elevation, increases in lodgepole pine density and cover appeared to be related to a decrease in grazing pressure. In low density communities, such as those dominated by Jeffrey pine, little change was observed.

Thus, changes in upper montane forests since the adoption of fire suppression policies vary by the species composition and density of a particular plant association as well as the temporal scale. Because many forested stands in the upper montane are dominated by shade tolerant species, changes more often involve modification of density rather than species replacement. Stands dominated by shade intolerant species, especially those of naturally low density, also seem to maintain their species composition for long periods. Stands of mixed species appear to be most subject to change in species composition, and generally shade tolerant species have been favored in the relatively short time since suppression became effective in these higher elevations.

In addition to possible changes in species composition, fire suppression has an effect on fuel loads and stand structure that influences fire behavior. Little work, however, has been done on these relationships in the upper montane. This classification report attempts to describe the density and distribution of coarse woody debris as it currently exists. However, information to compare these values in a historic sense is unavailable; thus, the results of this study are cast against a background that includes both recent management practices as well as climatic changes of the past several thousand years. In a general way, fire suppression has probably increased the fuel loads and increased the potential fire severity in dense, closed canopy plant communities in the upper montane. The accumulation of fine fuels and larger logs at the surface and the creation of a fuel ladder into the crowns of larger, older trees has probably increased the possibility of larger and more intense fires in current forests. In more open communities, probably little has changed in the time fire suppression has been in effect.

Grazing

Grazing history in the upper montane can be divided into two time periods: before and after formation of the Forest Reserves. The period before formation of the Reserves generally encompasses the time from occupation by the Spanish in the late 1700's through the early 1900's, while the second encompasses the time between formation of the Forest Reserves and the present. Grazing practices and impacts differed substantially between these two periods. From an ecological viewpoint, the most significant grazing use probably occurred between the 1850's and the 1900's.

Grazing began as soon as the Spanish arrived. Most of this use was limited to coastal areas in conjunction with mission activities, and it only spread gradually into the interior valleys. The great influx of grazing use in the Sierra Nevada began with the gold rush of 1849. Cattle use, for example, increased from an estimated 250,000 head in 1850 to 1,000,000 head in 1860, and by 1862 the number was 3,000,000. An estimated 40 percent were located in the Sacramento and San Joaquin Valleys adjacent to the range. Sheep became important for food and wool in the mining camps between 1852 and 1860, and flocks expanded and eventually peaked in the mid-1870's at about 6,400,000 head statewide (Ratliff 1985). In 1880, 2,864,000 sheep were estimated in the Sacramento and San Joaquin

Valleys alone (West 1935), and a few large ranches located in the central valley had herds of 100,000 to 200,000 sheep.

Grazing use was limited to the central valley and foothills until about the 1860's. In 1861, for example, cattle were first introduced to the current Sequoia-Kings Canyon National Park (Vankat and Major 1978), and the droughts of 1862-63 and 1876-77 added impetus to summer grazing in the mountains (Ratliff 1985). Grazing increased dramatically, and while cattle use was widespread, sheep soon became dominant (Ratliff 1985, Vankat and Major 1978). Often great circuits were made with sheep from the south being moved up the eastside of the range early in the year, across the many passes during the summer, and down the westside to the central valley in the fall. On the westside great numbers were driven across the crest throughout the summer and then returned over the same route to the central valley in the fall.

Few records exist to document the early numbers of sheep and cattle present during summer seasons in the upper montane, but the herds must have been abundant. In the southern Sierra Nevada many large flocks of sheep came from Orange County in southern California and the large ranches in the San Joaquin Valley. These flocks were moved into the mountains from the eastside as soon as melting winter snows permitted. Similar patterns were repeated on the westside. John Muir (1911) noted that in the 1870's large flocks of sheep were moved upcountry gradually as the snow melted, and they often spent several weeks at the best places until the snow at higher elevations cleared. Muir travelled with a flock of more than 2,000 sheep into Tuolumne Meadows in 1873, and while camped in the area he noted the presence of several other camps with large herds. One camp on Porcupine Creek had "thousands of sheep" in it. He also observes (1894) that "incredible numbers of sheep are driven to mountain pastures every summer. Everything is eaten and the woods are burned." LeConte (1930) reported the presence of 12,000 to 15,000 sheep in Tuolumne Meadows in August of 1870, and other studies acknowledge that the numbers of sheep must have been in the range of hundreds of thousands to a million (McKelvey and Johnston 1992).

Throughout the 1880's, sheep were driven to the mountains "by the hundreds of thousands and the policy of feed at any cost was well established" (West 1935). During the drought of 1897-99 the North Fork of the Tule River area was grazed intensively by about 200,000 sheep, and as late as 1900 this number of sheep were still grazing in the Sequoia-Kings Canyon region (Vankat 1970).

Early grazing was unregulated. Herders took advantage of any available forage at any time to graze their stock. During drought years high mountain forage was used intensively by a wide range of stock including cattle, sheep, milk cows, horses, goats, and pigs. Early accounts of Sequoia-Kings Canyon National Park document that most of the park was used to at least some extent, and most use was, in fact, intensive (Vankat and Major 1978). Entry onto the range too early caused as many problems as excessive stocking, and often several herds used the same routes into the mountains over a period of time. The first herd fed on immature shoots, the next herd chewed these even closer to the ground, and by the time the final herd arrived the ground was stripped of cover (Eldorado National Forest 1912).

Overgrazing during this time appears to have been widespread, and erosion resulting from these practices was extensive. "Tales of damage to resources were to become legendary" (Ratliff 1985). Burcham (1957) believed that changes in successional patterns on valley and foothill range lands provided clear indication of a downward trend in the range resource, particularly soil productivity. Commenting on sheep use, Muir (1894) observed that "their course is ever marked by desolation." Sudworth (1900) complained about difficulty finding feed for pack stock: "the forest floor is clean" with a "total lack of grass forage." Conversely, he recorded "that there was (formerly) an abundance of perennial forage grasses throughout the forests of the territory." In 1909 Eldorado National Forest records note: "it is generally conceded that the mountain ranges have greatly deteriorated in feed value since the country has been used for grazing purposes," and further that "it is difficult to understand how badly this range must have been used." Mud slides in the South Fork of the Kern river, the San Joaquin river, and the Kaweah river during the 1860's and 70's have been attributed to overgrazing.

After formation of the Forest Reserves and National Parks in the 1890's and early 1900's regulation of grazing practices commenced and use began to decline. Sheep grazing ended in the National Parks by the 1900's, and effective control of grazing through issuance of permits began with the formation of the National Forest System in 1905 (Ratliff 1985). Early efforts at regulation were often ineffective, but control was gradually gained. Fences were few, and early day enforcement was difficult because of terrain and limited personnel. Stock from private in holdings within and adjacent to National Forests grazed largely unrestricted on National Forest lands, and even permitted use on National Forests crossed the borders of adjacent National Forests unless patrolled adequately (Eldorado National Forest 1912).

Grazing is no longer permitted on National Park lands other than pack stock used in administration work and recreational travel. On National Forest lands use has decreased steadily since formation of the National Forest System, although numbers in individual years have varied in response to a variety of conditions. For example, most ranges were overstocked by presidential request to supply more meat during World War I. Conversely, hoof and mouth disease decimated stock levels on the Stanislaus National Forest during 1924, and no use was permitted during 1925 (Grace 1965). A substantial downward trend in cattle use began in 1925, and it has continued to the present as a result of higher costs of operation, difficulty in finding skilled range labor, changes to feedlot operation, and relinquishment of permits by larger operators. Sheep use declined from a peak during World War I to extremely low levels at present. Currently, numbers of all stock are at roughly 20 to 40 percent of those present at the time of formation of the National Forest System, and practically all of this is used by cattle and horses.

Although the numbers of livestock have been reduced greatly and range conditions are improving in general, the ecological impact of nearly 130 years of grazing, a major portion of which was concentrated in the 40 year period from 1860 to 1900, can only be speculated. Livestock grazing has been an event never before encountered by these forests. Changes to the landscape between the 1850's and early 1900's must have been particularly dramatic. Many studies show that, from the time of Spanish settlement until formation of the Forest Reserves, grazing completely changed the herbaceous layer of the grasslands and foothill woodlands (Burcham 1957, Vankat and Major 1978). Most detailed accounts and analysis, however, are from lower elevations in the central valley and foothills. Whether similar changes also occurred at the higher elevations of the upper montane is uncertain. For example, Burcham (1957) notes that replacement by introduced species at higher elevations apparently has not progressed to the same extent as at lower elevations, and he believes this is probably due to climatic differences. Vankat and Major (1978) believe that increased tree densities in the blue oak, lodgepole pine, and subalpine forests of the region resulted from reduction of grazing pressure in the early 1900's. Leiberg (1902) records areas that had been heavily grazed and subsequently contained 10,000 to 15,000 red fir trees per acre.

Some observations from the field may be helpful in understanding changes that may have occurred in the upper montane. First, more than 80 percent of all sample sites in this study outside of the National Parks showed the presence of livestock. This condition simply means that while cattle and sheep tend to congregate in riparian areas, they still range widely in the upland portions of the forest. Thus, the grazing patterns observed during sampling probably occur over a broader area. This theory is further substantiated with palatability estimates (U.S. Department of Agriculture 1969). Cattle and sheep generally do not feed on conifers and many of the shrubs in the upland portions of the upper montane. White fir and quaking aspen are the only two tree species in which browsing—particularly on seedlings—was consistently observed. Lotan and Critchfield (1990) also note that sheep browse new growth of lodgepole pine in the spring and "nibble needles and small branches if other feed is not abundant"; however, widespread evidence of such browsing was not observed in current stands containing young lodgepole pine. Most of the shrubs that are browsed have regeneration strategies such as sprouting and long-term storage of seed in the soil that permit rapid reestablishment after disturbance. Further, they tend to grow in dense clumps or patches and discourage browsing except at the edges. Many of the common species in the herbaceous layer are not palatable to livestock.

Of the herbaceous and graminoid species observed in the study, the overwhelming majority are native annuals and perennials. Introduced species do not dominate the upper montane. This condition would indicate most native species persisted under the early grazing practices, and that more than isolated refugia would be involved. In other words, recovery was sufficient each year to provide enough feed to carry livestock in succeeding years without depleting long-term seed availability or sprouting capability. Such recovery must have come from propagules that remained on or adjacent to most sites in sufficient numbers to revegetate sites annually.

Thus, the assemblage of species in the upland landscape today suggests that at least enough residual population of native species persisted to permit reestablishment once the grazing pressure eased. The spatial distribution, relative densities and cover values, the ratio of annuals to perennnials, and the genetic makeup of the historic assemblage are currently unknown. And, of course, species now missing from the landscape or that were pushed closer to extinction because of the grazing pressure are unknown. But most of the species currently found in the study area have been subject to other disturbances for millenia, and they have developed a degree of plasticity in response to changing environmental conditions that allows persistence despite unusual events.

Timber Harvest

Timber harvesting began as soon as humans arrived in the Sierra Nevada. Native-Americans and early Spanish settlers used whatever trees were available for construction, tools, and fuel. Such use was probably restricted primarily to lower elevations, and it was probably not significant in comparison to existing growth rates of the time. Heavy demands for wood began with settlement during the discovery of gold in 1849: early timber harvesting centered around the mines and towns that grew with them. As demand increased, harvesting extended further and required more sophisticated means to transport raw materials to centers of production. By the mid-1920's extensive railroad logging was in place in most of the lower and mid-elevations of the Sierra Nevada, and large acreages were harvested. During the 1940's technology changed from railroad logging to the use of tractors and trucks. Roads and harvesting extended even further. However, in most cases harvesting operations did not begin on the lands in the upper montane until the mid-1950's.

Early harvesting used sanitation and salvage cutting, release cutting, and improvement cuttings based on the concepts of "poor risk" (Salman and Bongberg 1942). Harvesting covered large areas since yield per acre was generally low using these cutting methods, and emphasis was placed on roading the ownership for future management. Although pine species were favored in cutting, the most obvious changes in stands during this time were structural as many of the larger trees were removed, densities were lowered, openings were created, large logs increased, and snags were reduced.

By the late 1960's road systems were generally established, and more formal silvicultural systems were used. On better sites even-aged silviculture used the clearcutting method. In suitable stands thinnings were conducted, and in many adjacent stands salvage and sanitation and improvement cuttings were repeated depending on stand condition. On poorer sites sanitation and salvage methods were generally used.

In clearcuts, essentially all the trees were removed, the debris resulting from the logging operation, including large logs and snags, was disposed of, and sites were then planted, in most cases, to Jeffrey pine. Few clearcuts were larger than 25 to 30 acres, and most were smaller than 10 acres. In stands that were thinned, densities were lowered, but other structural features and species composition remained little changed. The practice of removing all large logs and falling all snags in logged areas to lower fire hazards also began during this time.

In many of the clearcuts survival of planted Jeffrey pine was spotty, and species from adjacent stands seeded the sites. In some cases red fir, white fir, and Jeffrey pine became established naturally, and often lodgepole pine dominated the early regeneration on more mesic sites. Where Jeffrey pine planting was successful, particularly on south facing slopes or drier sites, plantations as old as 20 years now exist. Structurally, these successfully regenerated sites will emerge as even-aged stands in the immediate future. Where regeneration was unsuccessful sites are often occupied with persistent layers of shrubs, herbs, or grasses. Little clearcutting has been done at the highest elevations of the upper montane, but in those areas where it has occurred, the same practices were often followed, and most commonly, regeneration of tree species has been unsuccessful.

More recently, clearcutting has been less emphasized in the upper montane. Although harvesting under formal, uneven-aged silvicultural systems has been little tried, shelterwood cutting has been substituted for clearcutting where stand conditions permit, and the practice of removing all large logs and snags has been modified to meet wildlife needs. Clear patterns of regeneration success with the shelterwood method in the upper montane have not yet emerged, and so it is difficult to foresee long-term changes in species composition and structures under this cutting practice. Other methods such as sanitation and salvage and improvement cuttings continue with the exception that large logs and snags are retained at higher levels for wildlife needs. The general consensus seems to be that intensive harvesting in the upper montane has been of insufficient duration and scope to have made substantial long-term changes in the species composition and major structural elements of these forests. Field observations made during this study confirm this view.

Methods

Sampling

Before sampling, a preliminary reconnaissance of each major geographic region in the study area was performed to recognize variation in species composition and environmental setting of the more obvious plant communities and to guide placement of sample sites. During this initial phase, it became evident that the presence of red fir in the stands could be used in most cases to differentiate the upper montane from the lower montane and subalpine zones. The presence of this species was then used to establish the upper and lower elevational limits of each major area that was sampled.

Sampling was performed in late-seral stands of homogeneous cover and species composition with no evidence of recent disturbance. Tree cover was generally greater than 10 percent. Sites were selected based on variation in species composition, life form, structure, geology, soils, and general environmental setting to provide the basis for estimating species response to environment.

Individual sites were selected "subjectively without preconceived bias" (Mueller-Dombois and Ellenberg 1974). Although this method loses some of the strength of statistical interpretation that random and systematic sampling can provide, it is a practical solution to sampling the variation present in vegetation over an area as large as the study area. Initially, 75 to 100 samples were taken within each of the westside forests to develop an understanding of the nature and variation of the plant communities present. Refinements and adjustments were made in the sampling strategy as field work progressed, and plant communities that needed further sampling to build redundancy or provide definition became the focus for subsequent rounds of sampling. The final classification includes 757 sample sites distributed over the study area. Sampling generally followed an elevational transect using existing road and trail networks to provide coverage. Sample sites were well-separated to ensure that samples were independent and that vegetation patterns were similar over larger geographic areas and did not represent localized phenomenon.

The information collected at a particular site focused on five main areas of concern: location, environmental setting, geology and soils, species composition and cover, and productivity. Thirty variables described the location and environmental setting, 17 described the geologic setting and soil profile, 10 were used to describe the tree layer, and 4 variables were used for each of the shrub, forb, and grass layers. Eight variables describing site productivity were calculated as described in the USDA Forest Service's Forest Inventory and Analysis User's Guide (1992a). In addition, 4 derived variables were developed from the raw data taken with each sample. In total, 81 variables were measured or developed for each sample site *(appendix C)*. In addition, cover and abundance values were recorded for each plant species. Cover values for 104 species were used in the final analysis.

The first derived variable, solar radiation index (SRI), was a measure of the solar energy incident on a site. It was determined using tables by Frank and Lee (1966). The SRI was based on measures of latitude, aspect, and slope at each site. The second, stress index, was patterned after the topographic relative moisture index (Parker 1982). It combines SRI, the available water holding capacity (AWC) of the soil profile, elevation, and slope position. Conceptually, this index varies anticipated moisture stress to reflect changes in solar radiation levels and available water holding capacity. It also adjusts for elevation differences reflecting the adiabatic cooling effect of the atmosphere, and it accounts for slope position by assuming that moisture stress is reduced the further downslope a site is located due to subsurface water flow. The equation used for stress index is described in *appendix C*.

The remaining derived variables were measures of plant species diversity: Simpson's lambda and three Hill numbers (Ludwig and Reynolds 1985). Simpson's index varies from 0 to 1 and is based on the probability that two individuals drawn at random from a population belong to the same species. Hill number "N0" is the number of all species in a sample. Hill number "N1" is the number of abundant species, and Hill number "N2" is the number of very abundant species.

Description of environmental setting, composition and cover of shrubs, forbs, and grass, and geology and soils were based on samples from a 1⁄10-acre circular plot. Tree species composition, density, diameter distributions, and volume estimates were obtained from variable radius plots located in a 3 or 5 point "L"-shaped cluster situated around the centerpoint of the 1⁄10-acre plot in accordance with forest inventory standards of the Pacific Southwest Region (U.S. Department of Agriculture, Forest Service 1992a). Snag species and diameters were measured as part of the variable radius plot sample for the tree inventory on 604 sample sites. In addition, during some years of the sampling it was also possible to obtain additional information on snags and downed logs. During 2 years, snags smaller than 10 inches DBH and logs smaller than 10 inches diameter on the large end were measured for height or length, species, and decay class on the 1⁄10-acre plot. Snags and logs larger than 10 inches were measured on a ½-acre circular plot for these same variables. This data set provided information from 180 sample sites on 881 snags and 1,640 logs.

A separate data set was constructed to develop an understanding of climate relationships in the study area. Precipitation data came primarily from the monthly normals of temperature and precipitation from 1951 to 1980 (National Oceanic and Atmospheric Administration 1982). In addition, the California Data Exchange Center (CDEC) database was accessed to identify stations that had substantial long-term records but did not meet the criteria for a 30-year normal due to missing records within the period. From these sources, 72 stations covering both the westside and eastside were selected for precipitation records, and 43 were selected for temperature records. Snowpack and water content information was obtained from the California Cooperative Snow Surveys from 1941 through 1990. Records were selected for those drainage basins in the study area. In total, 11 basins from the American to the Kern River covered the westside, and 5 basins from the Truckee to the Owens River covered the eastside. In the 16 drainage basins, 193 snow courses were represented.

Precipitation and temperature records are scant at higher elevations, resulting in difficult analysis of the transition from rain to snow. To capture as much information as possible from the sparse data and to provide a more local perspective on precipitation and temperature, the study area was divided into subregions for analysis. Westside stations were divided at latitude 37°20'. to illustrate differences between north and south. All stations east of the Sierra Nevada crest were combined as the eastside subregion.

Data Analysis

Overview

Data analysis followed a concept of successive refinement. Essentially it involved examining the data first from a broad perspective and then on successively finer scales as the analysis proceeded. Typically a “cycle” of analysis began with an ordination or classification that would be examined for samples or species that clustered together. These clusters formed the basis for testing differences in environment through gradient analysis. If the environmental gradients separating clusters were substantial enough, the samples were separated and the process was repeated with each of the clusters to either further refine that cluster or define new clusters.

Ordination and classification attempts to summarize community structure in low dimensional space. Typically, relationships between samples or species are shown on one or two axis coordinate systems. Ordination attempts to portray the individuality of each stand; whereas classification groups individual stands into categories (Mueller-Dombois and Ellenberg 1974). Both techniques were used to identify samples with similar species composition, show relationships between samples and species, summarize redundancy in the data set, and identify outliers. Gradient analysis attempts to uncover the relationships between species composition and environment by assuming that species integrate environmental variables and can be used to understand environmental relationships on specific sites.

The computer programs used in ordination and classification were primarily DECORANA (Hill 1979a) and TWINSPAN (Hill 1979b). DECORANA is an ordination technique based on reciprocal averaging with detrending and axis rescaling. TWINSPAN is a hierarchical, divisive classification technique. Both programs are robust in their handling of complex data sets, and, in the present case, similar patterns and relationships generally emerged from the use of each technique. The Pacific Southwest Region's series of computer programs known as FIA (U.S. Department of Agriculture, Forest Service 1992a) and the PROGNOSIS stand model (Wykoff and others 1982) were used to estimate stand inventory attributes such as stand volumes, density, stocking levels, diameter distributions, and site index. Statistical analysis performed to understand gradients used the BMDP series of statistical software programs (Dixon 1990).[2]

The methods used in sampling for community classification limit statistical comparisons that can be made. Large data sets compensate for this in some degree, but analysis performed to determine gradients must be considered exploratory in nature (Jongman and others 1987). Also, commonly used data sets often contain variables with highly skewed distributions, and useful data transformations cannot be made in many cases. In addition, many of the variables used are nominal or categorical rather than continuous; consequently, no single statistical procedure was used throughout the analysis. Both multivariate and univariate techniques were used depending on the questions explored at a particular stage of analysis.

An approach that was consistently used in gradient analysis began with the examination of histograms and contingency tables to understand distributions of the data. Data transformations would then be performed on continuous variables as needed, and this would generally be followed by multivariate analysis by using principal component analysis, multiple regression, and discriminant analysis. Univariate techniques such as analysis of variance (ANOVA) were used to compare differences between continuous and categorical variables or between groupings of continuous variables. Non-parametric chi-square evaluation of frequency tables was used to test the goodness of fit of categorical variables. An exhaustive list of comparisons and their results will not be presented. Examples are presented to illustrate use of particular techniques during the analysis.

The most commonly used data transformations were logarithmic for bare ground, surface gravel, surface rock, overstory age, and litter thickness. Natural logarithms were used in transformation of forb, grass, and shrub cover, surface horizon depth, and coarse fragment content. Arcsin square root transformations were useful for litter cover and SRI. All subsets regression was used and results were evaluated using the adjusted R square and the standard error of the estimate. Jacknife results were used to evaluate the classification matrix from stepwise discriminant analysis. Statistical significance was assessed at the 5 percent level of probability. The F test in conjunction with the Tukey studentized range method for pairwise mean comparisons were used to evaluate significance in the ANOVA model. Levene's test was used to compare equality of group variability, and the Welch and Brown-Forsythe tests of significance were used if the Levene test indicated group variance was not equal. Yates corrected chi-square was used in evaluation of frequency tables.

Procedures

The first phase of analysis emphasized understanding the environmental gradients present in the study area by using information from all sites regardless of species composition. The intent was to uncover broad scale relationships in the environment that could provide insights during classification. This phase began by examination of a correlation matrix to identify important linear relationships among continuous variables. The matrix, for example, showed correlation coefficients greater than 0.50 between AWC and subsoil coarse fragments and between AWC and soil depth.

[2] Trade names or products are mentioned solely for information and do not imply endorsement by the U.S. Department of Agriculture.

Principal component analysis was then used to identify which group of variables were strongly correlated and accounted for most of the variation observed in the data. These groups, or factors, were retained so that collectively they accounted for less variance than a single variable. As an example, factors describing productivity and soil moisture relationships accounted for more than 50 percent of the variation between all factors. The variables underlying each of them include:

Factor 1 *(Productivity)*	*Factor 2* *(Soil Moisture)*
Available water holding capacity	Available water holding capacity
Total basal area	Topsoil coarse fragments
Total vegetative cover	Subsoil coarse fragments
Bare ground	Slope
Surface gravel	Total soil depth
Slope position	Surface rock
Total forb cover	
Total soil depth	

Selected variables (such as AWC) were then explored in more detail through multiple regression to highlight which group of variables best explained the variation in the selected variable. For example, variation in AWC could be described (adjusted R-squared = 0.62; S.E.= 0.89) through a combination of elevation, total basal area, total forb cover, total soil depth, topsoil coarse fragments, and subsoil coarse fragments.

ANOVA was then used to examine relationships between continuous and categorical variables. For example, AWC was compared to topsoil textures, and a significant difference (F = 64.8; df = 4/294) was obtained between sandy and loamy soil textures. Finally, comparisons were made between categorical variables using the chi-square statistic. As an illustration, soil textures were compared to parent material, and granitic and cindery soils were found to contain significantly higher proportions of sandy soils than those derived from other parent materials in the study area (chi-square statistic = 110.5; df = 8).

The analysis was repeated for geographic subregions of the study area as a way of identifying environmental differences between each subregion. Division into subregions was based on differences in species composition and environment that were noted during sampling. The westside was separated from the eastside at the crest of the range, and the northern portion of the westside was separated from the southern at latitude 37°20', or roughly an east-west line just north of the Kaiser Wilderness on the Sierra National Forest near Huntington Lake. In this comparison stepwise discriminant analysis was substituted for multiple regression because interest at this point was in identifying environmental differences between subregions. Samples from the westside were compared to those from the eastside, and those from the northern portion of the westside were compared to those from the southern. As a result of this analysis, for example, AWC was found to be significantly higher on westside samples than on eastside samples (F = 10.2; df = 2/645).

Next, the entire set of samples were classified, based on floristic composition, with TWINSPAN. The data set was first "weeded" of species occurring less than three times. In subsequent iterations, species that seemed to have little affinity for any classified group and thus provided little information to the classification were also eliminated. The classification was finally based on 104 species. From this initial classification, several species groups emerged that were similar in floristic composition and defined the major plant communities in the study area. This effort provided insights into the major species that influenced the classification.

A subsequent classification and ordination was then performed by subregion on just the tree and major shrub species. This examination used trees and shrubs because they were major elements of the initial classification. They are long-lived, able to capture site resources and dominate stands, relatively resistent to minor disturbances, and are believed to reflect major environmental differences reasonably well. The intent was twofold: to separate sample sites based on tree and shrubs as a basis for defining communities to the series and subseries level; and to examine whether these species displayed similar environmental responses in each subregion. To assist in this second objective, an ordination was performed to provide values or "scores," on the basis of weighted average species cover values, for each sample site. These values were used in indirect gradient analysis to examine relationships between species distribution and environment by subregion. Results were then compared across subregions. In this way the major environmental differences expressed by cover of tree and shrub species were identified and could be used in refinement of the classification.

The analysis continued by examining each series separately and in detail using a concept of progressive fragmentation (Peet 1980). Samples that occurred in series that were identified in the previous classification were separated from the larger data set and classified and ordinated separately. For example, samples that had originally been grouped based on the presence of a characteristic species such as Jeffrey pine and considered to represent the Jeffrey pine series were isolated and reclassified. The result was a refinement in classification of the series that highlighted species groupings and provided the basis for further subdivision of the series into plant associations. The Jeffrey pine series might thus be characterized by sites with huckleberry oak and those with greenleaf manzanita in the understory as proposed plant associations within the series.

Proposed plant associations identified in this way were tested for differences in environment concurrently with ordination and classification. Samples within a series were generally first examined by comparing ordination scores to distinguish overall gradients underlying the series. Generally, gradients expressed by linear relationships of species to environment within a series were weak. Potential associations were often environmentally unique from others in the series, but these differences were not expressed along the continuum described by the ordination scores. Univariate comparisons through ANOVA and chi-square evaluations often provided the most valuable understanding of differences between tentative plant associations. If an association was considered sufficiently homogeneous in species composition and different from others in environmental conditions, it was removed from the data set, and the process was repeated with the remaining samples if necessary. Further classification ceased when species composition and environmental conditions were not considered sufficiently unique, or too few samples remained. Potential plant associations were generally not divided into smaller groups if less than 10 samples remained. In those few cases where less than 10 samples remained, scientific judgement was used to determine if the association existed but was simply dispersed on the landscape and difficult to sample.

The final phase of analysis compared environmental conditions typified by some of the more common species. This phase was a separate analysis from those performed for classification. It was designed to examine autecological relationships on a broad scale for these species *(appendix D)*. The analysis involved examining environmental differences for samples with the species present versus those in which the species was absent. This analysis provided a basis for considering if a species reflected unique site conditions and could be used to characterize specific plant associations. Forbs and grasses were tested using a presence/absence approach while trees and shrubs were tested generally using a cutoff value of 5 percent cover for the species. In other words, samples that contained more than 5 percent cover of a tested tree or shrub species were compared to those that contained less than 5 percent of the species. This level was chosen based on experience indicating that levels above this point showed species that appeared to reflect definite changes in both species composition and environmental condition. The small size and wide distribution of many of the forbs and grasses, on the other hand, indicated presence/absence as a more appropriate measure.

Results

General Relationships

Several patterns were found in the data that are important in understanding the overall physical setting of the study area. Although these general patterns are not consistent across all plant communities as the descriptions of individual plant associations illustrate, they can be used as a reasonable "initial approximation" of conditions observed on a specific site.

First, important relationships were observed between measures of productivity, site openness, and soil characteristics. Stocking levels, vegetation cover, measures of site openness (bare ground, surface gravel, surface rock, and litter cover), and soil characteristics such as AWC, soil depth, and soil temperature tend to be highly correlated. In general, sites with shallow soils, lower levels of AWC, and warmer soil temperatures are reflected in lower tree densities, less forb cover, and higher shrub cover. Surfaces on these sites are characterized by higher levels of bare ground, gravel, and surface rock.

In addition, soil coarse fragments and soil depth influence AWC and moisture stress. As might be expected, rocky sites with large amounts of soil coarse fragments or sites with shallow soil depths have lower water holding capacities and higher levels of moisture stress.

Next, a general trend was noted of increasing elevation as latitude and longitude decrease. Both latitude and longitude are important in understanding changes in plant communities correlated with elevation. The rise and subsequent fall in elevation from west to east across the crest is obvious; however, there is also an increase in elevation of upper montane forest communities from north to south. Thus, similar plant communities occupy higher elevations on the eastside as compared to the westside, and they also occur at higher elevations in the southern than in the northern end of the Sierra Nevada. This rise in elevation appears to be nearly 500 feet per degree of latitude on both the westside and eastside. A 3° change in latitude can result in almost 1,500 feet of elevation difference up and down the range for the same plant community. Other broad scale effects are increases in soil coarse fragments and a general decrease in AWC and productivity with increasing elevation.

SRI, which is a measure of the radiant energy received at a particular site, is strongly correlated with aspect and, to a lesser degree, slope. Because aspect, slope, and latitude are components of the SRI, a correlation between these variables would be expected; however, the strong correlation with aspect indicates aspect can be used as a reasonable approximation of SRI at these latitudes, and it can be used to understand the typical north-south aspect changes in vegetation that is characteristic of these forests. Vegetation on steep, north facing slopes receives substantially less radiant energy than flatter or more southerly facing stands. Examples of this relationship occur in communities containing mountain hemlock that often occupy north facing slopes as compared to Jeffrey pine communities that commonly occupy south facing slopes.

Important relationships were also found between certain soil properties, slope position, and slope steepness. As might be anticipated, soil depth increases as sites are located progressively further down the slope or as benches are encountered. Similarly, AWC tends to increase as moisture stress decreases with increasing soil depth and location on lower slopes and benches. Slope steepness also influences soil moisture relationships. Steeper slopes in these forests tend to have shallower soils with lower AWC and higher moisture stress. In addition, soil textures in both surface and subsurface horizons are significantly more sandy on slopes greater than 40 percent while they are more loamy on slopes less than 20 percent. Sites that occupy steep slopes can also generally be expected to have excessive drainage as compared to those that occur on shallower slopes.

Generally, stands that appear to be naturally open with high proportions of bare ground, gravel, or surface rock, or those with a substantial shrub component, lie on southerly aspects, occupy steeper slopes, or that occur in upper slope positions can be expected to have lower productivity and vegetative cover. The open conditions of these plant communities reflect the shallow soils, excessive drainage, lower AWC, warmer soil temperatures, and higher levels of moisture stress that is often present.

Parent materials also show important correlations with soil characteristics. In these forests, granitic soils have high proportions of sandy soil textures and drainage is often excessive. Even though subsurface horizons are often gravelly, cobbly, and stoney, coarse fragments are generally lower than soils derived from other parent materials. Soils derived from pyroclastic materials, such as the cinder deposits around Mammoth Mountain, have significantly lower levels of AWC resulting from sandy textures and high proportions of coarse fragments in the form of gravels throughout the profile. These soils also tend to be excessively drained; they have higher summertime soil temperatures, and they are generally less productive. Soils that develop from metamorphic parent materials also have lower AWC. This appears to result from cobbly coarse fragments in the profiles because they are well drained and have loamy textures that usually tend to increase water holding capacity. Flow rocks and lahars produce soils with higher AWC due to higher levels of loamy textures and good drainage despite high proportions of gravelly coarse fragments throughout the profile.

From a geomorphic perspective, colluvial and alluvial soils also have important characteristics influencing plant growth. Soils developed in colluvial deposits tend to have lower AWC resulting from sandy textures, excessive drainage, and high levels of gravel and cobbles. These deposits generally lie on steep slopes. Alluvial deposits, in contrast, also have sandy textures and excessive drainage, but they are deep soils with low coarse fragment content and high AWC. They lie on lower slopes, benches, and bottom locations.

North-South Relationships

Variables that describe most of the variation within the total data set also describe most of the variation in each subregion (north, south, and east). Thus, most of the factors influencing plant communities outlined above are important in each of the subregions, and they influence vegetation in similar ways.

Samples in the southern portion of the range lie at significantly higher elevations, indicating the gradual rise in elevation as latitude and longitude decrease. Slopes in the samples were significantly steeper and bare ground was higher in the south as well. Steepening of slopes became particularly noticeable south of the Middle Fork of the Kings River near the boundary between the Sierra and Sequoia National Forests. Understories in the north contained higher levels of grass cover than samples from the south. However, other than climatic and elevation differences, the major difference between northern and southern samples was found in soil variation.

Volcanic parent materials (lahars, andesitic and rhyolitic ash and mud flows, and basalt deposits) and the soils derived from them occupied the northern portion of the central and southern Sierra Nevada. They were seldom encountered south of the Stanislaus National Forest. Parent materials in the south were predominantly granitic. Samples in the north also occurred more commonly on glacial deposits such as glacial till and outwash.

Taxonomically, soils in the south had a higher proportion of Entisols. These were less developed soils. A significantly higher portion were Orthents and Psamments. Orthents were typical of steeper, less stable slopes while the Psamments were reflective of the sandy subsurface textures derived from higher portions of granitic parent materials. Particle size classes in the north were more commonly medial and medial-skeletal whereas those in the south were more often skeletal.

In the north, topsoils were better developed. Surface horizon thickness was generally deeper in the north, which reflected the higher percentage of Inceptisols. Samples from the south contained a higher percentage of Ochrepts—Inceptisols with light colored, and presumably less developed, profiles. Soil reactions were strongly acidic (pH less than 5.0) more often in the south due to the presence of the volcanic flow rocks, lahars, and ash deposits in the north which tended to have higher proportions of pH greater than 6.5. Soils in the north tended to be darker in color. A higher proportion of subsurface colors were dark gray to very dark brown in the north while they tended to be light gray and yellow to dark yellow-brown in the south. This difference may be attributed to higher rates of weathering in the north. Coarse fragment content was more gravelly, cobbly, and stoney throughout the profile in the north due to the higher percentages of volcanic soils encountered in northern samples. Soil textures were finer and clay development appeared to be higher in these same soils; thus, subsoil textures were more often loamy in the north and sandy in the south.

East-West Relationships

Samples from the Kern Plateau on the southern tip of the project area were included as part of the eastside samples because conditions there were similar to the eastside. Elevations of samples on eastside sites were substantially higher than the westside, and slopes were steeper. Bare ground and surface gravel were significantly higher, but shrub, forb, and grass cover were also higher. Conversely, westside forests contained a greater moss component, and tree cover, litter cover, and litter depths were higher compared to the drier conditions on the eastside.

Soils derived from pyroclastic deposits such as pumice and cinders were located only on the eastside in the vicinity of Mammoth Mountain, which has experienced such deposits in relatively recent times. Flow rocks, and ash deposits were also sampled in higher proportions on the eastside while those derived from granitic and metamorphic parent materials as well as the lahars were sampled in higher proportions on the westside. Soils from eastside samples were formed incolluvial and alluvial deposits in significantly higher proportions because of the steeper slopes. Finally, glacial outwash deposits were encountered more often on the eastside.

Soil taxonomy was similar to the north-south relationships. Inceptisols were found in higher numbers on westside samples, and Entisols were found in higher numbers on eastside samples, indicating the drier climatic conditions for soil formation on the eastside that is comparable to the southern portion of the study area. Of the soils classified as Entisols, Orthents and Psamments were found in significantly higher proportions due to the steeper slopes and sandy textures of eastside samples.

Soil reactions showed higher pH (greater than 6.5) in surface horizons on the eastside. Although the relationship was not strong, this possibly reflects the effect of lower precipitation with possible reduced leaching of cations. Soil pH was probably not affected by differences in parent material nor the presence of hardwoods (quaking aspen, for example) because significant differences were not found in eastside versus westside samples when differentiated by these variables. Eastside soil temperatures were substantially higher apparently in response to more open sites and lower vegetative cover. Soils were darker in color on the westside. Soil colors tended to range from dark brown to very dark red brown on the westside and light gray to yellow on the eastside, suggesting possibly higher levels of weathering on the westside.

Soil textures were sandy in both topsoil and subsoil on eastside samples. Surface horizon coarse fragments were somewhat higher in content as compared to westside sites. Subsurface horizons were also more gravelly as opposed to the cobbly, stoney soils of the westside. Eastside samples were excessively drained, and they had significantly lower AWC in general. These results are consistent with the higher soil component derived from tephra deposits.

Ordination of Trees and Shrubs

DECORANA ordination was used for trees in each of the subregions (north, south, and east) *(fig. 14)*. The results showed that the relative position of species from each subregion was similar even though the solution to each ordination was unique. Although several variables were important in defining the position of a species in each ordination, only three consistently explained the distribution of tree species across all subregions as plotted on two axes.

On the first axis, species distributions were correlated with elevation and SRI. As scores increased there was a general decrease in elevation and an increase in SRI. Mountain hemlock, for example was a high elevation species that occurred on sites with low SRI's while, quaking aspen was a moderate to lower elevation species occurring on sites with high SRI's. On the second axis correlations were considerably less well defined, and distributions were consistently explained between subregions only by elevation and moisture stress. Elevation and moisture stress increased with increasing scores in the northern and eastern ordinations while they decreased with increasing scores on the southern ordination. Higher order axes, such as axis 3 or 4, yielded no consistent pattern among variables. Thus, the results showed that the observable patterns in tree species within these upper montane forests that can be used to describe plant communities to a series level are related in large measure to changes in elevation, SRI, and moisture stress.

To illustrate these relationships, plots comparing importance values[3] with elevation and SRI are shown for several major tree species by subregion *(fig. 15a)*. Curves were smoothed with a locally weighted least squares algorithm to show overall patterns. The shape of the curves among species in each of the subregions was similar, and red fir was dominant in these forests between elevations of about 7,000 and 9,000 feet on the westside and 7,700 to 9,500 feet on the eastside.

The upper elevations of red fir dominance were unclear from the samples in the eastern portions of the range. Observation in the field indicate they were similar to southern situations. Western white pine and lodgepole pine both increased and white fir and Jeffrey pine decreased as elevation increased. Mountain hemlock, while not plotted, showed patterns similar to western white pine. The patterns of Jeffrey pine at lower elevations in the south were not as distinct as the northern and eastside samples. Based on field observations, it was suspected this may represent sampling distribution more than a real effect. SRI patterns were also quite consistent, with red fir occupying mid-range values and other species occupying more extreme positions *(fig. 15b)*. The ability of white fir to maintain its status among a wide range of SRI values was an interesting feature of this species.

Comparisons were also made using ordinations of shrub species *(fig. 16)*. The patterns were less defined with shrubs. In contrast to the ordination of tree species, shrubs did not result in similar positions in the ordination space.

[3] Importance values were calculated from relative cover and relative frequency of tree species within a given elevation or SRI band using the following equation:

$IV = Sum((x/T) + (y/F))$, in which:

IV = Importance value of a species in a sample.
x = Tree cover of the species on a sample.
T = Total tree cover on a sample.
y = Occurrence of a species in a sample.
F = Sum of all species occurring in a sample.

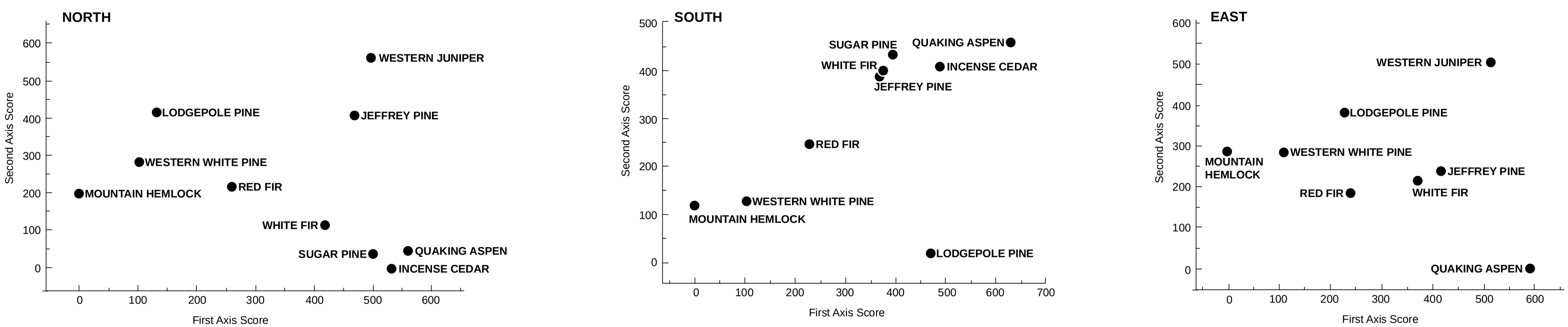


Figure 14—DECORANA ordination by subregion for tree species in the central and southern Sierra Nevada.

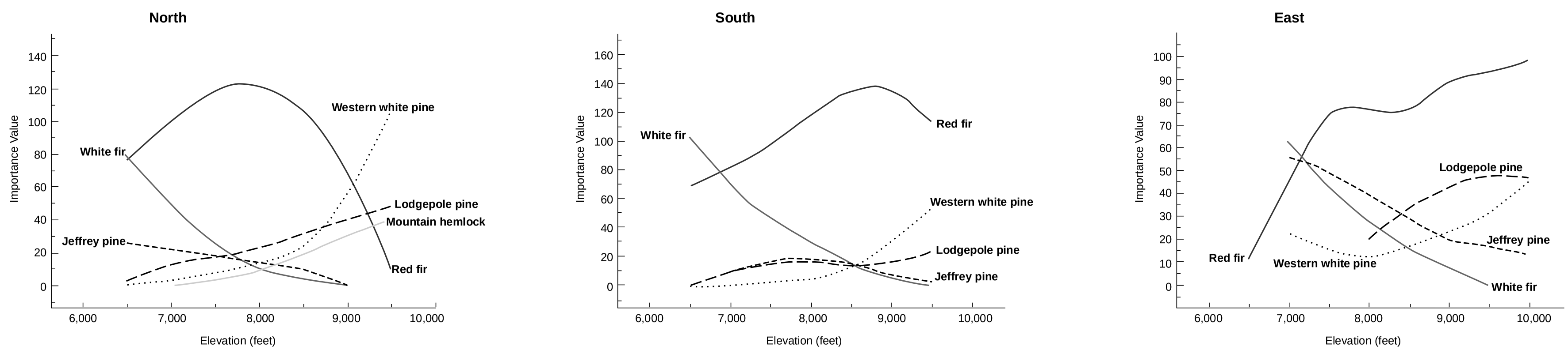


Figure 15a—Importance value by elevation and subregion for tree species in the central and southern Sierra Nevada.

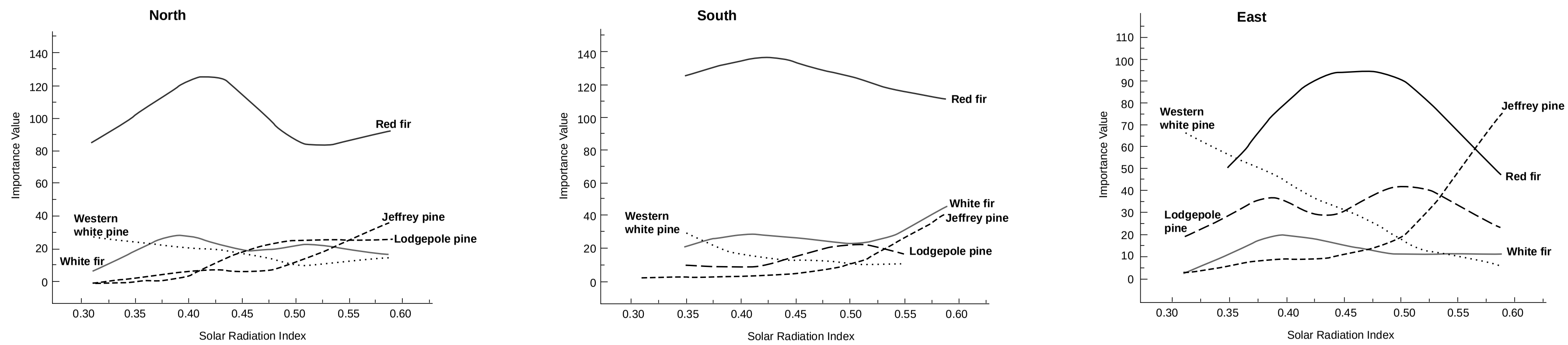


Figure 15b—Importance value by solar radiation index and subregion for tree species in the central and southern Sierra Nevada.

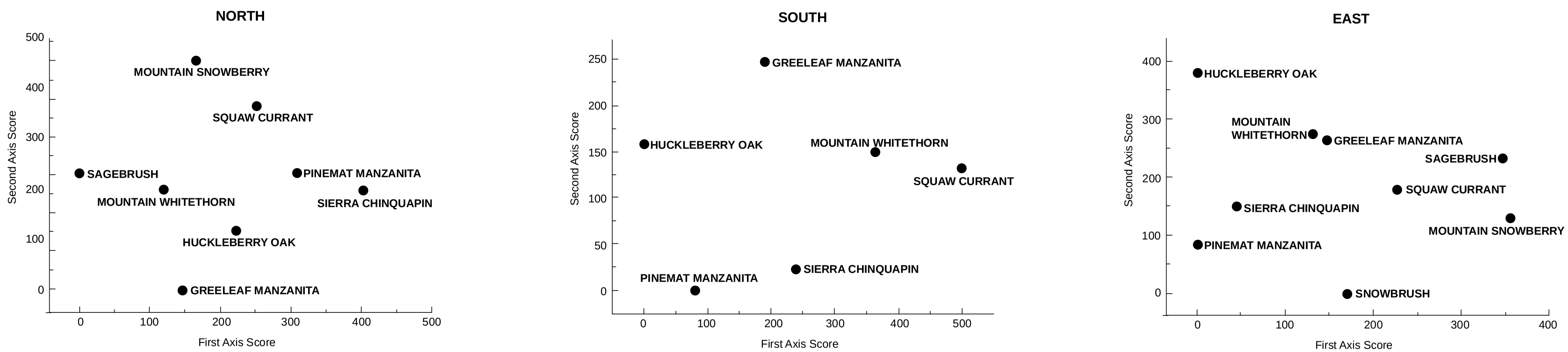


Figure 16—DECORANA ordination by subregion for selected shrub species in the central and southern Sierra Nevada.

Furthermore, examination of gradients, as was done for tree species, was performed for shrubs, and only moisture stress defined positions on the first axis among all subregions. Moisture stress increased with increasing scores in the northern ordination, while stress decreased with increasing scores in the southern and eastern ordinations. No overall gradients emerged from second axis scores. Thus, elevation increased on the second axis in the north; it decreased with increasing scores on the eastside; and no pattern with elevation emerged in the south. Similar to the analysis of tree species, shrub species were often differentiated by several variables; however, none formed linear relationships across all subregions.

Ordinations were also performed for each series. These were conducted to define plant associations within a series. The results of these ordinations and analysis within series are not presented here. They are included with the description of each association. Generally, gradients expressed by linear relationships within a single series were not strong, and a multivariate approach often did little to adequately describe important relationships. Plant associations within a series were often unique from others in the series, but these differences were not expressed along the continuum of the ordination axis in an indirect analysis. Direct gradient analysis using ANOVA and chi-square evaluations often provided the understanding of differences between plant associations that aided classification to plant association.

Using the Classification

This classification is designed for use in forested plant associations of the upper montane where tree cover is generally greater than 10 percent. In some cases individual sample sites contained less than 10 percent cover because they represented the variation encountered within the association, and in one association, Bolander's locoweed, tree cover values in general were less than 10 percent due to the nature of the plant communities involved.

The classification includes a key for field identification of each plant association, a description of each, and summary tables for cross referencing features between plant associations *(appendices E-H)*. The description of each association includes comments on the distribution, environment, vegetative composition and structure, soils, productivity, and management implications.

Species names are based on the flora described by Munz and Keck (1959). An updated version of the taxonomy is now available in the Jepson Manual (Hickman 1993), and name changes have occurred; however, the original identification and analysis of the taxa were completed before the Jepson Manual became available. Furthermore, before the classification was initiated, each species was assigned a code for field data entry and analysis. These codes follow Munz and Keck (1959), and they were not revised to incorporate the changes resulting from the new flora at the time of preparation of the classification. In those instances in which name changes have occurred in important upper montane taxa, serious users should consult both references and be aware of the changes. Some of the more obvious changes for the upper montane are a shift in family for pyrola species (wintergreen), and a shift in genera for pyrola secunda, sitanion (squirreltail), and stipa (needlegrass). Pyrola species are now placed in the Ericaceae, and *pyrola secunda* is *orthilia secunda* in the Jepson Manual while sitanion is placed in the genus Elymus, and the stipa are now listed in the genus Achnatherum. Common names follow those of Abrams and Ferris (1975) and McMinn (1939) in most cases.

Codes assigned to each species follow those in electronic data processing codes for California wildland plants (Reed and others 1963). They were supplemented by codes from the *Plants of California—Alphabetical Listing* (U.S. Department of Agriculture, Soil Conservation Service 1994), for cases in which the former reference did not contain codes. Each species code is a five-unit alphanumeric combination of Latin names and numbers *(appendix I)*. They consist of the first two letters of the genus followed by the first two letters of the specific epithet (species). A fifth letter code is used to distinguish between variety or subspecies. A fifth number code is added if species duplications occur or to indicate unidentified species of a genera. Thus, Sierra arnica, *arnica nevadensis*, is coded as ARNE1 to distinguish it from pinemat manzanita, *arctostaphylos nevadensis*, which is coded as ARNE2.

The title of each association is identified by four elements. First, a title consisting of common names is presented for communication among users who are familiar with the vegetation and setting. Second, a title consisting of the complete Latin names of the indicator species is provided to allow cross referencing and use in other studies. Third, a title consisting of the five-unit species codes for the indicator species in the association is used; and fourth, a regional code is used for correlation with other surveys and identification in large data bases.

Association names are subdivided by life form first. This is followed by an abiotic component if necessary. A slash (/) is used to represent a change in life form, while a hyphen (-) is used to separate species in the same life form. For example, ABMA-PIMO3/ARNE2 represents a plant association with indicator species in two life forms (trees and shrubs) and two tree species (ABMA and PIMO3) in the same life form. The order of species listing in the name is ranked by cover, and it further identifies the vegetation series and subseries. The first name indicates the species with highest cover and the series. The second and third name identifies those species with the next lowest cover and the subseries. In forested associations the tree layer identifies the series and subseries. The abiotic component is separated by two slashes (//). Thus, TSME//STEEP represents a single species association with an important topographic element of slope steepness.

Association descriptions attempt to highlight important differences or features of each association that are not presented or readily apparent in the tabular material. Extremes and statistically significant ($p>0.05$) relationships are noted where applicable. The term "mean" is the arithmetic average of the values sampled for a variable, while the term "mode" is the value or category that occurs most frequently. Median values are those that occur halfway between the range of observations. The species lists included with each description are not comprehensive. Only species with greater than 20 percent constancy are listed. Constancy is the percentage occurrence of a species in the samples used to describe the association. For example, a constancy of 50 refers to the presence of a plant in 50 percent of the samples. A complete listing of all species encountered during sampling is included in *appendix I*.

Cover values are the average cover values, expressed as a percent of the sample plot surface, where the species occurred. For example, a cover value of 20 means 20 percent of the sample plot was covered by that species. It does not include areas within the stand that contained no cover of the species. This is important when species are widely spaced in stands. To obtain a reasonable estimate of the average cover of such species throughout a stand, one can multiply the cover values by the constancy in decimal form. If a species occurred on 50 percent of the samples and the cover value was reported as 10, the average cover in a typical stand would be approximately 5 percent. The minimum value recorded for species cover was 1 percent. For small forbs and grasses such values are really indications of presence or absence, and they do not reflect the actual cover of these species which, in many cases, are less than 1 percent.

Management implications are based on field observation of different treatments throughout the range over several years, review of the literature, and interpretation of data from the classification.

In the descriptions certain adverbs are used to indicate the degree of occurrence of a particular feature and to avoid a graphical presentation or a complete listing of distributions for all variables. The use of defined adverbs attempts to portray modal situations or more closely describe the range of conditions one can expect to see in the field. The terms used together with the range of values expressed in percent are:

		Occurrences		
Less than 20	*21-40*	*41-60*	*61-80*	*Greater than 80*
Rare	Occasional	Usual	Common	General
Seldom	Some	Often	Typical	Characteristic
Few	Uncommon	Normal	Most	Predominant
Infrequent	Ordinary	Frequent	Majority	
Tend	Many			

Use of the Key

- A "stand," as used in the classification, is considered to be a contiguous group of plants sufficiently uniform in species composition, arrangement of age and size classes, and condition to be a homogeneous and distinguishable unit. No size is specified or implied in the use of the word "stand" in the classification. A stand is defined by the user and generally will be size-sufficient for use in management applications.
- Inclusions, or small areas with a different vegetative composition, may lie within a stand. For purposes of classification, the user will have to decide whether the area is small enough to represent the normal variation in species within a stand or whether it is large enough to merit recognition as a different plant association within a larger stand.
- Presence in the stand does not require a minimum percent of cover. Occurrence is sufficient to establish presence.
- Time of year must be considered when identifying plants used as indicator species. Plant identification early in the spring or late in the fall is often difficult; however, familiarity with the plants and their environment will often aid in the keying of a plant association during these times. If a critical decision must be reached it is best to schedule identification during early to midsummer for the associations described in this classification.
- Canopy cover, as used in the classification, means the estimated vertical projection on the ground of the area covered by those species used to determine or describe the association.
- The convention used to key associations does not necessarily rely on the most "common" or obvious species in the stand. It relies on those species or life forms that distinguish the stand from others in the upper montane forest. In some cases the difference may be obvious, but often the plants will not be conspicuous. Thus, a PICO/LIGR1 association will contain a large component of lodgepole pine and a somewhat consistent but often inconspicuous component of Gray's lovage.
- The key is self-referential in that sometimes a key step will lead to a series or group of associations depending on overstory composition and then lead back out of that group into another based on understory

composition. This is most noticeable in associations with large shrub components, and it was done to allow stands with variation in overstory composition but a similar understory to be keyed to the appropriate association. For example, there were samples in which the overstory was composed predominantly of red fir but with a huckleberry oak understory. These cases occurred seldom enough that insufficient samples were obtained to separately classify or describe such an association. During analysis, these samples were classified with the Jeffrey pine/huckleberry oak association. Descriptions of plant associations include the resulting variation in stand composition.

- Suggested procedures that can be used to determine the associations identified in the classification include:
    - Walk the stand completely noting the species present and approximate cover values by life form and crown position.
    - Make an "initial approximation" of the series or association for the stand. This approximation is designed to focus the classification on the more likely associations that will be examined, to reinforce decision points as they are reached, and to prevent major errors in keying.
    - Start at the beginning of the key for each stand and follow the steps exactly to the final classification.
    - Compare your classification with the description of the plant association. Note constancy and cover values and compare them with your observations of the stand.
    - Return to the last decision point that seemed questionable if the description does not correspond to your observations. Verify your analysis at this point by taking the alternative choice in the Key. Proceed with this choice to a new description, and again compare it with the stand. Choose the description that best fits the stand.
    - Remember that variation in vegetation across the landscape is continuous, and many ecotonal areas will not fit neatly into any particular association. Such areas should be classified with the most similar association. In most cases, similar types have similar characteristics and management properties.

Key to Plant Associations

A. Red fir (*Abies magnifica*) present in the stand or adjacent stands . . . . B

AA. Red fir absent from stand or adjacent stands . . . . Not Classified

B. Bolander's locoweed (*Astragalus Bolanderii*) cover greater than 5 percent:
BOLANDER'S LOCOWEED ASSOCIATION 59

BB. Bolander's locoweed cover less than 5 percent C

C. Quaking aspen (*Populus tremuloides*) cover greater than 5 percent . . . . a

a. Western juniper *(Juniperus occidentalis)* and/or mountain mule ears *(Wyethia mollis)* and/or sagebrush *(Artemesia tridentata)* and/or mountain pennyroyal *(Monardella odoratissima)* and/or Jessica's stickseed *(Hackelia jessicae)* and/or Sierra wallflower *(Erysimum perenne)* and/or Brewer's angelica *(Angelica Brewerii)* present:
QUAKING ASPEN/MOUNTAIN PENNYROYAL ASSOCIATION 65

b. Not as above:
QUAKING ASPEN/CALIFORNIA CORN LILY ASSOCIATION 73

CC. Quaking aspen cover less than 5 percent . . . . D

D. Western juniper *(Juniperus occidentalis)* cover greater than 5 percent . . . . a

a. Sagebrush and/or mountain mule ears cover greater than 5 percent:
WESTERN JUNIPER/SAGEBRUSH ASSOCIATION 81

b. Not as above:
WESTERN JUNIPER ASSOCIATION 89

DD. Western juniper cover less than 5 percent . . . . E

E. Lodgepole pine *(Pinus contorta)* cover greater than 5 percent. . . . . a

a. Sagebrush and/or bitterbrush *(Purshia tridentata)* and/or mountain mule ears cover greater than 5 percent:
LODGEPOLE PINE/SAGEBRUSH ASSOCIATION 201

b. Not as above . . . . F

EE. Lodgepole pine cover less than 5 percent . . . . F

F. Mountain mule ears cover greater than 5 percent:
RED FIR/MOUNTAIN MULE EARS ASSOCIATION 97

FF. Mountain mule ears cover less than 5 percent . . . . G

G. Tree cover greater than 10 percent . . . . H

GG. Tree cover less than 10 percent:

(Talus, rock outcrops, shrub, forb, grass, meadow, and riparian communities) . . . . Not classified

H. Mountain hemlock *(Tsuga mertensiana)* cover greater than 5 percent . . . . a

a. Slope greater than 30 percent:
MOUNTAIN HEMLOCK//STEEP ASSOCIATION 105

b. Slope less than 30 percent:
MOUNTAIN HEMLOCK ASSOCIATION 113

HH. Mountain hemlock cover less than 5 percent. I

I. Western white pine *(Pinus monticola)* cover greater than 5 percent . . . . a

a. Pinemat manzanita *(Arctostaphylos nevadensis)* cover greater than 5 percent:

RED FIR-WESTERN WHITE PINE/PINEMAT
MANZANITA ASSOCIATION 121

b. Not as above c

c. Bush chinquapin *(Castenopsis sempervirens)* cover greater than 5 percent:

RED FIR-WESTERN WHITE PINE/SIERRA
CHINQUAPIN ASSOCIATION 129

d. Not as above . . . . e

e. Lodgepole pine cover greater than 5 percent:

RED FIR-WESTERN WHITE PINE-LODGEPOLE PINE ASSOCIATION. 137

f. Not as above:

RED FIR-WESTERN WHITE PINE ASSOCIATION. 145

II. Western white pine cover less than 5 percent . . . . J

J. Sugar pine (*Pinus lambertiana*) and/or incense cedar *(Calocedrus decurrens)* present:
WHITE FIR-SUGAR PINE-RED FIR ASSOCIATION 153

JJ. Sugar pine and/or incense cedar absent . . . . K

K. Jeffrey pine *(Pinus Jeffreyii)* cover greater than 5 percent . . . . a

a. Huckleberry oak *(Quercus vaccinifolia)* cover greater than 5 percent:

JEFFREY PINE/HUCKLEBERRY OAK ASSOCIATION 161

b. Not as above c

c. Greenleaf manzanita *(Arctostaphylos patula)* and/or snowbrush *(Ceanothus velutinus)* cover greater than 5 percent:

JEFFREY PINE/GREENLEAF MANZANITA-SNOWBRUSH ASSOCIATION 169

d. Not as above . . . . e

e. Mountain white thorn *(Ceanothus cordulatus)* and/or Fresno ceanothus *(Ceanothus fresnensis)*, and or sagebrush and/or bitterbrush and/or sticky leaved rabbit brush *(Chrysothamnus viscidiflorus)* cover greater than 5 percent:

JEFFREY PINE/MOUNTAIN WHITETHORN-SAGEBRUSH ASSOCIATION 177

f. Not as above . . . . g

g. Pinemat manzanita cover greater than 5 percent:

RED FIR/PINEMAT MANZANITA ASSOCIATION. 249

h. Not as above i

i. White fir *(Abies concolor)* cover greater than 5 percent:

RED FIR-WHITE FIR-JEFFREY PINE ASSOCIATION 185

j. Not as above . . . . aa

aa. Lodgepole pine cover greater than 5 percent. L

bb. Not as above: . . . .
JEFFREY PINE-RED FIR ASSOCIATION 193

KK. Jeffrey pine cover less than 5 percent L

L. Lodgepole pine cover greater than 5 percent . . . . a

a. Pinemat manzanita cover greater than 5 percent:
RED FIR-WESTERN WHITE PINE/PINEMAT MANZANITA ASSOCIATION 121

b. Not as above c

c. Sagebrush and/or bitterbrush and/or sticky leaved rabbit brush cover greater than 5 percent:
LODGEPOLE PINE/SAGEBRUSH ASSOCIATION 201

d. Not as above . . . . e

e. Gray's lovage *(Ligusticum grayii)* and/or Parish's yampa *(perideridia parishii)* and/or one sided wintergreen *(Pyrola secunda)* and/or arrowhead butterweed *(Senecio triangularis)* and/or clover *(Trifolium spp.)* present:
LODGEPOLE PINE/GRAY'S LOVAGE ASSOCIATION 209

f. Not as above . . . . g

g. Stand basal area less than 225 square feet per acre, and/or total tree cover less than 50 percent:
LODGEPOLE PINE//WOODLANDS ASSOCIATION 217

h. Not as above i

i. Red fir cover greater than 5 percent:
RED FIR-LODGEPOLE PINE/WHITE FLOWERED HAWKWEED ASSOCIATION 233

i. Not as above:
LODGEPOLE PINE ASSOCIATION 225

LL. Lodgepole pine cover less than 5 percent . . . . M

M. White fir cover greater than 5 percent . . . . a

a. Huckleberry oak cover greater than 5 percent:
JEFFREY PINE/HUCKLEBERRY OAK ASSOCIATION 161

b. Not as above c

c. Greenleaf manzanita and/or snowbrush cover greater than 5 percent:
JEFFREY PINE/GREENLEAF MANZANITA-SNOWBRUSH ASSOCIATION 169

d. Not as above . . . . e

e. Mountain whitethorn and/or sagebrush and/or bitterbrush and/or sticky leaved rabbit brush cover greater than 5 percent:
JEFFREY PINE/MOUNTAIN WHITETHORN-SAGEBRUSH ASSOCIATION 177

f. Not as above:
RED FIR-WHITE FIR ASSOCIATION 241

MM. White fir cover less than 5 percent . . . . N

N. Red fir cover greater than 5 percent . . . . a

a. Pinemat manzanita cover greater than 5 percent:
RED FIR/PINEMAT MANZANITA ASSOCIATION 249

b. Not as above c

c. Huckleberry oak cover greater than 5 percent:
JEFFREY PINE/HUCKLEBERRY OAK ASSOCIATION 161

d. Not as above . . . . e

e. Greenleaf manzanita and/or snowbrush cover greater than 5 percent:
JEFFREY PINE/GREENLEAF MANZANITA-SNOWBRUSH ASSOCIATION 169

f. Not as above . . . . g

g. Sagebrush and/or bitterbrush and/or sticky leaved rabbit brush cover greater than 5 percent:
JEFFREY PINE/MOUNTAIN WHITETHORN-SAGEBRUSH ASSOCIATION 177

h. Not as above:
RED FIR ASSOCIATION 257

NN. Red fir cover less than 5 percent . . . . Not classified

Association Descriptions

Bolander's Locoweed Association

Astragalus bolanderii

ASBO
FBLFBL11
Sample size: 10

Distribution

The Bolander's locoweed plant association occurs only on the westside in widely separated locations between latitudes of 36°59' and 38°50'. It was sampled on the Sierra, Stanislaus, and Eldorado National Forests. It is found at several locations on the Sierra National Forest near Dinkey Creek and as far north as Wrights Lake on the Eldorado National Forest. Although the dominant forb, *Astragalus bolanderii*, occurs in small populations scattered throughout westside forests, it becomes dominant only in the relatively small patches occupied by this plant association. These communities are small in total area, but they form an important component of the landscape diversity in upper montane forests. Stands exceeding 10 acres have been observed; however, most stands are less than 5 acres in size.

Environment

Elevations average nearly 8,000 feet; however, a high proportion of sites lie at elevations above 8,000 feet on northeast and northwest aspects. They generally occupy upper slope positions, and microrelief is characteristically uniform to gently undulating. Slopes are usually less than 20 percent. Shallow slopes and northerly aspects result in SRI levels that are moderate to low. Locoweed stands have significantly more bare ground and surface gravel than most other sites, while litter cover and litter depths are substantially less than surrounding forested stands. The location of many sites on upper slopes results in stress indexes that are moderate to high for the upper montane.

Variable	*Mean*	*Range*
Elevation (feet)	7,962	7,060-8,800
Slope (pct.)	19	8-31
Solar radiation index	0.475	0.399-0.574
Bare ground (pct.)	43	21-80
Surface gravel (pct.)	24	6-42
Surface rock (pct.)	3	0-15
Litter (pct.)	25	1-58
Litter depth (inches)	0.4	0.1-1.0
Stress index	0.51	0.42-0.57

Aspect: NE, NW.
Range: All.
Position: Upper slopes.
Range: Ridgetops, upper and middle slopes, benches.

Vegetation

Sites in this association are basically low forb dominated communities with scattered trees. Adjacent stands are commonly dense forests. Total vegetative cover is among the lowest of the forested communities of the upper montane. It is significantly lower than most adjacent forest stands due to low tree cover and the somewhat open growth habit of locoweed. This association has the lowest tree cover of any in the upper montane, but sites carry high forb and grasscover compared to other associations. Interestingly, species diversity is low given the open conditions of this association. The total number of species is low compared to most other sites, and stands tend to be dominated by a few species in the forb layer which are relatively evenly distributed.

Red fir is the dominant tree species although trees are typically widely scattered. A shrub layer is nonexistent. In addition to Bolander's locoweed, the forb layer is dominated by pussy paws and spurry eriogonum. These particular forbs occur in these communities at higher cover levels than any other observed in the upper montane. Sites have the appearance of open, dry environments, but species such as pussy paws and Coville's gayophytum are indicative of moderately moist conditions, and soil conditions indicate relatively moderate habitats.

Conifer regeneration is the lowest of all the associations in the forested portions of the upper montane. No conifer species is regenerating well on these sites. The average number of seedlings is less than 45 per acre, and regeneration is absent over much of the area within a stand. The regeneration layer is characterized by widely scattered red fir and lodgepole pine.

Average stand ages are relatively young compared to ages for other late seral communities, and this would indicate these stands may be in transition to occupation by conifers. Ages of the oldest trees on the sites were ±321 years for red fir and ±176 years for lodgepole pine. These are comparable to ages achieved by these same species in adjacent stands.

Examination of aerial photos from the 1940's indicate these communities have maintained their basic size, shape, and cover since that time. Ages of older trees in adjacent forested stands would indicate there has been ample seed sources and time for development of forested communities if such were possible. This has not occurred, and future successional direction is difficult to predict at this time.

Cover (percent)	*Mean*	*Range*
Total vegetative	64	25-90
Tree	4	0-15
Shrub	6	0-55
Forb	44	9-85
Grass	14	0-41
Moss	0.2	0-1
Stand age (years)	159	54-249
Diversity index		
Simpson	0.39	0.14-0.87
Hill numbers		
N0	8.9	3.0-16.0
N1	4.22	1.41-8.46
N2	3.58	1.16-7.22

Characteristic Vegetation

Code	*Common name*	*Constancy*	*Percent cover Mean*	*Percent cover Range*
I. Overstory trees				
ABMA	Red fir	60	6	1-15
II. Understory trees				
ABMA	Red fir	20	1	1-1
PICO	Lodgepole pine	20	1	1-1
III. Shrubs	None			
IV. Forbs				
ASBO	Bolander's locoweed	100	29	2-80
CAUM2	Pussy paws	100	17	1-60
ERSP2	Spurry eriogonum	80	10	1-40
GAER	Coville's gayophytum	70	2	1-7
STTO	Mountain streptanthus	50	3	1-7
MOOD	Western pennyroyal	30	1	1-1
ERBR2	Brewer's daisy	20	6	2-10
VIPU	Mountain violet	20	1	1-1
V. Grasses and grass-like				
SIHY	Bottle brush squirreltail	40	2	1-5
STOC1	Western needlegrass	40	1	1-2
STCA1	California needlegrass	30	1	1-2
STCO1	Columbia needlegrass	30	14	1-4

Soils

Soils in this association are primarily Umbrepts in the Inceptisol order. Particle size classes are varied and almost evenly divided between skeletal, sandy, loamy, and medial. These size classes are indicative of the generally lower levels of rock fragments in these profiles. One sample originated from metamorphic quartzite, and a few samples in the north originated from lahar and tuff; however, soils were typically formed in place from granitic parent materials.

These soils are deep. Generally, they are deeper than 35 inches, and often they exceed 40 inches. Topsoil depths are varied, but they also tend to be quite deep. Depths usually exceed 12 inches, and on average they are the deepest of all plant associations in the upper montane. Conversely, coarse fragments are low throughout the profile. Average coarse fragment contents in both the topsoil and subsoil are the lowest of any in these high elevation forests, and coarse fragments in both the topsoil and subsoil are characteristically less than 25 percent. Usually both topsoil and subsoil are medium and moderately coarse textured sandy loams with occasional sands and loams.

AWC ranges from moderately low to high in almost equal proportions, and sites are not substantially different from other forested stands in the upper montane. Commonly, these soils are well drained, and they often lie over bedrock formations that are massive and unrootable. Erodibility is low to moderate on most sites due to gentle slopes and moderately coarse soil textures. Soil temperatures are significantly higher than most other sites. In spite of generally lower solar radiation levels, the open conditions of this association apparently allows average soil temperatures to reach the highest of any in the upper montane. All stands had summertime soil temperatures which exceeded 54° Fahrenheit. This is consistent with temperatures experienced by other open sites in the study area.

Variable	*Mean*	*Range*
Depth of soil sample (inches)	38	30-40+
Topsoil		
Depth (inches)	17	4-40+
Coarse frag. (pct.)	13	7-20
pH	5.4	4.8-6.2
Subsoil		
Coarse frag. (pct.)	18	6-30
pH	5.8	5.1-6.6
AWC (inches)	3.7	2.1-6.5
Temp (20 inches) (Fahrenheit)	58	54-59

Productivity

These are essentially non-forested plant communities; consequently, potential yields are low. Stand structures are irregular. Several tree size classes are usually present; however, overall stand density is quite low, and smaller size classes are under-represented *(fig. 17)*. Pacific Southwest Region (Region 5) site index averages 3, and site indexes are usually 3 or 4. The average stand density index is the lowest of any forested association in the upper montane. Stand density indexes are generally less than 165 in these stands, and values are only 15 percent of those attained by denser stands such as the Red fir-white fir association. Basal area stocking levels and cubic foot and board foot yields are also the lowest of any of the forested associations.

Variable	Mean	Range
Region 5 site index	3	1-4
Forest survey site class	4	2-5
Stand density index	76	0-167
Quadratic mean diameter	21.8	0-46.0
Softwood volume (mcf/ac)	2.1	0-4.8
Softwood volume (mbf/ac)	14.7	0-33.3
Softwood basal area (sq ft/ac)	48	0-140
Hardwood volume (mcf/ac)	0	0
Hardwood basal area (sq ft/ac)	0	0

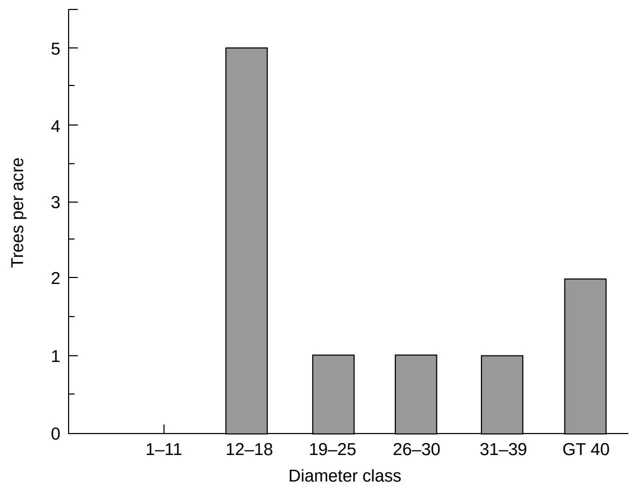


Figure 17—Number of trees by diameter class in the Bolander's locoweed plant association.

Tree species composition by percent of basal area

Species	ABMA	ABCO	PICO	PIJE	PIMO3	TSME
Percent	87	-	9	-	4	-
Species	JUOC	PILA	LIDE3	PIAL	POTR	QUKE
Percent	-	-	-	-	-	-

Coarse Woody Debris

Snags and down logs are not a common feature of this plant association since sites are essentially open herbaceous communities. Some coarse woody debris falls into the stand from adjacent vegetation types and occasionally from scattered trees growing on the sites themselves, but contributions from these sources are rare.

Wildlife

Bolander's locoweed communities are moderately foraged by large game. Several species such as locoweed, squirreltail, western needlegrass, and columbia needlegrass are used by large game as staple foods; however, except for locoweed and columbia needlegrass, constancy and cover of most of these species are often low. Deer use was commonly observed, but no pocket gopher activity was observed on any of the sample sites.

Range

These are transitional range sites that are used by livestock to access primary range sites such as meadows and other moist habitats. Occasional cattle use was observed. Bottle brush squirreltail and California needlegrass are primary forage species, while western needlegrass, and columbia needlegrass are secondary species in this association. All other species commonly occurring on these sites are of low forage value.

Management Recommendations

Even though stands in this plant association are open, forb dominated communities, they are not substantially different from other forested stands in the upper montane, and they are commonly surrounded by dense forests. This association has the environmental characteristics to produce denser stands of trees and other vegetation, but this has not occurred. It is possible that factors such as allelopathy, past fire severity, past grazing practices, or prehistoric use patterns are influencing these sites, but such conclusions are speculative. Attempts to convert these sites and change species composition to conifers or other shrub, forb, or grass dominated communities should be treated with caution. This association is best suited to providing general wildlife habitat, plant species richness, and landscape level diversity in the upper montane.

Quaking Aspen/Mountain Pennyroyal Association

Populus tremuloides/Monardella odoratissima

POTR/MOOD
HQAHQA12
Sample size: 19

Distribution

Quaking aspen is one of the most widely distributed trees in North America, and it is present throughout the central and southern Sierra Nevada. Stands become more extensive north and east in the range. The quaking aspen/mountain pennyroyal plant association extends north generally from the John Muir and Kaiser Wilderness on the Sierra National Forest near latitude 37°19'. Longitude of the samples all lie west of 119°. It is best developed on the eastside of the Sierra Nevada north of Bridgeport on the Toiyabe National Forest. Stands are never very large or extensive except near Carson Pass and Hope Valley, and most stands, particularly on the westside, are less than 5 acres in size.

Environment

This association is typically located on middle and lower slopes; a few stands are found adjacent to wetlands and meadows, and some occur on benches and high on slopes where subsurface water appears to be plentiful. In general, a significantly higher proportion of sites lie on lower slope positions compared to other forested plant associations. Slopes are gentle. Most sites occur on slopes that are less than 25 percent. This association is not substantially different from the quaking aspen/California corn lily association in general position on the landscape; however, it does occur more often in upland settings. Environments do not appear to be substantially different from other forested plant communities in the upper montane; however, this plant association is often found on southeast and southwest facing aspects where SRI levels are frequently moderately high to high. Stress indexes range widely from low to high reflecting differences in AWC and slope position of specific stands.

Variable	Mean	Range
Elevation (feet)	8,046	6,920-9,100
Slope (pct.)	18	3-33
Solar radiation index	0.503	0.442-0.560
Bare ground (pct.)	4	0-12
Surface gravel (pct.)	7	0-55
Surface rock (pct.)	3	0-25
Litter (pct.)	81	5-98
Litter depth (inches)	1.0	0.2-1.9
Stress index	0.44	0.33-0.55

Aspect: SE, SW, NW.

Range: All.

Position: Middle and lower slopes.

Range: Upper, middle, and lower slopes, toeslopes and benches.

Vegetation

Stands are mixed hardwood-conifer forests. In the north, stands are sometimes interspersed within the red fir/mountain mule ears and western juniper/ sagebrush associations. Total vegetation cover is high resulting from combinations of high tree, forb, and grass cover. Stands are characterized by the presence of quaking aspen that may be present as either overstory or middle layer trees. Red fir is common in the stands, although western juniper, a dry site indicator, is usually a member of the tree canopy, particularly in eastside stands. Other species are less well represented. Quaking aspen is indicative of moist sites generally in upper montane forests; however, this association is not significantly different in this regard than most other forested sites.

A shrub layer is characteristically present, and it occurs in higher amounts than in many other associations. On most sites at least one of three species of snowberry are present. Thus, either creeping snowberry, mountain snowberry, or Parish's snowberry are generally present on these sites. Creeping snowberry suggests mesic conditions, although sagebrush, mountain snowberry, and Parish's snowberry suggest moderate to dry conditions. Forb and grass cover are substantially higher than other forested associations. The species present also reflect the moderate to dry conditions. Mountain pennyroyal, Coville's gayophytum, and bottle brush squirreltail indicate dry to moderate habitats although mountain mule ears, mountain sweet cicely, and Fendler's meadow rue reflect moderate to moist conditions. Among the grasses, Bolander's bluegrass indicates moist sites while large mountain brome reflects moderate to dry conditions.

The total number of tree seedlings in these stands averages over 1,400 per acre, and stands typically have more than 500 per acre. Overall, tree regeneration is more common in the quaking aspen/mountain pennyroyal association than on most other sites. This difference results from an abundance of aspen sprouts. Tree regeneration is dominated by quaking aspen, but red fir is also common in this layer. Western juniper is usually present, and lodgepole pine is sometimes present as well. Both quaking aspen and western juniper are regenerating significantly more often in this association than on most other sites.

Plant species diversity is high. It is among the highest in the forested communities in the upper montane, and it is substantially higher than most other forested stands except those in the western juniper series. This plant association has many total species as well as a relatively large number of species with high cover values. Abundant species are distributed among several life forms.

The average age of stands in this association is significantly lower than most others in the upper montane. Aspen trees are generally relatively young in the Sierra Nevada; breast height ages of this species are commonly less than 90 years. Aspen ages in these late seral stands ranged from 53 to 135 years for the oldest trees. On the other hand, scattered predominants of conifer species, especially western juniper, are considerably older. For example, the oldest tree measured was a western juniper estimated at $\pm$710 years, and the ages of older trees were usually greater than 200 years. The scattered nature of the older conifers in these stands, and the relatively uniform sizes of the younger aspen middle layer would appear to indicate that quaking aspen undergoes relatively constant turnover in these stands. In general, the ages of the current aspen component in many stands corresponds relatively well with the end of intensive grazing pressures in the late 1800's and the institution of fire suppression policies in the early 1900's.

Stands appear to be following a successional sequence that would result in dominance by conifers—usually red fir. Several samples, in fact, had a few remnant aspen below an almost closed canopy of conifers, and usually many aspen logs littered the forest floor in these cases. This condition appears to result from both suppression of fire over the past several decades and grazing pressure that keeps aspen sprouts severely hedged to the favor of conifers which are not grazed as heavily. Before widespread fire suppression and the introduction of grazing, aspen was favored on these sites due to available moisture and fire that opened stands, encouraged aspen sprouting, and killed competing conifer seedlings. Clearly, regeneration potential in the long-term lies with aspen in the presence of fire and the absence of grazing. In the absence of fire and with continued grazing pressure many of these stands will probably experience reduction in the aspen component.

Cover (percent)	*Mean*	*Range*
Total vegetative	94	70-100
Tree	71	33-85
Shrub	13	0-55
Forb	50	8-90
Grass	43	1-90
Moss	0.1	0-1
Stand age (years)	188	32-428
Diversity index:		
Simpson	0.20	0.08-0.67
Hill numbers		
N0	20.9	10.0-27.0
N1	8.86	2.44-14.57
N2	6.40	1.49-12.26

Characteristic Vegetation

Code	*Common name*	*Constancy*	*Percent cover* *Mean*	*Percent cover* *Range*
I. Overstory trees				
POTR	Quaking aspen	100	48	16-81
ABMA	Red fir	63	21	1-52
JUOC	Western juniper	42	9	1-30
PICO	Lodgepole pine	37	8	1-20
PIJE	Jeffrey pine	32	2	1-2

Characteristic Vegetation, continued

	Code	*Common name*	*Constancy*	*Percent cover* *Mean*	*Range*
II.	Understory trees				
	POTR	Quaking aspen	95	4	1-15
	ABMA	Red fir	63	2	1-20
	JUOC	Western juniper	42	1	1-1
	PICO	Lodgepole pine	32	1	1-1
	ABCO	White fir	26	1	1-2
III.	Shrubs				
	SYAC	Creeping snowberry	47	9	1-50
	ARTR	Sagebrush	32	4	1-10
	RICE	Squaw currant	26	1	1-2
	ZRIMO	Alpine prickly currant	21	22	1-55
	RIRO	Sierra gooseberry	21	2	1-3
	SYVA	Mountain snowberry	21	6	2-9
IV.	Forbs				
	COTOW	Wright's blue eyed mary	58	14	1-60
	DERII	Mountain tansy mustard	58	2	1-30
	MOOD	Mountain pennyroyal	58	5	1-30
	OSCH	Mountain sweet cicely	58	6	1-70
	THFE	Fendler's meadow rue	58	11	1-30
	CIAN1	Anderson's thistle	53	5	1-40
	COLI2	Narrow leaved collomia	47	3	1-30
	HAJE	Jessica's stickseed	47	4	1-15
	GAER	Coville's gayophytum	42	4	1-50
	SEAR	California butterweed	42	1	1-2
	ANBR2	Brewer's angelica	37	1	1-2
	ERPE3	Sierra wallflower	37	1	1-2
	PODO3	Douglas' knotweed	37	8	1-30
	WYMO	Mountain mule ears	37	5	1-13
	ALCA2	Sierra onion	32	1	1-3
	COTO1	Torrey's blue eyed mary	32	10	1-40
	CAAP	Indian paint brush	26	1	1-2
	LIGR1	Gray's lovage	26	2	1-3
	OSOC	Western sweet cicely	26	1	1-3
	PHHY	Waterleaf phacelia	26	1	1-2
	ALOB	Red sierra onion	21	1	1-2
	PESE3	Pine woods lousewort	21	1	1-1
	VECA1	California corn lily	21	3	1-40
	VIPU	Mountain violet	21	6	1-20
V.	Grasses and grass-like				
	POBO1	Bolander's bluegrass	68	5	1-15
	BRMA3	Large mountain brome	63	11	1-80

Characteristic Vegetation, continued

Code	*Common name*	*Constancy*	*Percent cover* *Mean*	*Range*
ELGL	Blue wildrye	47	26	3-80
SIHY	Bottle brush squirreltail	47	9	1-40
STCA1	California needlegrass	42	7	1-20
CARO1	Ross' sedge	32	2	1-10
STCO1	Columbia needlegrass	26	2	1-3

Soils

Soils are commonly Inceptisols. Most are Xerumbrepts and Cryumbrepts, but a few Xerochrepts are also encountered. Alfisols and Mollisols are present in rare cases; most often these are boralfs and borolls. Throughout the profile, particle size classes are normally skeletal, but loamy size classes are not uncommon. Soils are usually derived from either volcanic, granitic, or mixed parent materials. Mixed lithologies are most commonly granitic-volcanic combinations characteristic of parent materials found in the northern portion of the range where this association occurs most often. These soils are usually formed in place from bedrock, but many are also formed from material that has been moved. Soils on nearly 50 percent of the samples were formed in alluvial and colluvial deposits characteristic of locations on lower slopes. A few occurred in glacial deposits.

These soils are quite deep. Occasionally samples were less than 35 inches, but most were greater than 40 inches deep. Textures in the topsoil are usually loams with occasional sandy loams and sandy clay loams and a few sands. Subsoil textures are varied, but they tend to be finer textured than the topsoils. Thus, sands and sandy loams are encountered, but loams, sandy clay loams, clay loams, and clays occur just as often, and a significantly higher proportion of the soils in this plant association are medium and moderately fine textured compared to adjacent forested communities. A significantly higher portion of the subsoils are also 10 YR in hue with low chroma. These subsoils are essentially grayer in color than most other sites.

AWC and stress indexes on these sites are not substantially different from many other stands, but AWC is considerably less than those of the quaking aspen/California corn lily association indicating drier conditions in this closely related community. Topsoil pH values are significantly higher than most other sites reflecting the presence of aspen and a tendency for hardwood litter to decrease surface acidity. Soils usually lie over parent materials that are hard but fractured and therefore rootable. These soils are essentially well-drained, and erodibility is low to moderate due to finer soil textures and moderate slopes.

Variable	*Mean*	*Range*
Depth of soil sample (inches)	36	28-40+
Topsoil		
Depth (inches)	12	4-38
Coarse frag. (pct.)	22	5-80
pH	6.4	5.7-7.1
Subsoil		
Coarse frag. (pct.)	38	5-98
pH	6.0	5.4-7.6
AWC (inches)	3.4	0.5-5.1
Temp (20 inches) (Fahrenheit)	50	41-59

Productivity

Site indexes show more variation than the quaking aspen/California corn lily association, and they generally tend to be lower. Typical Pacific Southwest Region (Region 5) site indexes are 3 and lower, and often they are less than 4. Uncommon stands will have site indexes of 1 or 2. Stand densities are moderate, and sites will usually have stand density indexes that exceed 400. Based on stand density indexes, the average stocking is over 75 percent of fully stocked red fir-white fir stands, which is one of the densest upper montane associations. Most stands had basal area stocking levels of less than 200 square feet per acre. Tree height in this type is also significantly less as a result of the abundance of aspen that seldom exceeds 80 feet. In conjunction with lower site indexes and the smaller heights and diameter of aspen, these stands carry substantially less basal area, cubic, and board foot volume than most other forested sites.

Stand structures are typically two-storied, with scattered large conifers over a middle layer of aspen mixed with conifer saplings and young trees. Substantially more trees less than 11 inches DBH occur than in most stands in the upper montane, and size classes larger than 18 inches DBH are also less than most other stands *(fig. 18)*. This structure reflects the high number of aspen stems present. Aspen in the Sierra Nevada does not typically exceed 24 inches DBH, and the average diameter of aspen in these late seral stands was 15 inches. Quadratic mean diameters for these stands are substantially lower than most other forested sites in the upper montane. An equally important component of the stocking in smaller size classes in this association is red fir which, as noted earlier, appears to be successionally dominant. Larger trees in these stands are often western juniper.

Variable	*Mean*	*Range*
Region 5 site index	3	1-5
Forest survey site class	4	2-6
Stand density index	401	163-711
Quadratic mean diameter	12.2	1-23.2
Softwood volume (mcf/Ac)	6.4	1.9-10.6
Softwood volume (mbf/Ac)	26.6	0-77.0
Softwood basal area (sq ft/ac)	117	7-240
Hardwood volume (mcf/ac)	7.6	1.4-18.2
Hardwood basal area (sq ft/ac)	124	26-266

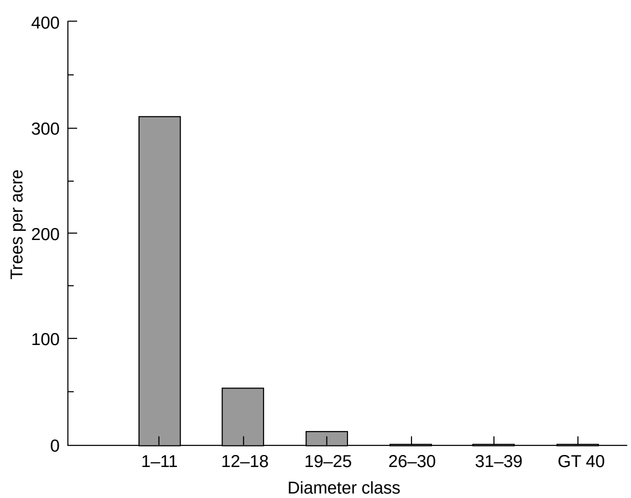


Figure 18—Number of trees by diameter class in the quaking aspen/mountain pennyroyal plant association.

Tree species composition by percent of basal area

Species	ABMA	ABCO	PICO	PIJE	PIMO3	TSME
Percent	26	4	7	2	-	-
Species	JUOC	PILA	LIDE3	PIAL	POTR	QUKE
Percent	11	-	-	-	50	-

Coarse Woody Debris

Snag numbers are moderate. In general, mortality is concentrated in trees less than 18 inches in diameter, reflecting the aspen component of these stands. Snag numbers in large diameter classes are low. Most snags are shorter than 50 feet in length, which also reflects the presence of aspen that tends to topple rather than break off when dead. Snags tend to be sound. The majority occur in decay classes between 1 and 3. Logs are short as well and evidence higher levels of decay. Decay classes between 3 and 5 predominate.

Snags

	Breast Height Diameter Class (inches)						
	<11	***11-17.9***	***18-24.9***	***25-29.9***	***30-39.9***	***>40***	***Total***
Snags per acre	4.4	3.7	1.5	0	0.2	0.1	9.9
Snag height (feet)							
<20	2.1	0.9	0.5	-	-	-	3.5
20-50	2.3	2.2	0.5	-	0.1	0.1	5.2
>50	-	0.6	0.5	-	0.1	-	1.2
Snag decay class							
1	-	0.9	0.5	-	-	-	1.4
2	0.8	0.9	0.5	-	0.1	-	2.3
3	2.6	1.6	0.5	-	-	0.1	4.8
4	0.8	0.3	-	0.1	-	1.2	
5	0.2	-	-	-	-	-	0.2

Logs

	Large End Diameter Class (inches)				
	11-20	**21-30**	**31-40**	**>40**	**Total**
Logs per acre	8.7	5.0	1.0	0.3	15.0
Log length (feet)					
<20	5.4	1.7	1.0	-	8.1
20-50	3.3	2.7	-	0.3	6.3
51-100	-	0.6	-	-	0.6
>100	-	-	-	-	-
Log decay class					
1	-	-	-	-	-
2	0.7	0.4	-	-	1.1
3	5.4	3.0	-	0.3	8.7
4	2.3	1.3	0.3	-	3.9
5	0.3	0.3	0.7	-	1.3

Wildlife

Wildlife forage appears to be moderate to high. Aspen is a preferred large game forage species, and it is readily available from sprouts that are usually heavily browsed. Mountain snowberry, mountain tansy mustard, Brewer's angelica, large mountain brome, and Bolander's bluegrass are all staple foods in the large game diet. They appear to be occurring often enough and in sufficient quantity to be a component in the large game diet. Deer presence on these sites was moderate to high, and pocket gopher presence was common.

Range

Stands sometimes occur adjacent to meadows and other moist areas where livestock congregate in the summer season for shade, forage, and access to water. Occasional stands are primary range sites, and use of range forage plants on these sites can become heavy. Of the more common range species in these stands, aspen appears to be a primary browse species. In most of the stands aspen seedlings are heavily browsed by livestock, and this seriously reduces the ability of aspen to regenerate. Only through continual resprouting can aspen escape browsing enough times to permit it to eventually develop into tree form. Brewer's angelica and mountain sweet-cicely are secondary forb species. Large mountain brome and California needlegrass are primary forage species, while bottle brush squirreltail and blue wildrye are secondary species that occur with enough frequency and high enough cover values to contribute to livestock forage.

Management Recommendations

Fire is an effective tool in the regeneration of these stands (Schier and others 1985). Examples from wildfires demonstrate abundant aspen regeneration after stand replacing fires. Alternate prescriptions and results from efforts to convert these stands to conifers is unknown at this time.

Except on the eastside, late seral stands in this plant association are often small. Most are much less than 5 acres, and they are somewhat widely spaced across the landscape. However, these stands appear to be important wildlife habitat forage areas, and they are important elements in landscape diversity. They may be among the oldest organisms in the Sierra Nevada. It would seem appropriate at this time to maintain this association as a small but important component of these forests. To accomplish this, however, will require management emphasis to reduce grazing pressure and encourage aspen establishment and growth most likely through the reintroduction of fire.

Quaking Aspen/California Corn Lily Association

Populus tremuloides/Veratrum Californicum

POTR/VECA1
HQAHQA11
Sample size: 16

Distribution

The quaking aspen/California corn lily plant association is represented throughout the Sierra Nevada. However, it is more common on the westside and as one travels north through the range. More than 80 percent of the samples lay north of 37°30′ latitude and west of 119° longitude or essentially from the Middle Fork of the San Joaquin River north to the study area boundary. Stands are widely spaced across the landscape generally in drainage bottoms. Best development of the association occurs on the northern forests of the Stanislaus, Eldorado, and Toiyabe. Except on the eastside, for example near Carson Pass, stands are never very large or extensive, and most are less than 10 acres in size.

Environment

This is a lower elevation plant community. Sites are generally found at elevations less than 8,000 feet, and the lowest stand sampled was at 6,500 feet on the Eldorado National Forest. The lower elevations of this association result both from the occurrence on northern forests in which upper montane plant associations in general lie at lower elevations as well as its setting in lower slope positions on the landscape. Aspects are varied and not significant in differentiating this type. Slopes, however, are significantly less than other associations. The majority of sites have slopes of less than 15 percent, and they are often less than 10 percent. Stands characteristically lie on the lower one-third of slopes, on benches, and in toeslope or bottom situations as part of a meadow or riparian complex. It differs from the quaking aspen/mountain pennyroyal association that occurs more often in upland settings. There is abundant moisture available to these sites. Their location on lower slope positions probably results in high water tables. They have the lowest stress index of any association in the upper montane.

Variable	*Mean*	*Range*
Elevation (feet)	7,417	6,500-8,600
Slope (pct.)	12	2-31
Solar radiation index	0.486	0.378-0.536
Bare ground (pct.)	2	0-12
Surface gravel (pct.)	2	0-15
Surface rock (pct.)	3	0-10
Litter (pct.)	93	63-99
Litter depth (inches)	1.1	0.2-2.9
Stress index	0.40	0.31-0.54

Aspect: All.

Range: All.

Position: Lower slopes.

Range: Middle and lower slopes, toeslopes, benches.

Vegetation

Stands are generally mixed hardwood-conifer forests with high forb and grass cover. Total vegetative cover is quite high; stands are usually quite dense. The tree canopy is distinguished by relatively high levels of aspen cover particularly in size classes between 6 and 18 inches in diameter. Aspen is mixed typically with red fir and white fir which is indicative of lower elevations. Lodgepole pine is an occasional component in the smaller size classes. Aspen is typically present as a middle layer beneath a scattered upper layer of predominant conifers, but in many cases late seral stands contain aspen as part of the upper tree canopy as well. All of these species, but particularly quaking aspen, are indicative of moderate to quite moist sites.

A shrub layer is generally not dominant in the association. Sierra gooseberry, a moist site indicator is usually present as scattered shrubs, but the constancy and cover of other shrubs is usually low. Understories of this plant association are overwhelmingly defined by the presence of a relatively large number of moist site indicators in the forb layer. Thus, mountain sweet-cicely, Fendler’s meadow rue, Gray’s lovage, arrowhead butterweed, and California corn lily are all indicators of the substantial moisture available on these sites. Although California corn lily does not carry the high frequency sought in indicator species for which an association is generally named, it is a constant, although sometimes scattered, member of many stands, and it is used in the name to aid in distinguishing the central concept of this association.

In general, there are significantly higher levels of tree regeneration in this plant association than most others in the upper montane. The average number of seedlings is over 1,800 per acre. Distributions in the samples are somewhat skewed, but typically seedling counts will exceed 500 per acre. Regeneration is dominated by quaking aspen, usually in the form of sprouts, which reflects overstory species composition, but white and red fir are also present in relatively high numbers. Both quaking aspen and white fir are significantly more abundant as regeneration in this association compared to many others.

Plant species diversity is moderately high. It is significantly higher than most other forested communities in the upper montane although it does not attain as high a level as the species rich western juniper/sagebrush and quaking aspen/

mountain pennyroyal plant associations. Most stands have moderately high numbers of total species and moderate levels of species with high cover values. Quaking aspen and red fir tend to dominate, but cover is usually distributed somewhat uniformly among species of all life forms.

These stands are significantly younger than most others. This results from the younger ages of aspen in general in the Sierra Nevada, and from the presence of younger age classes in the conifer component. Aspen ages in these late seral stands ranged from 79 to 129 years for the oldest individuals, although the oldest conifer measured was a Jeffrey pine at ±526 years. Ages for the oldest predominant red and white fir were ±277 and ±379 years, respectively. The majority of the stems on these sites, particularly those in the smaller size classes, however, are younger aspen. The scattered nature of the older conifers in this type, and the relatively uniform size of the younger aspen in the middle layer would appear to suggest that quaking aspen undergoes a relatively constant turnover in these stands. The ages of the current aspen component appears to correspond relatively well with the end of intensive grazing pressures in the late 1800's and the institution of fire suppression policies in the early 1900's.

Stands in the quaking aspen/California corn lily plant association appear to be following a successional sequence that would result in dominance by conifers—usually red fir. Evidence from this study indicate an increase in conifer cover as stand age increases. This pattern appears to result from both suppression of fire over the past several decades and grazing pressure that keeps aspen sprouts severely hedged and favors conifers that are not grazed as heavily. Prior to widespread fire suppression and the introduction of grazing, aspen was favored on these sites due to the abundance of available moisture and fire that opened stands, encouraged aspen sprouting, and killed competing conifer seedlings. Clearly, regeneration potential in the long run lies with aspen in the presence of fire and the absence of grazing. In the absence of fire and with continued grazing pressures many of these stands will experience reductions in the aspen component.

Cover (percent)	*Mean*	*Range*
Total vegetative	94	82-99
Tree	78	49-96
Shrub	12	0-60
Forb	36	0-95
Grass	18	0-80
Moss	0.1	0-4
Stand age (years)	162	73-517
Diversity index		
Simpson	0.29	0.09-0.67
Hill numbers		
N0	15.3	7.0-26.0
N1	6.16	1.99-12.57
N2	4.48	1.49-10.48

Characteristic Vegetation

Code	*Common name*	*Constancy*	*Percent cover* *Mean*	*Range*
I. Overstory trees				
POTR	Quaking aspen	94	36	7-80
ABMA	Red fir	81	28	7-82
ABCO	White fir	69	18	1-51
PICO	Lodgepole pine	38	16	2-73
II. Understory trees				
POTR	Quaking aspen	100	4	1-15
ABCO	White fir	62	3	1-15
ABMA	Red fir	56	2	1-7
PICO	Lodgepole pine	31	1	1-2
III. Shrubs:				
RIRO	Sierra gooseberry	44	5	1-22
SYAC	Creeping snowberry	31	15	1-55
IV. Forbs				
OSCH	Mountain sweet cicely	75	4	1-40
THFE	Fendler's meadow rue	56	2	1-5
SETR	Arrowhead butterweed	50	4	1-20
VECA1	California corn lily	50	6	1-35
KEGA	Kellogg's bedstraw	38	1	1-2
LIGR1	Gray's lovage	38	1	1-1
ACLA2	Common yarrow	31	5	2-10
BRLU2	Yellow brodiaea	25	1	1-2
ERPEA	Wandering daisy	25	2	1-5
HIAL	White flowered hawkweed	25	1	1-1
PESE3	Pine woods lousewort	25	2	1-3
PEPA5	Parish's yampa	25	2	1-3
PTAQ	Western bracken fern	25	17	2-60
VIPU	Mountain violet	25	1	1-1
V. Grasses and grass-like				
ELGL	Blue wildrye	56	17	1-70
POBO1	Bolander's bluegrass	56	1	1-3
CARO1	Ross' sedge	44	3	1-10
BRMA3	Large mountain brome	31	6	1-20

Soils

Soils are typically Inceptisols. Rare sites contain Alfisols or Mollisols. The Inceptisols characteristically lie in the Xerumbrept great group, and the Alfisols and Mollisols are generally represented by Haploxeralfs and Haploxerolls. Particle size classes are commonly loamy, indicative of the lower levels of rock fragments in the profiles. These soils are usually derived from granitic parent materials although sites occasionally develop from volcanic substrates, and a few developed from mixed lithologies involving both granitic and volcanic materials on the same site. These parent materials are those typically found in the northern portion of the range where this association occurs most often. The majority of these soils are formed in material that is transported from other areas as alluvium and colluvium or glacial till and glacial outwash.

Soil depths can be considered deep. These soils commonly exceed 40 inches, and only occasionally are they less than 35 inches. Textures in the topsoil are most often loams with some sandy loams; a few sites contain clay loams. A significantly higher proportion of the soils in this plant association have medium and moderately fine textures in the surface horizons compared to adjacent forested communities. Subsoil textures are similar. Usually, they are loams or sandy loams with a few sandy clay loams and clay loams. Subsoils tend to carry a higher proportion of sandy loams than topsoils. Coarse fragments in both the topsoil and subsoil are low, and the average coarse fragment content throughout the profile is among the lowest in the upper montane. Topsoils typically contain less than 15 percent coarse fragments, and subsoils commonly contain less than 35 percent. Subsoil colors contain significantly higher proportions of 7.5 YR hues than most other sites. Most of these have low value and high chroma. These soils tend to be redder in hue, and they are usually darker and more strongly colored as well.

These communities have the highest AWC of all associations in the upper montane. It is substantially and significantly higher than most others in these forest communities. This reflects the deep soils, finer soil textures, and low levels of coarse fragments throughout the soil profile. Water holding capacities are significantly higher than those in the quaking aspen/mountain pennyroyal communities with which it is commonly associated. Soils are essentially well-drained, and erodibility is moderate due to the fine textures and shallow slopes. They commonly overlie parent materials that are hard but fractured and rootable and therefore able to provide additional sources of moisture to sites. Soil temperatures are moderate for the upper montane; often they are less than 49° Fahrenheit throughout the summer.

Variable	*Mean*	*Range*
Depth of soil sample (inches)	37	27-40+
Topsoil		
Depth (inches)	12	2-37
Coarse frag. (pct.)	15	1-55
pH	6.1	5.5-7.0
Subsoil		
Coarse frag. (pct.)	27	7-55
pH	5.9	5.0-6.8
AWC (inches)	4.7	1.7-6.3
Temp (20 inches) (Fahrenheit)	50	42-57

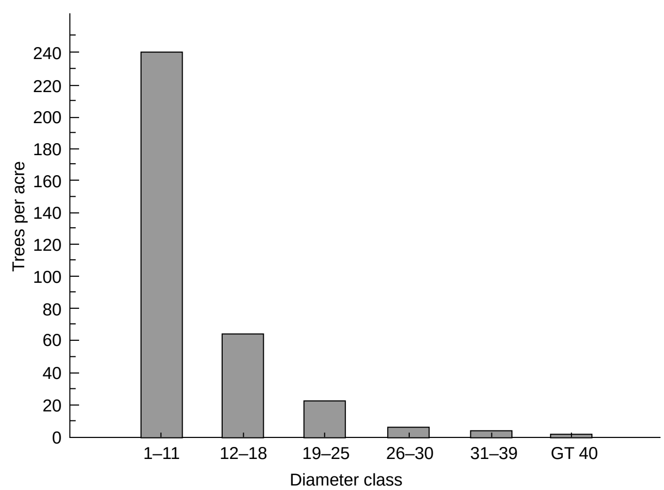
Productivity

Pacific Southwest Region (Region 5) site indexes are characteristically better than 2, and many stands have site indexes better than 1. Stand densities are normally greater than 400, and they are among the highest in the upper montane. Although there is more variation in stand density in this association, they are comparable, on average, to the densest stands in the study area. Based on stand density index these stands are fully stocked. Tree height, as might be expected, is significantly less than other major forested associations such as red fir and red fir-white fir. Aspen tree heights ranged between 69 and 121 feet in this association compared to the tallest conifer, a white fir, at nearly 180 feet. Thus, although densities may be high, individual aspen trees do not carry as much volume as conifers, and lower values are observed for measures of productivity. Basal area, cubic foot volume, and board foot volume are significantly less than denser stands elsewhere in these forests.

Stand structures are typically even-aged or two storied with scattered predominant conifers over a layer of aspen mixed with conifer saplings and young trees *(fig. 19)*. In many stands aspen clearly dominates the middle layer and few conifers occur. There are significantly higher numbers of trees smaller than 18 inches in diameter compared to dense stands in the rest of the study area. There are also significantly fewer stems larger than 24 inches DBH. This structure reflects the high number of smaller aspen stems present and the fact quaking aspen in the Sierra Nevada does not generally exceed 24 inches in diameter. The average diameter of aspen in these late seral stands was approximately 16 inches. Larger trees are usually red and white fir, and these are characteristically widely distributed in stands. Quadratic mean diameters for these stands are substantially lower than typical conifer associations in these late seral forests reflective of the high aspen component.

Variable	*Mean*	*Range*
Region 5 site index	1	0-3
Forest survey site class	2	1-4
Stand density index	519	119-1124
Quadratic mean diameter	14.5	6.6-24.0
Softwood volume (mcf/ac)	11.5	5.6-28.8
Softwood volume (mbf/ac)	43.7	7.1-125.3
Softwood basal area (sq ft/ac)	229	20-547
Hardwood volume (mcf/ac)	7.4	1.7-23.9
Hardwood basal area (sq ft/ac)	110	24-440

Figure 19—Number of trees by diameter class in the quaking aspen/ California corn lily plant association.



Tree species composition by percent of basal area

Species	ABMA	ABCO	PICO	PIJE	PIMO3	TSME
Percent	32	21	14	2	-	-
Species	JUOC	PILA	LIDE3	PIAL	POTR	QUKE
Percent	-	-	-	-	31	-

Coarse Woody Debris

Snag numbers in this association are among the highest in the upper montane. In particular, the number of snags less than 11 inches diameter is substantially higher than most other stands. Most of the snags come from the smaller diameter aspen. Snag heights are frequently taller than 50 feet reflecting the presence of aspen that tends to topple rather than break off when dead. These snags tend to be sound; the majority are decay classes 1 and 2. Log diameters are also smaller in general, but lengths are variable. Commonly, they lie between 20 and 100 feet. Logs are more decayed than snags, and typical decay classes in these logs is distributed between 3 and 5.

Snags

	Breast Height Diameter Class (inches)						
	<11	***11-17.9***	***18-24.9***	***25-29.9***	***30-39.9***	***>40***	***Total***
Snags per acre	36.7	4.8	1.5	0.6	0.1	0.5	44.2
Snag height (feet)							
<20	2.2	-	0.2	-	0.1	0.2	2.7
20-50	12.9	1.1	0.3	0.1	-	0.1	14.5
>50	21.6	3.7	1.0	0.5	-	0.2	27.0
Snag decay class							
1	17.3	2.4	0.3	0.4	-	0.1	20.5
2	16.2	2.4	0.8	0.1	-	0.1	19.6
3	3.2	-	0.1	0.1	0.1	0.1	0.4
4	-	-	0.1	-	-	0.1	0.2
5	-	-	0.2	-	-	0.1	0.3

Logs

	Large End Diameter Class (inches)				
	11-20	***21-30***	***31-40***	***>40***	***Total***
Logs per acre	12.0	5.3	0.7	0.3	18.3
Log length (feet)					
<20	4.0	1.6	-	-	5.6
20-50	6.0	1.7	-	-	7.7
51-100	2.0	2.0	0.4	0.3	4.7
>100	-	-	0.3	-	0.3
Log decay class					
1	1.0	-	0.4	-	1.4
2	2.7	0.3	-	-	3.0
3	5.3	3.0	-	-	8.3
4	2.7	2.0	0.3	0.3	5.3
5	0.3	-	-	-	0.3

Wildlife

Wildlife forage appears to be moderate to high since aspen is a preferred large game food, and it is readily available from sprouts that are usually heavily browsed. Common yarrow, western bracken fern, Bolander's bluegrass, Ross' sedge, and large mountain brome are all staple foods that occur with enough frequency and cover to be important components of the large game diet. These sites appear to also provide high values for hiding and thermal cover since they are generally quite dense and often located near streams and meadows. Deer and pocket gopher presence was common in this association.

Range

These stands often lie adjacent to meadows and other moist areas where livestock congregates in the summer season for shade, forage, and access to water. Many of these stands are primary range, and use of forage plants can become heavy. Of the more common species, aspen appears to be a preferred browse species. In many of these stands, aspen seedlings are browsed severely by the end of the grazing season, and this seriously reduces the ability to regenerate. Only through continual resprouting can aspen eventually escape browsing enough times to permit it to develop into tree form. Mountain sweet-cicely and California corn lily are secondary forage species in the forb layer, and blue wildrye is a secondary grass forage species that occurs with sufficient constancy and cover value to be important livestock forage.

Management Recommendations

The quaking aspen/Californian corn lily plant association is one of the wettest habitats in the upper montane forests, and it is probably one of the more fragile. These may be among the oldest organisms in the Sierra Nevada. Stands are small; often they are less than 5 acres. They are somewhat widely spaced, subject to replacement by conifers, and, at the present time, they are impacted by cattle use. Species composition is somewhat varied. Often conifers make up a substantial part of the stocking, and it appears this may be the result of successional pressures on these sites as they develop into stands dominated by conifers. Continued grazing seems to exacerbate this situation since the conifers commonly associated with these stands are not preferred browse species. Thus, grazing pressure favors conifer establishment and growth over aspen.

In a few instances, management has been applied in these stands. Timber harvesting has been tried in a few scattered cases. This harvesting was primarily a form of partial tree removal designed to remove part of the conifer component and leave aspen. Smaller sub-merchantable conifers were also left on these sites. In such stands aspen regeneration has not seemed to increase, partially due to continued grazing pressure. Fire has been an effective tool in the regeneration of these stands (Jones and DeByle 1985a). One site was observed in which the stand was pushed over by mechanical means and the area broadcast burned. This was very successful in establishing aspen, and several thousand aspen saplings per acre now occupy this site. A few examples from wildfires also demonstrate abundant aspen regeneration after stand replacing fires.

Because of the small size and widely separated nature of these stands, it would seem reasonable at the present time to attempt to maintain the association as an important component in the upper montane forest. The main contributions of the quaking aspen/California corn lily association appear to be as wildlife habitat, maintenance of plant species diversity, and contributing to landscape level diversity. To maintain stands, however, will take management emphasis to reduce grazing pressure and encourage aspen regeneration and growth, most likely through the reintroduction of fire.

Western Juniper/Sagebrush Association

Juniperus occidentalis/Artemesia tridentata

JUOC/ARTR
CJOCJO12
Sample size: 17

Distribution

The western juniper/sagebrush plant association occurs in the northeast portion of the study area. It is best developed on the Toiyabe and Eldorado National Forests near Carson Pass. It was sampled on the westside from Sonora Pass north, and it has been observed south as far as the Kaiser Pass area. All samples occurred north of 38° latitude, and longitudes were west of 119°30′. Stands can cover extensive areas, but usually they are less than 25 acres due to normal landscape patchiness.

Environment

This is a middle to high elevation plant association. Stands are generally found between 7,500 and 8,500 feet elevation on southeast and southwest aspects. These are higher elevations in the northern portion of the range where this association commonly occurs. Slopes are commonly less than 30 percent. The community is typically found on upper slopes and ridges, with occasional occurrences on lower slope positions. Microrelief is commonly quite uniform. The southerly aspects and slope positions result in considerably higher levels of solar radiation compared to other sites in the study area. This association has substantially more bare ground, surface gravel, and surface rock than most others in the upper montane, and litter cover and depth are correspondingly less than more mesic types. These are dry sites. Stress indexes are higher than most other plant communities in these forests.

Variable	Mean	Range
Elevation (feet)	8,117	7,600-8,720
Slope (pct.)	26	8-42
Solar radiation index	0.533	0.470-0.580
Bare ground (pct.)	15	3-30
Surface gravel (pct.)	24	5-50
Surface rock (pct.)	13	0-62
Litter (pct.)	50	12-87
Litter depth (inches)	0.6	0.2-1.1
Stress index	0.54	0.44-0.64

Aspect: SE, SW.

Range: SE, SW, NW.

Position: Upper slopes.

Range: Ridgetops, upper, middle, and lower slopes.

Vegetation

Western juniper/sagebrush stands are open woodlands with a shrubby understory of sagebrush. Total vegetative cover is high due to an abundant understory, and although tree cover is low, sites have considerably higher levels of shrub, forb, and grass cover. Patches of quaking aspen/mountain pennyroyal and the red fir/ mountain mule ears plant associations are often interspersed within this association, indicating the variation of site conditions across the landscape. In addition to sagebrush, individual sites may have high cover of mountain mule ears which also indicates the association in these cases. Stands will sometimes transition into and lie adjacent to the western juniper, quaking aspen/mountain pennyroyal, and lodgepole pine/sagebrush plant associations, and on the eastside, this association will transition into the sagebrush dominated shrublands of the Great Basin which can cover large areas. Usually, however, stands are surrounded by dense forested types as mesic site conditions are encountered. Western juniper is the most abundant conifer in these communities, and it is the most dominant in terms of tree cover. Jeffrey pine is a common associate, while red fir, western white pine, and lodgepole pine are occasional components in the conifer overstory. Tree distribution is often clumped and patchy.

Understories are a mixture of moderate to dry site indicators. Thus, the understory is composed largely of sagebrush although other moderate to dry site shrubs such as Parish's snowberry, mountain whitethorn, mountain snowberry, and bitter cherry are sometimes present as well. In the forb layer, Coville's gayophytum, and broad seeded rock cress are common indicators of dry sites, and mountain pennyroyal is indicative of moderate to dry conditions. Mountain mule-ears is indicative of mesic conditions, but few of the more common moderate to moist site indicators are present. Bottle brush squirrel tail, large mountain brome, Ross' sedge, and Western needlegrass are the most common grass species, and these are usually associated with moderate to dry conditions. The presence of mountain mule ears in this association is reflective of the location of many sites on the volcanic soils in the northern portion of the study area.

Conifer regeneration is extremely low in this association. Western juniper is the most common species regenerating; occasional red fir and Jeffrey pine are found, but the total number per acre of all species is typically less than 100, and the median value is only 40 trees per acre. Conifer seedlings are often clumped in patches around existing overstory trees rather than evenly distributed throughout the stand. Western juniper and Jeffrey pine are regenerating significantly more often on these sites.

Plant species diversity is the highest of any plant community in the upper montane. The association has the highest average total number of species. Low tree cover in combination with a relatively uniform cover of several shrub, forb, and grass species results in the distribution of abundant species among several life forms.

The oldest trees in these stands typically exceed 250 years. Stands have high proportions of older trees, and average stand ages are substantially older than most other sites. This results from the relatively older ages that seem to be attained by western juniper. The oldest tree sampled was a western juniper estimated to be in excess of 2,000 years. The oldest Jeffrey pine was estimated at ±478 years, and the oldest red fir was ±362 years.

Stand replacing disturbances are probably uncommon in this association. Shrubby understories and southerly aspects favor larger, more intense fires. Conversely, the noncontinuous nature of the understory, widely spaced trees, the presence of large, somewhat fire resistant individuals, higher elevations, and the natural patchiness of upper elevation landscapes all tend to preclude stand replacing fires. The wide spacing of many of the existing individuals results in uneven coverage and some level of survival by most species after fire. These stands probably experience patchy burns that leave portions of the stand little damaged while others are burned intensely. Isolated large and small trees probably escape damage in most cases. Other disturbance elements such as windthrow or avalanche are not common features of these stands. Insects, disease, and lightning are more common, but they generally occur in localized situations or on select species, and they do not generally result in stand replacement.

Reproductive strategies such as sprouting, widespread seed dispersal, or delayed germination until seeds are scarified by fire is present in many of the species on these sites. Sagebrush burns readily, but it is not a sprouter, and it does not use fire to enhance seed germination. Often sagebrush does not reoccupy sites for a considerable period after fire—perhaps as long as 50+ years. Future occupancy of these sites by sagebrush is uncertain, and sites will probably change into persistent forb and grass dominated communities in the understory. The patchiness and wide spacing of many of the existing trees also results in uneven coverage by disturbance elements, and many plants are left undamaged. In most cases, future composition is largely determined by species currently on these sites.

Stand development appears to be sporadic as regeneration and growth opportunities arise in response to disturbance. Disturbance creates opportunities for regeneration, but many microhabitats are unsuitable for conifer reproduction, and conifer establishment is a prolonged process on these sites. Disturbance also provides opportunities of surviving individuals to increase growth. Isolated patches of conifer vegetation escape many disturbances and proceed through a period of crown closure and self-thinning. Isolated trees and small patches that escape repeated disturbance eventually mature into larger members of the stand. In time, an irregular structure develops reflecting numerous disturbances and containing scattered large trees as residuals from several stand modifying events.

Cover (percent)	*Mean*	*Range*
Total vegetative	74	35-99
Tree	31	4-75
Shrub	30	1-92
Forb	33	8-70
Grass	16	2-60
Moss	0.1	0-1
Stand age (years)	331	155-999

Cover (percent)	*Mean*	*Range*
Diversity index		
Simpson	0.14	0.06-0.27
Hill numbers		
N0	21.4	14.0-30.0
N1	11.08	6.40-20.19
N2	8.29	3.76-16.70

Characteristic Vegetation

Code	*Common name*	*Constancy*	*Percent cover* *Mean*	*Range*
I. Overstory trees				
JUOC	Western juniper	100	16	2-43
PIJET	Jeffrey pine	53	10	1-20
ABMA	Red fir	41	8	2-23
PIMO3	Western white pine	29	5	1-10
PICO	Lodgepole pine	24	16	1-45
II. Understory trees				
JUOC	Western juniper	59	1	1-4
ABMA	Red fir	41	2	1-8
PIJE	Jeffrey pine	35	1	1-1
PICO	Lodgepole pine	24	1	1-1
III. Shrubs				
ARTR	Sagebrush	100	16	1-50
RICE	Squaw currant	41	4	1-20
SYPA	Parish's snowberry	41	8	1-18
CECO2	Mountain whitethorn	35	8	1-25
PUTR	Bitter brush	35	5	1-14
SYVA	Mountain snowberry	35	1	1-2
PREM	Bitter cherry	24	2	1-5
RIRO	Sierra gooseberry	24	3	1-5
SYAC	Creeping snowberry	24	6	1-22
IV. Forbs				
MOOD	Mountain pennyroyal	76	4	1-15
ERPE3	Sierra wallflower	71	1	1-1
GAER	Coville's gayophytum	71	6	1-30
CAAP	Indian paint brush	65	2	1-5
WYMO	Mountain mule ears	65	9	1-30
ARPL	Broad seeded rock cress	53	2	1-10
COTOW	Wright's blue eyed mary	47	12	1-30
ERBR2	Brewer's daisy	47	5	1-20
PESE3	Pine woods lousewort	47	1	1-1
SEAR	California butterweed	41	1	1-3

Characteristic Vegetation (continued)

Code	Common name	Constancy	Percent cover Mean	Percent cover Range
ERSP2	Spurry eriogonum	35	2	1-5
PODO3	Douglas' knotweed	35	3	1-10
ALOB	Red Sierra onion	24	4	1-6
CIAN1	Anderson's thistle	24	10	1-20
COLI2	Narrow leaved collomia	24	1	1-3
CRY2	Cryptantha	24	4	1-10
ERNUD	Naked stemmed eriogonum	24	1	1-2
KEGA	Kellogg's bedstraw	24	1	1-2
LUAN2	Anderson's lupine	24	5	3-10
PHRA2	Branching phacelia	24	1	1-2
V. Grasses and grass-like				
SIHY	Bottle brush squirreltail	100	4	1-10
BRMA3	Large mountain brome	53	3	1-20
CARO1	Ross' sedge	53	2	1-8
STOC1	Western needlegrass	53	2	1-3
MEBU	Western oniongrass	41	1	1-2
POGR1	Pacific bluegrass	41	9	1-40
POBO1	Bolander's bluegrass	29	3	1-10
STEL1	Elmer's needlegrass	24	1	1-2

Soils

Soils are predominantly Inceptisols, and they typically belong to the Xerumbrept great group. Occasional Cryumbrepts are also present. Particle size classes on most sites are skeletal reflecting relatively high coarse fragment contents. Rare samples are derived from metamorphic parent materials, and occasional samples are derived from granite; however, the most common parent materials found are the volcanic lahars, andesitic and rhyolitic flow rocks, and ash deposits common in the northern portion of the range, and there is a significant relationship between the presence of this plant association and soils derived from these geologic substrates. Soils are typically formed in place from bedrock, but some are formed in material which was deposited through glaciation or as alluvium.

Soil depths are variable, but basically they are shallow. Average depths are among the shallowest of all plant associations in the upper montane Typical soils were less than 35 inches deep, and often they were less than 25 inches. Topsoil depths, on the other hand, are among the deepest in these upper elevation forests. Topsoil textures are usually sandy loams and loams; whereas subsoil textures are often cobbly or gravelly sandy loams with occasional loams. Coarse fragments throughout the profile are significantly higher than most other associations. Topsoils generally have greater than 15 percent coarse fragments, and subsoils commonly exceed 35 percent. Subsoil colors contain significantly higher portions of 5 Y hue or yellow soils in the Munsell color chart. They also carry substantially higher numbers of soils which are 10 YR in hue but of low value and chroma. Such soils tend to be very dark grayish brown.

The AWC in soils typical of this association are among the lowest in these forests. Shallow soils, higher coarse fragment content throughout the profile, and somewhat coarse textures result in the drier conditions experienced in these stands. Soils on these sites typically occur over bedrock which is fractured and rootable. Soil drainage is usually excessive, and erodibility is moderate to high based on soil textures and slopes commonly experienced on these sites. Summertime soil temperatures are substantially warmer than in most other associations reflecting the southerly aspects and open conditions of many stands. Most have temperatures which exceed 53° Fahrenheit.

Variable	*Mean*	*Range*
Total soil depth (inches)	26	7-40+
Topsoil		
Depth (inches)	12	4-28
Coarse frag. (pct.)	32	14-60
pH	6.0	5.2-6.5
Subsoil		
Coarse frag. (pct.)	47	15-79
pH	6.0	5.4-6.7
AWC (inches)	2.3	0.4-5.7
Temp (20 inches) (Fahrenheit)	54	40-63

Productivity

Pacific Southwest Region (Region 5) sites indexes are moderate to low. Typical indexes lie between 4 and 5. Stand densities are also low. Stand density indexes are typically less than 300, and stocking levels based on average stand density index are less than 45 percent of values attained in typical stands of the red fir-white fir association. Because of the presence of western juniper, which rarely exceeds 65 feet in the Sierra, average tree heights are substantially lower than most adjacent forested stands. The combination of lower site indexes, lower stand densities, and shorter tree heights, result in basal areas and cubic and board foot volumes which are considerably lower than well-stocked stands elsewhere in the upper montane.

Stand structures are irregular. The most characteristic feature of these stands are the low number of trees per acre, and the uniform distribution of trees in size classes greater than 12 inches *(fig. 20)*. Commonly, there are less than 100 trees per acre, and the number of trees in all size classes are substantially less than most other forested communities of the upper montane.

Variable	*Mean*	*Range*
Region 5 site index	4	3-5
Forest survey site class	5	4-6
Stand density index	242	117-438
Quadratic mean diameter	21.8	11.0-39.5
Softwood volume (mcf/ac)	4.5	1.6-7.7
Softwood volume (mbf/ac)	29.9	10.7-84.1
Softwood basal area (sq ft/ac)	159	48-267
Hardwood volume (mcf/ac)	0	0
Hardwood basal area (sq ft/ac)	0	0

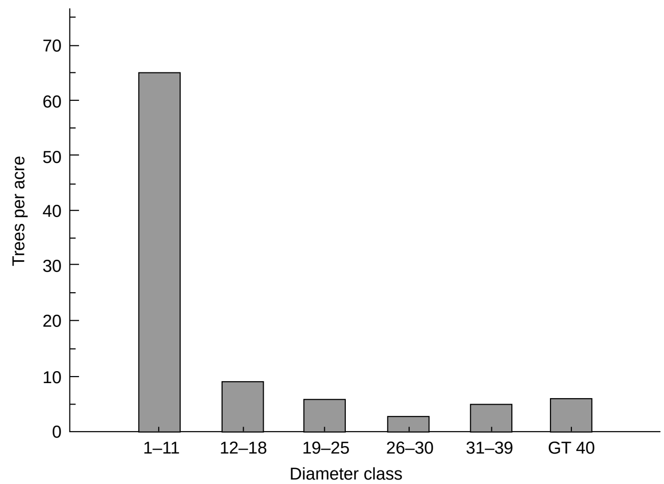


Figure 20—Number of trees by diameter class in the western juniper/ sagebrush plant association.

Tree species composition by percent of basal area

Species	ABMA	ABCO	PICO	PIJE	PIMO3	TSME
Percent	15	2	9	19	2	-
Species	JUOC	PILA	LIDE3	PIAL	POTR	QUKE
Percent	54	-	-	-	-	-

Coarse Woody Debris

Snag numbers are among the lowest in the upper montane. They reflect the open conditions of most stands. Snags are concentrated in the larger size classes. Most are less than 50 feet tall, and they are distributed among several decay classes. Logs were commonly less than 30 inches in diameter. All the samples in this association were less than 50 feet in length, and most were less than 20 feet. Logs showed more decay than snags. Log decay classes between 3 and 5 were generally encountered.

Snags

	Breast Height Diameter Class (inches)						
	<11	*11-17.9*	*18-24.9*	*25-29.9*	*30-39.9*	*>40*	*Total*
Snags per acre	0	0	0	0	0.1	0.3	0.4
Snag height (feet)							
<20	-	-	-	-	-	0.1	0.1
20-50	-	-	-	-	0.1	0.1	0.2
>50	-	-	-	-	-	0.1	0.1
Snag decay class							
1	-	-	-	-	-	0.1	0.1
2	-	-	-	-	-	-	-
3	-	-	-	-	0.1	0.1	0.2
4	-	-	-	-	-	0.1	0.1
5	-	-	-	-	-	-	-

Logs

	Large End Diameter Class (inches)				
	11-20	***21-30***	***31-40***	***>40***	***Total***
Logs per acre	0.7	2.3	1.0	0	4.0
Log length (feet)					
<20	0.7	1.6	0.3	-	2.6
20-50	-	0.7	0.7	-	1.4
51-100	-	-	-	-	-
>100	-	-	-	-	-
Log decay class					
1	-	-	-	-	-
2	-	-	-	-	-
3	-	1.0	0.7	-	1.7
4	0.4	0.7	0.3	-	1.4
5	0.3	0.6	-	-	0.9

Wildlife

Western juniper/sagebrush stands are moderate to highly foraged by wildlife. Bitter cherry and bitter brush are preferred species by large game, and sagebrush, squaw currant, and sierra gooseberry are all staple foods in the shrub component. All are present in at least moderate quantities. Indian paintbrush, Anderson's lupine, naked stemmed eriogonum, and branching phacelia are staples from the forb layer, and bottle brush squirreltail, large mountain brome, Ross's sedge, Western needlegrass, Western onion grass, and Bolander's bluegrass are frequently occurring staples from the grass layer. Deer use was moderate, and pocket gophers were often found on these sites.

Range

Range potential appears to be transitory as livestock move to primary range sites such as meadows and other moist habitats. Cattle use is common on these sites. These stands appear to be moderately productive for livestock. Bitter brush and mountain snowberry are secondary forage species, and although few forbs in this association are primary livestock forage, several of the grass species are valuable as forage. Large mountain brome and bottle brush squirreltail are primary grass species, and Western needlegrass and Pacific bluegrass are secondary species. All occur with reasonable frequency and cover in this association.

Management Recommendations

These sites have limited productive capacity and flexibility for stand management. The open nature of the stands indicates that regeneration and establishment is a lengthy and variable process under most conditions. Recommendations for harvesting at the present time would be to treat stands with caution and expect that results can be uncertain. Limited opportunities exist for salvage when it occurs, but under the open conditions of most sites it would appear that woody debris left in the form of snags and logs for wildlife or part of the nutrient pool would be better direction for this association. Management emphasis should provide for existing wildlife habitat, plant species richness, and the landscape level diversity this association provides to the upper montane forests.

Western Juniper Association

Juniperus occidentalis

JUOC
CJOCJO11
Sample size: 12

Distribution

The western juniper plant association is generally located at higher elevations in the northern and eastern portions of the study area where it occurs in somewhat widely separated patches across the landscape. Samples were located north of the Kern Plateau near Monache mountain on the east and the Kings River on the west. Longitudes were generally greater than 119°, reflecting locations in the north. Individual stands tend to be small; most appear to be less than 10 acres in size.

Environment

Elevations typically lie between 7,500 and 8,500 feet. This association can be considered a higher elevation community in the northern portions of the range where it is commonly found. Occasional stands are found at elevations above 8,500 feet, but rarely do they occur below 7,500 feet. Sites are typically located on southeast and southwest aspects where SRI levels are high, and they occur generally on upper and middle slopes that are steeper than 20 percent. Site microrelief is undulating to hummocky and broken. Surface features indicate dry conditions with significantly more bare ground and surface rock than most other associations. Surface rock is generally greater than 15 percent, and individual stands sometimes have more than 50 percent rock covering the ground surface. Stress indexes are the highest of any association in the upper montane.

Variable	*Mean*	*Range*
Elevation (feet)	8,133	7,560-8,960
Slope (pct.)	32	19-58
Solar radiation index	0.512	.361-.566
Bare ground (pct.)	6	1-20
Surface gravel (pct.)	13	2-65
Surface rock (pct.)	27	1-65
Litter (pct.)	58	6-96
Litter depth (inches)	0.9	0.3-2.9
Stress index	0.54	0.46-.60

Aspect: SE, SW.

Range: All.

Position: Upper slopes.

Range: Upper, middle, and lower slopes.

Vegetation

Stands are characteristically open, shrubby woodlands. Tree cover is substantially lower than most other sites, and shrub, forb, and grass cover are considerably higher than most other sites. Tree distribution is often clumped and patchy. Overstories are dominated by western juniper, lodgepole pine, and Jeffrey pine that are adapted to dry sites. Red fir, white fir, and western white pine are occasional components in the overstory. These stands are often surrounded by dense forested communities where conditions become more mesic.

Understories are dominated by species that favor dry habitats. In the shrub layer pinemat manzanita and huckleberry oak are usually present. In addition, moderate to dry site indicators such as mountain whitethorn, bittercherry, and mountain snowberry are sometimes present as well. The forb layer contains dry site species such as broad seeded rockcress and naked stemmed eriogonum as well as dry to moderate indicators such as western pennyroyal and Coville's gayophytum. Finally, the grass component typically contains bottle brush squirreltail and western needlegrass, both dry site indicators.

Conifer regeneration is extremely low. Except for the Jeffrey pine-red fir and Jeffrey pine/mountain whitethorn-sagebrush associations, this plant association has the lowest conifer regeneration of any of the forested communities in the upper montane. Sites typically had less than 100 seedlings per acre, and seedlings are often clumped in patches around existing overstory trees rather than evenly distributed throughout the stand. Western juniper and lodgepole pine regeneration are present significantly more often than in other associations, whereas red fir is present significantly less often.

Plant species diversity is one of the highest in the upper montane forests. Stands often have only a few less species on average than diverse communities such as the quaking aspen/mountain pennyroyal and Western juniper/ sagebrush associations. Lower tree cover in combination with relatively uniform cover of several shrub, forb, and grass species results in the distribution of abundant species among several life forms.

The oldest trees in these stands are typically greater than 250 years although average stand ages are comparable to others in these forests. Western juniper attains greater ages than most other tree species in the upper montane, and the oldest tree sampled in this association was a western juniper at about 630 years.

This compares to ages for the oldest Jeffrey pine at ±577 years and western white pine at ±506 years. The oldest lodgepole pine was estimated at ±333 years.

Stand replacing disturbances are probably uncommon in these stands. Fire patterns appear to be different from dense, forested associations. Shrubby sites and southerly aspects favor larger, more intense fires. Conversely, large diameter, widely spaced trees, and the noncontinuous distribution of the understory provide uneven coverage and some level of survival by most species after fire. Individual stand replacing fires may occur, but most stands probably experience patchy burns with some portion of the stand completely consumed and others left with little damage. Isolated large and small trees probably escape damage in most cases. Other disturbance elements such as windthrow and avalanche are not common features of these stands. Insects, disease, and lightning are more common, but they generally occur in localized situations or on select species, and they do not result in large scale stand replacement.

Reproductive strategies such as sprouting, widespread seed dispersal, or delayed germination until seeds are scarified by fire is present in many of the understory species on these sites. As examples, huckleberry oak is a rapid sprouter after fire, and mountain whitethorn germinates profusely from seed that has been scarified by fire. These species can rapidly reoccupy sites. Isolated, undisturbed trees also provide a conifer component to the species occurring on a site. In most cases, the species composition of future stands is largely determined by species currently on these sites.

Stand development appears to be sporadic as opportunities arise in response to disturbance. Disturbance creates opportunities for regeneration, but many microhabitats are unsuitable for conifer regeneration, and conifer establishment can be a prolonged process. Disturbance also provides opportunities for surviving individuals to increase growth. Isolated patches of conifers that escape repeated disturbance proceed through periods of crown closure and self-thinning. Isolated trees and small patches that escape disturbance eventually mature into larger members of the stand. In time the stand develops an irregular structure with several age classes reflecting numerous disturbances and containing scattered large trees as the survivors of multiple disturbances.

Cover (percent)	*Mean*	*Range*
Total vegetative	66	24-99
Tree	33	3-79
Shrub	31	3-65
Forb	24	1-80
Grass	13	1-80
Moss	0.7	0-2
Stand age (years)	288	129-625
Diversity index		
Simpson	0.16	0.08-0.34
Hill numbers		
N0	20.1	9.0-29.0
N1	9.63	4.27-14.78
N2	7.48	2.94-13.0

Characteristic Vegetation

Code	Common name	Constancy	Percent cover Mean	Percent cover Range
I. Overstory trees				
JUOC	Western juniper	92	12	3-26
PICO	Lodgepole pine	58	12	3-31
PIJE	Jeffrey pine	50	9	3-22
II. Understory trees				
JUOC	Western juniper	67	1	1-1
PICO	Lodgepole pine	58	1	1-1
PIJE	Jeffrey pine	25	1	1-1
III. Shrubs				
ARNE2	Pinemat manzanita	58	14	2-40
QUVA	Huckleberry oak	50	21	1-60
CECO2	Mountain whitethorn	42	12	1-30
PREM	Bitter cherry	42	2	1-5
RIRO	Sierra gooseberry	42	2	1-6
SYPA	Parish's snowberry	33	1	1-2
SYVA	Mountain snowberry	25	4	1-9
IV. Forbs				
ERBR2	Brewer's daisy	67	5	1-23
MOOD	Mountain pennyroyal	67	3	1-10
ARPL	Broad seeded rock cress	58	1	1-2
ERPE3	Sierra wallflower	58	1	1-1
ERNUD	Naked stemmed eriogonum	50	1	1-3
SEAR	California butterweed	50	2	1-4
GAER	Coville's gayophytum	42	2	1-3
CAAP	Indian paint brush	33	1	1-2
COTOW	Wright's blue eyed mary	33	11	1-30
KEGA	Kellogg's bedstraw	33	1	1-3
ACLA2	Common yarrow	25	1	1-1
BRLU2	Yellow brodiaea	25	1	1-1
CHBR3	Brewer's golden aster	25	4	1-10
CIAN1	Anderson's thistle	25	2	1-3
CRY2	Cryptantha	25	1	1-1
LUAN2	Anderson's lupine	25	6	1-15
PESE3	Pine woods lousewort	25	1	1-2
SIGL	Glaucous sidalcea	25	3	2-4
STTO	Mountain streptanthus	25	1	1-1
VIPU	Mountain violet	25	1	1-1
WYMO	Mountain mule-ears	25	1	1-1

Characteristic Vegetation (continued)

Code	*Common name*	*Constancy*	*Percent cover* *Mean*	*Range*
VI. Grasses and grass-like				
SIHY	Bottle brush squirreltail	83	2	1-4
CARO1	Ross' sedge	67	2	1-9
STOC1	Western needlegrass	58	2	1-3
PONE1	Hooker's bluegrass	42	4	1-10
POGR1	Pacific bluegrass	33	10	1-30
POBO1	Bolander's bluegrass	25	2	1-3
STCO1	Columbia needlegrass	25	3	1-6

Soils

The majority of soils in this association are Inceptisols. Most often they are Umbrepts with occasional Ochrepts. Entisols classified as Psamments are encountered on a few sites. Particle size classes in most stands are skeletal reflecting relatively high coarse fragment content in the profile. A few samples were derived from metamorphic and volcanic rocks, but soils were typically formed from granitic parent materials. These soils are generally formed either from alluvial deposits or weathered in place from bedrock.

Soils are moderately deep. They commonly exceed 25 inches in depth. Occasionally they are deeper than 35 inches, but rarely are they deeper than 40 inches. Textures in both the topsoil and subsoil are generally sands or gravelly sandy loams with rare occurrences of loams or clay loams. Coarse fragments in the topsoil commonly range between 15 and 65 percent. They are significantly higher than the western juniper/sagebrush association in the same series although they are not substantially different from most other sites. Average subsoil coarse fragments, on the other hand, are among the highest in the upper montane. They often exceed 35 percent, and occasional stands contain more than 65 percent.

The average AWC of these soils is the lowest of any association in the upper montane. Low values result from coarse textures and high coarse fragments. High stress indexes reflect the combination of high SRI levels resulting from southerly aspects and lower AWC. Soils commonly lie over parent materials that are fractured and rootable. They are typically excessively drained, and erodibility is moderate to high due to the coarse textures and moderately steep slopes of most sites. Summertime soil temperatures are among the highest in the upper montane. Temperatures characteristically lie above 53° Fahrenheit, and they reflect the open stand conditions, steeper slopes, and higher SRI levels present.

Variable	*Mean*	*Range*
Depth of soil sample (inches)	30	11-40+
Topsoil		
Depth (inches)	11	3-16
Coarse frag. (pct.)	25	10-46
pH	6.0	5.2-7.1
Subsoil		
Coarse frag. (pct.)	49	13-75
pH	6.0	5.2-7.1
AWC (inches)	2.1	0.5-3.8
Temp (20 inches) (Fahrenheit)	57	50-64

Productivity

Productivity is low. Pacific Southwest Region (Region 5) site indexes are commonly 4 and lower, and only rare stands will have a site index greater than 3; these values are significantly less than denser stands located on more mesic sites. Stand densities are also low; stand density indexes are typically less than 300, and stocking levels based on average stand densities are less than 45 percent of those attained in well-stocked stands elsewhere in the upper montane. Tree heights are substantially shorter than in most other associations due to the presence of western juniper, which is generally a shorter tree in the upper montane. In terms of basal area stocking, cubic, and board foot volumes these stands carry considerably less volume than most other forested associations due to poor site indexes, low densities, and shorter heights. Average cubic foot volumes, for example are 28 percent of volumes in typical red fir-white fir stands.

Stand structures are irregular, but a characteristic feature of these stands is the few trees per acre *(fig. 21)*. Commonly, stands will contain less than 200 trees per acre in all size classes. Trees smaller than 11 inches DBH are reasonably well represented compared to sites with higher stocking levels; however, trees in size classes greater than 12 inches are substantially less than in denser forested associations.

Variable	*Mean*	*Range*
Region 5 site index	4	2-5
Forest survey site class	5	3-6
Stand density index	225	44-464
Quadratic mean diameter	18.2	9.2-35.9
Softwood volume (mcf/ac)	4.2	1.7-8.8
Softwood volume (mbf/ac)	18.6	4.9-49.0
Softwood basal area (sq ft/ac)	129	40-320
Hardwood volume (mcf/ac)	0	0
Hardwood basal area (sq ft/ac)	0	0

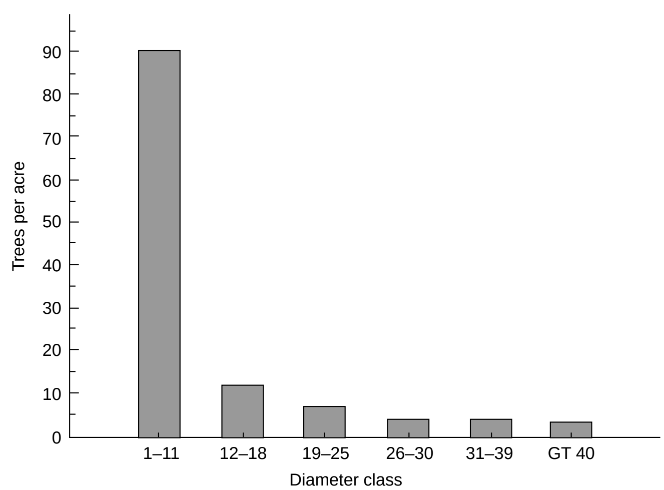


Figure 21—Number of trees by diameter class in the western juniper plant association.

Tree species composition by percent of basal area

Species	ABMA	ABCO	PICO	PIJE	PIMO3	TSME
Percent	8	19	20	23	-	-
Species	JUOC	PILA	LIDE3	PIAL	POTR	QUKE
Percent	30	-	-	-	-	-

Coarse Woody Debris

Snag numbers are low reflecting the open stand conditions characteristic of the association. Most snags sampled were larger than 25 inches DBH but less than 50 feet tall. Snags generally lie in decay classes 3 and 4. Downed logs are commonly less than 30 inches in diameter and 50 feet long. Often they are less than 20 feet long. Logs evidence higher levels of decay than snags. Most logs in these stands lie in decay classes 4 and 5.

Snags

	Breast Height Diameter Class (inches)						
	<11	***11-17.9***	***18-24.9***	***25-29.9***	***30-39.9***	***>40***	***Total***
Snags per acre	0	0	0.5	0.2	1.9	0.4	3.0
Snag height (feet)							
<20	-	-	-	0.2	1.0	0.2	1.4
20-50	-	-	0.5	-	-	0.1	0.6
>50	-	-	-	-	0.9	0.1	1.0
Snag decay class							
1	-	-	-	-	-	-	-
2	-	-	-	-	-	0.1	0.1
3	-	-	0.5	0.2	1.0	0.1	1.8
4	-	-	-	-	0.9	0.1	1.0
5	-	-	-	-	-	0.1	0.1

Logs

	Large End Diameter Class (inches)				
	11-20	***21-30***	***31-40***	***>40***	***Total***
Logs per acre	2.8	3.2	2.0	0.8	8.8
Log length (feet)					
<20	2.0	2.4	-	0.4	4.8
20-50	0.8	0.4	2.0	0.4	3.6
51-100	-	0.4	-	-	0.4
>100	-	-	-	-	-
Log decay class					
1	-	-	-	-	-
2	-	-	-	-	-
3	-	0.8	-	-	0.8
4	1.2	0.8	1.2	-	3.2
5	1.6	1.6	0.8	0.8	4.8

Wildlife

These sites appear to be moderate to good for large game forage production. Western juniper is a staple, and mountain whitethorn and bitter cherry are preferred large game shrubs, and Indian paint brush, common yarrow, and Anderson's lupine are staple foods that occur frequently enough to supply a consistent food source. Most of the grass species that are present in these sites are staples in the large game diet, and Hooker's bluegrass is a preferred grass species. Sites in the western juniper plant association often showed signs of deer and pocket gopher presence.

Range

Range potential appears to be transitory as livestock move to primary range sites such as meadows and other moist habitats. Livestock use was common on these sites. Bottle brush squirreltail and Hooker's bluegrass are primary forage species. Anderson's lupine, western needlegrass, and Columbia needlegrass are all secondary species. They occur with enough frequency and cover to be important contributors to livestock forage.

Management Recommendations

These are dry habitats, and most stands should not be considered suitable for timber production. Sites are harsh and not generally suitable for reforestation. Rocky soils on sites with very low AWC and high moisture stress would indicate low success rates with natural seeding or planting of nursery grown stock.

These stands have limited productive capacity and flexibility for stand management. Poor regeneration and the open nature of these stands indicates that conifer regeneration and establishment is a lengthy and variable process under most conditions. Recommendations for harvesting at the present time would be to treat stands in this type with caution and expect results to be uncertain. Limited opportunities exist for salvage as it occurs, but on these open sites it would appear that woody debris left in the form of snags and logs for wildlife or part of the nutrient pool on the site would be better direction for these stands. This is one of the most diverse plant associations in the upper montane forests, and it provides an important contribution to landscape diversity. Management emphasis should provide for existing wildlife habitat, plant species richness, and the landscape level diversity this association provides to upper montane forests.

Red Fir/Mountain Mule Ears Association

Abies magnifica/Wyethia mollis

ABMA/WYMO
CFRFME11
Sample size: 14

Distribution

The red fir/mountain mule ears plant association occurs only in the northern portion of the central and southern Sierra Nevada, and it is somewhat limited in extent within that region. It was sampled on the Eldorado and Stanislaus National Forests and the Lake Tahoe Basin Management Unit, and it has been observed on the Toiyabe National Forest. It occurs primarily from the Pinecrest Peak area on the Stanislaus north to an area east of Loon Lake on the Eldorado National Forest. Latitudes in the samples were all north of 38° and longitudes were most frequently west of 120°. Individual stands can cover large acreages such as those near Mt. Reba in Alpine County, but most stands are less than 50 acres in size.

Environment

Stands commonly lay between 7,500 and 8,500 feet elevation. They characteristically occupy southeast and southwest aspects on ridges and upperslope positions where site microrelief is generally quite uniform. Slopes are typically moderate; all samples were less than 35 percent. This plant association has the highest solar radiation levels of any in the upper montane, and it reflects the moderate slopes and southerly aspects typically encountered. Mountain mule ears communities have significantly higher levels of bare ground and surface gravel, and litter cover and litter depth are substantially less than most other sites. Sites have high stress index resulting from high levels of solar radiation and upper slope positions.

Variable	*Mean*	*Range*
Elevation (feet)	7,899	6,940-8,340
Slope (pct.)	22	5-38
Solar radiation index	0.534	0.498-0.570
Bare ground (pct.)	10	0-30
Surface gravel (pct.)	23	0-99
Surface rock (pct.)	4	0-14
Litter (pct.)	66	0-99
Litter depth (inches)	0.6	0.1-1.5
Stress index	0.53	0.38-.64

Aspect: SE, SW.

Range: SE, SW.

Position: Upper slopes.

Range: Ridgetops, upper and middle slopes, benches.

Vegetation

Stands are characteristically open, forested woodlands with an understory dominated by mountain mule ears. Adjacent stands are composed of open stands of western white pine, western juniper, and scattered lodgepole pine on ridges alternating with dense forests elsewhere. Total vegetative cover on these sites is high due to the high cover of mountain mule ears. Tree cover is considerably less than most other sites, and tree distribution is often clumped and patchy. Shrub cover is low, but forb and grass cover are substantially higher than associated communities.

Red fir and Jeffrey pine are the dominant overstory tree species. Lodgepole pine, western white pine, and western juniper are also encountered on some sites. Except for an occasional creeping snowberry or mountain snowberry, the shrub layer is essentially absent. Species composition in the forb and grass layers are dominated by mountain mule ears, mountain pennyroyal, and bottlebrush squirreltail. Mountain pennyroyal and squirreltail are often associated with dry sites, and mountain mule ears, Bolander's bluegrass, and blue wildrye are indicative of moderately moist conditions.

Given the open character of these sites, it is interesting that species diversity is only moderately high when compared to other plant associations in the upper montane. The total number of species is often not high, and treecover is low due to the relatively wide spacing of individual trees on most sites. The forb and grass layers often have cover values which match or exceed those in the tree layer. The number of abundant species is relatively high compared to other plant associations, and the cover is somewhat uniformly distributed among the tree, forb, and grass layer.

Conifer regeneration is among the lowest of all forested associations in the upper montane. The average number of seedlings per acre is 160, but distributions are skewed, and the median is only 50. Stands typically have less than 100 seedlings per acre. Red fir is the only conifer species consistently regenerating on these sites, and densities are usually very low.

The oldest trees in these stands are typically greater than 250 years. Ages of the oldest trees encountered on these sites were ±760 years for western juniper, ±726 years for western white pine, ±369 years for red fir, and ±311 years for lodgepole pine. These ages are comparable to those for the same species in dense forested stands adjacent to these sites.

A review of aerial photos from the 1940's indicate these communities have maintained their basic size, shape, and cover since that time. Ages of older trees from adjacent forested stands can exceed 400 years; thus, seed sources probably have been in place and sufficient time would appear to have passed for forested communities to develop if such were the successional direction these stands were headed. The root system of mountain mule ears contains a substantial taproot, almost tuberous in character, and the ability of this species to persist is evident. Early grazing or Native American burning may have created or maintained these communities, but work has not been done in support of these ideas, and there are arguments against such a hypothesis; consequently, the future successional direction of these communities is difficult to predict at this time.

Cover (percent)	*Mean*	*Range*
Total vegetative	79	52-99
Tree	25	0-89
Shrub	5	0-45
Forb	54	6-98
Grass	19	1-98
Moss	0	0
Stand age (years)	190	36-344
Diversity index		
Simpson	0.28	0.10-0.72
Hill numbers		
N0	13.8	4.0-20.0
N1	6.11	1.68-11.81
N2	4.66	1.38-9.80

Characteristic Vegetation

				Percent cover	
	Code	*Common name*	*Constancy*	*Mean*	*Range*
I.	Overstory trees				
	ABMA	Red fir	50	24	5-48
	PIJE	Jeffrey pine	43	17	1-37
	PIMO3	Western white pine	29	6	2-12
II.	Understory trees				
	ABMA	Red fir	57	2	1-2
	ABCO	White fir	21	2	1-2
	PIJE	Jeffrey pine	21	1	1-1
	PIMO3	Western white pine	21	1	1-1
III.	Shrubs				
	SYAC	Creeping snowberry	29	4	1-10
IV.	Forbs				
	WYMO	Mountain mule ears	100	36	25-98
	MOOD	Mountain pennyroyal	79	8	1-25
	COTOW	Wright's blue eyed mary	43	13	1-60
	ERPE3	Sierra wallflower	43	1	1-1
	GAER	Coville's gayophytum	36	2	1-5
	LUAN2	Anderson's lupine	36	1	1-2

Characteristic Vegetation (continued)

	Code	Common name	Constancy	Percent cover Mean	Range
IV.	SIGL	Glaucous sidalcea	36	12	1-30
	ALCA2	Sierra onion	29	1	1-1
	BRLU2	Yellow brodiaea	29	2	1-5
	CAAP	Wavy leaved Indian paint brush	29	3	1-10
	CHBR3	Brewer's golden aster	29	2	1-5
	CRY2	Cryptantha	29	1	1-1
	PHHY	Waterleaf phacelia	29	3	1-10
	ARPL	Broad seeded rock cress	21	6	1-15
	CAUM2	Pussy paws	21	1	1-1
V.	Grasses and grass-like				
	SIHY	Bottle brush squirreltail	79	3	1-10
	BRMA3	Large mountain brome	29	1	1-2
	ELGL	Blue wildrye	29	9	1-30
	POBO1	Bolander's bluegrass	29	3	1-10
	STCA1	California needlegrass	29	4	1-8

Soils

Soils are characteristically Inceptisols which occur as Xerumbrepts and Cryumbrepts. Rare sites contain Alfisols. One sample originated from granitic parent material, and one originated from mixed lithologies; however, parent materials are predominantly the volcanic lahars of the Mehrten formation which are common in the northern portion of the range. Soil from the mixed lithology profile was a combination of volcanic and granitic parent materials that were mixed through glaciation. There is a significant correlation between the occurrence of this plant association and soils derived from volcanic parent materials. Typically, these soils are formed in place from bedrock, and rarely are they formed from deposited materials such as glacial till and colluvium.

These soils are often deep. Commonly, they exceed 35 inches although occasional sites can be less than 25 inches. Topsoil coarse fragments tend to be low; usually they are less than 15 percent. Subsoil coarse fragments, on the other hand, are high, and they often exceed 35 percent. Topsoil textures are usually sandy loams with occasional loams and sands. Subsoil horizons are finer textured and usually contain loams, sandy clay loams, and clay loams. Occasional sites contain sands and sandy loams.

The AWC of these soils is variable, but it clusters at two extremes: sites with high to moderately high water holding capacity, and those with low water holding capacity. There appears to be no landscape pattern to these differences. They reflect differences in soil depth, soil texture, and coarse fragment content that represent the normal variation within these plant communities. Soils lie over bedrock formations which are both fractured and rootable and unfractured and unrootable in equal portions. Similarly, the soils in this plant association are either well or excessively drained, and they are usually moderately erodible. Soil temperatures are substantially higher than most other sites reflective of the open stand conditions and southerly aspects. Summertime soil temperatures are typically higher than 49° Fahrenheit.

Variable	Mean	Range
Depth of soil sample (inches)	34	15-40+
Topsoil		
Depth (inches)	11	3-22
Coarse frag. (pct.)	19	3-46
pH	5.9	5.5-6.7
Subsoil		
Coarse frag. (pct.)	40	6-92
pH	5.8	5.3-6.7
AWC (inches)	3.2	0.8-5.9
Temp (20 inches) (Fahrenheit)	54	46-67

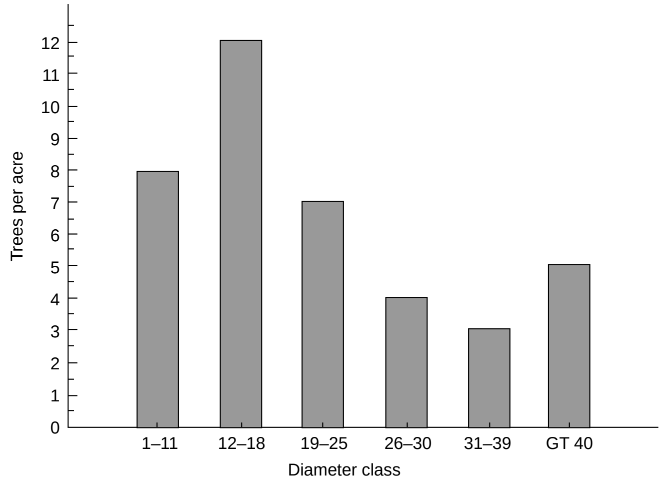
Productivity

Although Pacific Southwest Region (Region 5) site indexes are widely distributed, they rate as 3 and lower in most stands. Stand densities are also low. Stand density indexes are commonly less than 200, and stands will typically contain less than 50 trees per acre. Stocking levels average around 30 percent of those attained in the red fir-white fir plant association which is one of the densest of upper montane forested communities. Stocking in these late seral stands also resides in the larger individuals of the stand. Average quadratic mean diameters approach those of typical red fir stands which carry much of their stocking in larger size trees. Tree heights reflect the moderate to lower site indexes experienced on these sites. The tallest red fir measured 164 feet, but the tallest lodgepole measured only 87 feet, the tallest western white pine 70 feet, and the tallest western juniper 48 feet. Moderate to low site indexes coupled with lower stocking levels result in low basal area stocking and cubic and board foot volumes.

Stand structures are irregular, and smaller size classes are poorly represented. In general, stands are open, and there is a rather uniform distribution of trees in all size classes reflecting a lack of trees in size classes below 25 inches *(fig. 22)*.

Variable	Mean	Range
Region 5 site index	3	1-5
Forest survey site class	4	2-6
Stand density index	171	50-401
Quadratic mean diameter	23.6	8.6-32.0
Softwood volume (mcf/Ac)	5.4	1-16.6
Softwood volume (mbf/Ac)	33.6	4.0-111.6
Softwood basal area (sq ft/ac)	122	32-344
Hardwood volume (mcf/ac)	0	0
Hardwood basal area (sq ft/ac)	0	0

Figure 22—Number of trees by diameter class in the red fir/mountain mule ears plant association.



Tree species composition by percent of basal area

Species	ABMA	ABCO	PICO	PIJE	PIMO3	TSME
Percent	66	7	4	13	7	-
Species	JUOC	PILA	LIDE3	PIAL	POTR	QUKE
Percent	3	-	-	-	-	-

Coarse Woody Debris

Snag numbers are among the lowest in the upper montane. They reflect the open nature of these stands and the concentration of trees in larger size classes. Snags less than 30 inches DBH are few and widely scattered. Mortality in the larger size classes appears to be related to senescence and is randomly distributed among all species. Snag heights are variable, but typically they are shorter than 50 feet indicating a tendency for standing snags to break off over time. The majority of snags are decay class 3 and lower. Log diameters are also variable, but lengths are frequently less than 20 feet. They exhibit higher levels of decay than the snags. All logs sampled in these stands were decay classes 4 and 5.

Snags

Breast Height Diameter Class (inches)

	<11	*11-17.9*	*18-24.9*	*25-29.9*	*30-39.9*	*>40*	*Total*
Snags per acre	0	0	0	0	0.1	0.5	0.6
Snag height (feet)							
<20	-	-	-	-	0.1	-	0.1
20-50	-	-	-	-	-	0.3	0.3
>50	-	-	-	-	-	0.2	0.2
Snag decay class							
1	-	-	-	-	-	0.2	0.2
2	-	-	-	-	-	-	-
3	-	-	-	-	0.1	0.3	0.4
4	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-

Logs

	Large End Diameter Class (inches)				
	11-20	***21-30***	***31-40***	***>40***	***Total***
Logs per acre	0.3	0.9	0.3	0.6	2.1
Log length (feet)					
<20	0.3	0.9	0.3	-	1.5
20-50	-	-	-	0.6	0.6
51-100	-	-	-	-	-
>100	-	-	-	-	-
Log decay class					
1	-	-	-	-	-
2	-	-	-	-	-
3	-	-	-	-	-
4	0.3	0.6	-	0.3	1.2
5	-	0.3	0.3	0.3	0.9

Wildlife

Large game forage possibilities appear moderate. Of the more abundant and commonly occurring forage, Indian paint brush, waterleaf phacelia, bottle brush squirreltail, and Bolander's bluegrass are considered staple foods for large game; however, except for bottle brush squirreltail, most of these species are of relatively low constancy and cover. In general, deer use and pocket gopher activity on these sites were observed to be low.

Range

Range potential appears to be transitory as livestock move between primary forage sites such as meadows and other moist habitats. Cattle presence was often observed, but sites in this association do not appear to be highly used. Bottle brush squirreltail, large mountain brome, and California needlegrass are primary forage species for livestock.

Management Recommendations

Red fir/mountain mule ears sites have many environmental characteristics that are similar to more heavily forested communities in the upper montane, but they do not have higher levels of tree cover. Soil properties are similar to many stands with dense forest cover, and other features of the environmental setting are similar to stands with much higher levels of tree cover. These sites do share higher solar radiation levels and warmer soil temperatures with other open-canopied plant communities such as those in the western juniper and Jeffrey pine series. Additional factors such as competition during seedling establishment, allelopathy, past fire severity, past grazing practices, or prehistoric use patterns may influence these sites, but such conclusions are speculative at this time.

Limited opportunities exist for salvage when it occurs, but on these open sites, retaining woody debris in the form of snags and logs for wildlife or part of the nutrient supply would be better management for this association. Attempts to change species composition to conifer or other shrub, forb, or grass dominated communities should be treated with caution. Management emphasis should provide for existing wildlife habitat, plant species richness, and the landscape level diversity this association contributes to upper montane forests.

Mountain Hemlock//Steep Association

Tsuga mertensiana//steep

TSME//STEEP
CHMCHM11
Sample size: 17

Distribution

The mountain hemlock//steep plant association is located in the northwestern and northeastern portions of the study area. In general, mountain hemlock does not extend south of latitude 37° in the Sierra Nevada although isolated small stands are reported as far south as latitude 36°37'. The most southerly stand in this association was sampled west of Margaret Lake on the Sierra National Forest. Latitude at this point is slightly greater than 37°. Most samples occurred north of Latitude 37°30', and west of longitude 119°. Some were located on the Inyo and Toiyabe National Forests and the Lake Tahoe Basin Management Unit. Stands are usually smaller than 10 acres in size, and in many cases they cover but a small portion of an acre.

Environment

This association occurs over a wide range of elevations in the upper montane although stands characteristically lie above 7,500 feet. Stands often signal the transition into subalpine forests above. Some stands lie above 8,500 feet especially in the south and on the eastside. Aspects are predominantly northeast to northwest, and slopes exceed 30 percent. Microrelief is frequently broken and hummocky. SRI values on these steep north facing slopes are the lowest of any in the upper montane, and winter snow packs often linger for a considerable period into the summer season as one effect of these lower solar radiation levels. Stands typically lie on upper slopes. Most often they are found just below ridge tops on very steep north facing aspects. Stress indexes in this association are low due to lower solar radiation levels resulting from north aspects and steep slopes.

Variable	*Mean*	*Range*
Elevation (feet)	8,241	7,120-9,360
Slope (pct.)	45	30-60
Solar radiation index	0.355	0.273-0.478
Bare ground (pct.)	1	0-3
Surface gravel (pct.)	5	1-20
Surface rock (pct.)	13	0-49
Litter (pct.)	82	45-99
Litter depth (inches)	1.8	0.2-8.0
Stress index	0.49	0.37-0.57

Aspect: NE, NW.

Range: NE, NW.

Position: Upper slopes.

Range: Upper, middle, lower slopes, bottoms.

Vegetation

Stands are dense forests with open understories. The overstory is dominated by mountain hemlock, but western white pine and red fir are also important components in the overstory layer. Lodgepole pine is a rare member of this association. Stands are often found associated with the red fir-western white pine and red fir associations on mesic sites at high elevations.

Understories are sparse, and a shrub layer is essentially nonexistent. In the forb layer a range of species from mesic to dry site indicators are typical; however, none are abundant. Thus, both a mesic site indicator such as white-flowered hawkweed, and a dry site indicator such as broad-seeded rockcress can be present in the same stand. The grasses suggest a similar character with the presence of a mesic to dry indicator such as Ross' sedge, and a moist site indicator such as Bolander's bluegrass sometimes occurring in the same stand. More often, however, these species indicate differences between sites. Moss is present in these stands significantly more often compared to many other associations.

Conifer regeneration is moderate. Often more than 500 seedlings per acre are present, and the average is almost 800. Although regeneration is predominantly red fir, both mountain hemlock and western white pine are regenerating with significantly higher frequency than in other upper montane stands.

Plant species diversity is moderate to low. This association has few species in general, and sites are dominated by relatively few tree species that outweigh the cover values of the shrub, forb, and grass layers. Abundant species are few in number, and they are concentrated in the tree layer.

The oldest trees in these stands are typically greater than 250 years. Average stand ages are significantly older than most other stands in the upper montane although the age of the oldest trees are comparable to those found in other associations. The oldest mountain hemlock in the sample was ±394 years, and the oldest red fir was estimated at ±449 years.

Large scale, stand replacing disturbances are probably uncommon in this association. Although they may occur, field observation and examination of stand structures indicates they do not appear to be widespread phenomenon. The setting of many stands on cooler, north aspects at high elevations, the structure of many stands with open understories, the presence of relatively large, somewhat fire resistant individuals, and the natural patchiness of the landscape tend to preclude fire-caused stand replacing events. Most stands probably experience patchy burns with portions of the stand being completely consumed, and others are left with little damage. Avalanche can replace stands on these steep slopes. Most of these appear to be infrequent and occur at scattered locations across the landscape. Understories, including smaller trees, generally remain intact. Other disturbance elements such as windthrow, insects, disease, and lightning do not appear to affect large areas in these stands. In most cases disturbance occurs continuously at various scales, and this results in the creation of gaps of various sizes with constantly changing structures through time.

Stand development appears to be sporadic as opportunities for regeneration and growth arise in response to disturbance. It does not appear these stands go through a prolonged period in a grass/forb or shrub phase following disturbance, but it also appears conifer establishment is a process that can occupy a considerable period of time. Eventually regeneration becomes established in openings created through disturbance, and it grows, self-thins, and matures while other portions of the stand continue to undergo disturbance. In time, several size classes, including a substantial portion of larger trees, are represented, and the stand exhibits an irregular structure with many small relatively even-aged patches. As stands occupy sites for longer periods, successive disturbances continue to develop and maintain stand structures until an infrequent stand replacing event occurs and a new stand emerges.

Cover (percent)	*Mean*	*Range*
Total vegetative	68	38-85
Tree	65	37-81
Shrub	1	0-2
Forb	2	0-5
Grass	1	0-8
Moss	1	0-4
Stand age (years)	261	134-359
Diversity index		
Simpson	0.44	0.27-0.86
Hill numbers		
N0	8.6	4.0-14.0
N1	4.29	1.56-6.49
N2	2.49	1.17-3.68

Characteristic Vegetation

				Percent cover	
	Code	*Common name*	*Constancy*	*Mean*	*Range*
I.	Overstory trees				
	TSME	Mountain hemlock	100	37	10-74
	PIMO3	Western white pine	82	11	1-27
	ABMA	Red fir	76	23	2-60
II.	Understory trees				
	TSME	Mountain hemlock	100	2	1-5
	PIMO3	Western white pine	94	1	1-1
	ABMA	Red fir	82	3	1-13
	PICO	Lodgepole pine	24	1	1-1
III.	Shrubs				
	None				
IV.	Forbs				
	ARPL	Broad seeded rock cress	53	1	1-1

Characteristic Vegetation (continued)

	Code	Common name	Constancy	Percent cover Mean	Percent cover Range
IV.	PHHY	Waterleaf phacelia	41	1	1-1
	PESE3	Pine woods lousewort	35	1	1-1
	HIAL	White flowered hawkweed	29	1	1-1
V.	Grasses and grass-like				
	POBO1	Bolander's bluegrass	29	1	1-1
	CAR-1	Sedge	24	1	1-1
	CARO1	Ross' sedge	24	1	1-1
	POGR1	Pacific bluegrass	24	3	1-8

Soils

The predominant soils in this association are Inceptisols. Entisols were sampled in a few cases. Most of the Inceptisols are Xerumbrepts and Xerochrepts, and the most common great group in the Entisols are Cryorthents. Samples were typically described as skeletal reflecting high coarse fragment contents in the profiles. Samples occurred almost equally on granitic and volcanic parent materials; rare samples occurred in metamorphic rocks and mixed materials. Soils are formed in place from bedrock in about equal portions with those that are formed from transported material such as alluvial and colluvial deposits and glacial tills.

Soils are moderately deep to deep. Most often depths exceed 40 inches, and only on occasion are they less than 30 inches. Average topsoil depth is among the lowest in the upper montane; many stands had topsoils of less than 7 inches, and often they were less than 4 inches. Topsoils commonly contained more than 15 percent coarse fragments, and subsoils typically contained more than 35 percent coarse fragments. Subsoil coarse fragments are considerably higher than those on most other sites in the upper montane. Textures in the topsoil were evenly distributed between gravelly sands, gravelly sandy loams, and gravelly loams. Subsoils were usually sandy loams with some sands and loams.

The AWC of these soils is typically low. It results from coarse textures and higher coarse fragment contents in the subsoils. Topsoil pH is substantially more acid than many other sites. They reflect similar conditions in the mountain hemlock association. Soils commonly lie over bedrock that is fractured and rootable. They are often excessively drained, and erodibility is moderate to high due to the steep slopes. These are cold soils; soil temperatures are considerably lower than most other sites, and they are only slightly higher than temperatures in the mountain hemlock association which has the lowest of any in the upper montane. Summertime soil temperatures are often less than 49° Fahrenheit.

Variable	Mean	Range
Depth of soil sample (inches)	35	22-40+
Topsoil		
Depth (inches)	6	1-20
Coarse Frag. (pct)	32	1-75
pH	5.4	4.3-6.5
Subsoil		
Coarse Frag. (pct)	48	1-88
pH	5.8	5.2-6.8
AWC (inches)	2.3	0.5-5.4
Temp (20 inches) (Fahrenheit)	47	39-54

Productivity

Pacific Southwest Region (Region 5) site indexes range from 2 to 5, but site indexes in most stands are 2 or 3. Stand densities can be quite high. Generally, stand density indexes are greater than 400, and they compare to those found in dense red fir-white fir stands that are some of the densest in the upper montane. Tree heights, however, are substantially shorter than most other associations due to the presence of mountain hemlock, western white pine, and lodgepole pine, which are shorter trees in the Sierra Nevada. Mountain hemlock ranged between 83 and 122 feet for larger individuals in these stands compared to the tallest red fir of 152 feet. The net effect of shorter trees but higher densities is basal area stocking and cubic and board foot volumes that are comparable to most other densely forested stands in the upper montane although they are substantially less than highly productive associations such as red fir or red fir-white fir.

Stands are irregular in structure. Quadratic mean diameters reflect the presence of smaller trees in many stands. Compared to a balanced uneven-age distribution with comparable stocking levels, trees up to 18 inches are well represented, but the number of trees in size classes above 18 inches are excessive *(fig. 23)*. When compared to even-aged structures, trees smaller than 24 inches and those larger than 30 inches are over represented. Diameters of large mountain hemlock averaged 31 inches, and none were sampled that exceeded 45 inches. Quadratic mean diameters averaged 18 inches, which is substantially below that of most other dense, forested stands in the upper montane.

Variable	*Mean*	*Range*
Region 5 site index	3	2-5
Forest survey site class	4	3-6
Stand density index	523	295-816
Quadratic mean diameter	17.8	12.1-31.8
Softwood volume (mcf/ac)	10.0	4.2-16.5
Softwood volume (mbf/ac)	59.8	22.5-118.9
Softwood basal area (sq ft/ac)	353	213-507
Hardwood volume (mcf/ac)	0	0
Hardwood basal area (sq ft/ac)	0	0

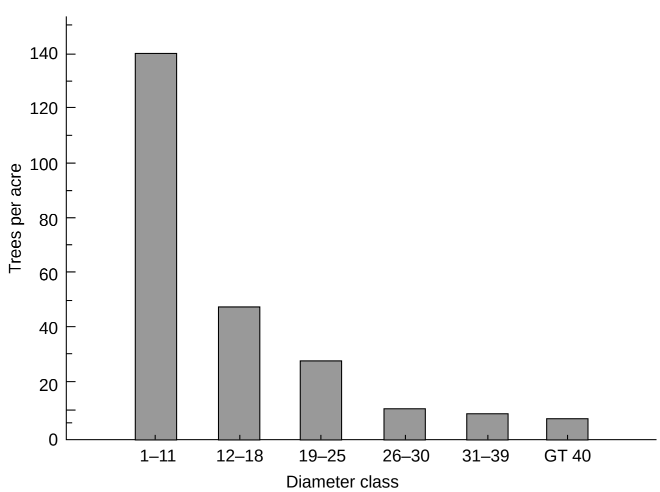


Figure 23—Number of trees by diameter class in the mountain hemlock//steep plant association.

Tree species composition by percent of basal area

Species	ABMA	ABCO	PICO	PIJE	PIMO3	TSME
Percent	33	-	5	-	14	48
Species	JUOC	PILA	LIDE3	PIAL	POTR	QUKE
Percent	-	-	-	-	-	-

Coarse Woody Debris

Snag numbers are low in this association. Snags are distributed somewhat uniformly among all size classes and species. Most are less than 20 feet tall, and they appear to be sound. Snags in these stands generally lie in decay classes between 1 and 3. Logs are commonly less than 30 inches in diameter reflecting the presence of mountain hemlock. They are generally less than 50 feet long, and often they are less than 20 feet in length. Logs exhibit higher levels of decay than snags, and the majority occur in decay classes between 3 and 5.

Snags

	Breast Height Diameter Class (inches)						
	<11	***11-17.9***	***18-24.9***	***25-29.9***	***30-39.9***	***>40***	***Total***
Snags per acre	0	0.6	0.3	0.5	0.4	0.8	2.6
Snag height (feet)							
<20	-	0.6	0.2	0.5	-	0.4	1.7
20-50	-	-	-	-	-	0.1	0.1
>50	-	-	0.1	-	0.4	0.3	0.8
Snag decay class							
1	-	-	-	-	0.4	0.2	0.6
2	-	-	-	-	-	0.5	0.5
3	-	0.3	0.2	0.5	-	-	1.0
4	-	0.3	0.1	-	-	-	0.4
5	-	-	-	-	-	0.1	0.1

Logs

	Large End Diameter Class (inches)				
	11-20	***21-30***	***31-40***	***>40***	***Total***
Logs per acre	4.0	10.0	2.0	3.3	19.3
Log length (feet)					
<20	2.7	6.0	0.7	1.3	10.7
20-50	1.3	4.0	0.7	0.7	6.7
51-100	-	-	0.6	1.3	1.9
>100	-	-	-	-	-
Log decay class					
1	-	-	-	-	-
2	-	-	-	-	-
3	2.0	4.0	0.7	0.7	7.4
4	1.3	2.0	0.7	1.3	5.3
5	0.7	4.0	0.6	1.3	6.6

Wildlife

Large game forage production appears to be quite low. Of the species present in these stands only Ross' sedge and Bolander's bluegrass are staples, and it is doubtful there is enough cover to provide any real forage. Deer use of these stands, however, was common, and pocket gophers were observed in the majority of stands.

Range

Range potential in this association appears to be transitory as livestock move to primary range sites such as meadows and other moist habitats. The mountain hemlock//steep plant association appears to be marginal from a range forage standpoint. None of the more commonly found species on these sites are primary or secondary forage species. In addition, the steep slopes that characterize these stands would appear to preclude use by livestock. On the other hand, signs of cattle use were common on these sites.

Management Recommendations

Most late seral stands have moderate levels of natural conifer regeneration present, but in the few cases where logging or other disturbance has occurred, it has had little effect on increasing conifer stocking levels. Stocking on many of these sites generally results from established seedlings and saplings that survive disturbance. It appears that stand establishment can be a fairly lengthy process in this association. Time periods may exceed 25 to 30 years or more. Techniques for planting mountain hemlock, western white pine, and red fir on these sites has not been developed, and currently success rates from planting can be expected to be low. Research has not been directed at appropriate cutting methods or stocking levels for these stands, and early successional sequences after disturbance are not well understood.

Stands have moderate productive capacity and flexibility for stand management. Stand structures are variable, but species composition and site indexes are limiting, and the ability of sites to respond to treatment is uncertain. The ability to predict results of treatment are not based on wide experience or research results at this time. Intensive timber production is not recommended for these sites. Where harvesting is scheduled, recommendations for cutting methods would be those that rely on natural regeneration, and it appears best at this time to conduct any silvicultural treatments in this type on a small scale and with caution.

This plant association provides landscape level diversity through differences in species composition and stand structures even though the species diversity within a stand is not high. Appropriate management emphasis would maintain this difference and the processes that create it as essential components in upper montane forests.

Mountain Hemlock Association

Tsuga mertensiana

TSME

CHMCHM12

Sample size: 32

Distribution

The mountain hemlock plant association is located throughout the range of mountain hemlock in the Sierra Nevada; however, stands occur predominantly north of the Kings River. In general, mountain hemlock as a species does not extend much south of latitude 37° in the Sierra Nevada although isolated small stands are reported as far south as latitude 36°37′. Samples in this association lay generally north of latitude 37°30′ and west of longitude 119°. The most southerly stand sampled was near Hatch lake east of Dinkey Creek on the Sierra National Forest. This association then extends northward though the Eldorado National Forest and the Lake Tahoe Basin Management Unit. In the north stands become more common and larger in size. The association typically occurs as scattered, relatively small stands that seldom exceed 25 acres and may be as small as a fraction of an acre.

Environment

This is a higher elevation association. Although average elevations are not unusually high for the range of the upper montane, it is located in the northern portion of the study area where elevations of most plant communities are lower than those to the south. Stands generally lie above 8,000 feet, and usually above 8,500 feet. Aspects are typically northeast, and most sites lie between northeast and northwest. Few stands occur on south aspects. Slopes are gentle; all are less than 30 percent, and often they are less than 20 percent. Microrelief is commonly broken and hummocky. Sites occur uniformly from upper to lower slope positions. Rarely, however, are they located on ridge tops. These stands have significantly less bare ground than stands in most other associations. SRI values are characteristically low reflecting lower radiation levels from northerly aspects; however, this association has substantially higher radiation indexes than the mountain hemlock//steep association with which it often occurs. Stress indexes on these sites is typically moderately high to high. This results in most cases from a combination of lower AWC on specific sites in conjunction with locations on upper slopes.

Variable	*Mean*	*Range*
Elevation (feet)	8,390	7,380-9,160
Slope (pct.)	18	2-29
Solar radiation index	0.437	0.385-.533
Bare ground (pct.)	1	0-20
Surface gravel (pct.)	4	0-32
Surface rock (pct.)	9	0-43
Litter (pct.)	85	27-99
Litter depth (inches)	1.3	0.4-3.0
Stress index	0.50	0.38-0.60

Aspect: NE, NW.
Range: All.
Position: Upper, middle, lower slopes.
Range: All positions.

Vegetation

This association is a dense forest with open understories. The overstory is dominated by mountain hemlock mixed with red fir and western white pine. Lodgepole pine is an occasional member of the overstory. Both mountain hemlock and western white pine are indicators of moderate to dry habitats. Trees larger than 40 inches in diameter are generally predominant red fir which rise above the main forest canopy. Stands in this association are often found associated with the mountain hemlock//steep, red fir-western white pine, and red fir associations on mesic sites.

Understory vegetation is sparse and dominated by moderate to moist site indicators. Shrub and grass cover are considerably less than most other sites. Of the few shrubs present, sierra gooseberry and alpine prickly currant are both moist site indicators. Brewer's golden aster and white flowered hawkweed in the forb layer are common indicators of mesic sites, and Bolander's bluegrass also indicates somewhat moderate moisture regimes. Broad seeded rockcress and Ross' sedge are indicators of moderate to dry conditions. Moss occurs in this association significantly more often compared to many other sites in the upper montane.

Conifer regeneration is high. The average number of seedlings per acre is more than 1,000, and stands usually have more than 500 per acre. Red fir dominates the regeneration followed by substantially lower numbers of mountain hemlock. Western white pine and lodgepole pine are present in lesser amounts. Mountain hemlock, western white pine, and lodgepole pine, on the other hand, are regenerating with significantly higher frequency than in most other associations.

Plant species diversity is moderate. This association has a moderate number of species overall, and sites are dominated by a relatively few tree species that far outweigh cover values of the shrub, forb, and grass layers. Abundant species are concentrated in the tree layer.

Most late seral stands contain trees that are older than 250 years, but average stand ages were not substantially different than other stands in the upper montane. The oldest tree sampled was a red fir estimated at ±507 years although a western white pine was estimated at ±431 years, and a mountain hemlock was recorded at ±427 years.

Large scale, stand replacing disturbances are probably uncommon in this association. Although such events may occur, they do not appear to be widespread phenomenon. The setting of many stands on cooler north aspects at high elevations, the structure of stands with open understories, the presence of relatively large, somewhat fire resistant individuals, and the natural patchiness of the landscape tend to preclude fire-caused stand replacing events and ensure some level of survival by most species after a fire. Most stands probably experience patchy burns with portions of the stand being completely consumed, and others are left with little damage. Avalanche can replace stands on middle and lower slope positions, but it appears to be infrequent in late seral stands, and it occurs at scattered locations across the landscape. Understory trees generally remain intact. Other disturbance elements such as windthrow, insects, disease and lightning are more common, but they generally occur in localized situations or on select species and do not cause stand replacement in most cases. It is probable that disturbance occurs continuously on various scales, and this results in the creation of various sized gaps with constantly changing structures through time.

Stand development appears to be sporadic as opportunities for growth and regeneration arise in response to disturbance. After disturbance, stands do not appear to go through a prolonged period in a grass/forb or shrub phase. On the other hand, it also appears conifer establishment is a process that can occupy a considerable period of time. Regeneration generally becomes established in openings created through disturbance, and it grows, self-thins, and matures as other portions of the stand continue to undergo disturbance. In time, several size and tree classes, including a substantial portion of larger trees, are represented, and the stand exhibits an irregular structure with many small relatively even-aged patches. As stands occupy sites for longer periods, successive disturbances continue to develop and maintain stand structures until an infrequent stand replacing event occurs and a new stand emerges.

Cover (percent)	*Mean*	*Range*
Total vegetative	77	23-97
Tree	68	22-88
Shrub	1	0-15
Forb	7	0-35
Grass	5	0-45
Moss	2	0-13
Stand age (years)	229	99-440
Diversity index		
Simpson	0.37	0.12-0.71
Hill numbers		
N0	11.2	4.0-21.0
N1	5.79	2.21-13.68
N2	3.27	1.40-8.69

Characteristic Vegetation

			Percent cover	
Code	*Common name*	*Constancy*	*Mean*	*Range*
I. Overstory trees				
TSME	Mountain hemlock	100	23	4-75
ABMA	Red fir	88	30	1-76
PIMO3	Western white pine	62	13	2-44
PICO	Lodgepole pine	53	21	1-54

Characteristic Vegetation (continued)

	Code	*Common name*	*Constancy*	*Percent cover Mean*	*Percent cover Range*
II.	Understory trees				
	TSME	Mountain hemlock	94	2	1-7
	ABMA	Red fir	78	4	1-17
	PIMO3	Western white pine	75	1	1-2
	PICO	Lodgepole pine	38	1	1-2
III.	Shrubs				
	RIMO	Alpine prickly currant	22	1	1-1
	RIRO	Sierra gooseberry	22	1	1-2
IV.	Forbs				
	CHBR3	Brewer's golden aster	66	2	1-10
	PESE3	Pine woods lousewort	50	1	1-3
	HIAL	White flowered hawkweed	34	2	1-12
	ARPL	Broad seeded rockcress	31	1	1-1
	ERPEA	Wandering daisy	28	5	1-16
V.	Grasses and grass-like				
	CARO1	Ross' sedge	56	2	1-8
	LUCO1	Common woodrush	31	2	1-5
	POGR1	Pacific bluegrass	31	2	1-10
	POBO1	Bolander's bluegrass	28	2	1-5

Soils

Typical soils are Inceptisols. Entisols and Alfisols are encountered in a few cases. Most Inceptisols are Umbrepts; the remainder are Ochrepts. Entisols are usually described as Psamments, and the Alfisols are distributed between Xeralfs and Boralfs. Particle size classes were normally skeletal although a significantly higher proportion of the samples were loamy compared to most other associations. These soils developed primarily from granitic parent materials; however, a few samples in the north were derived from volcanic or mixed materials. The association occurs equally on soils that are formed in place from bedrock or from deposited materials such as colluvium, alluvium, or glacial tills.

Soil depths are somewhat variable although modal sites are moderately deep to deep. Profiles often exceed 35 inches in depth although, on occasion, they can be less than 25 inches. Soil textures in the topsoil are typically sandy loams or loams with occasional sands. Subsoil textures are usually sandy loams with some sands and occasional loams. A significant portion of the topsoils in this association are ochric, and a significant number of the subsoils are 7.5 YR with low values and high chroma. Topsoils tend to be brownish yellow, and subsoils tend to range from strong brown to light gray when moistened.

The AWC is usually low to moderately low but not substantially different from most other sites in the upper montane. Topsoil pH is significantly more acid than those in most other associations, and they reflect similar conditions in the mountain hemlock//steep association. In most cases, stands lie over bedrock formations that are fractured and rootable thus increasing potential rooting depth and moisture supply. Sites are often well drained, but a relatively high number are also excessively drained. Erodibility on these moderate slopes ranges from low to high primarily in response to differences in soil textures. Average summertime soil temperatures are the lowest of any in the upper montane. Soil temperatures are typically less than 49° Fahrenheit.

Variable	Mean	Range
Depth of soil sample (inches)	32	14-40+
Topsoil		
Depth (inches)	8	0-26
Coarse frag. (pct.)	19	2-65
pH	5.3	4.5-6.4
Subsoil		
Coarse frag. (pct.)	32	2-70
pH	5.9	4.8-6.7
AWC (inches)	2.8	0.7-5.3
Temp (20 inches) (Fahrenheit)	45	39-56

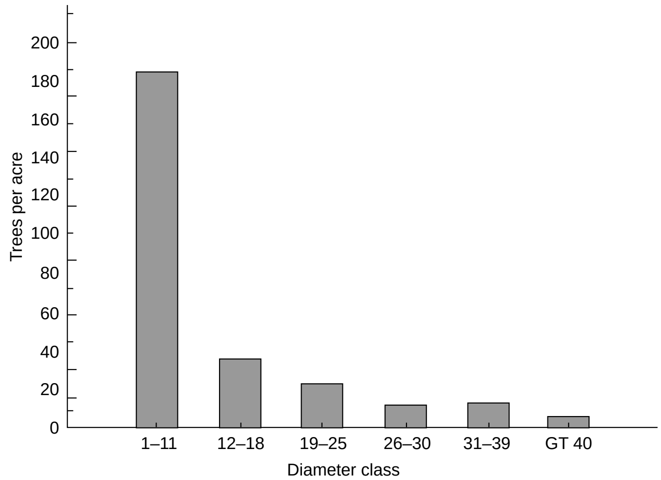
Productivity

These stands have a wide range of site indexes reflective of the variation in soil depths. Most often Pacific Southwest Region (Region 5) site indexes are 2 and 3. Rare stands have site indexes greater than 2, but occasional sites will have site indexes of 4 or 5. Stand density can be quite high. This plant association has one of the highest stand density indexes in the upper montane. Index values often exceed 500, and average values are exceeded only by the red fir-lodgepole pine/white-flowered hawkweed association, which carries the highest density of any forested association in the upper montane. Lower quadratic mean diameters reflect the high number of trees in smaller size classes, and average heights of dominant trees are significantly shorter than other dense forested plant associations due to the presence of mountain hemlock, western white pine, and lodgepole pine in the stands. The tallest mountain hemlock recorded was an estimated 123 feet tall, and the tallest western white pine and lodgepole pine were measured at 126 and 110 feet respectively. These are compared to the tallest red fir measured at 174 feet. Average stand diameters are also less than other high density forested stands. The net effects of high stand density and shorter trees distributed on smaller diameter trees are basal areas and cubic and board foot volumes that are comparable to other forested stands in the upper montane, although they are somewhat less than highly productive associations such as red fir and red fir-white fir.

Stand structures in general are irregular, although individual late seral stands range from even to uneven-age distributions. Typically, they contain more trees in both the smaller and larger size classes than would be the case in an even-aged distribution, and they contain more trees in the larger size classes and fewer in the smaller size classes than would be the situation in balanced uneven-age distributions of similar stocking *(fig. 24)*. Overall, stands approach an uneven-aged distribution with excessive trees in size classes less than 18 inches.

Variable	Mean	Range
Region 5 site index	3	1-5
Forest survey site class	4	2-6
Stand density index	541	141-1239
Quadratic mean diameter	18.6	7.2-34.6
Softwood volume (mcf/ac)	10.2	1.3-21.0
Softwood volume (mbf/ac)	64.1	11.9-124.8
Softwood basal area (sq ft/ac)	364	116-680
Hardwood volume (mcf/ac)	0	0
Hardwood basal area (sq ft/ac)	0	0

Figure 24—Number of trees by diameter class in the mountain hemlock plant association.



Tree species composition by percent of basal area

Species	ABMA	ABCO	PICO	PIJE	PIMO3	TSME
Percent	40	-	18	-	11	31
Species	JUOC	PILA	LIDE3	PIAL	POTR	QUKE
Percent	-	-	-	-	-	-

Coarse Woody Debris

Snag numbers are moderate. Mortality in late seral stands is concentrated in size classes below 25 inches and appears to be related to thinning of suppressed individuals. Mortality in the larger size classes seems to be related to senescence and is randomly distributed among all species. Snags in the samples were typically shorter than 50 feet, indicating a tendency of standing snags to break off over time. They lie predominantly between decay classes 1 and 3. Logs are commonly smaller than 30 inches reflecting the presence of mountain hemlock. Most are less than 50 feet in length, and they show higher levels of decay than snags. Log decay classes generally lie between 3 and 5.

Snags

	Breast Height Diameter Class (inches)						
	<11	*11-17.9*	*18-24.9*	*25-29.9*	*30-39.9*	*>40*	*Total*
Snags per acre	6.9	3.1	2.3	1.4	0.6	0.9	15.2
Snag height (feet)							
<20	4.6	0.5	0.7	0.4	0.3	0.3	6.8
20-50	2.3	0.7	0.5	-	-	-	3.5
>50	-	1.9	1.1	1.0	0.3	0.6	4.9
Snag decay class							
1	2.9	0.5	-	0.4	-	0.4	4.2
2	2.9	1.7	1.1	0.7	0.3	0.1	6.8
3	1.1	0.9	0.7	0.3	0.3	0.2	3.5
4	-	-	0.5	-	-	0.2	0.7
5	-	-	-	-	-	-	-

Logs

	Large End Diameter Class (inches)				
	11-20	***21-30***	***31-40***	***>40***	***Total***
Logs per acre	6.2	13.1	4.7	1.8	25.8
Log length (feet)					
<20	3.1	4.5	1.1	0.7	9.4
20-50	2.0	6.2	2.5	0.2	10.9
51-100	1.1	2.4	1.1	0.7	5.3
>100	-	-	-	0.2	0.2
Log decay class					
1	0.2	-	0.2	-	0.4
2	-	0.9	0.4	0.4	1.7
3	2.9	3.8	1.6	-	8.3
4	1.8	4.2	1.6	0.7	8.3
5	1.3	4.2	0.9	0.7	7.1

Wildlife

These stands may offer some hiding and thermal cover to large game, but forage possibilities appear transitory. Of the species present, only Ross' sedge and Bolander's bluegrass are staples in the large game diet. They occur consistently enough and with sufficient cover value to provide forage for marginal big game use. Observation of deer sign was common, and evidence of pocket gopher use was generally high in these stands.

Range

These are transitional range sites that are used by livestock to access primary range sites such as meadows and other moist habitats. Sign of cattle use was present in typical stands; however, none of the more commonly occurring species on these sites are primary or secondary range forage species, and it would appear range forage potential is low in these late seral stands.

Management Recommendations

Little harvesting has occurred in the mountain hemlock plant association. Where harvesting has occurred, it has had little effect on increasing conifer stocking levels. Stocking on many of these sites generally results from established seedlings and saplings that survive timber harvest and site preparation. It appears that natural regeneration and stand establishment can be a fairly lengthy process. Time periods may exceed 25 to 30 years or more. Techniques for planting mountain hemlock, western white pine, and red fir have not been developed in this association, and currently success rates from planting attempts can be expected to be low. Research has not been directed at appropriate cutting methods or stocking levels for these stands, and early successional sequences are not well understood.

These stands have moderate productive capacity and flexibility for stand management. Stand structures are variable, but species composition is limiting, and the ability of sites to respond to treatment is uncertain. The ability to predict results of treatment are not based on wide experience or research at this time.

Management for intensive timber production is not recommended. Where harvesting is scheduled, recommendations for cutting methods and regeneration strategies would be those that rely on natural regeneration. It would appear best at this time to conduct any silvicultural treatments in this association on a small scale and with caution.

This association provides landscape level diversity in these forests through differences in species composition and stand structures even though the species diversity within a stand is not high. It would therefore seem appropriate to maintain this diversity and the processes that create it as essential components of upper montane forests.

Red Fir-Western White Pine/Pinemat Manzanita Association

Abies magnifica-Pinus monticola/Arctostaphylos nevadensis

ABMA-PIMO3/ARNE2
CFRCPW12111
Sample size: 31

Distribution

The red fir-western white pine/pinemat manzanita plant association is located throughout the study area on both the westside and eastside of the range. All stands were located north of 36° latitude and generally west of 118° longitude. Stand size is usually not large; however, some sites were observed that appear to be in the range of 100 acres or larger.

Environment

This is a high elevation association. Although the elevation range is wide, sites characteristically lie above 8,000 feet, and seldom do they occur at lower elevations. Stands do lie at significantly lower elevations than others in the western white pine subseries, however. It differs from the red fir/pinemat manzanita plant association with which it is comparable in many respects by occupying generally higher elevation sites. Aspects are varied. Sample stands were generally quite evenly distributed between aspects although a slightly higher portion was located on southeast-and southwest-facing slopes. Stands lie predominantly on ridges and upper to middle slope positions on sites with broken and varied microrelief. Slopes commonly occur between 20 and 40 percent. Bare ground and surface rock are both significantly higher than most other sites. Surface rock usually occupies between 5 and 25 percent of the ground surface. Litter depths are also considerably less than in many other associations. Stress indexes are characteristically high. These reflect variations of shallow soils, lower water holding capacities, upper slope positions, and solar radiation levels on specific sites.

Variable	Mean	Range
Elevation (feet)	8,364	7,200-9,120
Slope (pct.)	28	6-59
Solar radiation index	0.484	0.308-.565
Bare ground (pct.)	6	0-25
Surface gravel (pct.)	5	0-40
Surface rock (pct.)	11	0-65
Litter (pct.)	79	25-99
Litter depth (inches)	1.0	0.2-3.5
Stress index	0.54	0.42-0.65

Aspect: SE, SW.
Range: All.
Position: Upper and middle slopes.
Range: Ridgetops, upper and middle slopes, benches.

Vegetation

Stands are open woodlands with a picturesque understory of pinemat manzanita. Total vegetation and shrub cover are higher than most other plant associations due to the abundance of this species. Conversely, these stands have the lowest tree cover of any western white pine association, and tree cover is substantially lower than most other associations in the upper montane. Overstory composition is characterized by higher levels of western white pine mixed with red fir which serves to differentiate it from the red fir/pinemat manzanita plant association that it resembles. Western white pine along with pinemat manzanita, broad seeded rock cress, mountain pennyroyal, squirrel tail, and western needlegrass are indicators of the generally dry habitats encountered on these sites.

Conifer regeneration is moderate to low, and it is usually clumped rather than evenly distributed in the stand. The average number of seedlings is 450 per acre, and seedling counts were commonly higher than 100. Occasional stands contain more than 500 seedlings per acre. Regeneration is dominated by red fir although western white pine is typically present. In some cases lodgepole pine is also a component of conifer regeneration. Western white pine is regenerating significantly more often than in most other associations.

Plant species diversity is also moderate. Most stands have a moderate number of species overall compared to other forested stands in the upper montane. Sites are dominated by relatively few tree species and a major shrub layer. Together these outweigh cover values of the remaining forb and grass layers. Abundant species are relatively few in number, and cover values are somewhat uniformly distributed between trees and shrubs.

The oldest trees in these stands are generally older than 250 years. This association carries high proportions of older trees, and average stand ages are substantially older than most others in the upper montane. The oldest tree sampled was a red fir at ±519 years, and the oldest western white pine and lodgepole pine were measured at ±453 and ±319 years, respectively.

Stand replacing events probably occur in this association, but they do not appear to be frequent or large scale phenomena. The setting of many stands at higher elevations, the structure of the stands with stocking concentrated in widely spaced, relatively large, somewhat fire resistant individuals and the discontinuous cover and low growth form of pinemat manzanita would tend to preclude stand replacing fires. These stands probably experience patchy burns with portions of the stand being consumed and others left with little damage. Isolated large trees probably escape damage in most cases. Disturbance elements such as windthrow, insects, disease, lightning, or avalanche do not appear to affect large areas in these stands. It is likely that disturbance is occurring continuously on various scales, and this results in the creation of various sized gaps with constantly changing structures through time.

Reproductive strategies such as consistent seed production, sprouting, or delayed germination of seed until scarified by fire is present in some of the species on these sites. Red fir and western white pine are reasonably consistent seed producers. Pinemat manzanita sprouts from stems, but it does not crown sprout. Thus, patchy burns would ensure survival of at least some of these stems to allow reoccupation of disturbed sites. In addition, the patchy distribution and wide spacing of many of the existing trees would result in uneven coverage of sites by most disturbance elements.

Stand development appears to be sporadic as opportunities for regeneration and growth arise in response to disturbance. Disturbance creates opportunities for regeneration, but many microhabitats are unsuitable for regeneration, and conifer establishment is often a prolonged process. Disturbance provides opportunities for surviving individuals to increase growth. Isolated patches of conifers that escape repeated disturbance proceed through periods of crown closure and self thinning. Other portions of the stand continue to undergo disturbance although there are probably always isolated trees and small patches that escape and mature into larger individuals. In time, the stand develops an irregular structure reflecting numerous disturbances, and containing scattered large trees as survivors of these disturbance events.

Cover (percent)	*Mean*	*Range*
Total vegetative	69	30-100
Tree	43	11-79
Shrub	31	2-82
Forb	3	0-25
Grass	2	0-9
Moss	0.2	0-2
Stand age (years)	275	168-410
Diversity index		
Simpson	0.37	0.11-0.74
Hill numbers		
N0	9.6	3.0-20.0
N1	4.03	1.85-9.50
N2	3.12	1.35-8.76

Characteristic Vegetation

				Percent cover	
	Code	*Common name*	*Constancy*	*Mean*	*Range*
I.	Overstory trees				
	PIMO3	Western white pine	94	12	1-41
	ABMA	Red fir	90	29	3-68
II.	Understory trees				
	ABMA	Red fir	84	2	1-20
	PIMO3	Western white pine	61	1	1-1
	PICO	Lodgepole pine	23	1	1-2
III.	Shrubs				
	ARNE2	Pinemat manzanita	100	28	1-78
	CASE3	Sierra chinquapin	23	3	1-7

Characteristic Vegetation (continued)

	Code	*Common name*	*Constancy*	*Percent cover* *Mean*	*Range*
IV.	Forbs				
	ARPL	Broad seeded rock cress	77	1	1-2
	PESE3	Pine woods lousewort	61	1	1-2
	MOOD	Mountain pennyroyal	32	1	1-5
	CHBR3	Brewer's golden aster	29	2	1-5
V.	Grasses and grass-like				
	SIHY	Bottle brush Squirreltail	40	2	1-5
	STOC1	Western needlegrass	40	1	1-2
	CARO1	Ross' sedge	30	1	1-2

Soils

Soils are predominantly Inceptisols and Entisols although stands include a substantially higher proportion of Entisols than most other associations in the upper montane. Considerable variation occurs among these soils below the suborder level. Samples were distributed evenly between Umbrepts, Ochrepts, Orthents, and Psamments. Particle size classes are commonly skeletal and indicate somewhat higher levels of coarse fragments throughout the profile. Parent materials are predominantly granite, and soils are usually formed in place from bedrock. A few soils are formed from materials that have been deposited such as glacial till or alluvium.

Soil depths are moderately deep to deep, but average depths are considerably less than in many other associations. Typical depths were less than 35 inches, and, some were less than 25 inches. Topsoil depths are also shallow. Topsoils were commonly less than 7 inches, and occasionally they were less than 4 inches deep. These are coarse to moderately coarse textured soils. Most frequently topsoil textures were sands or sandy loams. Loams were seldom encountered. Subsoil textures were also evenly divided between sands and sandy loams. Subsoil colors are significantly different from most other associations. They characteristically have 10 YR hues, but values are consistently high, and colors range from gray to brownish yellow when moist.

The AWC in these stands is among the lowest in the upper montane. It is significantly lower than on most other sites. Bedrock formations were usually fractured and rootable thus supplying additional sources of moisture to the site. Many sites are well drained, but drainage can also be excessive. Erodibility is low to moderate reflecting coarse soil textures and moderate slopes. Stress indexes are considerably higher than most other sites in the upper montane due to lower AWC resulting from coarse textured and somewhat shallow soils, and the upper slope positions common to these sites.

Variable	*Mean*	*Range*
Depth of soil sample (inches)	31	8-40+
Topsoil		
Depth (inches)	6	2-11
Coarse frag. (pct.)	19	5-38
pH	5.7	4.4-6.5
Subsoil		
Coarse frag. (pct.)	45	10-86
pH	5.9	4.7-6.8
AWC (inches)	2.1	0.3-4.4
Temp (20 inches) (Fahrenheit)	51	41-60

Productivity

Pacific Southwest Region (Region 5) site indexes are considerably lower than dense, well-stocked stands elsewhere in these forests. No site index was higher than 2, and commonly samples had site indexes of 4 and 5. Stand densities are moderately low. Stand density indexes are typically less than 300. They are substantially lower than adjacent dense forested stands. Based on stand density indexes stocking levels attain about 50 percent of values reached in dense forested types in the upper montane. Stocking resides in the larger individuals of the stand. The average quadratic mean diameter is larger in this association than typical red fir stands that are stocked with many large trees per acre. Average tree heights are also considerably less than many other associations reflecting overall lower site quality and the presence of western white pine, a shorter tree, in stands. The tallest red fir in this association was 159 feet compared to the tallest western white pine at 115 feet. This combination of factors result in lower cubic and board foot yields from this association.

Stands tend to be open with few trees per acre overall and stocking that is concentrated in large trees *(fig. 25)*. Compared to an uneven-aged stand with a balanced diameter distribution and similar stocking levels, these stands have too few trees in size classes smaller than 18 inches, and an excess of trees in size classes larger than 30 inches. Compared to an even-age distribution, they have an excess of trees in both smaller and larger size classes.

Variable	*Mean*	*Range*
Region 5 site index	4	2-5
Forest survey site class	5	3-6
Stand density index	274	124-482
Quadratic mean diameter	25.4	11.7-37.9
Softwood volume (mcf/ac)	6.1	2.5-12.9
Softwood volume (mbf/ac)	39.9	15.1-94.9
Softwood basal area (sq ft/ac)	196	5-400
Hardwood volume (mcf/ac)	0	0
Hardwood basal area (sq ft/ac)	0	0

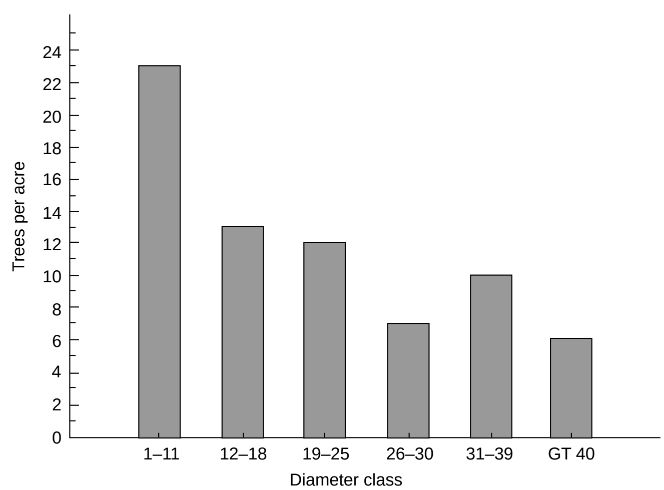


Figure 25—Number of trees by diameter class in the red fir-western white pine/pinemat manzanita plant association.

Tree species composition by percent of basal area

Species	ABMA	ABCO	PICO	PIJE	PIMO3	TSME
Percent	63	-	10	2	25	-
Species	JUOC	PILA	LIDE3	PIAL	POTR	QUKE
Percent	-	-	-	-	-	-

Coarse Woody Debris

Snag numbers are moderate to low, but they are distributed more or less uniformly across all size classes. Mortality is distributed among all species. Snags are typically shorter than 50 feet in height indicating a tendency of large standing snags to break off over time. All decay classes are represented but most snags sampled occurred in classes 3 to 5. Logs are usually smaller than 30 inches, and lengths less than 50 feet predominate. Logs evidence somewhat higher levels of decay compared to snags, and decay classes 4 and 5 are typical.

Snags

	Breast Height Diameter Class (inches)						
	<11	*11-17.9*	*18-24.9*	*25-29.9*	*30-39.9*	*>40*	*Total*
Snags per acre	0.8	0.9	0.8	0.6	0.7	0.7	4.5
Snag height (feet)							
<20	0.8	0.2	0.2	0.2	0.5	-	1.9
20-50	-	0.2	0.3	-	0.2	0.7	1.4
>50	-	0.5	0.3	0.4	-	-	1.2
Snag decay class							
1	-	-	0.3	0.2	-	-	0.5
2	-	0.7	-	-	0.1	-	0.8
3	0.8	0.2	0.3	0.2	0.2	-	1.7
4	-	-	0.1	0.2	0.2	0.7	1.2
5	-	-	0.1	-	0.2	-	0.3

Logs

	Large End Diameter Class (inches)				
	11-20	*21-30*	*31-40*	*>40*	*Total*
Logs per acre	4.7	14.0	5.8	1.1	25.6
Log length (feet)					
<20	4.3	7.5	2.0	0.9	14.7
20-50	0.4	5.8	2.5	-	8.7
51-100	-	0.7	1.3	0.2	2.2
>100	-	-	-	-	-
Log decay class					
1	-	-	-	-	-
2	-	0.7	-	0.2	0.9
3	0.7	2.2	1.6	-	4.5
4	2.4	4.7	1.8	0.7	9.6
5	1.6	6.4	2.4	0.2	10.6

Wildlife

Forage values appear to be low and concentrated in the scattered grass component. Of the species occurring on these sites, bottle brush squirreltail, western needlegrass, and Ross' sedge are staples in the big game diet. They occur with moderate frequency but low cover values, and they would appear not to be major contributors to the large game diet. On the other hand, deer use was generally observed on these sites, and pocket gophers were usually present as well.

Range

These are transitional range sites that are used by livestock to access primary range sites such as meadows and other moist habitats. Nevertheless, cattle evidence was common on these sites. Squirreltail and western needlegrass are secondary livestock forage species; however, the moderate constancy and low cover would appear to preclude these sites from heavy livestock use. It appears livestock forage potential is low in these late seral stands.

Management Recommendations

Relatively few stands in this type have been harvested. As a consequence, silvicultural systems, cutting methods, regeneration strategies, early successional sequences, and stocking levels important in the management of any forested type are relatively unknown. Where stands have been harvested and disturbance has occurred, regeneration patterns are unclear at this time. No sites were observed where stands were harvested, sites prepared, and planting has occurred with any systematic approach.

These stands have limited productive capacity and flexibility for stand management. The open nature of these stands indicates that regeneration and establishment is a lengthy and variable process under most conditions. Recommendations for harvesting at the present time would be to treat stands in this association with caution and the expectation that results can be uncertain. Limited opportunities exist for salvage when it occurs, but on these open sites it would appear that woody debris left in the form of snags and logs for wildlife or part of the nutrient pool would be better direction for this association. Management emphasis should provide for existing wildlife habitat, plant species richness, and the landscape level diversity this association provides to upper montane forests.

Red Fir-Western White Pine/Sierra Chinquapin Association

Abies magnifica-Pinus monticola/Castanopsis sempervirens

ABMA-PIMO3/CASE3
CFRCPW14
Sample size: 11

Distribution

The red fir-western white pine/Sierra chinquapin plant association is located at higher elevations primarily in the southern and eastern portions of the study area. Sample sites were located on the Sequoia, Inyo, and Toiyabe National Forests, but it is likely the association extends further, and sites have been observed but not sampled in Yosemite National Park on the westside. Stand size is usually quite small. In many cases stands cover only fractions of an acre on rock outcrops; however, some sites appear to be larger than 50 acres such as those near Sherman Pass on the Sequoia National Forest.

Environment

This is a high elevation plant association. Stands characteristically lie above 8,000 feet, and many occur above 8,500 feet. Higher elevations reflect locations in the southern and eastern portions of the study area. Aspects are predominantly northeast and northwest, and the majority of stands are located on upper and middle slopes that exceed 30 percent. Average slopes are considerably steeper than most other associations in the upper montane. Solar radiation levels are generally moderately low to low reflecting steeper slopes and northerly aspects. Micro relief is evenly distributed between sites that are uneven and broken and those which are uniform. Stress indexes are moderately high to high resulting from lower AWC and upper slope positions.

Variable	Mean	Range
Elevation (feet)	8,696	8,000-9,200
Slope (pct.)	39	25-65
Solar radiation index	0.438	0.328-.552
Bare ground (pct.)	3	0-10
Surface gravel (pct.)	6	0-15
Surface rock (pct.)	18	1-60
Litter (pct.)	73	28-89
Litter depth (inches)	1.3	0.5-2.7
Stress index	0.52	0.46-0.56

Aspect: NE, NW.
Range: All.
Position: Upper and middle slopes.
Range: Ridgetops, upper and middle slopes.

Vegetation

Stands are open woodlands with a prominent shrub understory. Shrub cover is significantly higher than most other associations due to the abundance of Sierra chinquapin. Overstory composition is characterized by western white pine mixed with red fir. In some stands western white pine may attain cover as high as 30 percent, but in most cases red fir is the dominant species. Jeffrey pine and white fir are occasional members of stands. Western white pine indicates the drier conditions within this association.

Understories are dominated by Sierra chinquapin in the shrub layer. In some cases greenleaf manzanita is present, and understories appear as a mixed shrub plant community. Both Sierra chinquapin and greenleaf manzanita, however, indicate the drier conditions that prevail on these sites. The forb layer is composed of widely scattered rock cress and an occasional Sierra wallflower. These two species also indicate dry to moderately dry habitats. A single grass species, western needlegrass, occurs with reasonably high constancy, and it, too, indicates drier conditions.

Conifer regeneration is low. The average number of seedlings per acre is slightly more than 125, and often seedling counts are less than 100 trees per acre. Red fir is generally present, but western white pine is only present on some sites, and it occurs in low numbers. Nevertheless, western white pine is regenerating significantly more often in this association.

Plant species diversity is also low. Stands tend to have few species overall, and sites are dominated by relatively few tree species and a shrub layer. The species in these two layers outweigh the cover values of the forb and grass layers. Abundant species are few in number and distributed somewhat uniformly between trees and shrubs on these sites.

The oldest trees in these stands are generally older than 250 years although the average age of stands is not substantially different from most others in the upper montane. The oldest tree sampled was a western white pine at ±364 years, and the oldest red fir was estimated at ±360 years.

Stand replacing disturbances are probably uncommon in this association. The shrub layer favors larger more intense fires, but non-uniform cover in the shrub layer, the setting of many stands on cooler north aspects at high elevations, the structure of the stands with stocking concentrated in relatively large, widely spaced trees, and the natural patchiness of upper elevation stands, tends to preclude large scale, intense fires. These stands probably experience patchy burns with portions of the stand being completely consumed and others left with little damage. Isolated large trees probably escape damage in most cases. Disturbance elements such as windthrow, insects, disease, lightning, or avalanche do not appear to affect large areas in these stands, and they do not generally result in stand replacement.

Reproductive strategies such as consistent seed production or sprouting are present in some species on these sites. Both western white pine and red fir consistently produce seed crops from relatively early ages, and Sierra chinquapin is a sprouting species in the shrub layer. The patchy nature of vegetation within stands results in uneven coverage of sites by many of the disturbance elements, and many plants are left undamaged.

Stand development appears to be sporadic as opportunities for regeneration and growth arise in response to multiple disturbances. Disturbance creates opportunities for regeneration, but many micro habitats are unsuitable for conifer regeneration, and conifer establishment can be a prolonged process on these sites. Isolated patches of conifers that escape repeated disturbance proceed through periods of crown closure and self-thinning. Isolated trees and small patches that escape disturbance eventually mature into larger members of the stand. In time, the stand develops an irregular structure reflecting numerous disturbances, and containing large trees as the survivors of several stand-altering events.

Cover (percent)	*Mean*	*Range*
Total vegetative	70	40-95
Tree	51	26-81
Shrub	29	2-85
Forb	9	0-40
Grass	1	0-4
Moss	0.3	0-1
Stand age (years)	248	142-362
Diversity index		
Simpson	0.31	0.15-0.51
Hill numbers		
N0	8.8	4.0-19.0
N1	4.49	2.37-9.56
N2	3.72	1.98-6.48

Characteristic Vegetation

	Code	*Common name*	*Constancy*	*Percent cover Mean*	*Percent cover Range*
I.	Overstory trees				
	PIMO3	Western white pine	100	13	2-27
	ABMA	Red fir	100	27	12-52
	PIJE	Jeffrey pine	36	9	3-19
	ABCO	White fir	27	22	1-54
II.	Understory trees				
	ABMA	Red fir	100	1	1-1
	PIMO3	Western white pine	36	1	1-1
III.	Shrubs				
	CASE3	Sierra chinquapin	91	19	3-45
IV.	Forbs				
	ARPL	Broad seeded rock cress	73	1	1-1
	PECA5	Cushion penstemon	36	1	1-2
	PYPI	White veined wintergreen	36	1	1-1
	ERPE3	Sierra wallflower	27	1	1-2
V.	Grasses and grass-like				
	STOC1	Western needlegrass	55	2	1-4

Soils

Soils are predominantly Entisols, and they normally fall into two great groups: Xerorthents and Xeropsamments. Particle size classes are commonly skeletal with the remainder being sandy. These classifications are indicative of the relatively high level of coarse fragments throughout the profiles but particularly in the subsoils. Parent materials are generally granitic, but occasional tephra deposits and metamorphic parent materials are also encountered reflecting locations in the south and eastside. Soils in this association are evenly distributed between those formed in place from bedrock and those formed from materials that were deposited as alluvium.

Soil depths are moderately deep to deep. Profiles often exceeded 35 inches, but only on occasion were they deeper than 40 inches. Average topsoil depths are among the shallowest of any in the forested portions of the upper montane. Commonly, topsoils are less than 7 inches, and sometimes depths are less than 4 inches. Textures in all horizons are typically sands with an occasional sandy loam. Coarse fragments in the subsoils tend to be high. Normally they exceed 50 percent.

The AWC on these sites is characteristically low. This association has the lowest average AWC of any in the upper montane. Bedrock is generally fractured and rootable thus supplying additional sources of moisture to the site. Generally, soils in this association are also excessively drained. Erodibility is moderate due to the coarse textures in the surface soils. These soils are substantially more acid in the subsoil than most other sites. Average summertime soil temperatures are significantly warmer than most other forested sites in the upper montane. They often exceed 53° Fahrenheit.

Variable	*Mean*	*Range*
Depth of soil sample (inches)	33	25-40+
Topsoil		
Depth (inches)	6	2-8
Coarse frag. (pct.)	24	2-60
pH	6.2	5.8-6.9
Subsoil		
Coarse frag. (pct.)	43	7-75
pH	5.6	4.8-6.3
AWC (inches)	2.0	0.9-2.8
Temp (20 inches) (Fahrenheit)	53	45-57

Productivity

Site indexes are considerably lower than dense stands elsewhere in these forests. Pacific Southwest Region (Region 5) site indexes are commonly 3 or 4, but few are higher than 2. Stand densities are low. Sites generally carry fewer than 100 trees per acre in all size classes. Stand density indexes are usually less than 300, and stocking levels in this association reach only about 50 percent of the stocking attained in dense forests of the upper montane. This stocking resides on the larger individuals of the stand. Average quadratic mean diameters are among the largest in the upper montane indicative of stocking that is concentrated in larger trees on most sites. Tree heights are also substantially shorter, reflecting overall lower site quality and the presence of western white pine, a shorter tree, in the stands. The combination of lower site index, lower stand density, and shorter trees results in moderately low basal area stocking and cubic and board foot yields.

These stands tend to be open with few trees per acre *(fig. 26)*. Compared to uneven-age distributions with similar stocking levels, these stands have far too few trees in size classes smaller than 18 inches, and an excess of trees in size classes larger than 30 inches. Compared to an even-age distribution, these stands have an excess of trees in both smaller and larger size classes.

Variable	*Mean*	*Range*
Region 5 site index	3	1-5
Forest survey site class	4	2-6
Stand density index	287	196-417
Quadratic mean diameter	26.2	13.4-35.3
Softwood volume (mcf/ac)	7.3	3.5-10.6
Softwood volume (mbf/ac)	48.4	21.8-72.6
Softwood basal area (sq ft/ac)	229	120-320
Hardwood volume (mcf/ac)	0	0
Hardwood basal area (sq ft/ac)	0	0

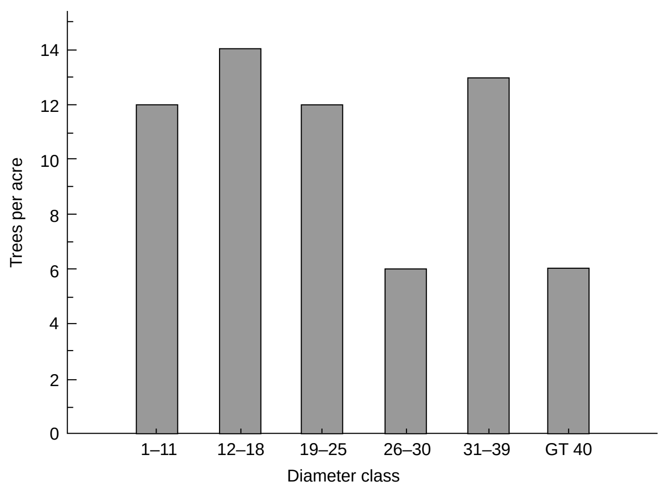


Figure 26—Number of trees by diameter class in the red fir-western white pine/Sierra chinquapin plant association.

Tree species composition by percent of basal area

Species	ABMA	ABCO	PICO	PIJE	PIMO3	TSME
Percent	60	11	3	5	21	-
Species	JUOC	PILA	LIDE3	PIAL	POTR	QUKE
Percent	-	-	-	-	-	-

Coarse Woody Debris

Snag numbers are low indicating the open stand conditions of this association. Snags are distributed primarily in two size classes: those between 18 and 25 inches and those larger than 30 inches, but this is reflective of a generally low number of sample snags in these open stands. Mortality appears to be randomly distributed among all species. Most snags are less than 50 feet in height indicating a tendency for large standing snags to break off over time. They frequently occur in decay classes between 1 and 3. Logs are distributed across all size classes, but most occurred in size classes less than 30 inches. The majority of logs are less than 50 feet in length, and they show higher levels of decay than snags. Log decay classes are typically 4 and 5.

Snags

	Breast Height Diameter Class (inches)						
	<11	***11-17.9***	***18-24.9***	***25-29.9***	***30-39.9***	***>40***	***Total***
Snags per acre	0	0	0.7	0	0.2	0.4	1.3
Snag height (feet)							
<20	-	-	0.4	-	-	0.2	0.6
20-50	-	-	-	-	0.2	0.1	0.3
>50	-	-	0.3	-	-	0.1	0.4
Snag decay class							
1	-	-	-	-	-	-	-
2	-	-	0.4	-	-	0.2	0.6
3	-	-	-	-	0.2	0.1	0.3
4	-	-	0.3	-	-	0.1	0.4
5	-	-	-	-	-	-	-

Logs

	Large End Diameter Class (inches)				
	11-20	***21-30***	***31-40***	***>40***	***Total***
Logs per acre	7.0	7.0	2.0	4.0	20.0
Log length (feet)					
<20	5.0	3.0	-	2.0	10.0
20-50	1.0	2.0	2.0	2.0	7.0
51-100	1.0	2.0	-	-	3.0
>100	-	-	-	-	-
Log decay class					
1	-	-	-	-	-
2	1.0	1.0	-	-	2.0
3	2.0	2.0	-	-	4.0
4	2.0	2.0	-	2.0	6.0
5	2.0	2.0	2.0	2.0	8.0

Wildlife

Forage values appear to be low. Of the species commonly occurring on these sites only western needlegrass is a staple in the big game diet. It occurs with moderate frequency and cover, and it appears to offer only transitory forage possibilities for large game. On the other hand, evidence of deer presence was generally observed in these stands, and signs of pocket gophers were usually encountered as well.

Range

These are transitional range sites that are used by livestock to access primary range sites such as meadows and other moist habitats. Cattle evidence was common in these stands. Western needlegrass is a secondary range species that occurs with moderate constancy and cover. Other shrub, forb, and grass species occurring on these sites, however, are of low value for forage, and it would appear range forage potential is low in these late seral stands.

Management Recommendations

Relatively few stands in this plant association have been harvested. As a consequence, silvicultural systems, cutting methods, regeneration strategies, successional sequences and stocking levels important in the management of any forested stand are relatively unknown. Where stands have been harvested and disturbance has occurred, regeneration patterns are unclear at this time. No sites were observed where harvesting, site preparation, and planting has occurred with any systematic approach.

These stands have limited productive capacity and flexibility for stand management. The open nature of these stands indicates that regeneration and establishment is a lengthy and variable process under most conditions. Recommendations for harvesting at the present time would be to treat stands in this association with caution and the expectation that results can be uncertain. Limited opportunities exist for salvage when it occurs, but on these open sites it would appear that woody debris left in the form of snags and logs for wildlife or part of the nutrient pool would be better direction. Management emphasis should provide for existing wildlife habitat, plant species richness, and the landscape level diversity this association provides to upper montane forests.

Red Fir-Western White Pine-Lodgepole Pine Association

Abies magnifica-Pinus monticola-Pinus contorta

ABMA-PIMO3-PICO
CFRCPW13
Sample size: 25

Distribution

The red fir-western white pine-lodgepole pine plant association straddles the Sierra crest at high elevations throughout the range. Most samples were located on the Inyo and Toiyabe National Forests, but they also occurred at high elevations on the westside. Latitudes were generally north of 37°, and longitudes were generally west of 119°. The most southerly sample was located on the Kern Plateau near Monache Meadows. Stands can be extensive in size, but in most cases, they are smaller than 100 acres.

Environment

Elevations commonly lie above 8,500 feet. This association differs from other stands in the western white pine subseries by occurring at significantly higher elevations, and it occurs at higher elevations than most other plant associations in the upper montane in general. The lowest stand sampled was at 7,640 feet on the Toiyabe National Forest, and the highest was at 9,640 feet on the Inyo National Forest. Most frequently, aspects are northeast and northwest, but south aspects are not uncommon. Slopes are varied and evenly distributed between those that are less than 20 percent and those that are steeper; however, stands can occupy slopes that are quite steep in some cases, and a substantial proportion lie on slopes greater than 40 percent. Stands are typically located on ridges and upper to middle slopes. Rarely are they located on lower slope positions. Microrelief is variable and evenly distributed between sites that are uneven and broken and those that are uniform. This association has significantly higher levels of exposed gravel compared to most other sites. Solar radiation levels are considerably lower than other sites reflecting steep north aspects in many stands.

Variable	Mean	Range
Elevation (feet)	8,602	7,360-9,640
Slope (pct.)	24	3-65
Solar radiation index	0.441	0.319-0.541
Bare ground (pct.)	2	0-12
Surface gravel (pct.)	10	0-55
Surface rock (pct.)	9	0-50
Litter (pct.)	76	17-99
Litter Depth (inches)	1.1	0.6-2.2
Moisture index	0.83	0.52-1.13
Stress index	0.50	0.39-0.60

Aspect: NE, NW.

Range: All.

Position: Ridges and upper and middle slopes.

Range: Ridgetops, upper, middle, lower slopes, and benches.

Vegetation

Stands are moderately dense forests with sparse understories. Tree cover is generally less than other dense forested stands, and total shrub and forb cover are substantially less than other plant associations in the upper montane. The overstory is a mix of western white pine and lodgepole pine with scattered red fir predominants. Western white pine or lodgepole pine rarely have cover values greater than 30 percent individually, but it is the mix of species, and the higher cover of both that distinguishes these stands from other associations. Stands commonly occur with the mountain hemlock and lodgepole pine plant associations on mesic sites, and together they mark the transition into the subalpine forests above. Western white pine is generally a dry site indicator, but lodgepole pine and red fir generally indicate mesic conditions. It is the presence of all species that indicate the dry to mesic conditions present on these sites.

The shrub layer is essentially nonexistent. The forb and grass cover are also quite low, but the species present are indicative of dry to moderate conditions. Thus, broad seeded rock cress occurs on drier sites, and white veined wintergreen indicates moderate sites. Ross' carex, a moderate to dry site indicator, is usually present in the grass layer as well as western needlegrass, a dry site indicator.

Conifer regeneration is moderate to high. The average number of seedlings per acre is nearly 900, and stands generally have some regeneration present. Red fir is the most common species regenerating, and western white pine and lodgepole pine are present in substantially lower numbers. Nevertheless, western white pine and lodgepole pine are regenerating significantly more often on these sites compared to most other associations. Both species are also regenerating with higher frequency than in any other western white pine association.

Plant species diversity in this plant association is moderate. Most stands have a moderate number of species overall; however, stands are dominated by relatively few tree species, and these outweigh the cover values of the shrub, forb, and grass layers in the majority of cases. Abundant species are relatively few in number and distributed predominantly in the tree layer.

The oldest trees in these stands are typically older than 250 years, but average stand ages are not substantially different than most others in the upper montane. The oldest tree sampled was a red fir at $\pm$459 years. This compares with the oldest western white pine at 399 years and the oldest lodgepole pine at 308 years.

Stand replacing events probably occur in this association, but they do not appear to be frequent or large scale phenomena. The setting of many stands on cooler north aspects at high elevations, the structure of the stands with open understories, the presence of relatively large, somewhat fire resistant individuals, and the natural patchiness of the landscape tend to preclude stand replacing fires. Stands probably experience patchy burns with portions of a stand being completely consumed while others are left with little damage. Avalanche can replace stands on middle slopes in this association. Most of these appear to be infrequent and occur at scattered locations across the landscape. Understories generally remain intact. Other disturbance elements such as windthrow, insects, disease, or lightning also do not appear to affect large areas in these stands.

Reproductive strategies such as reasonably constant seed production are present in most of the tree species on these sites. Red fir and western white pine are reasonably consistent seed producers, and lodgepole pine often produces abundant seed. Shade intolerant species such as western white pine and lodgepole pine are undoubtedly maintained by disturbances that open stands and provide seed beds.

Few trees in this association appear to originate as a result of a single disturbance event that uniformly covers the site. Stand development appears to be sporadic as opportunities for regeneration and growth arise in response to disturbance. After disturbance, stands do not go through a prolonged period in a grass/forb or shrub phase, but in most cases conifer regeneration is a process that can occupy a considerable period of time. Once regeneration is established, it grows, self thins, and matures. In time, several size and tree classes, including a substantial portion of larger trees, are represented, and the stand exhibits an irregular structure with many small relatively even-aged patches. As stands occupy sites for longer periods, successive disturbance continues to maintain stand structures until an infrequent stand replacing event occurs and a new stand emerges.

Cover (percent)	*Mean*	*Range*
Total vegetative	73	48-99
Tree	63	37-91
Shrub	1	0-12
Forb	9	1-40
Grass	5	0-33
Moss	0.2	0-2
Stand age (years)	242	109-369
Diversity index		
Simpson	0.36	0.19-0.65
Hill numbers		
N0	10.2	3.0-19.0
N1	4.11	1.74-7.50
N2	3.10	1.54-5.31

Characteristic Vegetation

	Code	Common name	Constancy	Percent cover	
				Mean	**Range**
I.	Overstory trees				
	PIMO3	Western white pine	96	16	4-33
	PICO	Lodgepole pine	88	21	2-48
	ABMA	Red fir	84	33	1-84

Characteristic Vegetation (continued)

	Code	Common name	Constancy	Percent cover Mean	Range
II.	Understory trees				
	PIMO3	Western white pine	88	1	1-2
	ABMA	Red fir	88	4	1-25
	PICO	Lodgepole pine	72	1	1-3
III.	Shrubs				
	None				
IV.	Forbs				
	ARPL	Broad seeded rock cress	72	1	1-5
	PESE3	Pine woods lousewort	52	2	1-15
	PYPI	White veined wintergreen	32	1	1-1
	CHBR3	Brewer's golden aster	24	1	1-2
	LUAN2	Anderson's lupine	20	10	1-35
V.	Grasses and grass-like				
	CARO1	Ross' sedge	64	2	1-10
	STOC1	Western needlegrass	36	2	1-8
	POGR1	Pacific bluegrass	32	5	1-25
	PONE1	Hooker's bluegrass	20	1	1-2

Soils

Soils are Entisols and Inceptisols, and although Inceptisols are often present, significantly higher proportions of Entisols are encountered compared to most other associations. Taxonomically, these soils are variable at the suborder and great group levels. Orthents occurred in the highest number of samples with nearly 38 percent, but the remaining samples were distributed between Umbrepts, Ochrepts, and Psamments. Particle size classes show similar variation. They tend to be skeletal, but sandy, loamy, and ashy size classes also occur often, and collectively they are more common than skeletal size classes. Parent materials too are derived from a variety of sources. Thus, samples were often found on granitic parent materials, but a significant proportion occurred on the volcanic flows and lahars of the north and the tephra and ash deposits of the Mammoth Mountain region. Soils are formed in place from bedrock or in almost equal portions from colluvial deposits.

These soils are moderately deep to deep. Seldom were they less than 25 inches, and commonly they were deeper than 40 inches. Topsoil depths, however, are among the shallowest of any in the forested portions of the upper montane. Topsoils are commonly less than 7 inches, and on some sites depths were less than 4 inches. Textures in the topsoil are usually gravelly sands with occasional sandy loams. Subsoil textures are similar except they contain an even higher proportion of sands. Soils in this association are significantly sandier in all horizons than most others in the upper montane. Subsoil colors are primarily 10 YR in hue, but they have significantly higher values than most other associations. Such subsoils range from light brownish gray to brownish yellow when moist.

The AWC of these sites is frequently low due to the coarse textured soils, although average water holding capacities are not substantially lower than in many other associations. Parent materials are characteristically fractured and rootable and provide additional sources of moisture to these stands. The majority of sites are excessively drained, and erodibility is low to moderate due to coarse soil textures. As slopes increase above 30 percent, erodibility on these soils becomes moderate to high.

Variable	Mean	Range
Depth of soil sample (inches)	35	19-40+
Topsoil		
Depth (inches)	6	3-16
Coarse frag. (pct.)	28	5-95
pH	5.9	4.8-6.5
Subsoil		
Coarse frag. (pct.)	38	1-87
pH	5.9	5.0-7.2
AWC (inches)	2.7	0.6-5.5
Temp (20 inches) (Fahrenheit)	50	34-64

Productivity

Site indexes are variable, but they are generally lower than most other stands in the study area. Pacific Southwest Region (Region 5) site indexes were commonly 3 or 4, but often they were as low as 4 or 5, and rarely better than 3. Stand densities are moderate to high compared to other dense forested stands in the upper montane. Stand density indexes are usually greater than 400, and based on stand density indexes, stocking levels can be as high as 80 percent of those reached in fully stocked stands of the red fir-white fir association, one of the densest in these forests. Tree heights and average stand diameters are considerably smaller than many other stands, reflecting the presence of shorter and smaller diameter western white pine and lodgepole pine. The tallest western white pine and lodgepole pine, for example, measured 110 feet and 100 feet, respectively, compared to the tallest red fir of 150 feet. The quadratic mean diameter is also substantially less than most other dense forested stands reflecting a higher number of small trees that is often present. Yields resulting from this combination of factors are considerably lower than typical red fir or red fir-white fir stands in the study area.

Although many stands appear even-aged, this association in general approximates an uneven-aged distribution *(fig. 27)*; however, as is typical for most stands in these forests, when compared to uneven-aged stands with similar stocking levels and balanced diameter distributions, they have a deficit of trees in size classes smaller than 18 inches. Compared to an even-age distribution with equivalent stocking levels, both smaller size classes and larger size classes are over-represented.

Variable	*Mean*	*Range*
Region 5 site index	4	2-5
Forest survey site class	5	3-6
Stand density index	425	114-659
Quadratic mean diameter	18.2	8.9-30.7
Softwood volume (mcf/ac)	7.0	2.0-15.2
Softwood volume (mbf/ac)	42.0	11.0-105.3
Softwood basal area (sq ft/ac)	287	88-453
Hardwood volume (mcf/ac)	0	0
Hardwood basal area (sq ft/ac)	0	0

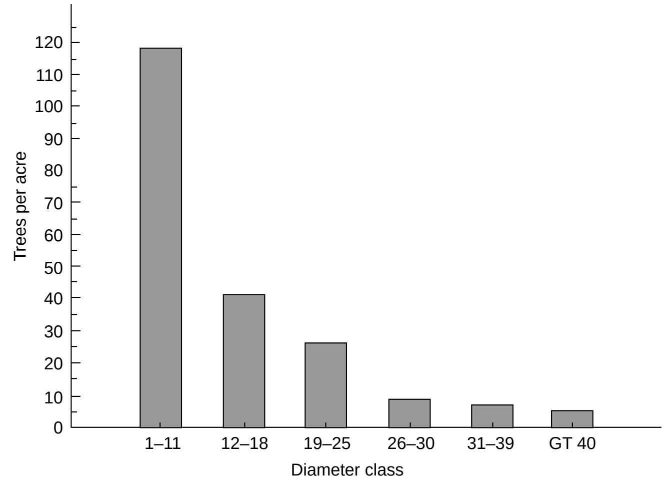


Figure 27—Number of trees by diameter class in the red fir-western white pine-lodgepole pine plant association.

Tree species composition by percent of basal area

Species	ABMA	ABCO	PICO	PIJE	PIMO3	TSME
Percent	43	1	31	-	23	1
Species	JUOC	PILA	LIDE3	PIAL	POTR	QUKE
Percent	-	-	-	1	-	-

Coarse Woody Debris

Snag numbers are moderate to low. Mortality is distributed across all size classes and species. It appears to be related to thinning in smaller size classes and senescence in larger size classes. Snags are commonly shorter than 50 feet indicating a tendency of larger standing snags to break off over time. Most lie in decay classes between 1 and 3. Logs are distributed in all size classes as well, but many are smaller than 30 inches, indicating losses from smaller western white pine and lodgepole pine. Generally, logs are less than 50 feet in length, and they show higher levels of decay than snags. Decay classes 4 and 5 are relatively common.

Snags

	Breast Height Diameter Class (inches)						
	<11	*11-17.9*	*18-24.9*	*25-29.9*	*30-39.9*	*>40*	*Total*
Snags per acre	1.3	0.8	0.6	0.4	1.0	1.1	5.2
Snag height (feet)							
<20	1.1	0.4	0.2	0.1	-	0.8	2.6
20-50	0.2	0.3	0.2	0.1	0.6	-	1.4
>50	-	0.1	0.2	0.2	0.4	0.3	1.2
Snag decay class							
1	0.6	-	0.1	0.1	0.4	0.2	1.4
2	-	0.3	0.2	0.1	0.2	0.3	1.1
3	0.6	0.3	0.1	0.1	0.2	0.2	1.5
4	0.1	0.2	0.1	0.1	0.2	0.4	1.1
5	-	-	0.1	-	-	-	0.1

Logs

	Large End Diameter Class (inches)				
	11-20	**21-30**	**31-40**	**>40**	**Total**
Logs per acre	3.5	15.2	3.5	3.0	25.2
Log length (feet)					
<20	1.5	5.5	0.8	1.0	8.8
20-50	1.8	7.2	2.0	1.0	12.0
51-100	0.2	2.5	0.7	1.0	4.4
>100	-	-	-	-	-
Log decay class					
1	-	-	-	-	-
2	-	1.0	0.2	0.5	1.7
3	1.3	5.0	0.7	0.8	7.8
4	1.2	3.7	1.3	0.7	6.9
5	1.0	5.5	1.3	1.0	8.8

Wildlife

Big game forage appears to be moderate to low. Shrubs are absent, and Anderson's lupine is the only staple forage species occurring in the forb layer. Hooker's bluegrass is a preferred forage species that occurs with low frequency and cover in the grass layer. Ross' sedge and western needlegrass are staple forage species for large game that occur with higher levels of frequency and cover and may provide a reliable source of forage. Evidence of deer presence was generally observed on these sites, and pocket gopher presence was usually observed as well.

Range

These are transitional range sites that are used by livestock to access primary range forage sites such as meadows and other moist habitats. Cattle evidence on these sites was quite common. The only primary forage species is Hooker's bluegrass that occurs with low frequency and cover. Western needlegrass, a secondary range species, is also present on occasion, and it may provide a part of the diet when available. Other shrubs, forbs, and grasses occurring on these sites are of low value for range forage, and it appears range forage potential is low in these late seral stands.

Management Recommendations

Few stands in this association have been harvested, and a clear picture of regeneration strategies, successional sequences, and stocking levels important in management have not been developed. Early succession does not appear to result in high shrub or grass cover in most cases.

These stands have moderate productive capacity and flexibility for stand management. Stand structures are variable, but the ability of sites to respond to treatment is uncertain, and the ability to predict results of treatment are not based on wide experience or research results at this time. Recommendations for harvesting at present would be to treat stands with caution by keeping harvest units small and seed supply close. Natural regeneration of existing species should be encouraged whether sites are planted or not, and extensive time periods should be expected for regeneration success. Jeffrey pine would not be a preferred species to plant. Particularly on sites with low site index, management emphasis directed at maintaining existing wildlife habitat, species richness, and the landscape level diversity this association provides may be more appropriate.

Red Fir-Western White Pine Association

Abies magnifica-Pinus monticola

ABMA-PIMO3
CFRCPW11
Sample size: 35

Distribution

The red fir-western white pine plant association is located at higher elevations throughout the central and southern Sierra Nevada. It becomes more common on the landscape south of Kaiser pass in a region where mountain hemlock begins to diminish in abundance, and it appears to replace mountain hemlock in the landscape as one continues south. Stands can be somewhat extensive, but in most cases they appear to be less than 50 acres in size.

Environment

This association is commonly located at elevations above 8,000 feet. This reflects somewhat higher occurrences in the southern portion of the range where elevations for similar plant associations in general tend to be higher. The lowest elevation sampled was on the Eldorado National Forest; whereas, the highest elevation sampled was on the Sequoia National Forest. Aspects can be varied, but sites typically face northeast and northwest. Slopes are generally moderate. Most stands lie on slopes of less than 35 percent, and often they lie on slopes less than 20 percent. Stands occur generally on ridges and upper to middle slope positions where microrelief is smooth and uniform. SRI values are moderately low to low reflecting northerly aspects. Stress indexes are moderately high and reflect combinations of drier soils but lower SRIs.

Variable	*Mean*	*Range*
Elevation (feet)	8,465	7,140-9,520
Slope (pct.)	25	2-60
Solar radiation index	0.458	0.301-0.542
Bare ground (pct.)	4	0-36
Surface gravel (pct.)	7	0-75
Surface rock (pct.)	8	0-63
Litter (pct.)	80	15-99
Litter depth (inches)	1.2	0.2-3.8
Stress index	0.51	0.33-.61

Aspect: NE, NW.

Range: All.

Position: Ridges, upper and middle slopes.

Range: All.

Vegetation

Stands are moderately dense forests with little understory vegetation. Tree cover is substantially higher than other western white pine associations. Overstory layers are characterized by the presence of western white pine in mix with red fir. In rare stands western white pine may comprise nearly 50 percent of the crown cover, but generally red fir has the highest cover values. Nevertheless, it is the relatively higher cover values for western white pine that distinguishes stands from other associations. Western white pine in general is a dry site indicator, and it differentiates this association which is a drier habitat than many others.

Understories are quite open. The shrub layer is essentially absent. On a few sites in the northwestern portion of the study area, huckleberry oak or, on the eastside, snowbrush constitute a substantial shrub layer, but generally this is not the case. The sparse forb component is distinguished by the presence of Brewer's golden aster and broad seeded rock cress, which are dry site indicators. Occasionally, western pennyroyal and Sierra wallflower which also indicate drier sites are present. The grass layer is also very sparse, but it is characterized by dry site indicators such as bottle brush squirreltail and western needlegrass.

Conifer regeneration is relatively high. The average number of seedlings per acre was over 900, and usually there are more than 500 seedlings per acre occurring naturally. Regeneration is dominated by red fir which is almost always present. Western white pine is often present as well, but this species occurs in far fewer numbers than red fir. Both red fir and western white pine, however, are regenerating significantly more often than in other associations.

Plant species diversity is low. Stands often have few species overall, and sites are commonly dominated by relatively few tree species with cover values that far outweigh those in the shrub, forb, and grass layers. Thus, abundant species are few in number and concentrated in the tree species.

The oldest trees in these late seral stands are commonly older than 250 years, although average stand ages are not substantially different than most other associations in the upper montane. The oldest tree sampled was a red fir at $\pm$585 years, and the oldest western white pine was $\pm$359 years.

Stand replacing disturbance events probably occur in this association, but they do not appear to be frequent or large scale phenomena. The setting of many stands on cooler north aspects at high elevations, the structure of the stands with open understories, the presence of relatively large, somewhat fire resistant individuals, and the natural patchiness of the landscape tend to preclude such fire related events over large areas. Stands probably experience patchy burns with portions of a stand being completely consumed and others left with little damage. Avalanche can replace stands in this association on middle and lower slopes. Most of these appear to be somewhat infrequent and occur at scattered locations across the landscape. Understories, including smaller trees, generally remain intact. Other disturbance elements such as windthrow, insects, disease, and lightning also do not appear to affect large areas in these stands. It is likely that disturbance occurs continuously at various scales, and this results in the creation of various sized gaps with constantly changing structures through time.

Reproductive strategies such as reasonably constant seed production are present in most of the tree species on these sites. Since red fir is shade tolerant, understory trees can occupy sites for long periods of time. Shade intolerant species such as western white pine are undoubtedly maintained by disturbance that open stands and provide seed beds.

Few trees in this association appear to originate as a result of a single disturbance that uniformly covers the site. Stand development appears to be sporadic as opportunities for regeneration and growth arise in response to disturbance. After disturbance stands do not seem to go through a prolonged period in a grass/forb or shrub phase, but in most cases it also appears conifer regeneration is a process that can occupy a considerable period of time. Once regeneration is established it grows, self-thins, and matures while other portions of the stand continue to undergo disturbance. In time, several size and tree classes, including a substantial portion of larger trees, are represented, and the stand exhibits an irregular structure with many small relatively even-aged patches. As stands occupy sites for longer periods, successive disturbance continues to maintain stand structures until an infrequent stand replacing event occurs and a new stand emerges.

Cover (percent)	*Mean*	*Range*
Total vegetative	75	24-99
Tree	66	20-91
Shrub	2	0-35
Forb	7	0-47
Grass	2	0-13
Moss	0.1	0-2
Stand age (years)	255	100-448
Diversity index		
Simpson	0.51	0.16-0.80
Hill numbers		
N0	8.9	2.0-19.0
N1	3.17	1.58-8.82
N2	2.36	1.25-6.32

Characteristic Vegetation

			Percent cover	
Code	*Common name*	*Constancy*	*Mean*	*Range*
I. Overstory trees				
PIMO3	Western white pine	100	15	5-56
ABMA	Red fir	100	50	10-84
II. Understory trees				
ABMA	Red fir	97	4	1-25
PIMO3	Western white pine	54	1	1-1
III. Shrubs				
None				

Characteristic Vegetation (continued)

Code	Common name	Constancy	Percent cover Mean	Percent cover Range
IV. Forbs				
PESE3	Pine woods lousewort	60	1	1-3
ARPL	Broad seeded rock cress	49	1	1-3
CHBR3	Brewer's golden aster	49	1	1-2
MOOD	Mountain pennyroyal	34	2	-18
PHHY	Waterleaf phacelia	31	1	1-1
ERPE3	Sierra wallflower	23	1	1-1
PYPI	White veined wintergreen	23	1	1-3
V. Grasses and grass-like				
SIHY	Bottle brush squirreltail	23	2	1-10
STOC1	Western needlegrass	23	1	1-2
CARO1	Ross' sedge	20	1	1-3

Soils

Most soils are Inceptisols. Entisols are occasionally encountered. Inceptisols are normally described as Xerumbrepts or Xerochrepts, and most of the Entisols are Xerorthents. This association differs from other western white pine associations in containing a higher frequency of soils classified as Inceptisols. Particle size classes are essentially skeletal indicating the somewhat higher levels of coarse fragment contents in the subsoils. Parent materials are usually granite; however, volcanic, metamorphic, or mixed parent materials can be encountered in some cases. These soils are often formed in place from bedrock, but occasional sites are formed from materials that have been deposited as alluvium or glacial till.

The majority of soils in this association are moderately deep to deep. Depths in nearly one-half of the samples exceeded 40 inches, and rarely were depths of less than 25 inches encountered. Topsoils, on the other hand, are shallow. Average topsoil depths are some of the lowest in the upper montane, and usually they are less than 7 inches in this association. Topsoil textures are commonly sandy loams with occasional gravelly sands and gravelly loams. Typical subsoils are sandy loams that are often stoney, cobbly, and gravelly. Occasional subsoils are also gravelly sands, and a few are gravelly loams. Average coarse fragment contents in subsoils are among the highest in the upper montane. They commonly exceed 35 percent. Subsoil pH is also substantially more acid in this association compared to many other upper montane sites.

The AWC of these sites is moderately low to low reflecting coarser and sandier soil textures. Soils in this association are uniformly distributed between those that are well drained and those that are excessively drained. Erodibility is often moderate due to the coarse soil textures. Parent materials are also evenly divided between those that are unfractured and unrootable and those which are fractured and rootable. Stress indexes reflect coarser textured soils and lower levels of AWC.

Variable	*Mean*	*Range*
Depth of soil sample (inches)	34	16-40+
Topsoil		
Depth (inches)	7	3-15
Coarse frag. (pct.)	22	2-55
pH	5.9	4.5-6.8
Subsoil		
Coarse frag. (pct.)	49	10-98
pH	5.5	4.5-6.4
AWC (inches)	2.5	0.4-5.0
Temp (20 inches) (Fahrenheit)	49	39-57

Productivity

The average Pacific Southwest Region (Region 5) site index is 3 in this association. However, stands are frequently less than 3, and rarely are they higher. Stand densities are moderately high. Stand density indexes are usually greater than 400. Stocking levels based on stand density indexes can be nearly 80 percent of those attained in fully stocked red fir-white fir stands which are some of the densest in the upper montane. Quadratic mean diameters are among the largest in the upper montane and reflect the presence of many large trees in these stands. Tree heights, however, are substantially lower than dense forested stands elsewhere in the study area. They reflect the presence of both western white pine, a shorter tree, as well as generally lower site indexes. Cubic foot and board foot volumes are moderate reflecting the interaction of higher stand density and shorter trees. Compared to other stands in the western white pine subseries, this association carries considerably higher stocking levels and yields.

Stand structures in many individual sites appear even-aged; however, overall stands approach an uneven-age distribution *(fig. 28)*. Compared to a balanced uneven-age distribution with similar stocking levels, trees in size classes below 18 inches are under-represented, and trees in size classes larger than 30 inches are over-represented. They contain more trees in both the smaller and larger size classes than would be appropriate with an even-age distribution.

Variable	*Mean*	*Range*
Region 5 site index	3	1-5
Forest survey site class	4	2-6
Stand density index	411	135-723
Quadratic mean diameter	24.8	11.0-35.8
Softwood volume (mcf/ac)	10.3	2.8-25.7
Softwood volume (mbf/ac)	69.0	17.5-185.7
Softwood basal area (sq ft/ac)	316	80-600
Hardwood volume (mcf/ac)	0	0
Hardwood basal area (sq ft/ac)	0	0

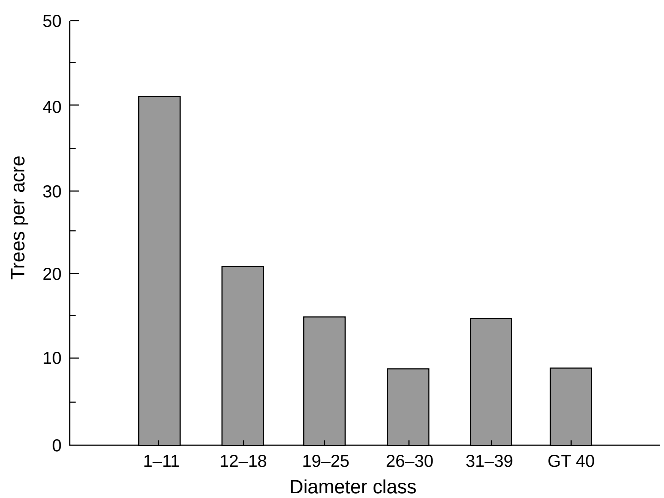


Figure 28—Number of trees by diameter class in the red fir-western white pine plant association.

Tree species composition by percent of basal area

Species	ABMA	ABCO	PICO	PIJE	PIMO3	TSME
Percent	76	1	3	-	20	-
Species	JUOC	PILA	LIDE3	PIAL	POTR	QUKE
Percent	-	-	-	-	-	-

Coarse Woody Debris

Snag numbers are moderate to high, and they are distributed among all size classes. Snags in size classes less than 11 inches are abundant reflecting self-thinning within small patches of sapling and pole size trees. Mortality is distributed randomly among the species present. Snag heights and decay classes are also distributed among all classes, but snags in this association are typically less than 50 feet in height, and they occur in decay classes 1 and 2. Logs are also distributed among all size classes. They are generally shorter than 50 feet in length, and they show higher levels of decay than snags. Decay classes between 3 and 5 predominate.

Snags

	Breast Height Diameter Class (inches)						
	<11	***11-17.9***	***18-24.9***	***25-29.9***	***30-39.9***	***>40***	***Total***
Snags per acre	8.5	1.1	1.6	0.6	0.5	0.8	13.1
Snag height (feet)							
<20	7.1	-	-	0.3	0.3	-	7.7
20-50	1.4	0.5	-	0.1	0.1	0.5	2.6
>50	-	0.6	1.6	0.2	0.1	0.3	2.8
Snag decay class							
1	7.1	-	-	0.1	-	-	7.7
2	-	1.1	1.6	0.1	0.1	0.3	3.2
3	1.4	-	-	0.2	0.2	0.5	2.3
4	-	-	-	0.1	0.1	-	0.2
5	-	-	-	0.1	0.1	-	0.2

Logs

	Large End Diameter Class (inches)				
	11-20	***21-30***	***31-40***	***>40***	***Total***
Logs per acre	2.5	7.5	3.5	2.0	15.5
Log length (feet)					
<20	1.5	5.0	2.0	1.5	10.0
20-50	0.5	1.0	1.0	-	2.5
51-100	0.5	1.5	0.5	-	2.5
>100	-	-	-	0.5	0.5
Log decay class					
1	-	-	-	-	-
2	-	-	-	0.5	0.5
3	1.5	3.0	-	-	4.5
4	1.0	4.0	3.0	1.5	9.5
5	-	0.5	0.5	-	1.0

Wildlife

These stands may offer hiding and thermal cover to large game, but forage possibilities appear transitory. Of the species occurring in this type few are preferred wildlife forage. Waterleaf phacelia in the forb component and bottle brush squirreltail, western needlegrass, and Ross' sedge in the grass component are staple parts of the large game diet. Constancy and cover values for these species, however, are relatively low. On the other hand, evidence of deer and pocket gopher presence was common in these stands.

Range

These are transitional range sites that are used by livestock to access primary range such as meadows and other moist habitats. Bottle brush squirreltail and western needlegrass are secondary forage species, but constancy and cover values are low. No other commonly occurring species in this association are of primary or secondary range value. Range forage potential is low in these late seral stands although cattle presence in this association was quite common.

Management Recommendations

Relatively few stands in this association have been harvested for long enough periods to develop a clear picture of appropriate silvicultural systems, cutting methods, regeneration techniques, successional sequences, and stocking controls important in management. In a few cases clearcutting under the even-age silvicultural system has been used. Practices on these sites included planting Jeffrey pine. In general, Jeffrey pine plantings have not been successful. Regeneration strategies for planting red fir or western white pine have not been developed for this association. Natural regeneration from both red fir and western white pine seems to be abundant as long as stand sizes are kept small. Early succession does not seem to result in high shrub or grass cover in most cases.

These stands have moderate productive capacity and flexibility for stand management. Stand structures are variable, but the ability of sites to respond to treatment is uncertain, and the ability to predict results of treatment are not based on wide experience or research results at this time. Recommendations for harvesting on high sites at present would be to treat such stands with caution by keeping stand size small and adjacent seed supply close. Topsoils can be shallow on many sites, and site preparation should be done with care. Jeffrey pine would not be a preferred species to plant. Natural regeneration of existing species should be encouraged whether sites are planted or not. On poorer sites management emphasis may be more appropriately directed at maintaining existing wildlife habitat and the landscape level diversity this association provides.

White Fir-Sugar Pine-Red Fir Association

Abies concolor-Pinus lambertiana-Abies magnifica

ABCO-PILA-ABMA
CFWCPR11
Sample size: 33

Distribution

The white fir-sugar pine-red fir plant association is widespread at lower elevations in the upper montane. Stands are located only on westside forests, and they define the transition into upper montane forests from white fir-sugar pine dominated communities that lie at lower elevations. Latitudes and longitudes span the range of the study area. Stands can be quite extensive such as those near Crane Flat in Yosemite National Park, but most are smaller and probably cover less than 50 acres.

Environment

This association occurs at the lowest elevations in the upper montane, and it often serves to identify the transition into the upper montane from lower elevations. It typically occurs below 7,500 feet. The lowest elevation observed was at 5,860 feet on the Eldorado National Forest, and the highest was on the Sequoia National Forest at 7,880 feet. Aspects and slopes are varied, but solar radiation levels are among the lowest in the upper montane. Typically, sites are located on middle and lower slope positions, reflecting a tendency for stands to be located in cold air drainages at lower elevations. Microrelief is commonly undulating or hummocky. This association has significantly less bare ground and surface gravel than most other sites, and litter depths are among the highest of the upper montane forests, reflecting higher levels of tree cover and debris on the forest floor which is characteristic of these stands. Stress indexes are not substantially different than most other sites, and they indicate moderate levels of moisture stress.

Variable	*Mean*	*Range*
Elevation (feet)	6,881	5,860-7,880
Slope (pct.)	27	3-60
Solar radiation index	0.477	0.326-0.582
Bare ground (pct.)	0.8	0-3
Surface gravel (pct.)	0.9	0-10
Surface rock (pct.)	3	0-20
Litter (pct.)	95	80-99
Litter depth (inches)	1.9	0.2-5.5
Stress index	0.51	0.35-0.62

Aspect: All.

Range: All.

Position: Middle and lower slopes.

Range: All.

Vegetation

Stands are dense multilayered forests with a moderate cover of understory shrubs and forbs. Total vegetative cover is high in conjunction with tree cover, which is considerably higher than most associated stands. These stands are often adjacent to and interspersed with the red fir-white fir and redfir-white fir-Jeffrey pine associations on mesic sites. The overstory is characterized by red fir in mix with several other conifer species. White and red fir are generally dominant both in frequency of occurrence and cover. Sugar pine is a characteristic species, although it typically occurs as widely scattered predominants, resulting in lower constancy. Jeffrey pine and incense cedar are occasionally present as well, and incense cedar can be used as an indicator of the association when present. Black oak is a seldom occurring but useful hardwood indicator of the association as well. Often sugar pine, incense cedar, or black oak are all present, but it is the occurrence of sugar pine or incense cedar in mixture with red fir that indicates the association.

Understories are a mix of species indicating variation in site conditions from dry to mesic. Understory shrubs commonly occupy between 5 and 25 percent cover as scattered individuals and patches. This layer is typically characterized by relatively high constancy and cover of Sierra chinquapin, which is a dry site indicator. Individual sites can be dominated by Sierra chinquapin, or on occasion, pinemat or greenleaf manzanita. Although these species occur less often, they are also indicators of drier conditions when present. The occasional appearance of creeping snowberry and Sierra gooseberry confirm mesic conditions when present. White-veined wintergreen, Kellogg’s bedstraw, white flowered hawkweed, and western bracken fern are all forb species that are usually present in moist habitats. The grass cover is essentially absent, but the rare occurrences of Bolander’s bluegrass or blue wildrye are useful in distinguishing moderate conditions.

An important element in the understory of these stands is the presence of several shrub and forb species that occur at low constancy and can dominate sites after disturbance. In the shrub layer these are species such as mountain whitethorn, bittercherry, and Sierra chinquapin. In the forb layer western bracken fern, Drew’s silky lupine, Anderson’s lupine, and broad leaved lupine are further examples.

Conifer regeneration is moderate. The average number of seedlings is 448 per acre, and stands commonly contain more than 100 per acre. The majority of sites have white and red fir regeneration occurring at relatively high levels and in equal abundance. Sugar pine and incense cedar are occasionally present but in numbers substantially below those of white and red fir. Jeffrey pine is a rare occurrence in the regeneration layer, reflecting lower presence in the overstory and the effects of high cover on this shade intolerant species. White fir, sugar pine, and incense cedar are regenerating significantly more often than in other plant associations.

Plant species diversity is moderate. When compared to other associations in the upper montane, the total number of species is mid-range. Diversity in these stands resides in the overstory tree species that far outweigh cover values of the shrubs, forb, and grass layers. Abundant species are moderate in number, and they are concentrated in the trees species.

The oldest trees in these stands are often older than 250 years, but the average age of stands is significantly younger than most other associations in these forests. The oldest tree sampled was an incense cedar at ±530 years Other older individuals in these stands were a white fir at ±348 years, a redfir at ±252 years, and a sugar pine at ±248 years. These ages are typical of upper montane forests in general. The reason for the relatively younger average stand ages is unclear. Higher numbers of younger trees in the overstory obviously contributes to this, but the origin of these younger trees is somewhat obscure at present. It is possible that historically higher fire frequency associated with lower elevations maintained a substantial number of young trees in these stands.

Since stands lie adjacent to lower montane forests with high fire frequency and intense burns, stand replacing fires probably occur in this association more frequently than many others in the upper montane. However, the location of many stands on lower and middle slope positions or along drainage bottoms, and the structure of the stands with relatively large, somewhat fire resistant individuals tend to preclude large scale loss of all individuals from most fires. Stands probably experience both small scale patchy burns with occasional large scale stand replacing fires. Both patterns can be observed in existing stand structures.

Other disturbance elements such as windthrow and avalanche are not widespread features of these stands. Insects, disease, and lightning are more common, but mortality from these factors often occurs in localized situations or in select species. Disturbance occurs continuously on various scales in these stands. This results in the creation of various sized gaps with constantly changing structures through time.

Reproductive strategies such as reasonably constant seed production is present in most of the tree species in these stands. Other reproductive strategies, such as sprouting or delayed germination of seed until scarified by fire, are also present in many of the shrub species on these sites. Sierra chinquapin is a sprouting species for example. Shade intolerant species such as Jeffrey pine are undoubtedly maintained by disturbances that open stands and provide seed beds.

Stand development appears to be sporadic as opportunities for regeneration and growth arise in response to disturbance. After disturbance, the most likely successional sequence involves early dominance by shrubs, forbs, and grass. These early communities can be quite persistent, and replacement by trees can be a prolonged process. Once regeneration is established, however, it grows, self-thins, and matures while other portions of the stand continue to undergo disturbance. In time, a patchy distribution of trees emerges with several size and tree classes represented, including a substantial portion of larger trees. The stand exhibits an irregular structure with small relatively even-aged patches distributed throughout. As stands occupy sites for longer periods, successive disturbance continues to develop and maintain these structures until an infrequent stand replacing event occurs and a new stand emerges.

Cover (percent)	Mean	Range
Total vegetative	85	62-98
Tree	76	37-93
Shrub	12	0-66
Forb	7	0-41
Grass	0.5	0-2
Moss	0.3	0-3
Stand age (years)	187	76-379
Diversity index		
Simpson	0.39	0.16-0.73
Hill numbers		
N0	10.7	3.0-21.0
N1	4.76	1.67-8.97
N2	3.14	1.37-6.23

Characteristic Vegetation

				Percent cover	
	Code	Common name	Constancy	Mean	Range
I.	Overstory trees				
	ABCO	White fir	97	33	3-81
	ABMA	Red fir	97	32	1-81
	PILA	Sugar pine	61	13	1-34
	PIJE	Jeffrey pine	21	19	7-41
	LIDE3	Incense cedar	15	13	7-21
II.	Understory trees				
	ABMA	Red fir	85	1	1-8
	ABCO	White fir	82	1	1-6
	PILA	Sugar pine	45	1	1-1
	LIDE3	Incense cedar	30	1	1-1
III.	Shrubs				
	CASE3	Sierra chinquapin	67	10	1-65
	SYAC	Creeping snowberry	27	5	1-19
	RIRO	Sierra gooseberry	21	1	1-4
IV.	Forbs				
	PYPI	White veined wintergreen	67	1	1-2
	KEGA	Kellogg's bedstraw	42	1	1-4
	PTAQ	Western bracken fern	42	6	1-35
	HIAL	White flowered hawkweed	36	1	1-4
	PESE3	Pine woods lousewort	36	1	1-1
	COMA4	Spotted coral root	30	1	1-1
	APMEF	Western dogbane	27	1	1-1
	CHBR3	Brewer's golden aster	27	1	1-2
	PHHY	Waterleaf phacelia	24	1	1-1
V.	Grasses and grass-like				
	None				

Soils

Soils are commonly Inceptisols. These soils usually lie in the Xerumbrept great group, but Xerochrepts can be encountered on occasion. Entisols and Alfisols are of minor occurrence, and most are Orthents, Psamments, and Xeralfs. Particle size classes are distributed almost evenly between skeletal and loamy, indicative of moderate levels of larger sized coarse fragments in the profile. Typical soils are derived from granitic parent materials and rarely from volcanic, metamorphic, or sedimentary substrates. Most of these soils are formed in place from bedrock. Glacial till and colluvial deposits occur on infrequent sites.

Soils are deep. More than 50 percent of the sample sites had soils that exceeded 40 inches. Rare sites had depths less than 30 inches. Soil textures in the topsoil are characteristically sandy loams or loams with rare sands and sandy clay loams also present. Topsoils, however, contain a significantly higher proportion of cobbles and gravels in the horizon. Subsoil textures are similar to topsoils, but they contain higher proportions of sands and fewer loams, and they also have higher proportions of cobbles and gravels.

The AWC of these sites ranges considerably; average values, however, are not substantially different from most other sites. They can be considered to be moderate and reflect the variation in soil textures and coarse fragment content of individual sites. Bedrock below the soil profile is typically fractured and rootable providing additional sources of water, and most sites are well drained. Stands with excessive drainage often lie on steep slopes with sandy textures. Erodibility ranges from moderate to high in response to soil textures or slope steepness.

Variable	*Mean*	*Range*
Depth of soil sample (inches)	37	26-40+
Topsoil		
Depth (inches)	10	3-24
Coarse fragments (pct.)	23	5-75
pH	6.2	5.1-7.2
Subsoil		
Coarse fragments (pct.)	38	5-80
pH	6.0	5.3-7.0
AWC (inches)	3.4	0.8-6.6
Temp (20 inches) (Fahrenheit)	49	42-59

Productivity

Site indexes are very high. They are substantially higher than most others, and they are comparable to the red fir-white fir association that consistently has some of the highest site indexes in the upper montane. Commonly, Pacific Southwest Region (Region 5) site indexes are 1 or better. Rare stands had site indexes lower than 2. Stand densities are also high. Stand density indexes frequently exceed 400, and average stocking levels based on stand density indexes are nearly 90 percent of those attained in a fully stocked red fir-white fir stand. Trees are also considerably taller than those in most associated stands reflecting better site indexes. Heights of the tallest trees measured in this association, for example, were 212 feet for red fir, 203 feet for white fir, and 174 feet for the tallest sugar pine. Cubic and board foot yields are among the highest in the upper montane, and they compare favorably to values attained in the most productive associations in these forests.

Most stands are irregular in structure, and distributions tend to approach those of an uneven-aged stand *(fig. 29)*. Compared to uneven-aged stands with similar stocking and balanced diameter distributions, trees in size classes smaller than 18 inches are higher in number than expected, although they also carry more trees in size classes larger than 35 inches. Compared to an even-aged distribution with similar stocking levels, both smaller and larger size classes are over-represented. Stands closely parallel the distributions of trees in the red fir association.

Variable	*Mean*	*Range*
Region 5 site index	1	0-3
Forest survey site class	2	1-4
Stand density index	458	99-824
Quadratic mean diameter	24.4	11.3-39.8
Softwood volume (mcf/ac)	13.5	1.1-24.3
Softwood volume (mbf/ac)	97.3	20.1-175.8
Softwood basal area (sq ft/ac)	347	88-587
Hardwood volume (mcf/ac)	0	0
Hardwood basal area (sq ft/ac)	0	0

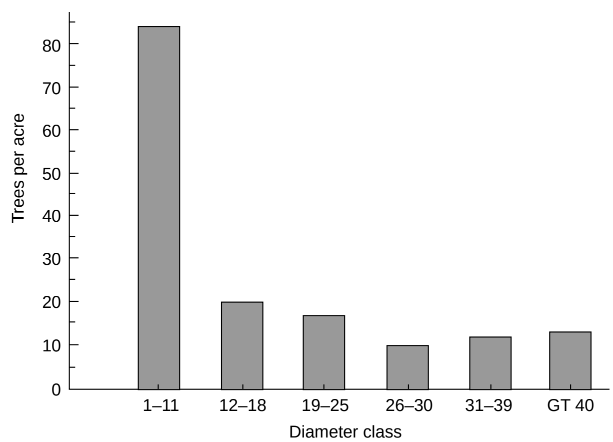


Figure 29—Number of trees by diameter class in the white fir-sugar pine-red fir plant association.

Tree species composition by percent of basal area

Species	ABMA	ABCO	PICO	PIJE	PIMO3	TSME
Percent	41	41	-	6	-	-
Species	JUOC	PILA	LIDE3	PIAL	POTR	QUKE
Percent	-	9	3	-	-	-

Coarse Woody Debris

Snag numbers are high. Snags in the 6 to 11 inch size class are among the highest in the upper montane, and snags in the 25 to 30 inch size class and those larger than 40 inches in diameter occur in substantially higher numbers than most other stands. Mortality in smaller size classes appears to be related to thinning of suppressed individuals, and mortality in the larger size classes appears to be related to senescence of large individuals. Mortality is uniformly distributed among species. Most snags are less than 50 feet tall indicating a tendency of large standing snags to break off over time. They typically lie in decay classes between 1 and 3. Logs commonly are less than 30 inches in large end diameter, but larger sizes are well represented in some stands. The majority of logs are shorter than 50 feet in length, and they evidence higher levels of decay than snags. Decay classes 3 through 5 are most common.

Snags

	Breast Height Diameter Class (inches)						
	<11	***11-17.9***	***18-24.9***	***25-29.9***	***30-39.9***	***>40***	***Total***
Snags per acre	16.0	1.6	1.6	1.1	1.0	2.3	23.6
Snag height (feet)							
<20	11.0	0.7	-	-	0.2	0.3	12.2
20-50	2.5	0.1	0.8	-	0.3	1.0	4.7
>50	2.5	0.8	0.8	1.1	0.5	1.0	6.7
Snag decay class							
1	0.8	0.1	-	0.7	-	0.1	1.7
2	6.7	0.7	0.8	0.4	0.5	0.8	9.9
3	2.5	0.3	0.8	-	0.3	1.2	5.1
4	6.0	0.5	-	-	0.2	-	6.7
5	-	-	-	-	-	0.2	0.2

Logs

	Large End Diameter Class (inches)				
	11-20	***21-30***	***31-40***	***>40***	***Total***
Logs per acre	5.3	6.5	3.8	2.5	18.1
Log length (feet)					
<20	3.9	3.3	2.5	0.2	9.9
20-50	1.0	2.5	0.5	0.8	4.7
51-100	0.4	0.7	0.8	1.2	3.0
>100	-	-	-	0.5	0.5
Log decay class					
1	0.3	0.2	-	-	0.5
2	0.7	1.9	0.7	0.5	3.8
3	2.3	1.1	1.3	1.0	5.7
4	1.7	2.4	1.1	0.7	5.9
5	0.3	0.9	0.7	0.3	2.2

Wildlife

These stands may offer some hiding and thermal cover to large game, but forage possibilities appear transitory. Stands provide few staples for the large game diet. Western bracken fern and waterleaf phacelia are staples, but constancy and cover values for phacelia in particular are low. Grass is generally a major constituent of large game diets, but this taxon is essentially missing from the association. Evidence of deer and pocket gopher presence, however, was common.

Range

These stands are transitional range forage sites that are used by livestock to access primary forage sites such as meadows and other moist habitats, although cattle were generally present in these stands. Grass is generally a major constituent of the range diet, but this group is missing from the association. Other shrubs and forbs that are present are low value forage. It appears forage production on these sites is low.

Management Recommendations

Many stands in this plant association have been harvested in the upper montane. Early harvests were directed at improvement cuttings, but in recent years a variety of harvests designed to create essentially even-aged stands has been practiced. Little reliance has been placed on obtaining natural regeneration in these cuttings. Many sites have been planted to Jeffrey pine and sugar pine. Occasionally white fir has been planted as well. Results in most cases are good with many well stocked and growing plantations. Recent failures with sugar pine planting can be attributed to a rise in the presence of white pine blister rust in the region, with a corresponding increase in sugar pine mortality. White fir plantings have also not done as well in some cases. This seems to result from problems with early survival rather than competition at a later stage of development. The low levels of natural Jeffrey pine regeneration in the dense stands typical of this association are probably in direct relationship to high stand densities. This species seems to do well once stand density is lowered.

These sites also produce high levels of shrub and forb cover when disturbed. Except for Sierra chinquapin, the original cover values for competing shrub and forb species are low; however, through resprouting and germination of stored seed, early succession on these sites can be dominated by persistent shrub and forb competition. Squaw currant, bitter cherry, and Sierra chinquapin in the south, and mountain whitethorn elsewhere can quickly dominate a specific site. Western bracken fern, Anderson's lupine, Drew's silky lupine and broad leaved lupine in the forb component can do the same.

These stands have tremendous productive capacity and flexibility for stand management. Stand structures are variable, and options for silvicultural systems and cutting methods can vary to take advantage of the shade tolerance and high stand densities attainable in these stands. Natural regeneration can be a viable option. Stand openings should be kept small and seed source near. On north-facing slopes small clearcuts can be utilized, but on south aspects shelterwood cutting or a silvicultural system that maintains constant tree cover is recommended. High levels of shrub, forb, and grass competition should be anticipated when openings are created. In particular sites at lower elevations on south aspects can become occupied with species that offer serious competition to new seedlings. Most reforestation prescriptions in this type should plan for vigorous vegetation control early in the life of any plantation.

These sites also have the potential to contribute to wildlife values. In their present condition they are an important source of snags, and through management, they can continue to provide snags for a period of time after harvest. Many of the species expected to offer competition to conifer seedlings are also preferred or secondary large game food sources. Mountain whitethorn and bitter cherry are preferred forage. Careful vegetation management early in the life of plantations can probably maintain wildlife forage and not seriously impact reforestation efforts.

Jeffery Pine/Huckleberry Oak Association

Pinus Jeffreyii/Quercus vaccinifolia

PIJE/QUVA
CPJCPJ12
Sample size: 32

Distribution

The Jeffrey pine/huckleberry oak plant association is located in the northwestern portion of the study area. In general, huckleberry oak does not extend south of latitude 37° in the Sierra Nevada, and this association characteristically occurs north of latitude 37°30′. The most southerly stand sampled was on the Sierra National Forest near Chilkoot Lake. As one travels north these communities become more common. This is predominantly a westside association. Longitudes were generally greater than 119°30′, and few stands were sampled on the eastside. Stands are often quite extensive and can cover areas of 100 acres or more.

Environment

This is a lower elevation plant association. This reflects distributions in the northern portion of the study area in which similar associations commonly appear at lower elevations than further south, but it also is a typically lower elevation association even in the north. Stands often mark the transition into the upper montane from lower elevation forests. Slopes are varied, but normally they are steeper than 20 percent, and a few exceed 40 percent. Stands generally occupy ridges and upper and middle one-third slope positions. They commonly face southeast to southwest where SRI levels are substantially higher than most other sites. Typical stands have more surface gravel than most other sites, and site microrelief is frequently hummocky and broken. These are dry sites, and this is reflected in stress indexes which are considerably higher than most other associations.

Variable	*Mean*	*Range*
Elevation (feet)	7,320	6,300-8,320
Slope (pct.)	27	4-58
Solar radiation index	0.517	0.392-0.594
Bare ground (pct.)	3	0-15
Surface gravel (pct.)	4	0-20
Surface rock (pct.)	13	1-46
Litter (pct.)	80	32-96
Litter depth (inches)	1.2	0.2-2.4
Stress index	0.56	0.45-0.64

Aspect: SE, SW.

Range: All.

Position: Ridges and upper slopes.

Range: All.

Vegetation

Stands are open woodlands with a characteristically heavy cover of huckleberry oak and pinemat manzanita. Total vegetative cover is high due to the substantial cover of shrubs, but tree cover is significantly lower than most other associations, and trees tend to occur as scattered clumps and individuals.

The overstory is characterized by the presence of Jeffrey pine which is a dry site indicator. Both white and red fir are typical associates although western white pine, western juniper, and lodgepole pine occur as rare, scattered individuals. Occasional stands are dominated by red or white fir, and Jeffrey pine can be a scattered or missing component in these cases, but the understory is dominated by huckleberry oak which indicates the association. The presence of white fir and Jeffrey pine are generally indicative of the lower elevations of this association. These stands often lie adjacent to white fir-sugar pine-red fir, red fir-white fir, and red fir-white fir-Jeffrey pine plant associations as conditions become mesic at lower elevations.

The understory is predominantly a mix of huckleberry oak and pinemat manzanita with an occasional mountain whitethorn in the shrub layer. Both huckleberry oak and pinemat manzanita are dry site indicators, and mountain whitethorn inhabits moderate to dry sites. Broad seeded rock cress, naked stemmed eriogonum, Coville's gayophytum, and mountain pennyroyal in the forb layer all indicate the drier conditions in this association. Bottle brush squirreltail and western needlegrass in the grass component are also dry site indicators.

Conifer regeneration is moderate to low. The average number of seedlings per acre is 376, but distributions are skewed, and the median value is only 85 per acre. Over 50 percent of the samples had less than 100 seedlings per acre, and only on occasion did sites carry more than 500 per acre. White and red fir dominate the regeneration layer. Interestingly, Jeffrey pine is present infrequently, and it occurs in very low numbers, but both white fir and Jeffrey pine are regenerating significantly more often than in other associations.

Plant species diversity is moderate to high for these upper montane forests, and sites are considerably more diverse than many associated stands. They have moderate to high numbers of species overall. The number of tree species present is higher than on many other sites, and tree cover is relatively low because of the wide spacing of individuals. Several species are present in the shrub layer, and although shrubs can dominate the understory, several forb and grass species also generally occupy sites. Overall, the number of abundant species is somewhat higher than in many other stands, and these species are somewhat uniformly distributed between trees and shrubs.

The oldest trees in these stands were typically older than 250 years. Although they are not substantially older than other stands in these forests on average, Jeffrey pine, as a species, can attain a considerable age. Often it is older than most other species when it occurs in combination in these late seral stands, and the older ages of many stands appears to lie in the greater ages attained by Jeffrey pine. The oldest tree measured in this association was a Jeffrey pine at ±631 years. By comparison, the oldest white fir was ±298 years, and the oldest red fir was estimated at ±246 years.

Stand replacing disturbance events probably occur in this association at somewhat higher frequencies than others in the upper montane. Shrubby sites on somewhat steeper slopes and drier, southerly aspects with irregular tree distributions would indicate a different fire regime than many others in these forests. High shrub cover and south aspects favor larger more intense fires; however, shrub cover is seldom continuous, and the structure of most stands with stocking concentrated in widely spaced, relatively large, somewhat fire resistant individuals would tend to ensure some level of tree survival after a fire. Burns are probably patchy, and portions of the stand are left with little damage while others burn intensely. Isolated large trees probably escape damage in most cases. Other disturbance elements such as windthrow and avalanche are not common features of these stands. Insects, disease, and lightning are more common, but they generally occur in localized situations or on select species and do not cover large areas.

Reproductive strategies such as consistent seed production, germination on mineral soil, sprouting, widespread seed dispersal, or delayed germination until seeds are scarified by fire is present in species on these sites. Jeffrey pine is a consistent seed producer that does well on mineral seedbeds. Huckleberry oak and mountain whitethorn are sprouting species, and pinemat manzanita sprouts from stems, but it does not crown sprout. In most cases the species composition of future stands is largely determined by species currently on these sites.

Disturbance creates opportunities for regeneration, but many microhabitats are unsuitable for establishment, and regeneration is often a prolonged process on these sites. Disturbance also provides opportunities for surviving individuals to increase growth. Scattered patches of trees probably escape many disturbances and proceed through a period of crown closure and self thinning. Isolated trees and small patches that escape repeated disturbance eventually mature into larger members of the stand. In time, stands develop an irregular structure reflecting numerous disturbances and containing large trees that are the survivors of multiple disturbances.

Cover (percent)	*Mean*	*Range*
Total vegetative	83	38-99
Tree	36	8-67
Shrub	55	13-90
Forb	10	0-80
Grass	1	0-8
Moss	0.4	0-3
Stand age (years)	243	112-496
Diversity index		
Simpson	0.28	0.12-0.50

Cover (percent)	Mean	Range
Hill numbers		
N0	13.0	7.0-24.0
N1	5.50	2.71-11.09
N2	4.25	2.00-8.65

Characteristic Vegetation

	Code	Common name	Constancy	Percent cover Mean	Percent cover Range
I.	Overstory trees				
	PIJE	Jeffrey pine	88	15	1-52
	ABCO	White fir	69	16	1-45
	ABMA	Red fir	59	19	4-41
II.	Understory trees				
	ABCO	White fir	78	2	1-8
	ABMA	Red fir	75	1	1-4
	PIJE	Jeffrey pine	38	1	1-1
III.	Shrubs				
	QUVA	Huckleberry oak	100	30	1-81
	ARNE2	Pinemat manzanita	62	29	1-89
	CECO2	Mountain whitethorn	38	4	1-17
	PREM	Bitter cherry	31	1	1-3
	SYAC	Creeping snowberry	28	3	1-10
IV.	Forbs				
	PESE3	Pine woods lousewort	44	2	1-10
	ARPL	Broad seeded rockcress	41	1	1-3
	ERNUD	Naked stemmed eriogonum	38	1	1-80
	GAER	Coville's gayophytum	38	4	1-30
	CHBR3	Brewer's golden aster	34	1	1-1
	APMEF	Western dogbane	31	1	1-1
	ERBR2	Brewer's daisy	31	2	1-40
	ALOB	Red Sierra onion	28	1	1-2
	PYPI	White veined wintergreen	28	1	1-1
	MOOD	Mountain pennyroyal	25	2	1-20
	SEAR	Woody butterweed	25	1	1-30
V.	Grasses and grass-like				
	SIHY	Bottle brush squirreltail	31	1	1-3
	STOC1	Western needlegrass	25	1	1-3

Soils

Soils in this association are predominantly Inceptisols with occasional Entisols. Alfisols are encountered in rare cases. The Inceptisols lie typically in the Xerumbrept great group, but Xerochrepts are sometimes encountered as well. Entisols are evenly divided between Orthents and Psamments. Particle size classes are commonly skeletal indicating the higher levels of coarse fragments in the profile. These soils are generally derived from granitic parent material, and although they are normally formed in place from bedrock, they are occasionally formed from glacial tills and glacial outwash materials. Glacial deposits form a significant component in these stands when compared to other associations.

Soils are moderately deep to deep. Usually they exceed 35 inches in depth, and some were greater than 40 inches. Depths of less than 25 inches were uncommon.

Compared to depths in dense forested stands in the upper montane, these soils are shallow. Soil textures in both the topsoil and subsoil are often sandy loams with occasional sands. Loams are seldom encountered. Topsoil sands are typically gravelly or cobbly, and overall there are significantly higher proportions of cobbly textures in the topsoil, and stoney textures in the subsoil. Topsoils have a considerably higher portion of sites with coarse fragments between 35 and 65 percent compared to most other sites. Subsoils have among the highest average coarse fragment contents of all the upper montane plant associations. Sites typically have more than 35 percent coarse fragments in these lower horizons. These features are reflective of sites that lie on glacial deposits.

The AWC of these sites is lower than most other plant associations in the study area. Stress indexes are high due to both lower AWC and locations on upper slope positions. Soils frequently occur on substrates that are fractured and rootable and able to supply additional sources of moisture to stands. These sites also differ substantially from many others in that drainage is typically excessive and reflects the coarse textures present in the soil. Erodibility is moderate as a result of these same soil textures.

Variable	*Mean*	*Range*
Depth of soil sample (inches)	32	13-40+
Topsoil		
Depth (inches)	9	2-38
Coarse fragments (pct.)	25	3-65
pH	5.7	5.0-6.5
Subsoil		
Coarse fragments (pct.)	46	5-85
pH	5.9	5.0-6.9
AWC (inches)	2.4	0.6-5.4
Temp (20 inches) (Fahrenheit)	52	44-66

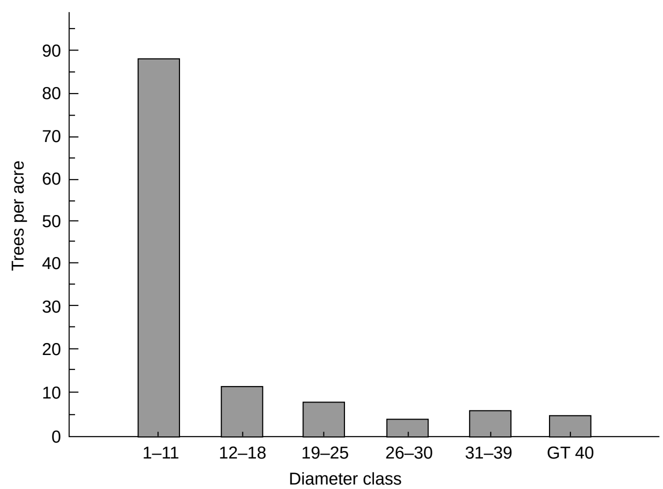
Productivity

Pacific Southwest Region (Region 5) site indexes tend to be lower than dense well-stocked stands in the study area. In general, site indexes were evenly distributed between higher and lower sites; however, these stands have a high proportion of sites with indexes of 4 and 5. Stand density is also low. Average stand density indexes are typically lower than 300, and stocking levels based on average stand density indexes are less than 45 percent of those reached in the red fir-white fir association, which is one of the densest in the upper montane. Stocking resides in the larger individuals of the stand. The average quadratic mean diameter is similar to those in the red fir-white fir association, which is stocked with many large trees per acre. Tree heights are significantly lower than associations with higher site index. The tallest tree measured was a Jeffrey pine at 172 feet. The tallest white fir encountered was 156 feet, and the tallest red fir was 141 feet. The majority of heights on dominant trees in this association were less than 150 feet. The combination of lower site indexes, lower stand densities, and shorter tree heights result in less basal area stocking and lower cubic foot and board foot yields from these stands.

Structures in individual stands are irregular. Considered as a whole, however, the association has the appearance of an uneven-age structure *(fig. 30)*. Stands tend to be open with few total trees per acre. They commonly carry fewer than 100 trees per acre. Compared to an uneven-aged structure with a balanced diameter distribution and similar stocking levels, these stands have too few trees in size classes smaller than 18 inches and an excess of trees larger than 30 inches. When compared to even-aged distributions, they have an excess of trees in both smaller and larger size classes.

Variable	*Mean*	*Range*
Region 5 site index	3	2-5
Forest survey site class	4	3-6
Stand density index	224	50-592
Quadratic mean diameter	23.0	9.7-39.7
Softwood volume (mcf/ac)	5.2	1.2-14.2
Softwood volume (mbf/ac)	36.9	8.9-98.8
Softwood basal area (sq ft/ac)	155	40-320
Hardwood volume (mcf/ac)	0	0
Hardwood basal area (sq ft/ac)	0	0

Figure 30—Number of trees by diameter class in the Jeffrey pine/ huckleberry oak plant association.



Tree species composition by percent of basal area

Species	ABMA	ABCO	PICO	PIJE	PIMO3	TSME
Percent	32	36	2	28	1	-
Species	JUOC	PILA	LIDE3	PIAL	POTR	QUKE
Percent	1	-	-	-	-	-

Coarse Woody Debris

Snag density is low reflecting the open stand conditions that are common. Most snags were larger than 25 inches DBH. Overall, mortality was distributed more heavily in red and white fir on these sites. This was particularly so in the smaller size classes. Snags taller than 50 feet are well represented and reflect the presence of both larger diameter snags and the presence of Jeffrey pine, which decays slowly and can remain standing for long periods. Snags generally lie in decay classes 1 to 3. Logs were typically less than 30 inches in diameter. They were predominantly less than 50 feet in length and demonstrate higher levels of decay than snags. Decay classes of the samples were characteristically between 3 and 5.

Snags

	Breast Height Diameter Class (inches)						
	<11	*11-17.9*	*18-24.9*	*25-29.9*	*30-39.9*	*>40*	*Total*
Snags per acre	0	0.2	0.1	0.5	0.7	0.6	2.1
Snag height (feet)							
<20	-	0.1	-	0.2	0.2	-	0.5
20-50	-	0.1	0.1	0.2	0.2	-	0.6
>50	-	-	-	0.1	0.3	0.6	1.0
Snag decay class							
1	-	-	0.1	0.2	0.1	-	0.4
2	-	-	-	-	0.3	-	0.3
3	-	-	-	0.2	0.3	0.6	1.1
4	-	0.2	-	0.1	-	-	0.3
5	-	-	-	-	-	-	-

Logs

	Large End Diameter Class (inches)				
	11-20	*21-30*	*31-40*	*>40*	*Total*
Logs per acre	2.4	4.0	1.4	1.0	8.8
Log length (feet)					
<20	2.0	3.2	0.8	-	6.0
20-50	0.4	0.8	0.6	0.6	2.4
51-100	-	-	-	-	-
>100	-	-	-	0.4	0.4
Log decay class					
1	-	-	-	-	-
2	0.6	0.2	0.2	0.2	1.2
3	1.0	2.4	-	0.2	3.6
4	0.4	0.8	0.6	0.6	2.4
5	0.4	0.6	0.6	-	1.6
Logs per acre	2.4	4.0	1.4	1.0	8.8

Wildlife

Forage values appear to be moderate since several species are present that can provide large game forage. Mountain whitethorn and bittercherry are preferred species, and naked stemmed eriogonum and Brewer's daisy are staples in the large game diet. These species occur with reasonable constancy and cover values and would appear to contribute to forage values on these sites. Bottle brush squirreltail and western needlegrass are also staples, but they occur with lower constancy and cover. Deer sign was often observed in these stands, but observations were lower than on many other sites. Gophers were common.

Range

Range potential in this association appears to be transitory as livestock move to nearby primary range sites such as meadows and other moist habitats. Nevertheless, cattle presence was observed in a majority of the stands. Bottle brush squirreltail and western needlegrass are secondary forage species, but frequency of occurrence and cover values are low. Other shrub, forb, and grass species occurring on these sites are of low value for range forage, and it would appear that contributions to range forage from this association are also low.

Management Recommendations

This plant association has not been extensively harvested. The harvesting that has occurred has generally been a form of partial cutting with no clearly defined silvicultural system other than salvage. Management in many cases has relied on established stocking to regenerate sites, but most late seral stands have low levels of natural regeneration, and disturbance due to harvesting has not increased conifer stocking. Competition from existing shrubs appears to be severe, and trees can be under stress for long periods. Mortality rates in seedlings is probably high, and seed flow into the site is low due to the low density of mature trees. Long time periods can be expected to establish stocking through natural regeneration. Techniques for reforestation strategies involving planting have not been developed on these sites at this time, and success rates from such attempts can be expected to be low with current experience.

These stands have moderate productive capacity and flexibility for stand management. Stand structures are variable, but species composition, site index, or stand density is often limiting, and the ability to predict results of treatment is not based on wide experience at this time. The open nature of these stands indicates that regeneration and establishment is a lengthy and variable process under most conditions. Recommendations for harvesting at the present time would be to treat stands in this type with caution and expect that results can be uncertain. Appropriate management should be directed at maintaining the landscape level diversity such plant communities provide through treatments which maintain the species composition experienced in these stands.

Jeffrey Pine/Greenleaf Manzanita-Snowbrush Association

Pinus jeffreyii/Arctostaphylos patula-Ceanothus velutinus

PIJE/ARPA
CEVE3 CPJCPJ13
Sample size: 32

Distribution

The Jeffrey pine/greenleaf manzanita-snowbrush plant association is widespread at middle to upper elevations in the Sierra Nevada. It was sampled on most National Forests and Parks in the study area, but the association was encountered more often under southern and eastside conditions. Longitudes were typically east of 119°30′. On the west side from the Sierra, north through the Eldorado National Forest, the association appears to diminish in occurrence, but it is still represented at these latitudes on the Toiyabe and Lake Tahoe Basin Management Unit. Stands can be quite extensive and cover areas of several hundred acres, but in most cases they are moderate in size and cover a few tens of acres.

Environment

Elevations are wide ranging and evenly distributed above and below 7,500 feet. A high proportion of stands occur above 8,500 feet reflecting locations in the south and on the eastside portions of the study area where elevations for similar plant communities are generally higher. It was sampled as high as 9,520 feet on the Inyo, and the lowest site was at 5,920 feet on the Stanislaus National Forest. Aspects commonly face southeast through southwest. Slopes are significantly steeper than other types. Most are steeper than 20 percent, and occasionally they exceed 40 percent. The combination of steep slopes and southerly aspects result in SRI levels that are among the highest in the upper montane and significantly higher than most other forested plant associations. Sites are characteristically located on ridge tops and the upper and middle thirds of slopes. Significantly higher levels of bare ground, surface gravel, and bare rock are present compared to most other plant associations in the upper montane. These features are indications of dry habitats. Stress indexes in these sites is substantially higher than most other associations.

Variable	*Mean*	*Range*
Elevation (feet)	8,255	6,660-9,520
Slope (pct.)	30	4-64
Solar radiation index	0.516	0.357-0.591
Bare ground (pct.)	8	1-49
Surface gravel (pct.)	9	0-43
Surface rock (pct.)	7	0-30
Litter (pct.)	77	30-96
Litter depth (inches)	1.1	0.3-2.2
Stress index	0.55	0.39-0.64

Aspect: SE, SW.

Range: All.

Position: Ridges, upper slopes.

Range: Ridgetops, upper, middle and lower slopes, benches.

Vegetation

Stands are characteristically open woodlands with a prominent shrub layer. Tree cover is among the lowest of any of the upper montane associations. Conversely, shrub cover is significantly higher than most other sites. The overstory is characterized by a relatively high component of Jeffrey pine, a dry site indicator. Red fir is commonly present, and white fir is sometimes a member of stands as well. In some cases, Jeffrey pine may be the only member of the overstory although other stands are dominated by red or white fir, and Jeffrey pine becomes a scattered or missing component. In these cases, the understories are dominated by greenleaf manzanita or snowbrush and indicate the association.

In most cases, understories show a high abundance of greenleaf manzanita and Sierra chinquapin. On the Inyo, Toiyabe, and Lake Tahoe Basin Management Unit a variation of this association occurs that is dominated by snowbrush. There is no environmental difference, other than location, between these communities, and they have been combined in the classification. On these sites greenleaf manzanita, pinemat manzanita, and Sierra chinquapin are usually present to help verify the association. These species are all dry site indicators in these forests. Broad seeded rock cress, Coville's gayophytum, and naked stemmed eriogonum are dry site indicators in the forb layer, and pussy paws, mountain pennyroyal, and Sierra wallflower inhabit moderate to dry sites. Bottle brush squirreltail and western needlegrass are dry site indicators in the grass layer.

Conifer regeneration is low. Although the average was 150 per seedlings per acre, distributions are skewed, and the median value is only 30. Late seral stands typically had less than 100 seedlings per acre. Red fir is the most common species present in the regeneration layer, while white fir and Jeffrey pine occur less often and in substantially lower numbers. Jeffrey pine regenerates significantly more often compared to other associations.

Plant species diversity is moderate; however, stands tend to be more diverse generally than many others in the upper montane. Stands have a moderate number of species overall, and sites are not dominated by a tree canopy alone. Several species are often present in the shrub layer, and although shrubs dominate the understory, several forb species also occupy sites. The number and distribution of abundant species is moderate for these forests, and they are somewhat uniformly distributed between trees and shrubs.

The oldest trees in these stands are typically older than 250 years. Although average stand ages are not substantially different than many others in these forests, Jeffrey pine, as a species, can attain a considerable age. Often, it is older than most other species when it occurs in combination with other species in late seral stands, and the older average age of many stands appears to lie in the greater ages attained by Jeffrey pine. The oldest tree measured in this association was a Jeffrey pine at ±427 years. By comparison, the oldest red fir was ±396 years, and the oldest white fir was estimated at ±252 years.

Stand replacing disturbance events probably occur in this association at somewhat higher frequencies than others in the upper montane. Shrubby sites on steeper, drier, south-facing aspects with irregular tree distributions would indicate a different fire regime than others in these forests. Shrub layers and south aspects generally favor larger more intense fires. Conversely, the structure of the stands with stocking concentrated in relatively large, widely spaced, somewhat fire resistant individuals and the noncontinuous distribution of the shrub layer would tend to ensure some level of survival for most species after a fire. These stands probably experience patchy burns that leave portions of the stand with little damage while other portions are burned intensely. Isolated large trees probably escape damage in many cases.

Disturbance elements such as windthrow and avalanche are not common features of these stands. Insects, disease, and lightning are more common, but they generally occur in localized situations or on select species. In most cases disturbances occur continuously at various scales, and this results in the creation of various sized gaps as well as a persistent shrub understory that is continually changing through time.

Reproductive strategies such as consistent seed production, germination on mineral soil, sprouting, or delayed germination of seed until scarified by fire is present in species on these sites. Jeffrey pine is a consistent seed producer that does well on mineral seedbeds for example, and greenleaf manzanita, Sierra chinquapin, and snowbrush are all sprouting species. Snowbrush establishes well from seed after burns.

Stand development appears to be sporadic as opportunities for regeneration and growth arise in response to disturbance events. Disturbance creates opportunities for regeneration, but many microhabitats are unsuitable for regeneration, and conifer establishment is a prolonged process on these sites. Disturbance also provides opportunities for surviving individuals to increase growth. Scattered patches probably escape many disturbances and proceed through a period of regeneration followed by crown closure and self thinning. Isolated trees and small patches that escape repeated disturbance eventually mature into larger members of the stand. In time, stands develop an irregular structure reflecting numerous disturbances and containing large trees that remain from several stand altering events.

Cover (percent)	*Mean*	*Range*
Total vegetative	74	30-99
Tree	40	10-79
Shrub	41	1-82
Forb	7	0-53
Grass	4	0-40
Moss	0.4	0-6
Stand age (years)	236	95-402

Cover (percent)	*Mean*	*Range*
Diversity index		
Simpson	0.28	0.12-0.46
Hill numbers		
N0	12.0	4.0-20.0
N1	5.11	2.33-10.25
N2	3.88	2.20-8.64

Characteristic Vegetation

	Code	*Common name*	*Constancy*	*Percent cover* *Mean*	*Range*
I.	Overstory trees				
	PIJE	Jeffrey pine	84	25	3-72
	ABMA	Red fir	69	20	2-52
	ABCO	White fir	34	13	1-42
II.	Understory trees				
	ABMA	Red fir	56	1	1-6
	ABCO	White fir	41	1	1-4
	PIJE	Jeffrey pine	41	1	1-1
III.	Shrubs				
	ARPA9	Greenleaf manzanita	72	19	1-58
	CEVE3	Snowbrush	41	24	1-53
	CASE3	Sierra chinquapin	38	11	1-37
	CECO2	Mountain whitethorn	28	8	1-30
	ARNE2	Pinemat manzanita	25	22	1-51
	PREM	Bitter cherry	25	2	1-10
IV.	Forbs				
	ARPL	Broad seeded rock cress	62	1	1-2
	GAER	Coville’s gayophytum	50	2	1-8
	PESE3	Pine woods lousewort	34	1	1-1
	CAUM2	Pussy paws	31	1	1-1
	ERBR2	Brewer’s daisy	31	2	1-3
	ERNUD	Naked stemmed eriogonum	31	1	1-2
	MOOD	Mountain pennyroyal	28	2	1-30
	ERPE3	Sierra wallflower	22	1	1-1
V.	Grasses and grass-like				
	SIHY	Bottle brush squirreltail	47	3	1-15
	STOC1	Western needlegrass	38	2	1-10

Soils

Soils are almost evenly distributed between Inceptisols and Enitsols. In a few instances Mollisols are present. Most of the Inceptisols are Xerumbrepts with occasional Xerochrepts. Entisols are typically Xeropsamments and Xerorthents. Particle size classes are commonly skeletal and sandy, indicating higher levels of coarse fragments in the profiles. Granitic parent materials are most frequent in these stands. Some are derived from volcanic materials from a wide range of sources such as the andesitic and rhyolitic flow rocks and lahars typical of the northern portion of the study area and the tephra and tuff deposits from the eastside near Mammoth Mountain. Soils formed from these substrates are commonly weathered in place from bedrock, although some are formed from alluvial and colluvial materials.

Soil depths are moderately deep to deep. Almost 40 percent of the sample sites had depths greater than 40 inches, and depths less than 25 inches were infrequent. Topsoil textures are usually sands with some sandy loams and a few loams. Subsoil textures are similar, but they contain a higher proportion of sands and fewer loams. These are coarse textured soils that contain significantly higher proportions of sands than most other sites in the upper montane.

The average AWC of these soils is among the lowest in the forested portions of the upper montane. Soils typically lie over parent materials that are fractured and rootable thereby increasing the available moisture supply to vegetation. Drainage is characteristically excessive reflecting locations on slopes with coarse textured soils. Erodibility is low to moderate on slopes because of these coarse textured soils. Soils are significantly warmer than those in most other associations in the study area. Summertime soil temperatures are commonly higher than 53°.

Variable	*Mean*	*Range*
Depth of soil sample (inches)	32	5-40+
Topsoil		
Depth (inches)	8	2-23
Coarse fragments (pct.)	22	2-55
pH	6.0	4.7-7.0
Subsoil		
Coarse fragments (pct.)	43	3-92
pH	5.9	4.9-7.2
AWC (inches)	2.2	0.2-5.2
Temp (20 inches) (Fahrenheit)	56	38-72

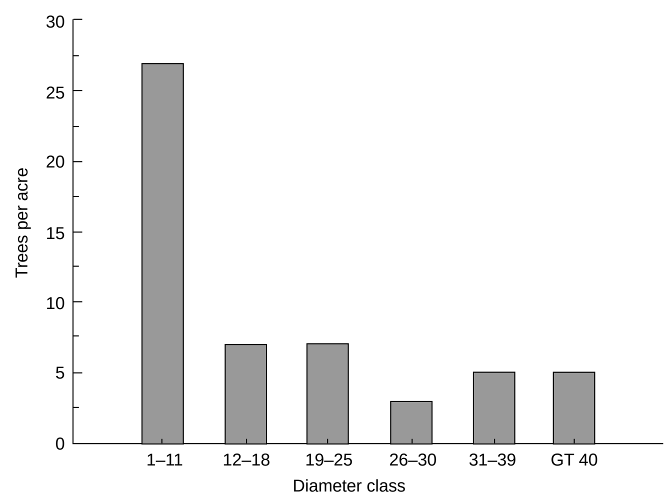
Productivity

Pacific Southwest Region (Region 5) site indexes are significantly less than dense, well-stocked stands in the study area. Site indexes were generally 3 or 4; no site index was better than 2. Stand density is also low. Stand density indexes are characteristically less than 300, and stocking levels are only 34 percent of values reached in the red fir-white fir association, which is one of the densest in the upper montane. Stocking also resides in the larger individuals of the stand. The average quadratic mean diameter for these stands is among the highest of any of the forested associations in the study area. Tree heights are also considerably shorter than associations with better site index. The tallest tree measured was a red fir at 150 feet, while the tallest white fir was 133 feet, and the tallest Jeffrey pine was 118 feet. The combination of lower site indexes, lower stand densities, and shorter tree heights result in substantially lower basal area stocking and cubic and board foot yields in these stands.

Stand structures are irregular. These are open stands with few trees per acre *(fig. 31)*. The total number of trees per acre is substantially lower than most other sites. Stands in this association generally carry fewer than 100 trees per acre, and often they contain less than 50 trees per acre. This stocking is concentrated in a few large trees. Compared to an uneven-aged structure with a balanced diameter distribution and similar stocking levels, these stands have far fewer trees in smaller size classes and an excess of trees in larger size classes. Compared to even-aged distributions, they have an excess of trees in both smaller and larger size classes.

Variable	*Mean*	*Range*
Region 5 site index	3	2-4
Forest survey site class	4	3-5
Stand density index	177	50-324
Quadratic mean diameter	26.1	9.8-40.7
Softwood volume (mcf/ac)	4.3	1.6-12.9
Softwood volume (mbf/ac)	28.0	10.5-92.6
Softwood basal area (sq ft/ac)	122	27-307
Hardwood volume (mcf/ac)	0	0
Hardwood basal area (sq ft/ac)	0	0

Figure 31—Number of trees by diameter class in the Jeffrey pine/ greenleaf manzanita-snowbrush plant association.



Tree species composition by percent of basal area

Species	ABMA	ABCO	PICO	PIJE	PIMO3	TSME
Percent	41	14	3	41	1	-
Species	JUOC	PILA	LIDE3	PIAL	POTR	QUKE
Percent	-	-	-	-	-	-

Coarse Woody Debris

Snag numbers are low, reflecting the open conditions of most stands. Snags smaller than 11 inches DBH are sparse, but otherwise mortality is somewhat uniformly distributed among all size classes. Mortality appears to occur more often in red and white fir in this association. This was particularly so in size classes smaller than 25 inches. Snags are uniformly distributed between height classes, but decay classes typically lie between 1 and 3. Logs are commonly smaller than 30 inches in large end diameter, and most of these are less than 20 feet in length. Logs evidence higher levels of decay than snags. Decay classes generally lie between 3 and 5.

Snags

	Breast Height Diameter Class (inches)						
	<11	*11-17.9*	*18-24.9*	*25-29.9*	*30-39.9*	*>40*	*Total*
Snags per acre	0	0.5	0.6	0.2	0.7	0.5	2.5
Snag height (feet)							
<20	-	-	0.2	-	0.3	0.2	0.7
20-50	-	0.5	0.2	0.1	0.1	-	0.9
>50	-	-	0.2	0.1	0.3	0.3	0.9
Snag decay class							
1	-	0.5	0.2	0.1	0.2	-	1.0
2	-	-	-	-	0.2	0.2	0.4
3	-	-	-	-	0.2	0.3	0.5
4	-	-	-	0.1	-	-	0.1
5	-	-	0.4	-	0.1	-	0.5

Logs

	Large End Diameter Class (inches)				
	11-20	*21-30*	*31-40*	*>40*	*Total*
Logs per acre	2.7	4.0	1.7	1.0	9.4
Log length (feet)					
<20	2.3	2.1	1.0	0.4	5.8
20-50	0.3	1.3	0.6	-	2.2
51-100	0.1	0.6	0.1	0.6	1.4
>100	-	-	-	-	-
Log decay class					
1	-	-	-	-	-
2	0.3	0.6	0.1	-	1.0
3	0.6	1.6	0.3	0.3	2.8
4	0.7	1.2	0.6	0.4	2.9
5	1.1	0.6	0.7	0.3	2.7

Wildlife

Forage values in these stands appear to be moderate. Several species are preferred or staple species in the large game diet, and constancy and cover values seem to be high enough to provide a reasonable food source. In the shrub layer, mountain whitethorn and bittercherry are preferred species, and greenleaf manzanita and snowbrush are staples. In the forb layer naked stemmed eriogonumand Brewer's daisy are staples, and bottle brush squirreltail and western needlegrass are staples in the grass layer. Evidence of deer and pocket gopher was commonly observed in this association.

Range

Range potential appears to be transitory as livestock move to primary range sites such as meadows and other moist habitats. Cattle presence was generally observed in these stands. Forage values lie primarily in the grass layer. Bottle-brush squirreltail and western needlegrass are secondary forage species.

Constancy is reasonably high for these species, although cover values appear to be moderate to low. All other species commonly occurring in the association are of low range value, and overall contributions to the range diet are probably low.

Management Recommendations

This association has been harvested only in the southern portion of the range. Harvesting has generally been a form of improvement cutting done either as salvage or stand improvement. In a few instances clearcutting was applied on some of the better sites. Where this was accomplished, planting with Jeffrey pine has succeeded in reforesting the stand in most cases. Few red fir naturals appear in such stands, and it is important to observe that only the better sites appear to have received this treatment.

These stands have moderate productive capacity and flexibility for stand management. Stand structures are variable, but species composition, site index, or stand density are limiting, and the ability of sites to respond to treatment are uncertain as slopes increase and site indexes decrease. The ability to predict results of treatment under these conditions are not based on wide experience or research at this time.

The open nature of these stands in combination with high shrub cover indicates that natural regeneration and establishment is a lengthy and variable process under most conditions. Competition from existing shrubs appears to be potentially severe, and trees can be under moisture stress for long periods. Mortality rates in seedling classes are probably high, and seed flow onto sites is low due to the low density of trees. Because site indexes are lower, planting success and stand establishment can be expected to diminish. Under any cutting method, these sites will require follow up vegetation control for conifer establishment in reasonable time frames, and needed vegetation control can be anticipated until the stand is established. Cutting methods relying on natural regeneration can be expected to result in erratic stocking and require long time periods for establishment.

Silvicultural systems, cutting methods, stocking levels, or regeneration strategies appropriate for stands in this plant association have not been determined, and successional sequences are not well understood. Recommendations for harvesting better sites at the present time would be to treat stands in this type with caution and expect that results can be uncertain. Management emphasis on poorer sites may be more appropriately directed at maintaining existing wildlife habitat, species richness, and the landscape level diversity such plant communities provide.

Jeffrey Pine/Mountain Whitethorn-Sagebrush Association

Pinus Jeffreyii/Ceanothus cordulatus-Artemesia tridentata

PIJE/CECO2-ARTR
CPJCPJ14
Sample size: 18

Distribution

The Jeffrey pine/mountain whitethorn-sagebrush plant association lies throughout the central and southern Sierra Nevada. The most southerly stands sampled were on the Sequoia and Inyo National Forests near Onion Meadow Peak and Brown Cow Camp, but locations generally lie north of the San Joaquin River near latitude 37°30′. As one travels north and east through the Sierra the association becomes more common. Longitudes typically lie between 119° and 120°30′. Stands can be somewhat extensive such as near Luther Pass, but they appear to lie in the range of 5 to 50 acres in most cases.

Environment

Elevations for this plant association are wide ranging, but it commonly occurs at middle to lower elevations. Sites are found most frequently below 8,000 feet, and the lowest stand sampled was on the Eldorado National Forest at 6,820 feet. Aspects characteristically face southeast through southwest on slopes that are generally less than 30 percent. Similar to other Jeffrey pine associations, SRI levels are among the highest in the upper montane. Stands frequently occupy middle and lower slope positions; and as one ascends, a transition to other Jeffrey pine associations, such as Jeffrey pine/greenleaf manzanita-snowbrush or Jeffrey pine/huckleberry oak, often occur. These stands have significantly more bare ground and surface gravel than most other sites, and litter thickness is substantially less. These features are indicative of drier habitats. Microrelief is characteristically uniform.

Variable	Mean	Range
Elevation (feet)	7,967	6,820-9,360
Slope (pct.)	20	1-51
Solar radiation index	0.533	0.488-0.594
Bare ground (pct.)	12	1-35
Surface gravel (pct.)	14	1-40
Surface rock (pct.)	3	0-12
Litter (pct.)	69	20-96
Litter depth (inches)	0.8	0.2-1.6
Stress index	0.52	0.38-0.62

Aspect: SE, SW.

Range: NE, SE, SW.

Position: Ridges and slopes.

Range: Ridgetops, upper, middle, and lower slopes, benches.

Vegetation

Stands are commonly open woodlands with scattered patches of shrubs. Total tree cover is among the lowest of any of the forested associations. Conversely, shrub cover is considerably higher than most other sites. The overstory is characterized by the presence of Jeffrey pine. Red fir is generally present as well, and occasionally lodgepole pine and white fir are part of the stand composition. Red fir, lodgepole pine, and white fir are often mesic site indicators, and Jeffrey pine is indicative of somewhat drier conditions. In a few cases Jeffrey pine may be the only member of the overstory, but other stands can be dominated by red fir, white fir, or, in some cases, Lodgepole pine. In these cases understories are dominated by mountain whitethorn, sagebrush, bitter brush, or rabbit brush and indicate the association.

The shrub layer is often a mix of species; however, they can generally be separated into two distinct types of communities that occur on westside or eastside forests. Westside stands are dominated by mountain whitethorn sometimes mixed with sagebrush. Eastside stands, on the other hand, can be dominated by any one of four species: mountain whitethorn, sagebrush, bitter brush, and sticky-leaved rabbit brush. Usually two of the four species occur on any particular site, but eastside stands dominated by sagebrush, bitter brush, and rabbit brush often do not contain mountain whitethorn. Thus, westside stands tend to be clearly dominated by mountain whitethorn; whereas eastside stands are mixed shrub communities, and mountain whitethorn may actually become a rare component in some cases. Two plant associations may actually exist in this complex, but environmentally they are similar except for the east-west geographic separation. They have been combined at this time in the classification and named to indicate the two possible communities. All of these shrub species indicate moderate to dry moisture regimes.

There is also a westside plant community that visually looks like the Jeffrey pines/mountain whitethorn-sagebrush association but contains Fresno ceanothus *(ceanothus fresnensis)* instead of mountain whitethorn in the shrub layer. It has been observed, but not sampled, in small areas near Liberty Hill on the Stanislaus National Forest. It occurs only on soils derived from volcanic lahars, and in all other respects appears to be similar environmentally to the Jeffrey pine/mountain whitethorn-sagebrush association. It is an uncommon plant community in the central and southern Sierra, and stands should be classified as a part of the Jeffrey pine/mountain whitethorn-sagebrush association at this time.

Broad seeded rockcress, Coville's gayophytum, and naked stemmed eriogonum in the forb layer are indicative of drier sites; mountain pennyroyal and Sierra wallflower generally occupy moderate to dry habitats; and mountain violet and Kellogg's bedstraw occupy moderate habitats. Bottle brush squirreltail and western needlegrass are dry site species present in the grass layer. The overall mix of common species in each life form of this association is indicative of moderate to somewhat dry conditions.

Conifer regeneration is among the lowest of any association in the upper montane. The average number of seedlings per acre is 100, but distributions are skewed, and median values are only 60. Stands typically have less than 100 seedlings per acre, and they are generally clumped rather than distributed evenly within the stand. Red fir is typically present in the tree regeneration; Jeffrey pine is present less often, and white fir is occasionally present, but no species is dominating the regeneration layer on most sites. Jeffrey pine regenerates with significantly higher frequency compared to other associations.

Plant species diversity is one of the highest in the upper montane. It has only a few less species on average than the Quaking aspen/mountain pennyroyal and western juniper/sagebrush associations which have some of the highest numbers of species in these forests. Although several tree species are often present, lower tree cover and high numbers of shrub, forb, and grass species with relatively uniform cover result in abundant species that are distributed in several life forms.

The oldest trees in these stands are typically older than 250 years. Although average ages of these stands are not substantially different from many others in these forests, Jeffrey pine, as a species, can attain a considerable age. Often, it is older than most other species when it occurs in combination with other species in these late seral stands, and the older average stand ages of many stands appears to lie in the greater ages attained by Jeffrey pine. The oldest tree sampled was a Jeffrey pine at ±457 years compared to the oldest red fir at ±310 years, the oldest white fir at ±270 years, and the oldest lodgepole pine at ±257 years.

Stand replacing events probably occur in this association at somewhat higher frequencies than many others in the upper montane. Shrubby sites on south aspects with patchy tree distributions would indicate a different fire regime than others in these forests. Shrub layers and south aspects favor larger, more intense fires. Conversely, the structure of stands with stocking concentrated in relatively large, widely spaced, somewhat fire resistant individuals and the non-continuous distribution of the shrub layer would tend to ensure some level of survival of many species after fire. Thus, although stand replacing fires may occur, these stands probably experience patchy burns with some portions of the stand completely consumed, and others are left with little damage. Isolated large trees probably escape damage in many cases. Disturbance elements such as windthrow and avalanche are not common features of these stands. Insects, disease, and lightning are more common, but they generally occur in localized situations or on select species and seldom are involved in stand replacement.

Reproductive strategies such as consistent seed production, widespread seed dispersal, germination on mineral soil, sprouting, or delayed germination of seed until scarified by fire is present in many species on these sites. Jeffrey pine is a consistent seed producer that does well on mineral seedbeds for example, and both mountain whitethorn and bitter brush tend to be sprouters after fire. Sagebrush, on the other hand, is a non-sprouter that appears to maintain dominance through competition. It may lose dominance on sites after fire, and it may actually indicate sites that have not experienced a recent fire. In many cases the species composition of future stands is determined by species currently on these sites.

Disturbance in these stands creates opportunities for regeneration, but in most cases it appears that stand regeneration is a prolonged process. Disturbance also provides opportunities for surviving individuals to increase growth. Scattered patches of trees probably escape repeated disturbances and proceed through periods of crown closure and self thinning. Isolated individuals and small patches that escape disturbance eventually mature into larger members of the stand. In time, the stand develops an irregular structure reflecting numerous disturbances, and containing large trees as the survivors of multiple disturbances events.

Cover (percent)	*Mean*	*Range*
Total vegetative	76	30-97
Tree	36	1-63
Shrub	28	1-77
Forb	19	1-65
Grass	15	1-55
Moss	0.1	0-1
Stand age (years)	243	96-409
Diversity index		
Simpson	0.20	0.03-0.41
Hill numbers		
N0	15.3	10.0-25.0
N1	7.64	3.82-16.43
N2	6.94	2.46-31.50

Characteristic Vegetation

				Percent cover	
	Code	*Common name*	*Constancy*	*Mean*	*Range*
I.	Overstory trees				
	PIJE	Jeffrey pine	94	16	1-37
	ABMA	Red fir	89	15	1-48
	PICO	Lodgepole pine	28	9	2-17
	ABCO	White fir	22	17	2-36
II.	Understory trees				
	ABMA	Red fir	67	1	1-3
	PIJE	Jeffrey pine	50	1	1-2
	ABCO	White fir	28	1	1-1
III.	Shrubs				
	CECO2	Mountain whitethorn	56	20	1-77
	ARTR	Sagebrush	39	14	1-30
	CHVI4	Sticky leaved rabbit brush	22	10	5-15
	PUTR	Bitter brush	22	16	1-60
IV.	Forbs				
	ARPL	Broad seeded rock cress	72	1	1-5
	GAER	Coville's gayophytum	61	3	1-60
	ERBR2	Brewer's daisy	44	4	1-25
	MOOD	Mountain pennyroyal	44	7	1-25
	ERNUD	Naked stemmed eriogonum	39	2	1-5
	ERPE3	Sierra wallflower	33	1	1-1
	PESE3	Pine woods lousewort	33	1	1-1
	VIPU	Mountain violet	33	1	1-1
	PHHY	Waterleaf phacelia	28	1	1-2
	PHRA2	Branching phacelia	28	1	1-1
	KEGA	Kellogg's bedstraw	22	3	1-8

Characteristic Vegetation (continued)

	Code	*Common name*	*Constancy*	*Percent cover Mean*	*Percent cover Range*
V.	Grasses and grass-like				
	SIHY	Bottle brush squirreltail	72	7	1-40
	STOC1	Western needlegrass	61	7	1-25
	BRMA3	Large mountain brome	33	6	1-23
	CARO1	Ross' sedge	33	4	2-15
	STEL1	Elmer's needlegrass	28	9	1-20
	ELGL	Blue wildrye	28	3	1-8
	POBO1	Bolander's bluegrass	22	1	1-1
	STCA1	California needlegrass	22	8	1-15

Soils

Soils in this association are commonly Inceptisols, but occasional Entisols and rare Mollisols are also encountered. Most of the Inceptisols lie in the Xerumbrept great group with a few Cryumbrepts and Cryochrepts also present. Entisols are usually Xeropsamments. Particle size classes are often skeletal, but sandy, loamy, and medial soils can also be present in a some cases. Parent materials are usually granitic; however, some of these soils are derived from volcanic lahars, and a few developed from other volcanic sources such as the andesitic and rhyolitic flow rocks and tuff deposits typical in eastern portions of the study area. Rare samples were derived from metamorphic deposits. These soils are usually formed in place from bedrock although occasional stands occur on soils formed from alluvium and a few are formed from glacial till and glacial outwash deposits.

Soil depths are generally moderately deep to deep. In some cases they can be quite deep. Approximately two-thirds of the samples had depths greater than 40 inches although rare sites had depths less than 25 inches. Topsoil textures are usually sandy loams with occasional sands. Loams are seldom encountered. Subsoils are also sandy loams with some sands and loams.

The AWC of these sites is variable, but, in general, they are not substantially different from many moderate sites in the study area. Bedrock formations were typically fractured and rootable and therefore able to supply additional moisture to these stands. Sites are often excessively drained due to a combination of coarse textures and locations on slopes. Erodibility is low to moderate due also to the coarse soil textures and moderate slopes. These are warm soils. Temperatures are among the warmest in these forests, and they are significantly higher than those in most other associations. Summertime soil temperatures on many sites exceed 53^{o} Fahrenheit.

Variable	*Mean*	*Range*
Depth of soil sample (inches)	35	17-40+
Topsoil		
Depth (inches)	10	3-22
Coarse fragments (pct.)	20	2-80
pH	6.0	5.5-6.5
Subsoil		
Coarse fragments (pct.)	37	4-90
pH	6.1	5.0-7.0
AWC (inches)	2.8	0.1-5.3
Temp (20 inches) (Fahrenheit)	56	44-66

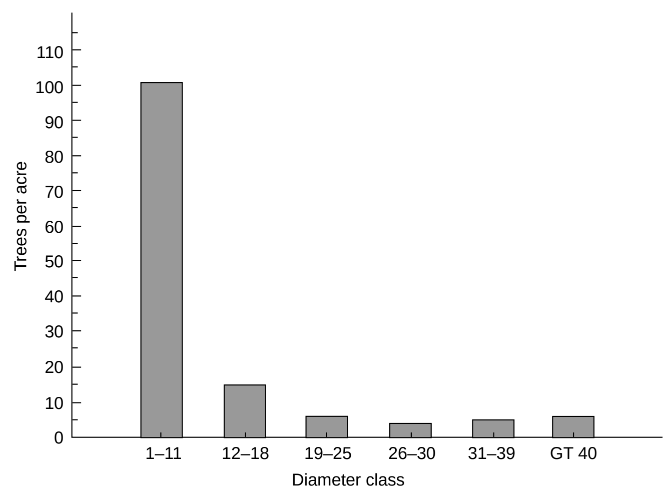
Productivity

Pacific Southwest Region (Region 5) site indexes are considerably lower than other well stocked stands in the upper montane. Typical site indexes were 3. In a few cases they were 2 or 4. Stand density is also substantially lower than other dense stands in the study area. Most stand density indexes are less than 300, and average stocking levels based on stand density indexes are only 48 percent of those attained in fully stocked stands such as the red fir-white fir association, which is one of the densest in the study area. Tree heights are commonly shorter than those on better sites. The height of the tallest Jeffrey pine was measured at 147 feet, and the height of the tallest red and white fir was 132 and 127 feet respectively. As a result of lower site classes, shorter heights, and lower stand densities, cubic and board foot volumes are moderate to low.

Stand structures are irregular. These are open stands with lower numbers of trees per acre *(fig. 32)*. Stands characteristically carry less than 200 trees per acre distributed among all size classes. Compared to an uneven-aged structure with a balanced diameter distribution and similar stocking levels, these stands have too few trees in size classes below 24 inches and an excess of trees in size classes above 30 inches. When compared to an even-age distribution, trees in size classes less than 24 inches and larger than 30 inches are higher than needed at similar stocking levels.

Variable	*Mean*	*Range*
Region 5 site index	3	2-4
Forest survey site class	4	3-5
Stand density index	252	106-491
Quadratic mean diameter	19.4	8.2-29.7
Softwood volume (mcf/ac)	5.5	2.5-8.7
Softwood volume (mbf/ac)	34.4	12.5-58.8
Softwood basal area (sq ft/ac)	157	56-280
Hardwood volume (mcf/ac)	0	0
Hardwood basal area (sq ft/ac)	0	0

Figure 32—Number of trees by diameter class in the Jeffrey pine/ mountain whitethorn-sagebrush plant association.



Tree species composition by percent of basal area

Species	ABMA	ABCO	PICO	PIJE	PIMO3	TSME
Percent	45	13	6	31	3	-
Species	JUOC	PILA	LIDE3	PIAL	POTR	QUKE
Percent	1	1	-	-	-	-

Coarse Woody Debris

Snag densities are moderate compared to other plant associations in the upper montane. Mortality appears to be distributed among all size classes, although higher levels of snags less than 11 inches and between 30 and 40 inches DBH occurred in the sample. Mortality was also distributed more heavily in red and white fir particularly in size classes smaller than 25 inches. Snags occurred uniformly in all height classes, but decay classes generally lie between 1 and 3. Logs typically were smaller than 30 inches in large end diameter, and they were characteristically less than 50 feet in length. Log decay classes were 4 and 5 in the samples.

Snags

	Breast Height Diameter Class (inches)						
	<11	*11-17.9*	*18-24.9*	*25-29.9*	*30-39.9*	*>40*	*Total*
Snags per acre	2.0	0.5	0.3	0.4	2.6	0.8	6.6
Snag height (feet)							
<20	0.8	-	-	0.2	1.3	0.3	2.6
20-50	1.2	-	-	0.2	-	-	1.4
>50	-	0.5	0.3	-	1.3	0.5	2.6
Snag decay class							
1	1.4	0.5	-	-	1.3	-	3.2
2	0.6	-	0.3	-	-	0.3	1.2
3	-	-	-	-	1.3	0.5	1.8
4	-	-	-	0.4	-	-	0.4
5	-	-	-	-	-	-	-

Logs

	Large End Diameter Class (inches)				
	11-20	*21-30*	*31-40*	*>40*	*Total*
Logs per acre	1.0	1.3	0.7	0.7	3.7
Log length (feet)					
<20	0.3	1.0	0.4	0.4	2.1
20-50	0.7	-	0.3	-	1.0
51-100	-	0.3	-	0.3	0.6
>100	-	-	-	-	-
Log decay class					
1	-	-	-	-	-
2	-	-	-	-	-
3	-	-	-	-	-
4	1.0	1.0	0.7	0.4	3.1
5	-	0.3	-	0.3	0.6

Wildlife

These stands appear to offer good forage possibilities for large game. Mountain whitethorn and bitter brush are preferred forage species, and sagebrush, Brewer's daisy, and naked stemmed eriogonum are staples in the shrub and forb layer. Bottle brush squirreltail, western needlegrass, large mountain brome, and Ross' sedge are all staples in the grass layer. All of these species appear to be occurring with high enough constancy and cover to contribute to the large game diet. The open shrubby nature of the stands together with good forage possibilities would appear to make them preferred sites for big game, but observations of deer presence were only occasional. Sign of gophers was also uncommon on these sites.

Range

Range potential appears to be transitory as livestock move to primary range sites such as meadows and other moist habitats. Cattle presence was common on these sites. Large mountain brome is a primary forage species, and bottle brush squirreltail and western needlegrass are secondary forage species. Most of the shrub and forb component, however, are low value forage species, and it appears that range forage potential is low in these late seral stands.

Management Recommendations

Some harvesting has taken place in these stands, particularly on the eastside. Most harvests have been in the form of improvement or salvage cutting with no defined regeneration plan. In recent years clearcutting has been practiced in some cases to create even-aged stands. Planting with Jeffrey pine has been performed in most of these. Results are mixed, and the reason for failures appear to be variable. On some sites competition from whitethorn appears to be significant, and seedlings can be under moisture stress for long periods. Early successional sequences in this association are not well understood, and regeneration patterns are unclear. Techniques for incorporating red fir as part of the species mix on these sites have not been developed, and it does not seem to be regenerating these stands naturally. Until experience is gained, caution should be exercised in treating these stands, and prolonged periods to achieve acceptable stocking should be expected on many sites.

These stands have moderate productive capacity and flexibility for stand management. Stand structures are variable, but species composition, site index, and stand density are limiting, and the ability of sites to respond to treatment are uncertain. The ability to predict results of treatment are not based on wide experience or research results at this time. The open nature of these stands indicates that regeneration and establishment is a lengthy and variable process under most conditions.

Recommendations for harvesting on high sites can involve both even- and uneven-aged silvicultural systems and a variety of cutting methods. Due to possible competition from shrub species such as mountain whitethorn, uneven-aged systems relying on single tree selection and natural regeneration is not recommended. Openings for regeneration should be kept small, probably less than 5 to 10 acres. A regeneration strategy recommended at this time would involve site preparation to reduce the shrub component, planting with Jeffrey pine as a preferred species and follow up vegetation treatment to control shrub competition, and developing the species composition that occurs in late seral stands. In stands with low site index, limited opportunities exist for salvage when it occurs, but in such stands it would appear that woody debris left in the form of snags and logs for wildlife or part of the nutrient pool would be better direction. Management emphasis on low sites should provide for existing wildlife habitat, plant species richness, and the landscape level diversity this association provides to the upper montane.

Red Fir-White Fir-Jeffrey Pine Association

Abies magnifica-Abies concolor-Pinus Jeffreyii

ABMA-ABCO-PIJE
CFRCFW12
Sample size: 31

Distribution

The red fir-white fir-Jeffrey pine plant association is widespread in the central and southern Sierra Nevada; however, it was sampled primarily on the westside of the range. Latitudes and longitudes spanned the range of the study area. Stands generally vary in size from smaller than 5 acres to over 100 acres.

Environment

This association is located at middle to lower elevations. Elevations generally lie between 6,500 feet and 8,000 feet. The lowest elevation encountered was on the Eldorado National Forest near Robbs Valley, and the highest was located on the Kern Plateau near Beer Keg Meadow. These locations reflect the gradual rise in elevation of similar plant communities from north to south. Aspects are varied, but a large portion lie on south facing slopes where solar radiation levels are substantially higher than many other sites. Stands often occur on upper slopes with a few located on ridgetops. Slopes are moderately steep. They usually lie between 20 and 35 percent. Stands have significantly less surface gravel and deeper litter than drier sites commonly encountered in these forests. Stress indexes are typically high due to locations at lower elevations and occurrences on upper slope positions.

Variable	Mean	Range
Elevation (feet)	7,507	6,300-8,800
Slope (pct.)	25	0-57
Solar radiation index	0.498	0.333-0.567
Bare ground (pct.)	5	0-40
Surface gravel (pct.)	2	0-10
Surface rock (pct.)	4	0-20
Litter (pct.)	89	52-99
Litter depth (inches)	1.9	0.2-6.0
Stress index	0.49	0.42-0.59

Aspect: SE, SW.
Range: All.
Position: Upper slopes.
Range: All.

Vegetation

These are moderately dense forested stands with light understory vegetation. Overstory layers are characterized by the presence of white fir and Jeffrey pine in mix with red fir. The mix appears to reflect long term response to environmental conditions such as different fire regimes resulting from lower elevations and southerly aspects. In such environments shade intolerant species such as Jeffrey pine are able to establish and grow in combination with shade tolerant species such as red and white fir.

Understories are somewhat sparse. Sierra chinquapin can occasionally become a major component in the shrub layer and dominate understories, but in most cases shrubs occur as scattered patches and individuals. Sierra chinquapin and infrequent occurrences of greenleaf manzanita indicate drier conditions, and creeping snowberry occurs in moderate habitats. The forb layer usually contains Kellogg's bedstraw, white flowered hawkweed, mountain violet, and white veined wintergreen as indicators of mesic sites. The sparse grass layer is composed of both dry and mesic species all occurring at low constancy. An important element in these understories is the presence of several shrub and forb species which occur at low constancy, but can dominate sites in early successional sequences. In the shrub layer these are species such as mountain whitethorn, bitter cherry, and snowbrush. In the forb layer bracken fern, Drew's silky lupine, and Anderson's lupine are further examples.

Conifer regeneration is moderate. The average number of seedlings exceeds 500 per acre, and sites usually have more than 250 per acre. Regeneration is usually composed of both red and white fir, but Jeffrey pine is an infrequent component in the regeneration layer, and numbers of this species are low. However, both Jeffrey pine and white fir are regenerating significantly more often than in most other upper montane associations.

Plant species diversity is moderately low. Compared to other associations in the upper montane, the total number of species is mid-range and influenced by the presence of relatively few species in the shrub, forb, and grass layers. Abundant species reside in the tree component that far outweigh cover values in other life forms.

The oldest trees in these stands are usually older than 200 years. Average ages of these stands are not substantially different in age than others in these forests; however, individual Jeffrey pine can attain a considerable age in the Sierra Nevada. Often Jeffrey pine is older than most other species when it occurs in combination in these late seral stands, and the older average stand ages attained in many cases appear to lie in the greater ages acquired by this species. The oldest tree sampled in this association was a Jeffrey pine at $\pm$556 years. The oldest white fir was estimated at ±375 years, and the oldest red fir sampled was ±251 years.

Since stands lie adjacent to lower montane forests with high fire frequency and more intense burns, stand replacing fires probably occur more often in this association than many others in the upper montane. The location of many stands on warm south aspects near ridges and upper slopes would further indicate a high fire frequency. On the other hand, large relatively fire resistant individuals tend to preclude the loss of all individuals from many fires, and no clear picture of larger more intense fires emerges from these stands. Stand structures indicate a fire regime characteristic of other dense stands in the upper montane with small gap formation and few stand replacing events. Stands probably experience both small scale patchy burns with infrequent large scale stand replacing fires typical of the upper montane in most cases. Other disturbance elements such as windthrow and avalanche are not widespread features of these stands. Insects, disease, and lightning are more common, but mortality from these factors often occurs in localized situations or in select species. Disturbance from all elements occurs continuously on various scales in these stands, and this appears to result in the creation of various sized gaps and constantly changing structures through time.

Reproductive strategies such as consistent seed production are present in most of the tree species in these stands. Sprouting or delayed germination of seed until scarified by fire is present in many of the shrub species. Sierra chinquapin and greenleaf manzanita are sprouting species for example. Mountain whitethorn, several lupine species, and western bracken fern are not common understory species in this association; nevertheless, they all have the ability to reoccupy disturbed sites rapidly through long term storage of viable seeds or rhizomes. Shade intolerant species such as Jeffrey pine are undoubtedly maintained by disturbances that open stands and provide seed beds.

Stand development appears to be sporadic as opportunities for regeneration and growth arise in response to disturbance. After disturbance, the most likely successional sequence involves early dominance by shrubs, forbs, and grass. These early communities can be quite persistent on the landscape, and replacement by trees can be a prolonged process. Once regeneration is established, however, it grows, self-thins, and matures while other portions of the stand continue to undergo disturbance. In time, a patchy distribution of trees emerge with mixed species. Several size and tree classes are represented, including a substantial portion of larger trees. The stand exhibits an irregular structure with many small relatively even-aged patches. As stands occupy sites for longer periods, successive disturbances continue to develop and maintain stand structures until an infrequent stand replacing event occurs and a new stand emerges.

Cover (percent)	*Mean*	*Range*
Total vegetative	76	39-97
Tree	65	30-90
Shrub	10	0-78
Forb	13	0-90
Grass	2	0-40
Moss	0.6	0-15
Stand age (years)	208	75-379
Diversity index		
Simpson	0.37	0.13-0.85
Hill numbers		
N0	11.9	3.0-22.0
N1	4.58	1.48-9.19
N2	3.36	1.18-7.71

Characteristic Vegetation

Code	Common name	Constancy	Percent cover Mean	Percent cover Range
I. Overstory trees				
ABCO	White fir	90	26	1-80
PIJE	Jeffrey pine	90	18	2-50
ABMA	Red fir	84	29	1-70
II. Understory trees				
ABMA	Red fir	81	2	1-5
ABCO	White fir	68	1	1-6
PIJE	Jeffrey pine	29	1	1-1
III. Shrubs				
CASE3	Sierra chinquapin	32	17	1-78
ARPA9	Greenleaf manzanita	23	2	1-4
SYAC	Creeping snowberry	26	5	1-15
IV. Forbs				
PESE3	Pine woods lousewort	55	1	1-6
KEGA	Kellogg's bedstraw	52	1	1-60
HIAL	White flowered hawkweed	32	2	1-11
PHHY	Waterleaf phacelia	32	1	1-5
VIPU	Mountain violet	32	1	1-70
COMA4	Spotted coral root	29	1	1-1
PYPI	White veined wintergreen	29	1	1-1
APMEF	Western dogbane	26	1	1-1
CHBR3	Brewer's golden aster	26	1	1-1
GAER	Coville's gayophytum	26	3	1-15
V. Grasses and grass-like				
None				

Soils

Soils are predominantly Inceptisols and typically classified as Xerumbrepts or occasional Xerochrepts. Entisols are rarely encountered in this association. Particle size classes are often loamy and indicate lower levels of large coarse fragments in the profile. These soils are characteristically formed from granitic parent materials, and volcanic or other parent materials are rarely encountered. These soils form from a variety of sources. They usually develop in place from bedrock; however, they are often formed from deposited materials such as colluvium, alluvium, or glacial tills.

Soils in these stands are deep. They are among the deepest in the upper montane, and they are substantially deeper than most other sites. Typical depths exceed 40 inches, and rarely are they less than 35 inches. Topsoil textures are commonly sandy loams with rare sands and loams. These top soils have a considerably higher proportion of sandy loams than soils in most other associations. Subsoils show a similar distribution to the topsoils except sands occur more frequently. Coarse fragments in both topsoil and subsoil are very low. The average coarse fragment content in the topsoil is the lowest of the forested associations in the upper montane. Topsoils commonly contain less than 15 percent coarse fragments. Coarse fragments in the subsoil are typically less than 35 percent.

The AWC of these sites is one of the highest of these forested associations. This reflects the deep soils, finer textures, and lower coarse fragment contents experienced on these sites. Soils are typically well drained. Occasional sites with excessive drainage tend to lie on coarse textured soils with steeper slopes. Bedrock formations were typically fractured and rootable thereby providing additional access to stored water. Erodibility is moderate to high based on soil textures and slopes encountered on individual sites.

Variable	*Mean*	*Range*
Depth of soil sample (inches)	39	28-40+
Topsoil		
Depth (inches)	8	3-20
Coarse fragments (pct.)	13	1-52
pH	6.0	5.2-6.9
Subsoil		
Coarse fragments (pct.)	26	5-80
pH	5.8	5.0-6.8
AWC (inches)	3.8	1.2-6.4
Temp (20 inches) (Fahrenheit)	50	40-62

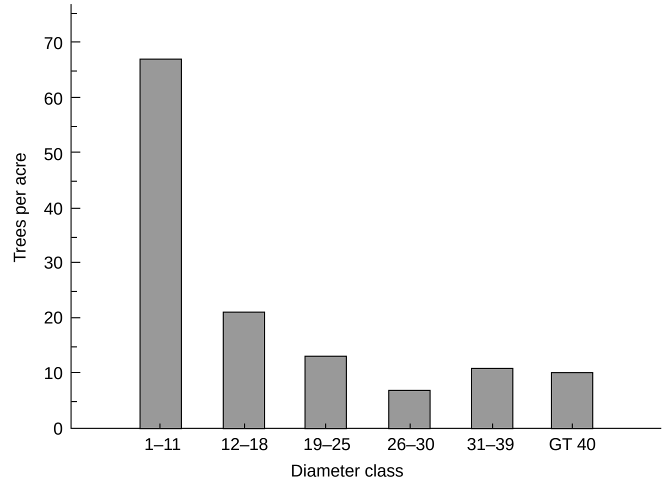
Productivity

Site indexes average 2. In the majority of stands they are 2 and better, and they are substantially higher than in many other stands of the upper montane. Stand densities are moderate. They are usually higher than 300, and stocking levels based on stand density indexes average as much as 75 percent of those attained in fully stocked stands of the red fir-white fir plant association, which is one of the densest in the upper montane forests. Average heights of dominant trees are as tall as those attained in stands of the red fir association. The tallest tree in this association, for example, was a Jeffrey pine measured at 198 feet, while the tallest white fir was 195 feet, and the tallest red fir measured 190 feet. Cubic foot and board foot yields are quite high, but they are somewhat lower than those in the red fir or red fir-white fir plant associations because of relatively lower stand densities.

Stand structures are irregular. In general, however, distributions approach those of an uneven-aged stand *(fig. 33)*. As is typical for most stands in these forests, when they are compared to uneven-aged stands with similar stocking levels and balanced diameter distributions, they carry a deficit of trees in size classes smaller than 18 inches and an excess of trees larger than 30 inches. Compared to an even-aged distribution with equivalent stocking levels, both smaller size classes and larger size classes are over-represented. They closely parallel the distributions of typical late seral red fir dominated stands.

Variable	*Mean*	*Range*
Region 5 site index	2	0-4
Forest survey site class	3	1-5
Stand density index	386	101-870
Quadratic mean diameter	23.9	9.6-37.9
Softwood volume (mcf/ac)	12.0	4.7-25.5
Softwood volume (mbf/ac)	77.5	11.4-187.6
Softwood basal area (sq ft/ac)	287	56-560
Hardwood volume (mcf/ac)	0	0
Hardwood basal area (sq ft/ac)	0	0

Figure 33—Number of trees by diameter class in the red fir-white fir-Jeffrey pine plant association.



Tree species composition by percent of basal area

Species	ABMA	ABCO	PICO	PIJE	PIMO3	TSME
Percent	39	38	2	20	1	-
Species	JUOC	PILA	LIDE3	PIAL	POTR	QUKE
Percent	-	-	-	-	-	-

Coarse Woody Debris

Snag numbers are moderately high. Snags less than 18 inches diameter are abundant reflecting mortality related to thinning of smaller suppressed individuals. Mortality is distributed relatively uniformly among the remaining size classes, and although all species experience losses they are more than twice as large in red fir compared to other species. Snags are commonly shorter than 50 feet reflecting a tendency of large standing snags to break off with increasing age. They are relatively sound; the majority lie in decay classes 1 and 2. Logs are somewhat uniformly distributed among size classes, and logs larger than 30 inches in large end diameter are relatively abundant. Most logs are less than 50 feet in length, and they lie in decay classes between 3 and 5.

Snags

	Breast Height Diameter Class (inches)						
	<11	*11-17.9*	*18-24.9*	*25-29.9*	*30-39.9*	*>40*	*Total*
Snags per acre	8.9	4.2	1.4	0.6	1.4	1.4	17.9
Snag height (feet)							
<20	4.5	0.8	0.5	0.2	0.3	0.5	6.8
20-50	2.2	1.7	0.5	0.2	0.6	0.5	5.7
>50	2.2	1.7	0.4	0.2	0.5	0.4	5.4
Snag decay class							
1	-	0.9	0.5	0.2	0.3	0.3	2.2
2	8.9	2.5	0.5	-	0.6	0.2	12.7
3	-	0.8	0.4	0.4	0.4	0.9	2.9
4	-	-	-	-	-	-	-
5	-	-	-	-	0.1	-	0.1

Logs

	Large End Diameter Class (inches)				
	11-20	*21-30*	*31-40*	*>40*	*Total*
Logs per acre	3.0	7.3	7.0	5.3	22.6
Log length (feet)					
<20	1.0	4.6	3.7	1.3	10.6
20-50	1.3	2.0	2.3	1.7	7.3
51-100	0.7	0.7	0.7	1.6	3.7
>100	-	-	0.3	0.7	1.0
Log decay class					
1	-	-	0.3	-	0.3
2	1.0	1.3	1.3	1.0	4.6
3	1.3	4.0	2.7	0.7	8.7
4	0.7	1.7	1.7	2.3	6.4
5	-	0.3	1.0	1.3	2.6

Wildlife

Stands in this association may offer some hiding and thermal cover to large game, but forage possibilities appear transitory. Of the species occurring in this association only occasional greenleaf manzanita or waterleaf phacelia are staples in the large game diet, and constancy and cover values for these species are low. Nevertheless, deer sign on these sites was common, and pocket gopher were often observed as well.

Range

These are transitional range forage sites that are used by livestock to access primary range such as meadows and other moist habitats. Cattle presence was generally observed within stands. Grass is essentially absent, and all other species occurring with reasonable constancy and cover are low value forage species. These late seral stands appear to offer only marginal livestock forage potential.

Management Recommendations

Many stands have been harvested in the study area. Early harvests were directed at improvement cuttings, but more recently, harvests in the form of clearcutting to develop even-age stands has been practiced. Little reliance has been placed on obtaining natural regeneration in such situations. Most sites have been planted to Jeffrey pine. Results are varied, and this practice has diminished in recent years. Many well stocked and growing Jeffrey pine plantations are present in the study area. Failures are probably due to a variety of factors; however, these sites are some of those in the upper montane forests that have the potential for serious competition from shrubs and, in some cases, forbs such as lupine and bracken fern.

Although original cover values are rarely high, several understory species have the ability to rapidly occupy freshly disturbed sites through germination of seed stored in the soil or resprouting. Sierra chinquapin, greenleaf manzanita, mountain whitethorn, bitter cherry, squaw currant, several lupine species, and bracken fern are such species, and all are present in varying degrees in these stands. In some cases they are already major understory components of existing stands, and they can quickly dominate a specific site.

Stands have high productive capacity and flexibility for management. Stand structures are variable, and options for silvicultural systems and cutting methods can vary to take advantage of the shade tolerance and high stand densities attainable. Natural regeneration can be a viable option. Stand openings should be kept small and seed source near. Topsoils on some sites can be shallow, and site preparation should be done with care. On north facing slopes small clearcuts can be utilized, but on south aspects shelterwood cutting or a silvicultural system that maintains constant tree cover is recommended. Early shrub, forb, and grass competition should be anticipated when openings are created. In particular, sites at lower elevations on south aspects can become occupied with species that offer serious competition to new seedlings. Most reforestation prescriptions in this association should thus plan for vigorous vegetation control early in the life of any plantation. As techniques for successfully planting white and red fir under field conditions improve, species composition in reforestation should begin to reflect the natural species distributions on these sites.

These sites also have the potential to contribute to wildlife values. In their present condition they are an important source of snags especially in smaller size classes, and through management, they can continue to provide high levels of snags for a period of time after harvest. Many of the species expected to offer competition to conifer seedlings are also preferred or secondary large game food sources. Mountain whitethorn and bitter cherry are preferred forage, and snowbrush and greenleaf manzanita are staples in the large game diet. Under some circumstances, careful vegetation management early in the life of plantations in this association can contribute to wildlife forage while not seriously impacting reforestation efforts.

Jeffrey Pine-Red Fir Association

Pinus jeffreyii-Abies magnifica

PIJE-ABMA
CPJCPJ11
Sample size: 8

Distribution

The Jeffrey pine-red fir plant association is primarily an eastside plant community. It was sampled on the Inyo National Forest and the Lake Tahoe Basin Management Unit, but it occurs at all latitudes on the eastside. The most southerly stand sampled was near Casa Vieja Meadows on the Kern Plateau. The most northerly stand occurred near Emerald Bay in Lake Tahoe. Stands can be somewhat extensive, but they lie in the range of 10 to 50 acres in most cases.

Environment

This association occurs at high elevations reflecting locations on the eastside. Stands occur at the highest elevations of all the Jeffrey pine dominated communities. They are typically located above 8,500 feet. The lowest stand sampled was on the Lake Tahoe Basin Management Unit at 7,340 feet although the highest was at 9,520 feet on the Kern Plateau. Aspects typically face southeast through southwest on slopes that commonly exceed 35 percent. With this combination of aspect and slope, SRI levels are frequently high. These stands characteristically occupy upper and middle slope positions. They have significantly more bare ground than dense forested types such as the red fir or red fir-white fir associations. Microrelief is variable; some locations are broken and hummocky, and others are quite uniform.

Variable	Mean	Range
Elevation (feet)	8,607	7,340-9,120
Slope (pct.)	33	12-47
Solar radiation index	0.509	0.386-0.576
Bare ground (pct.)	10	0-43
Surface gravel (pct.)	11	1-35
Surface rock (pct.)	5	0-24
Litter (pct.)	76	39-96
Litter depth (inches)	1.5	0.2-2.2
Stress index	0.52	0.46-0.58

Aspect: SE, SW.

Range: NE, SE, SW.

Position: Upper slopes.

Range: Upper, middle, and lower slopes.

Vegetation

Stands are somewhat open forests with sparse understories composed of scattered shrub, forb, and grass patches. The overstory is characterized by the presence of Jeffrey pine. Red fir is generally present as well, but it sometimes occurs in the middle and lower layers of the tree canopy. Lodgepole pine is an infrequent component of the species composition. Red fir is often a moist to mesic site indicator, but Jeffrey pine in most of these stands indicates the somewhat drier conditions that prevail.

A shrub layer occurs at very low levels on most sites; however, in the southern portion of the range stands can be dominated by Sierra chinquapin, a dry site indicator. In the north, sagebrush, bitter brush, and sticky-leaved rabbit brush are present reflecting dry to moderate eastside conditions. Broad seeded rock cress and naked stemmed eriogonum in the forb layer and western needlegrass in the grass layer are all indicators of drier habitats. The overall mix of species in each life form of this association are indicative of moderate to dry conditions.

Conifer regeneration is among the lowest of any sites in the upper montane. The average number of seedlings per acre is 85, but distributions are skewed and the median value is only 15. Stands typically have less than 100 seedlings per acre. Red fir is usually present, but Jeffrey pine is only present on occasional sites. When both species are present, red fir occurs in somewhat higher proportions, but neither species is dominating the sparse regeneration layer.

Plant species diversity is among the lowest of all associations in the upper montane. These communities have few species overall. Even though they are somewhat open sites, stands are dominated by two tree species that far outweigh the cover values of the shrub, forb, and grass layers. Abundant species are few in number and concentrated in the tree layer.

The oldest trees in these stands are commonly older than 250 years. Although stands are not substantially older than others in these forests, Jeffrey pine, as a species, can attain a considerable age. Often, it is older than most other species when it occurs in combination with other species in these late seral stands, and the older ages attained by many stands appear to lie in the greater ages attained by Jeffrey pine. The oldest tree sampled in this association, however, was a red fir at ±409 years, and the oldest Jeffrey pine sampled was ±392 years.

Stand replacing disturbances are probably not frequent in this association. Southerly aspects, steeper slopes, and upper slope positions favor larger, more intense fires. On the other hand, these factors are moderated by higher elevations, lower stand densities, large fire resistant individuals, open understories, and landscape fragmentation. Evidence from the field during sampling indicates low occurrence of fire in this association, and stand structures indicate smaller fires as a normal pattern. Stands in this association probably experience patchy burns with some portions of the stand completely consumed and others left with little damage.

Disturbance elements such as windthrow and avalanche are not common features of these stands. Insects, diseases, and lightning are more common, but they generally occur in localized situations or on select species and seldom involve replacement of a stand. In most cases disturbance is occurring continuously on various scales, and this results in the creation of various sized gaps with constantly changing structures through time.

Reproductive strategies such as consistent seed production, widespread dispersal of seed, germination on mineral seedbeds, sprouting, or delayed germination of seed until scarified by fire is present in some species on these sites. Jeffrey pine is a consistent seed producer that does well on mineral seedbeds while Sierra chinquapin and bitterbrush are sprouting species.

Stand development appears to be sporadic as opportunities for regeneration and growth arise in response to disturbance. After disturbance, stands may go through a period in a grass/forb phase, and it appears conifer establishment is a process that can occupy a considerable period of time. Eventually, however, conifer regeneration becomes established in openings. These trees grow, self thin, and mature while other portions of the stand undergo disturbance. As crowns close and tree cover increases, shade tolerant species such as red fir become established. These species continue to seed in and grow, and without further disturbance, they can dominate the overstory. Generally, however, disturbance occurs before the stand is dominated by fir, and Jeffrey pine reestablishes its position in the stand. In time, a patchy distribution of trees emerges with several size and tree classes, including a substantial portion of larger trees. Eventually the stand exhibits an irregular structure with relatively even-aged patches and large individuals scattered throughout. As stands occupy sites for longer periods, successive disturbances maintain these stand structures until an infrequent stand replacing event occurs and a new stand emerges.

Cover (percent)	***Mean***	***Range***
Total vegetative	72	18-98
Tree	54	17-83
Shrub	10	0-50
Forb	19	1-83
Grass	5	0-30
Moss	0	0
Stand age (years)	270	90-390
Diversity index		
Simpson	0.43	0.29-0.91
Hill numbers		
N0	7.2	2.0-14.0
N1	3.15	1.21-4.13
N2	2.59	1.10-3.44

Characteristic Vegetation

Code	*Common name*	*Constancy*	*Percent cover Mean*	*Percent cover Range*
I. Overstory trees				
PIJE	Jeffrey pine	100	26	4-73
ABMA	Red fir	100	30	9-79
II. Understory trees				
ABMA	Red fir	50	1	1-2
PIJE	Jeffrey pine	38	2	1-3
III. Shrubs				
CASE3	Sierra chinquapin	25	26	25-26
PUTR	Bitter brush	25	1	1-1
IV. Forbs				
ARPL	Broad seeded rock cress	88	1	1-4
ERNUD	Naked stemmed eriogonum	62	2	1-3
APMEF	Western dogbane	25	1	1-1
V. Grasses and grass-like				
STOC1	Western needlegrass	38	1	1-2
STEL1	Elmer's needlegrass	25	3	3-30

Soils

Soils in this association are Entisols. Most are Psamments indicative of sandy soils, and the remainder are Orthents. Particle size classes are usually sandy, and the association has a significantly higher proportion of sites with sandy particle size classes compared to most others in the upper montane. Occasional samples from the eastside near Mammoth Mountain are cindery. Soils in these stands are derived from two parent materials. A portion occur on granitic substrates, and an equal portion are derived from tephra deposits. These soils differ substantially from most other sites in that they are commonly formed from alluvial deposits and less often from bedrock.

Soils are characteristically deep. The majority of sites had soil depths that exceeded 40 inches, and only one sample had a soil depth of less than 25 inches. On the other hand, these soils are coarse textured. Textures in both the topsoil and subsoil are essentially gravelly sands. This association differs from many others in containing significantly higher levels of gravels in the topsoil. Coarse fragments are also significantly higher throughout the profile than most other sites. Topsoil coarse fragments, for example, are often greater than 35 percent, and occasionally they are greater than 65 percent. Subsoil coarse fragments commonly range between 15 and 35 percent, but they occasionally exceed 65 percent as well. Topsoil colors are typically 10 YR in hue and mollic in chroma and value although a significantly high portion were ochric. Such soils are light yellowish brown. Subsoil colors are also 10 YR in hue, but they have a significantly higher proportion that are high value compared to most other sites. Colors on such sites range from light brownish gray to brownish yellow when moist.

The AWC of these sites is wide ranging. The average AWC is among the lowest in the upper montane forests although there is substantial variation in values and this may not be true on specific sites. Bedrock contacts are commonly unfractured and unrootable, and drainage is frequently excessive. Subsoil pH is considerably more neutral than on most other sites. These soils are warm. Summertime temperatures commonly exceed 58^{o} Fahrenheit.

Variable	Mean	Range
Depth of soil sample (inches)	38	17-40+
Topsoil		
Depth (inches)	9	4-16
Coarse fragments (pct.)	36	6-80
pH	5.9	4.8-6.5
Subsoil		
Coarse fragments (pct.)	36	5-85
pH	6.1	5.5-6.7
AWC (inches)	2.2	0.5-3.9
Temp (20 inches) (Fahrenheit)	56	40-64

Productivity

Site indexes are moderate. Pacific Southwest Region (Region 5) site indexes are usually 3. None were encountered that were less than 3 nor higher than 2. Stand density is also moderate. Stand density indexes are commonly greater than 300, but few exceed 500. They are substantially less than stocking levels attained in the densest stands such as those in the red fir-white fir association, but commonly they will attain stocking levels that are more than 60 percent of those values, and occasionally values will reach more than 95 percent. Stocking in these late seral stands also resides in the larger individuals of the stand. Average quadratic mean diameters approach those of typical red fir stands that carry much of their stocking in larger size trees. Tree heights reflect the moderate site indexes experienced on these sites. The tallest red fir measured 162 feet, and the tallest Jeffrey pine measured 143 feet in this association. Moderate site indexes and stocking levels results in moderate cubic and board foot yields for these stands.

Stand structures are irregular; however, more than most other stands in the upper montane, they tend to approach an even-aged or two storied distribution in this association *(fig. 34)*. Trees larger than 24 inches are distributed almost evenly by size class, and trees smaller than 24 inches are present in substantially fewer numbers than in other associations, giving a relatively uniform distribution across all size classes. Compared to the balanced diameter distribution of an uneven-age stand with similar stocking levels, trees in size classes up to 24 inches are substantially fewer in number, and those in size classes above 30 inches are somewhat over-represented. When compared to a balanced even-age distribution, trees in size classes less than 24 inches and larger than 30 inches are higher in number than needed at similar stocking levels.

Variable	Mean	Range
Region 5 site index	3	2-3
Forest survey site class	4	3-4
Stand density index	324	92-647
Quadratic mean diameter	23.7	13.1-40.9
Softwood volume (mcf/ac)	8.0	3.4-12.8
Softwood volume (mbf/ac)	49.8	21.4-91.4
Softwood basal area (sq ft/ac)	234	88-413
Hardwood volume (mcf/ac)	0	0
Hardwood basal area (sq ft/ac)	0	0

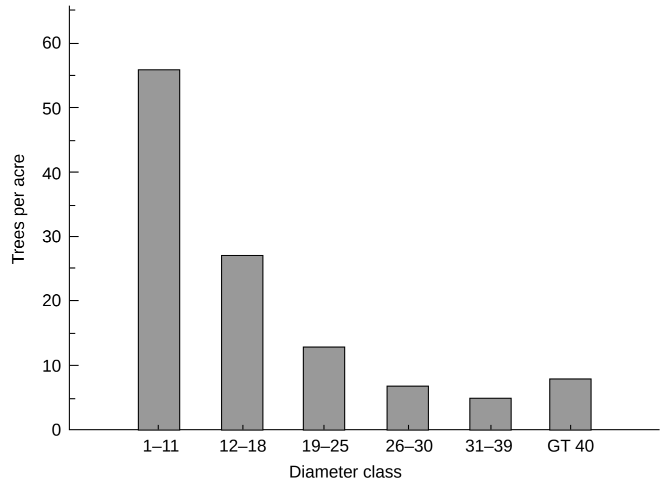


Figure 34—Number of trees by diameter class in the Jeffrey pine-red fir plant association.

Tree species composition by percent of basal area

Species	ABMA	ABCO	PICO	PIJE	PIMO3	TSME
Percent	46	-	-	53	1	-
Species	JUOC	PILA	LIDE3	PIAL	POTR	QUKE
Percent	-	-	-	-	-	-

Coarse Woody Debris

Snag densities are moderate to high. Most mortality occurred in size classes below 18 inches in diameter. This concentration appears to result primarily from self thinning as stands develop. Mortality is distributed evenly among species. Snag heights are concentrated in the 20 to 50 foot class reflecting the higher numbers of smaller size snags. Decay classes generally lie between 1 and 3. Logs from the samples were all less than 30 inches in large end diameter, and the majority were less than 50 feet in length. Log decay classes also differed from most other associations in containing an unusually high number between classes 1 and 3.

Snags

	Breast Height Diameter Class (inches)						
	<11	*11-17.9*	*18-24.9*	*25-29.9*	*30-39.9*	*>40*	*Total*
Snags per acre	15.8	2.8	2.0	1.7	0.5	0.3	23.1
Snag height (feet)							
<20	4.7	0.7	0.8	0.8	0.2	0.1	7.3
20-50	9.5	0.7	0.4	0.9	0.1	-	11.6
>50	1.6	1.4	0.8	-	0.2	0.2	4.2
Snag decay class							
1	3.2	1.4	-	-	-	-	4.6
2	6.3	-	2.0	-	0.2	0.1	8.6
3	6.3	1.4	-	1.7	0.2	0.2	9.8
4	-	-	-	-	-	-	-
5	-	-	-	-	0.1	-	0.1

Logs

	Large End Diameter Class (inches)				
	11-20	*21-30*	*31-40*	*>40*	*Total*
Logs per acre	16.0	8.0	0	0	24.0
Log length (feet)					
<20	12.0	4.0	-	-	16.0
20-50	4.0	2.0	-	-	6.0
51-100	-	2.0	-	-	2.0
>100	-	-	-	-	-
Log decay class					
1	4.0	-	-	-	4.0
2	6.0	6.0	-	-	12.0
3	2.0	2.0	-	-	4.0
4	4.0	-	-	-	4.0
5	-	-	-	-	-

Wildlife

Stands appear to offer marginal forage possibilities for large game. Bitter brush is a preferred forage species, but it occurs somewhat infrequently and with low cover. Naked stemmed eriogonum in the forb layer, and western needlegrass are staples in the large game diet that may provide some contribution to the large game diet. Deer use was observed to be uncommon, although a majority of sites had pocket gophers present.

Range

These are transitional range sites that are used by livestock to access primary sites such as meadows and other moist habitats. Evidence of cattle presence was observed on all sample sites in this association. Although most of the shrub component contains low value forage, bitter brush is a secondary forage species; however, constancy and cover values are low. Western needlegrass is a secondary range species in the grass layer. It occurs with sufficient frequency, but cover values are also low. It appears range forage potential is low in these late seral stands.

Management Recommendations

Some harvesting has taken place in this association. Most harvests have been in the form of improvement or salvage cutting, but in some cases clearcutting was practiced to create even-aged stands. Site preparation appears to have been marginal, planting was uncertain, and poor conifer establishment has resulted. The reasons for failure are unclear. Early successional sequences are poorly understood, and they have not been investigated closely at this time. On most sites, neither red fir nor Jeffrey pine seem to be naturally regenerating these stands. Until more experience is gained, caution should be exercised in treating these stands, and prolonged periods to achieve acceptable stocking should be expected.

These stands have moderate productive capacity and flexibility for stand management. Stand structures are variable. Recommendations for harvesting can involve both even- and uneven-aged siliv cultural systems and a variety of cutting methods, but the ability of sites to respond to treatment is uncertain, and the ability to predict results of treatment are not based on wide experience or research results at this time. The open nature of these stands indicates that regeneration and establishment is a lengthy and variable process under most conditions. Openings for regeneration should be kept small, probably less than 5 acres. A regeneration strategy recommended at this time would involve site preparation to prepare a mineral seedbed to encourage natural seeding, followed by planting with both Jeffrey pine and red fir as preferred species for early stocking of these sites. Future treatments should emphasize continued development of this species mix.

Lodgepole Pine/Sagebrush Association

Pinus contorta/Artemesia tridentata

PICO/ARTR
CPLCPL14
Sample size: 11

Distribution

The lodgepole pine/sagebrush plant association is predominantly an eastside plant community occurring at middle to upper elevations near the Sierra Nevada crest. It was sampled primarily on the eastside, but a few stands were located just west of the crest on westside forests. The association spans the full range of latitudes in the central and southern Sierra Nevada, but longitudes reflect the eastern setting of most samples. Along with the lodgepole pine and red fir-western white pine-lodgepole pine associations, these are the stands in the upper montane forest that transition into subalpine vegetation at still higher elevations. Stands can often cover extensive areas, but usually they are less than 50 acres due to natural patchiness of the landscape.

Environment

Elevations typically lie above 8,500 feet. The lowest stand sampled was at 7,560 feet on the Toiyabe National Forest, and the highest was in the Inyo National Forest at the southern limit of the upper montane on the Kern Plateau. Southeast and southwest aspects are common, but occasional northwest facing slopes are also encountered. Stands are often located on moderate slopes between 20 and 30 percent. They commonly occur on middle to lower slopes, but a high proportion are also found on upper slopes and broad ridge top locations. Microrelief is frequently uniform and relatively smooth. This association has substantially higher levels of surface gravel and shallower litter depth compared to most other sites in the upper montane.

Variable	Mean	Range
Elevation (feet)	8,510	7,560-9,480
Slope (pct.)	22	11-40
Solar radiation index	0.505	0.380-0.552
Bare ground (pct.)	10	2-25
Surface gravel (pct.)	13	2-30
Surface rock (pct.)	3	0-20
Litter (pct.)	74	48-86
Litter depth (inches)	0.6	0.2-1.0
Stress index	0.48	0.39-.59

Aspect: SE, SW.
Range: SE, SW, NW.
Position: Middle and lower slopes.
Range: Upper, middle, lower slopes, toeslopes.

Vegetation

Stands are open woodlands with a shrubby understory of sagebrush. Tree cover is low compared to many other sites in these forests, and trees tend to occur as scattered clumps and individuals. Sites are generally dominated by lodgepole pine. Red fir is often present as a member of the stand, but in most cases lodgepole pine is the only component of the overstory, and red fir occurs as scattered individuals in the understory. Other species such as western white pine, and Jeffrey pine are present in rare instances. These sites are often interspersed with western juniper/sagebrush and quaking aspen/mountain pennyroyal associations and sagebrush shrublands at the edge of the Great Basin. They usually lie adjacent to denser forested stands of the red fir-western white pine-lodgepole pine and lodgepole pine associations.

Understories are characterized by an open shrub layer dominated by sagebrush. Forb cover is among the highest in the upper montane, and both the shrub and forb layers are substantially higher than most other associations. The open growth habit of sagebrush in these forests moderates cover values, and as are sult, total vegetative cover is not much different from many other stands. Sagebrush generally indicates the moderate to dry conditions occurring on these sites. Squaw currant and mountain snowberry are usual members of the shrub component. They also indicate the moderate to drier conditions that prevail. The forb layer is composed of a mix of species which, in general, reflect moderate to dry conditions. Thus, broad-seeded rock cress, mountain pennyroyal, Sierra wallflower, and Coville’s gayophytum generally inhabit drier sites, and mountain mule-ears and Kellogg’s bedstraw occur on sites with moderate conditions. Mountain sweet cicely and Fendler’s meadow rue tend to occupy moist sites. In the grass layer bottle-brush squirreltail and western needlegrass favor dry sites, and Ross’ sedge is often indicative of dry to moderate habitats.

Conifer regeneration is moderate to low. Although the average is 513 seedlings per acre there is considerable variation between sites, and individual stands typically carry fewer than 250 seedlings per acre. Median values are only 80 per acre. Red fir and lodgepole pine are generally present , but red fir dominates this layer when it occurs. Western white pine, Jeffrey pine, and very rarely western juniper, are also present, but they occur in greatly reduced numbers. Lodgepole pine is regenerating significantly more often compared to other associations in the upper montane.

Plant species diversity is among the highest in these forests. It has only a few less species on average than the quaking aspen/mountain pennyroyal and western juniper/sagebrush associations. Lower tree cover in conjunction with higher cover of shrubs, forbs, and grass species result in relatively uniform distributions among high numbers of abundant species. Vegetative cover is spread somewhat uniformly among species of several life forms.

The oldest trees in these stands are typically older than 250 years. This includes the lodgepole pine, which although smaller in diameter, is not substantially different in age from other conifers in these forests. These stands are comparable in age to other upper montane associations. The oldest trees sampled were a lodgepole pine at ±303 years and a red fir at ±282 years.

Stand replacing events may occur in this association at somewhat higher frequencies than others in the upper montane. Shrubby sites on drier southerly aspects with irregular tree distributions would indicate a different fire regime than many others in these forests, and these factors would certainly favor larger, more intense fires. Conversely, the structure of stands with widely spaced individuals and the non-continuous distribution of the shrub layer would tend to ensure some level of tree survival after a fire. These stands probably experience patchy burns with portions of stands being completely consumed and others left with little damage. Isolated large and small trees probably escape damage in most cases. Disturbance elements such as windthrow, insects, disease, lightning, or avalanche are often localized or affect select species, and they do not appear to result in large scale stand replacement in the upper montane.

Reproductive strategies such as consistent seed production, widespread seed dispersal, germination on mineral soil, sprouting, or delayed germination of seed until scarified by fire are present in many of the species on these sites. Lodgepole pine is a consistent seed producer that does well on mineral seedbeds. Sagebrush burns readily, but it is a non-sprouter that may lose dominance on sites for as long as 50+ years after fire. It may actually indicate sites that have not experienced a recent fire. Future occupancy of these sites by sagebrush is uncertain for periods of 50+ years, and they will probably change into persistent forb and grass dominated communities in the understory. The patchiness of vegetation and the wide spacing of existing trees would result in uneven coverage of sites by many disturbance elements. In most cases the species composition of future stands is determined by species currently on these sites.

Stand development appears to be sporadic as opportunities for regeneration and growth arise in response to disturbance. Disturbance creates opportunities for conifer regeneration, but early succession on these sites may involve a persistent grass phase, and in most cases it appears conifer establishment can occupy a considerable period of time. Disturbance also provides opportunities for surviving individuals to increase growth. Isolated patches of conifers probably escape many disturbances and proceed through periods of crown closure and self thinning. Isolated trees and small patches that escape repeated disturbance eventually mature into larger members of the stand. In time, the stand develops an irregular structure reflecting numerous disturbances, and containing large trees that are the survivors of several stand altering events.

Cover (percent)	*Mean*	*Range*
Total vegetative	83	70-99
Tree	44	18-68
Shrub	26	3-52
Forb	37	2-70
Grass	25	4-75
Moss	0.1	0-1
Stand age (years)	176	95-300
Diversity index		
Simpson	0.21	0.10-0.36
Hill numbers		
N0	17.7	9.0-28.0
N1	7.83	4.07-13.47
N2	5.79	2.80-10.10

Characteristic Vegetation

Code	Common name	Constancy	Percent cover Mean	Percent cover Range
I. Overstory trees				
PICO	Lodgepole pine	100	31	10-57
ABMA	Red fir	54	21	8-34
II. Understory trees				
PICO	Lodgepole pine	64	1	1-1
ABMA	Red fir	64	4	1-17
PIJE	Jeffrey pine	27	1	1-1
III. Shrubs				
ARTR	Sagebrush	91	18	1-50
RICE	Squaw currant	64	3	1-11
SYVA	Mountain snowberry	45	4	2-6
PUTR	Bitter brush	36	1	1-2
SYPA	Parish's snowberry	36	2	1-5
CHVI4	Sticky leaved rabbit brush	27	1	1-2
IV. Forbs				
ARPL	Broad seeded rock cress	73	3	1-15
MOOD	Mountain pennyroyal	64	6	1-15
PESE3	Pine-woods lousewort	64	1	1-1
ERPE3	Sierra wallflower	55	2	1-5
CAAP	Indian paint brush	45	1	1-1
WYMO	Mountain mule ears	45	17	1-33
ERSP2	Spurry eriogonum	36	2	1-5
GAER	Coville's gayophytum	36	2	1-5
CHBR3	Brewer's golden aster	27	9	1-18
CIAN1	Anderson's thistle	27	3	1-6
COTOW	Wright's blue eyed mary	27	13	3-30
HACA1	California stickseed	27	2	1-3
HAJE	Jessica's stickseed	27	1	1-2
KEGA	Kellogg's bedstraw	27	1	1-2
OSCH	Mountain sweet cicely	27	1	1-1
SIGL	Glaucous sidalcea	27	7	1-30
THFE	Fendler's meadow rue	27	9	1-25
V. Grasses and grass-like				
SIHY	Bottle brush squirreltail	82	5	1-15
CARO1	Ross' sedge	45	4	1-10
MEBU1	Western oniongrass	36	2	1-5
STOC1	Western needlegrass	36	3	1-10
STCA1	California needlegrass	27	2	1-3

Soils

Usual soils are Inceptisols, but occasional and significantly higher levels of Alfisols are also encountered. Entisols and Mollisols seldom occur. The majority of Inceptisols are Umbrepts with occasional Ochrepts. Alfisols are commonly Xeralfs with a few Boralfs. Particle size classes are distributed between skeletal and loamy, with skeletal soils usually occurring more often and reflecting the higher levels of coarse fragments throughout the profiles. Parent materials are also somewhat varied. Normally, these soils are derived from volcanic substrates such as the andesitic and rhyolitic flow rocks and lahars of the northern portion of the study area, but some are derived from granitic parent materials, and it is suspected that overall in the range, granitic parent materials constitute a substantial part of the bedrock formations under this association. Soils are usually weathered in place from bedrock; however, some are formed in deposited materials such as glacial till, alluvial, and colluvial deposits.

These soils are generally deep. Samples were generally deeper than 35 inches, and rarely were they less. Average topsoil depths are also quite deep; they are among some of the deepest in the upper montane forested plant communities, and they are significantly deeper than most other sites. Topsoil textures are usually loams with some gravelly sandy loams. Subsoil textures tend to be more variable. Here sandy loams are encountered more often, and loams are less common. Textures are also more gravelly. Sands, sandy clay loams, and clay loams were also encountered in a few cases in the subsoils. Topsoil coarse fragments also tend to be high. They are substantially higher than soils in most other associations in the study area. Generally, coarse fragments exceeded 15 percent, and sites with greater than 35 percent coarse fragments in the topsoil were not uncommon. Soil colors in both the topsoil and subsoil are essentially 10 YR in hue. Subsoil colors, however, have significantly higher proportions of high values compared to most other sites in the upper montane. Such soils are basically lighter; most range from light brownish gray to brownish yellow when moist.

The AWC of these sites ranges considerably; however, they are not substantially different from most other sites. Most can be considered to be moderately high, and they reflect the combination of deeper soils with finer textures. Bedrock formations below the soil profile are generally fractured and rootable providing additional sources of water to these stands. Typical sites are well drained, and erodibility is moderate to high as a result of the finer textured surface horizons and somewhat steeper slopes. Even though stands lie at somewhat higher elevations, summertime soil temperatures are warm reflecting the more open stand conditions and southerly aspects. They are significantly warmer than most other associations with dense tree cover, and temperatures commonly exceed 53° Fahrenheit.

Variable	*Mean*	*Range*
Depth of soil sample (inches)	37	26-40+
Topsoil		
Depth (inches)	12	8-20
Coarse frag. (pct.)	30	10-75
pH	5.9	5.3-6.5
Subsoil		
Coarse frag. (pct.)	38	15-55
pH	5.9	5.2-7.1
AWC (inches)	3.3	1.9-4.6
Temp (20 inches) (Fahrenheit)	55	42-62

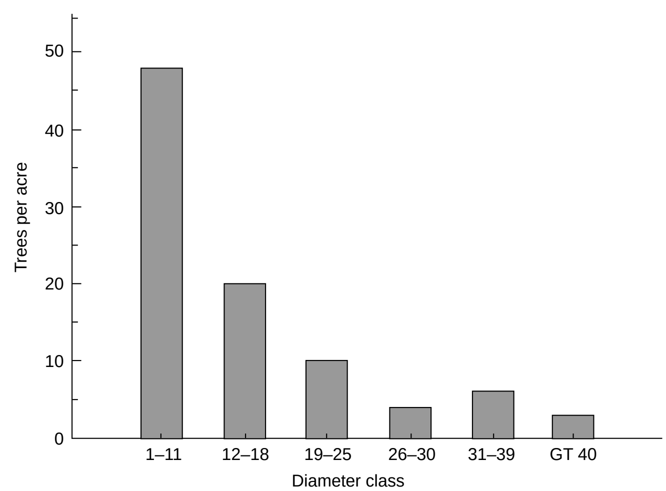
Productivity

Site indexes are moderate to low. In the majority of stands, Pacific Southwest Region (Region 5) site indexes are 3 or poorer. Most frequently they are 3 and 4. Stand densities are also quite low. Stand density indexes are characteristically less than 300. Based on average stand density indexes, these sites carry 40 percent of the stocking that can be carried by the red fir-white fir plant association, which is one of the densest in the upper montane. Tree heights are also substantially shorter than those in many other forested associations. This reflects both lower site indexes and the presence of lodgepole pine. The tallest tree was a red fir which measured 153 feet compared to the tallest lodgepole pine measured at 103 feet. Stocking is concentrated in the larger individuals of the stand. Quadratic mean diameters for stands in the association indicate the presence of relatively large trees. They compare reasonably well with forested stands of the red fir association that retains high stocking levels in larger trees. The largest lodgepole pine was measured at 43 inches. The combination of moderate site indexes and shorter trees in relatively open stands results in cubic and board foot yields that are among the lowest in the upper montane and less than 30 percent of stands in associations such as red fir or red fir-white fir.

Stand structures in late seral stands are irregular. These are open stands with low numbers of trees per acre, and individual stand structures appear variable. When examined collectively, the distribution of stems overall approximates that of an uneven-aged structure to a large degree *(fig. 35)*. Considering the low stocking levels of these stands, they fit an uneven-aged distribution quite well. When compared to uneven-aged structures in stands with similar stocking and balanced diameter distributions, they generally carry appropriate numbers of trees in all size classes below 40 inches and excess trees only in regeneration. Compared to the normal distribution of an even-aged stand, there are far too many trees in size classes below 24 inches and more trees in size classes larger than approximately 30 inches than would be appropriate. The largest portion of trees in all size classes is lodgepole pine. Red fir dominates only the regeneration layer and the largest size classes.

Variable	*Mean*	*Range*
Region 5 site index	4	2-5
Forest survey site class	5	3-6
Stand density index	225	99-429
Quadratic mean diameter	21.7	10.6-35.5
Softwood volume (mcf/ac)	4.3	1.5-9.8
Softwood volume (mbf/ac)	25.7	8.1-68.2
Softwood basal area (sq ft/ac)	154	56-240
Hardwood volume (mcf/ac)	0	0
Hardwood basal area (sq ft/ac)	0	0

Figure 35—Number of trees by diameter class in the lodgepole pine/sagebrush plant association.



Tree species composition by percent of basal area

Species	ABMA	ABCO	PICO	PIJE	PIMO3	TSME
Percent	33	-	54	8	1	-
Species	JUOC	PILA	LIDE3	PIAL	POTR	QUKE
Percent	4	-	-	-	-	-

Coarse Woody Debris

Snag numbers are low indicating the open conditions of this association. snags are apparently concentrated in the larger size classes, but this may be reflective of a low number of sample snags in these open stands. Mortality occurs randomly among species on these sites. Logs are characteristically less than 30 inches in large end diameter and less than 50 feet in length. Logs are distributed among all decay classes, but most occur in classes 4 and 5.

Snags

	Breast Height Diameter Class (inches)						
	<11	***11-17.9***	***18-24.9***	***25-29.9***	***30-39.9***	***>40***	***Total***
Snags per acre	0	0	0	0	0	0.3	0.3
Snag height (feet)							
<20	-	-	-	-	-	0.3	0.3
20-50	-	-	-	-	-	-	-
>50	-	-	-	-	-	-	-
Snag decay class							
1	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-
5	-	-	-	-	-	0.3	0.3

Logs

	Large End Diameter Class (inches)				
	11-20	***21-30***	***31-40***	***>40***	***Total***
Logs per acre	3.0	4.0	0.5	1.0	8.5
Log length (feet)					
<20	2.0	2.5	0.5	0.5	5.5
20-50	1.0	1.0	-	-	2.0
51-100	-	0.5	-	0.5	1.0
>100	-	-	-	-	-
Log decay class					
1	0.5	0.5	-	-	1.0
2	0.5	-	-	-	0.5
3	-	0.5	-	0.5	1.0
4	2.0	0.5	-	-	2.5
5	-	2.5	0.5	0.5	3.5

Wildlife

Forage values appear moderate to high for large game. Several species in this association are preferred and staple species in the large game diet. Thus, mountain snowberry and bitterbrush are preferred species in the shrub layer, and sagebrush is a staple. In the forb and grass layers, Indian paint brush, spurry eriogonum, bottle brush squirreltail, Ross' sedge, western oniongrass, and western needlegrass are all staples. They occur with enough frequency and cover to be reasonable sources of food. Surprisingly, evidence of deer and pocket gophers on these open sites was uncommon.

Range

Range potential appears to be transitory as livestock move to primary range sites in meadows or other moist habitats. Bitter brush and mountain snowberry are secondary forage species in the shrub component. In the grass layer California needlegrass is a primary species, and bottle brush squirreltail and western needlegrass are secondary species. The moderate levels of occurrence and cover of these species would appear to contribute to their potential as range sites. Evidence of cattle use was observed on these sites but at surprisingly lower levels than in other associations that appear to be less desirable for range forage.

Management Recommendations

Few stands in this association have been harvested. These have occurred primarily on the eastside as salvage and improvement cuttings. Formal silvicultural systems have apparently not been applied although varied stand structures are present. Establishment of natural regeneration is uncertain. Successional sequences are not well understood, but high levels of shrub competition would seem to be a factor in regeneration success. This association occupies large areas along the crest. It is felt they will continue to be dominated by lodgepole pine.

This is one of the more diverse plant associations in the upper montane forests, and it provides an important contribution to landscape diversity. Harvesting in these stands at the present time should be conducted with caution. Results from the application of formal silvicultural systems are uncertain at present. Limited opportunities exist for salvage when it occurs, but on these open sites management should emphasize existing wildlife habitat in combination with plant species richness and landscape level diversity.

Lodgepole Pine/Gray's Lovage Association

Pinus contorta/Ligusticum Grayii

PICO/LIGR1
CPLCPL11
Sample size: 23

Distribution

The lodgepole pine/Gray's lovage plant association is widespread in the Sierra Nevada. Latitudes and longitudes span the range of the study area, and it was sampled in every National Forest and Park in the study area except for the Toiyabe. This association generally occurs on moister sites, and stands often cover extensive areas bordering drainage bottoms and adjacent to meadows. Stands are often narrow; usually they are smaller than 10 acres, and in some cases, they can be less than an acre.

Environment

Lodgepole pine has a wide elevational distribution in the Sierra Nevada. Both the lowest and some of the highest elevations for this association occurred in the north reflecting this distribution. Aspects are varied, but frequently northeast and northwest facing slopes are encountered. The average SRI is among the lowest in the upper montane. Slopes are quite shallow, and stands characteristically occupy lower slope positions. Typical locations are adjacent to flat areas such as meadows, on toeslopes, or in gently undulating terrain where slope angles are typically less than 10 percent. Benches and shallow drainages higher on slopes are frequent locations. Microrelief on many sites is hummocky and broken reflecting the presence of small scale drainage patterns that often dissect these communities. This association has considerably less surface gravel than most others in the upper montane. There is abundant moisture available to these sites, and stress indexes are among the lowest of all forested sites in the upper montane.

Variable	*Mean*	*Range*
Elevation (feet)	7,973	6,660-8,920
Slope (pct.)	11	3-32
Solar radiation index	0.487	0.438-0.561
Bare ground (pct.)	1	0-4
Surface gravel (pct.)	1	0-6
Surface rock (pct.)	4	0-25
Litter (pct.)	91	61-99
Litter depth (inches)	1.4	0.4-2.4
Stress index	0.43	0.28-.56

Aspect: NE,NW.

Range: All.

Position: Lower slopes, benches.

Range: All.

Vegetation

Stands are dense forests with a rich understory of forbs. Along with stands in the quaking aspen series, this association has the highest average total vegetative cover of any in the upper montane. Tree, forb, and grass cover are all substantially higher than most other associations, and moss occurs significantly more often in these stands. The overstory is dominated by lodgepole pine, but red fir is usually present as well. These are moderate to moist site species that indicate the basically moist conditions within stands. In some stands lodgepole pine or red fir may be the only member of the overstory, but the characteristically dense understory of forbs and grass aids in identifying the association. Stands often lie adjacent to the red fir-lodgepole pine/white-flowered hawkweed association.

Understory vegetation, particularly in the forb and grass component, can be quite lush. Sierra gooseberry and alpine prickly currant are moist site indicators that are present as occasional shrubs, and a large assemblage of forbs such as Gray’s lovage, serrated wintergreen, Parish’s yampa, arrowhead butterweed, mountain sweet cicely and California corn lily are usually present as indicators of moist conditions. Finally, Bolander’s bluegrass, and common woodrush are mesic to moist site indicators in the grass layer that are typically present. Important variations of the forb species occupying these sites occur in the south and on the eastside. In these locations, the more typical members of the association such as Gray’s lovage and Parish’s yampa are not as common or simply do not occur. In most of these situations, serrated wintergreen is present, but where it is missing arrowhead butterweed, broad petaled strawberry or clover can often be used to identify the association.

Conifer regeneration is high in these stands. Late seral stands average 1,340 seedlings per acre, and they typically carry more than 500 per acre. Both red fir and lodgepole pine are generally present, but the number of lodgepole pine seedlings is often less than one-third that of red fir. Both species are regenerating in significantly higher frequencies than in other associations.

Plant species diversity is moderately high for upper montane forests. The total number of species is moderate, and diversity is influenced by the relatively high number of forb species. Stands compare with associations such as quaking aspen/California corn lily, the Jeffrey pine/mountain whitethorn, and red fir/mountain mule ears as far as total number of species present; however, abundant species are concentrated in a relatively few tree species which dominate the cover in these stands.

The oldest trees in these stands are typically greater than 150 years. Average stand ages are significantly younger than most other forested stands in the upper montane. This results from high numbers of younger trees in smaller size classes. Scattered throughout most stands are predominant lodgepole pine and red fir that are as old as those in the upper montane in general. The oldest tree sampled in this association, for example, was a lodgepole pine at ±354 years, and the oldest red fir sampled was ±202 years.

Stand replacing disturbance events probably occur in this association, but they do not appear to be frequent or large scale phenomenon. The location of many stands along cooler drainage bottoms, the gentle topography of most sites, the structure of the stands with abundant herbaceous understories, and the presence of relatively large, somewhat fire resistant individuals results in uneven coverage by fire. These features tend to preclude fire caused stand replacement. Other disturbance elements such as windthrow, insects, disease, lightning, or avalanche also do not appear to affect large areas in these stands. It is likely that disturbance from several elements occur continuously on various scales, and this results in the creation of various sized gaps with constantly changing structures through time.

Reproductive strategies such as reasonably constant seed production is present in most of the tree species on these sites. Lodgepole pine is a prolific seeder with rapid early height growth, but red fir is shade tolerant, and it can assume dominance as stands develop. Lodgepole pine is shade intolerant, but it can be maintained by disturbances that open stands and provide seed beds. In most cases the species composition of future stands is largely determined by species presently on these sites.

After disturbance it does not appear that these stands go through a prolonged period in a shrub phase during early succession; however, a forb/grass phase can often persist for long periods. Lodgepole pine can occupy grass dominated communities such as those in meadows. Once regeneration is established, it grows, self thins, and matures, but other portions of the stand continue to undergo disturbance. As tree cover increases, shade tolerant species such as red and white fir become established. These species continue to seed in and grow in height until they overtop the lodgepole pine. In time, and without further disturbance, they can dominate the overstory. Generally, however, disturbance will occur before the stand is dominated by fir, and this will allow an increase in the lodgepole component. In time, several size classes, including a substantial portion of larger trees, are represented, and the stand exhibits an irregular structure with many small relatively even-aged patches. As stands occupy sites for longer periods, multiple disturbances continue to be important in maintaining structures and species composition until an infrequent stand replacing disturbance occurs, and a new stand emerges.

Cover (percent)	*Mean*	*Range*
Total vegetative	94	82-99
Tree	76	61-95
Shrub	4	0-30
Forb	43	1-99
Grass	17	2-45
Moss	4	0-35
Stand age (years)	172	76-336
Diversity index		
Simpson	0.35	0.14-0.65

Cover (percent)	Mean	Range
Hill numbers		
N0	14.1	7.0-22.0
N1	4.99	2.43-10.20
N2	3.41	1.54-7.25

Characteristic Vegetation

Code	Common name	Constancy	Percent cover Mean	Range
I. Overstory trees				
PICO	Lodgepole pine	100	55	13-89
ABMA	Red fir	61	33	4-72
II. Understory trees				
PICO	Lodgepole pine	83	1	1-5
ABMA	Red fir	83	6	1-56
ABCO	White fir	22	4	1-18
PIMO3	Western white pine	22	1	1-1
III. hrubs				
RIMO	Alpine prickly currant	30	9	1-30
RIRO	Sierra gooseberry	30	2	1-4
IV. Forbs				
LIGR1	Gray's lovage	74	5	1-50
PYSE2	Serrated wintergreen	56	3	1-10
PESE3	Pine woods lousewort	52	1	1-3
PEPA5	Parish's yampah	43	1	1-6
SETR	Arrowhead butterweed	43	2	1-50
ACLA2	Common yarrow	39	5	1-16
ERPEA	Wandering daisy	39	5	1-30
HIAL	White flowered hawkweed	39	3	1-15
VIPU	Mountain violet	35	2	1-6
THFE	Fendler's meadow rue	30	4	1-15
VECA1	California corn lily	30	2	1-5
LULAC	Broad leaved lupine	26	8	3-20
OSCH	Mountain sweet cicely	26	6	1-20
BRLU2	Yellow brodiaea	22	2	1-4
V. Grasses and grass-like				
POBO1	Bolander's bluegrass	83	2	1-4
CARO1	Ross' sedge	70	8	1-35
LUCO1	Common woodrush	57	3	1-20
AGTH	Thurber's bent grass	43	2	1-5

Soils

Typical soils in this association are Inceptisols. Entisols, Mollisols, and Alfisols are encountered in a few cases. The Inceptisols are distributed between Xerumbrepts and Xerochrepts. Entisols commonly occur as Orthents. Particle size classes are also somewhat divided between skeletal and loamy, but usually they are loamy and indicate lower levels of rock fragments in profiles. The majority of these soils are derived from granitic rocks, and rarely do they occur on other substrates. Soils in this association are usually weathered in place from bedrock; however, they occasionally are formed from material that has been deposited such as glacial till, colluvium, or alluvium.

These soils are moderately deep to deep. Usually they are deeper than 35 inches; some exceed 40 inches, and few are less than 25 inches. Textures in the topsoil are typically loams with occasional sandy clay loams and sandy loams. Subsoils are usually loams as well, but they are coarser textured with higher proportions of sandy loams and sands. Overall, soils in this association are finer textured than most others in the upper montane. They can be considered medium to moderately coarse textured soils. Average coarse fragment contents in the topsoil are among the lowest of any in these forests. Colors in the topsoil are commonly 10 YR in hue and mollic in value and chroma. Basically these are dark brown soils when moist; however, topsoil colors show a wider range in hues than most other sites. Occasional samples had 5 YR and 7.5 YR hues with mollic value and chroma or 10 YR hues with ochric value and chroma. Subsoil colors are also considerably more variable in hue than most other sites, and samples with 5 YR, 7.5 YR, and 5 Y hues are sometimes encountered.

The average AWC of these soils is one of the highest in the upper montane. It reflects the moderately deep soils with finer textures and few topsoil coarse fragments. A noticeable feature of these stands is the abundance of forbs and grasses present throughout the season suggesting high water tables. This appears to be true even in cases where soil depths are shallow or AWC is low. Most sites lie over parent materials that are massive and unrootable, and although many sites are well drained, a significantly high proportion are also poorly drained. This indicates a tendency to retain water in the soil profiles. Lodgepole pine is known to be tolerant of persistently high water tables and is capable of stocking sites under these conditions. Erodibility ranges from moderate to high. Shallow slopes reduce erodibility, but this is often counterbalanced by the high proportion of loamy soil textures in this association. Summertime soil temperatures are cool. Average temperatures in this association are the lowest of any in these higher elevation forests, and they characteristically lie below 49^{o} Fahrenheit.

Variable	*Mean*	*Range*
Depth of soil sample (inches)	35	22-40+
Topsoil		
Depth (inches)	9	3-31
Coarse frag. (pct.)	14	1-42
pH	5.6	4.4-6.5
Subsoil		
Coarse frag. (pct.)	32	1-86
pH	5.9	4.3-6.7
AWC (inches)	3.8	1.7-5.7
Temp (20 inches) (Fahrenheit)	45	38-54

Productivity

Site indexes are moderate. In the majority of stands, Pacific Southwest Region (Region 5) site indexes are 2 or 3. Rarely are they better than 2 or less than 3. Stand densities, on the other hand, are quite high. Stand density indexes commonly exceed 400 in these stands. Based on average stand density indexes these sites can hold over 90 percent of the stocking of the red fir-white fir plant association, which is one of the densest in the upper montane. Tree heights, however, are substantially shorter than those in other dense forested plant associations. This reflects the presence of large numbers of lodgepole pine, which is generally a shorter tree in the Sierra Nevada. The tallest tree in the association was actually a lodgepole pine that measured 144 feet compared to the tallest red fir measured at 132 feet. Quadratic mean diameters are small in comparison to those in other late seral forested stands and reflect the presence of many smaller lodgepole pine. The combination of moderate site indexes and shorter, smaller diameter trees with higher stand densities results in cubic and board foot yields that are moderate for the upper montane, but about half those in highly productive associations such as red fir or red fir-white fir.

Individual stands often have the appearance of an even-aged or two storied structure; however, stands frequently exhibit other structures, and taken collectively they can be considered irregular. Distributions actually approximate those of an uneven-aged stand to a large degree *(fig. 36)*. Compared to uneven-aged structures in stands with similar stocking and balanced diameter distributions they tend to carry too many trees in size classes below 30 inches; however, the number of trees in size classes larger than 30 inches is appropriate for uneven-aged structures. When these stands are compared to an even-age structure, there are too many trees in size classes below 24 inches and more trees in size classes larger than 30 inches than would be appropriate. Lodgepole pine carries the largest portion of trees in size classes between 6 and 24 inches in most of these stands, and viewed as a separate component of the stand, distributions for this species appear even-aged.

Variable	*Mean*	*Range*
Region 5 site index	3	1-5
Forest survey site class	4	2-6
Stand density index	489	223-951
Quadratic mean diameter	17.2	9.1-28.2
Softwood volume (mcf/ac)	8.6	3.0-21.2
Softwood volume (mbf/ac)	47.0	13.1-141.5
Softwood basal area (sq ft/ac)	333	220-600
Hardwood volume (mcf/ac)	0	0
Hardwood basal area (sq ft/ac)	0	0

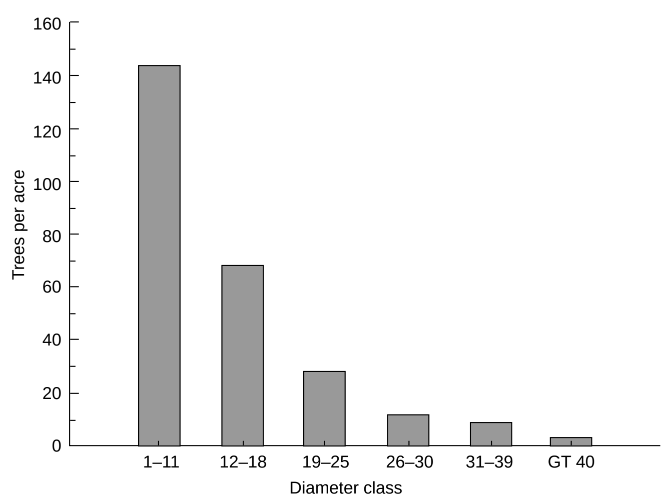


Figure 36—Number of trees by diameter class in the lodgepole pine/ Gray's lovage plant association.

Tree species composition by percent of basal area

Species	ABMA	ABCO	PICO	PIJE	PIMO3	TSME
Percent	28	-	70	-	2	-
Species	JUOC	PILA	LIDE3	PIAL	POTR	QUKE
Percent	-	-	-	-	-	-

Coarse Woody Debris

Total snag numbers are among the highest in upper montane forests. In particular, the number of snags with diameters less than 18 inches are substantially higher than most other sites. Mortality occurring in these size classes is predominantly lodgepole pine and represents a substantial amount of thinning within sapling and pole size trees. Most snags are less than 50 feet in height reflecting the presence of lodgepole pine in the stands. Snags taller than 50 feet are also well represented and indicate the presence of both red fir and lodgepole pine, which often topples intact rather than breaking down from above. Snag decay classes commonly lie between 1 and 2. Logs are typically less than 30 inches in large end diameter, and usually they are less than 20 feet in length. Logs are more decayed than snags; most logs lie between decay class 3 and 5.

Snags

	Breast Height Diameter Class (inches)						
	<11	***11-17.9***	***18-24.9***	***25-29.9***	***30-39.9***	***>40***	***Total***
Snags per acre	21.6	9.2	3.1	1.0	1.0	0.6	36.5
Snag height (feet)							
<20	10.3	1.4	-	0.1	0.1	0.3	12.2
20-50	0.1	4.6	0.3	0.2	0.3	-	14.5
>50	2.2	3.2	2.8	0.7	0.6	0.3	9.8
Snag decay class							
1	8.1	1.7	0.7	0.2	-	0.3	11.0
2	9.2	5.7	1.5	0.4	0.6	-	17.4
3	3.2	1.2	0.4	0.1	0.2	-	5.1
4	1.1	0.3	0.4	0.1	0.1	0.3	2.3
5	-	0.3	0.1	0.2	0.1	-	0.7

Logs

	Large End Diameter Class (inches)				
	11-20	***21-30***	***31-40***	***>40***	***Total***
Logs per acre	7.5	7.2	3.2	1.3	19.2
Log length (feet)					
<20	4.0	3.9	0.8	0.8	9.5
20-50	2.8	2.8	1.7	0.3	7.6
51-100	0.7	0.5	0.5	0.2	1.9
>100	-	-	0.2	-	0.2
Log decay class					
1	0.2	-	0.2	-	0.4
2	1.0	0.3	0.1	0.3	1.7
3	3.0	1.9	0.7	0.2	5.8
4	1.3	3.2	1.2	0.6	6.3
5	2.0	1.8	1.0	0.2	5.0

Wildlife

These stands may offer hiding and thermal cover to large game, but forage possibilities appear to be transitory. Most of the shrub and forb species occurring on these sites are low value components of the large game diet. Thus, of the substantial number of species occurring in these stands, wandering daisy and possibly broad leaved lupine are the only real staples in the forb layer that occur with reasonable frequency and cover. Bolander's bluegrass and Ross' sedge are also staples from the grass layer that occur with enough frequency and cover to provide reasonable amounts of forage. Evidence of deer and pocket gopher was common on these sites

Range

These are transitional range sites that are used by livestock since they often lie adjacent to primary range sites such as meadows and other moist habitats. In the forb layer, California corn lily, mountain sweet cicely, and possibly broad leaved lupine are secondary range forage species. Thurber's bent grass is a primary species in the grass layer. The moderate levels of occurrence and cover of the primary and secondary species probably provide important contributions to range use. Cattle use was often observed on these sites, and their locations near wet areas such as meadows and streams would encourage range utilization of available forage.

Management Recommendations

Few stands have been treated in this type. Where they have, silvicultural systems, cutting methods, and regeneration patterns are unclear. A few were treated as part of meadow restoration projects. In some cases lodgepole pine dominates early natural regeneration; in other cases the high water tables presumed to exist on these sites seems to preclude regeneration for a considerable period of time. Early stand development is poorly understood. Successional sequences after disturbance seem to indicate movement toward somewhat persistent forb and grass communities that are replaced in time with lodgepole pine forests. Over longer periods as crowns close, lodgepole pine becomes mixed with shade tolerant red fir, but lodgepole often continues to dominate these sites.

Stands have moderate productive capacity and flexibility for stand management. Stand structures are variable, but species composition is somewhat limiting, and the ability of sites to respond to treatment are uncertain. The ability to predict results of treatment are not based on wide experience or research results at this time. Recommendations for harvesting at the present time would be to treat stands in this association with caution. Any treatment planned in these stands should be done with the realization that a high degree of uncertainty must accompany expected results. Management may be more appropriately directed at maintaining the landscape level diversity this association provides.

Lodgepole Pine//Woodlands Association

Pinus contorta//woodlands

PICO//WOODLANDS
CPLCPL12

Sample size: 10

Distribution

The lodgepole pine//woodlands plant association is located at middle to upper elevations throughout the central and southern Sierra. Latitudes and longitudes span the range of the study area. Sample sites occurred in higher proportions on the Inyo National Forest but from two widely separated sources. One group was located on the Kern Plateau adjacent to the Sequoia National Forest on the southeastern side of the study area, and the other was located near Mammoth Mountain in the central portion of the eastside. Stands range in size from less than an acre to as much as 50 acres or larger, but most are less than 25 acres due to natural patchiness in the landscape.

Environment

Elevations are wide ranging, but generally stands lie above 7,500 feet. Aspects are varied and evenly distributed across the landscape on moderate to gentle slopes that characteristically are less than 20 percent. Stands occur in two somewhat disparate locations. Commonly, they lie on lower slopes and benches. These locations are characteristic of many lodgepole stands; however, a high proportion of this association also occurs on broad, somewhat rounded, ridge tops. Few appear to be located on middle slopes. Bare ground and surface gravel occur in these plant communities at significantly higher levels, and litter cover and litter depth are significantly less than on most other sites Microrelief is typically uniform and smooth; however, on occasional sites, surfaces are broken and hummocky due to large amounts of surface rock. Sites in this association have characteristics of dry habitats. Stress indexes are moderate to high and reflect dry conditions overall. Stands with abundant surface rock indicate there may be considerable subsurface variation in water availability that affects plant distribution in these stands. Thus, within the same stand, some soils are deep, and moisture supply is adequate, but in others depths are shallow and moisture supplies are low. The end result is variation of site conditions within a stand, and a patchy distribution of vegetation.

Variable	*Mean*	*Range*
Elevation (feet)	8,174	7,360-9,080
Slope (pct.) 12	5-30	
Solar radiation index	0.490	0.445-.536
Bare ground (pct.)	28	3-80
Surface gravel (pct.)	15	1-55
Surface rock (pct.)	10	0-53
Litter (pct.) 44	3-88	
Litter depth (inches)	0.6	0.1-1.0
Stress index	0.50	0.38-0.66

Aspect: All.
Range: All.
Position: All.
Range: All.

Vegetation

Stands are open woodlands with an understory of scattered forbs and grass. This association has the lowest average total vegetative cover and some of the lowest tree and shrub cover of all the forested associations in the upper montane. Overstory composition is characterized by lodgepole pine usually mixed with scattered red fir. These species usually indicate moderate to moist sites in most cases and, as noted, their dispersed distribution within the community may indicate a patchy nature to the moisture supply.

The shrub component is essentially missing or occurs at very low levels, but the forb layer is characterized by species that indicate generally dry habitats. Thus, pussy paws, broad seeded rock cress, naked stemmed eriogonum, and Coville's gayophytum are all reflective of generally drier habitats. The grass layer, too, contains moderate to dry site indicators such as bottle brush squirreltail, Ross' sedge, and western needlegrass. Bolander's bluegrass is present in some cases to indicate moderate to somewhat moist conditions at specific locations within stands.

Conifer regeneration is somewhat low. The average number of seedlings in over 300 per acre, but distributions are skewed, and the median is 115. Usually, seedling counts are higher than 100 per acre; but only occasionally will sites have more than 250. Red fir is the dominant species in the regeneration layer; lodgepole pine is commonly present as well, but it occurs in substantially fewer numbers than red fir. Other species are rarely encountered. Compared to other associations, lodgepole pine is regenerating on a significantly higher proportion of sites, and red fir is regenerating on a significantly lower proportion.

Plant species diversity is quite low. It is among the least diverse of the upper montane plant associations. Stands have a low number of species overall, and these are concentrated in the overstory tree layer. Sites are dominated by few tree species, which outweigh cover values of the shrub, forb, and grass layers. Abundant species are few in number and concentrated in the tree layer.

The oldest trees in these stands are typically older than 250 years, but average stand ages are comparable to most other late seral forested plant communities in the upper montane. Lodgepole pine, although somewhat smaller in diameter in general, is not substantially different in age from the red fir which occupies these sites. The oldest tree sampled was a lodgepole pine at ±443 years, and the oldest red fir sampled was ±392 years. The oldest western white pine sampled in the association was ±250 years old.

Stand replacing fires probably occur in this association, but they do not appear to be a widespread or frequent phenomenon. Open stands with widely separated trees, the natural patchiness of upper elevation landscapes, and the presence of larger, somewhat fire resistant individuals, tends to preclude fire caused stand replacement and results in uneven coverage and some level of vegetation survival in most cases. These stands probably experience patchy burns with little overall damage. Isolated large and small trees escape fire damage in most cases. Other disturbance elements such as windthrow, insects, disease, lightning, or avalanche are not common features of these stands, and they do not generally result in stand replacement.

Disturbance creates opportunities for regeneration, but many microhabitats are unsuitable for regeneration, and conifer establishment is a prolonged process on many sites. Disturbance also provides opportunities for surviving individuals to increase growth. Isolated patches of conifers probably escape many disturbances and proceed through periods of crown closure and self thinning. Isolated trees and small patches that escape repeated disturbance eventually mature into larger members of the stand. In time, the stand develops an irregular structure reflecting numerous disturbances, and containing large trees that are the survivors of several stand altering events.

Cover (percent)	*Mean*	*Range*
Total vegetative	49	18-72
Tree	33	16-48
Shrub	1	0-2
Forb	12	1-30
Grass	7	0-30
Moss	2	0-18
Stand age (years)	226	120-345
Diversity index		
Simpson	0.50	0.22-0.89
Hill numbers		
N0	8.5	2.0-17.0
N1	3.47	1.22-7.48
N2	2.42	1.12-4.54

Characteristic Vegetation

			Percent cover	
Code	*Common name*	*Constancy*	*Mean*	*Range*
I. Overstory trees				
PICO	Lodgepole pine	100	26	4-48
ABMA	Red fir	50	15	1-38
PICO	Lodgepole pine	70	1	1-3
ABMA	Red fir	70	1	1-2

Characteristic Vegetation (continued)

Code	Common name	Constancy	*Percent cover* Mean	Range
III. Shrubs				
RICE	Squaw currant	20	1	1-1
IV. Forbs				
CAUM2	Pussy paws	50	2	1-5
PESE3	Pine woods lousewort	50	1	1-1
ARPL	Broad seeded rockcress	40	1	1-1
ERNUD	Naked stemmed eriogonum	30	3	1-5
BRLU2	Yellow brodiaea	20	2	1-2
ERSP2	Spurry eriogonum	20	1	(1-2
GAER	Coville's gayophytum	20	10	1-20)
LUADU	Drew's silky lupine	20	1	1-1
STTO	Mountain streptanthus	20	1	1-1
V. Grasses and grass-like				
CARO1	Ross' sedge	50	1	1-2
SIHY	Bottle brush Squirreltail	50	5	1-20
STOC1	Western needlegrass	40	3	1-8
POBO1	Bolander's bluegrass	30	1	1-1
STEL1	Elmer's needlegrass	20	10	1-20

Soils

Soils are typically Entisols with occasional Inceptisols; however, stands in this association differ from most others in containing significantly higher proportions of Entisols. Most of these are Psamments although occasional Orthents are also encountered. Particle size classes are usually sandy, but loamy, ashy, and contrasting size classes are also present in some cases. Parent materials are typically granitic; however, soils formed from tephra and ash deposits are also present, reflecting locations near the Mammoth Mountain region. Soils are predominantly weathered in place from bedrock, and only rarely are they formed from deposited materials such as alluvium.

Soil depths are moderately deep to deep. Often they exceed 35 inches, but rarely are they less than 25 inches. Topsoils are shallow; average topsoil depths are some of the lowest in the upper montane plant communities. Usually they are less than 7 inches. Textures in both topsoils and subsoils are usually sands, but sandy loams also often occur in topsoils. Soils in this association differ significantly from those on most other sites in containing a proportionately higher number of sandy textures throughout the profile. Average subsoil coarse fragments are the lowest of all sites in the upper montane forested communities. Usually stands contain less than 15 percent coarse fragments in the subsoil.

The AWC of these soils is among the lowest in the upper montane, and it reflects the influence of the coarse textured soils commonly encountered. Bedrock formations underlying soil profiles were usually massive and unrootable thus limiting additional sources of moisture to the site. As would be expected from the sandy soil textures, soil drainage is typically excessive. Erodibility is low to moderate also as a result of the coarse soil textures and moderate slopes. These soils are also interesting from the standpoint they are among a small group that consistently contain strongly acid topsoils. Summertime soil temperatures are wide ranging, but they are usually high, and compared to most other sites, they have substantially higher occurrences of temperatures that exceed 53° Fahrenheit.

Variable	*Mean*	*Range*
Depth of soil sample (inches)	33	13-40+
Topsoil		
Depth (inches)	7	2-15
Coarse frag. (pct.)	15	2-45
pH	5.3	4.6-6.0
Subsoil		
Coarse frag. (pct.)	18	2-40
pH	5.8	5.0-7.0
AWC (inches)	2.7	0.5-4.6
Temp (20 inches) (Fahrenheit)	54	42-65

Productivity

Pacific Southwest Region (Region 5) site indexes are substantially lower than dense, well-stocked forested stands in the upper montane. No site index was higher than 3, and typically stands had site indexes of 4 or 5. Stand densities are also low. Stand density indexes are generally less than 300, and occasionally they are less than 200. These values are considerably lower than adjacent dense forested stands, and stocking levels in this association attain only about 40 percent of the values reached in a fully stocked stand in the red fir-white fir association, which is one of the densest in the upper montane. Average tree heights are also substantially lower, reflecting the overall lower site quality and the presence of lodgepole pine, a shorter tree in the Sierra Nevada. The tallest tree measured was a red fir at 140 feet, but the tallest lodgepole pine was only 105 feet. Quadratic mean diameters are also small compared to those in other late seral forested stands, and it reflects the presence of smaller lodgepole pine on these sites. The combination of low site indexes, low stand densities, and shorter trees results in cubic and board foot yields that on average are among the lowest in these forests. Average values are only 25 percent of those in well-stocked plant associations.

Stands generally have the appearance of an uneven-aged distribution of trees, and considered collectively stands do approach this distribution, but stands also tend to be very open *(fig. 37)*. They commonly carry less than 100 trees per acre, and the basal area stocking is concentrated in scattered large diameter trees. When compared to uneven-aged stand structures with a balanced diameter distribution and similar stocking levels, they have an excess of trees in size classes below 18 inches, and nearly appropriate numbers of trees in size classes larger than 24 inches. Trees larger than 40 inches in diameter are few. Compared to an even-age distribution, stands have an excess of trees in size classes below about 24 inches. Lodgepole pine carries the largest portion of trees in size classes between 10 and 30 inches in most stands, and when viewed as a separate component of the stand, distributions for this species appear even-aged. Red fir constitutes most of the stocking in size classes below 10 inches and larger than 35 inches, but it is poorly represented in intermediate size classes.

Variable	Mean	Range
Region 5 site index	4	3-5
Forest survey site class	5	4-6
Stand density index	212	53-390
Quadratic mean diameter	18.7	7.8-34.1
Softwood volume (mcf/ac)	3.8	1.4-9.0
Softwood volume (mbf/ac)	20.1	1.7-64.6
Softwood basal area (sq ft/ac)	139	32-248
Hardwood volume (mcf/ac)	0	0
Hardwood basal area (sq ft/ac)	0	0

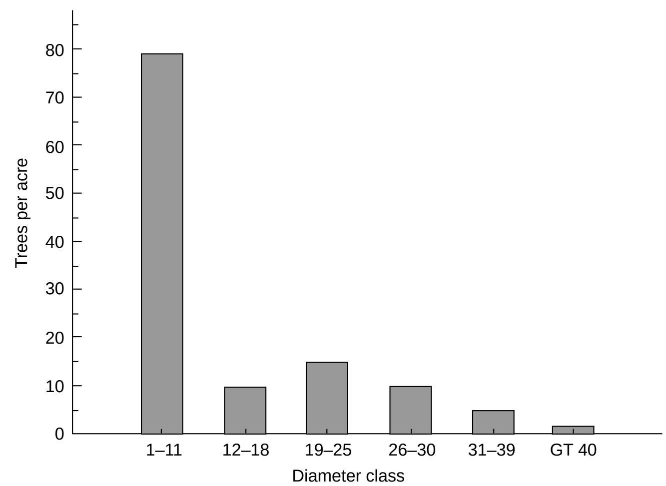


Figure 37—Number of trees by diameter class in the lodgepole pine// woodlands plant association.

Tree species composition by percent of basal area

Species	ABMA	ABCO	PICO	PIJE	PIM03	TSME
Percent	28	-	67	1	4	-
Species	JUOC	PILA	LIDE3	PIAL	POTR	OUKE
Percent						

Coarse Woody Debris

Snag numbers are low. When compared to many other sites in the upper montane, snags smaller than 11 inches diameter are particularly sparse. Otherwise, mortality appears more or less uniformly distributed in the remaining size classes. Snags taller than 50 feet are well represented reflecting a tendency for lodgepole pine to topple rather than break apart with time. These snags commonly lie in decay classes 1 to 3. Logs are characteristically less than 30 inches in large end diameter, reflecting the presence of lodgepole pine. They are typically less than 50 feet in length, and evidence higher levels of decay. Most logs in these stands lie in decay classes between 3 and 5.

Snags

	Breast Height Diameter Class (inches)						
	<11	***11-17.9***	***18-24.9***	***25-29.9***	***30-39.9***	***>40***	***Total***
Snags per acre	0	0.8	1.6	1.4	0.8	0.3	4.9
Snag height (feet)							
<20	-	0.4	0.8	0.3	-	-	1.5
20-50	-	0.4	0.8	-	-	-	1.2
>50	-	-	-	1.1	0.8	0.3	2.2
Snag decay class							
1	-	-	-	0.3	-	0.3	0.6
2	-	0.4	0.4	0.7	0.6	-	2.1
3	-	-	-	0.4	0.2	-	0.6
4	-	0.4	1.2	-	-	-	1.6
5	-	-	-	-	-	-	-

Logs

	Large End Diameter Class (inches)				
	11-20	***21-30***	***31-40***	***>40***	***Total***
Logs per acre	2.4	5.2	0.8	0.8	9.2
Log length (feet)					
<20	1.6	2.4	-	-	4.0
20-50	0.4	0.8	0.4	0.8	2.4
51-100	0.4	1.6	0.4	-	2.4
>100	-	0.4	-	-	0.4
Log decay class					
1	-	-	-	-	-
2	0.8	0.8	0.2	-	1.8
3	0.8	2.4	0.3	-	3.5
4	0.4	0.4	-	0.4	1.2
5	0.4	1.6	0.3	0.4	2.7

Wildlife

Wildlife forage values appear to be moderate. Of the species occurring on these sites naked stemmed eriogonum, spurry eriogonum, and Drew's silky lupine in the forb layer are all staples. Ross' sedge, bottle brush squirreltail, western needlegrass, and Bolander's bluegrass are also staples in the grass layer. Except for Ross' sedge, bottle brush squirreltail, and western needlegrass, however, the other forb and grass species occur as scattered members of this association. Deer sign was generally observed on these sites, but pocket gophers tended to be infrequent.

Range

Range potential in this association appears to be transitory as livestock move between primary range sites such as meadows and other moist habitats. Cattle use was usually observed in these stands. Drew's silky lupine is perhaps a secondary forage species in the forb layer, but frequency and cover are low. Bottle brush squirreltail and western needlegrass are secondary livestock forage species that occur with reasonable frequency and cover in this association. Other shrub, forb, and grass species occurring on these sites are of low value for livestock, and it would appear forage potential is generally low in these late seral stands.

Management Recommendations

Relatively few stands in this association have been harvested. Silvicultural systems, cutting methods, regeneration strategies, and stocking levels used in the management of any forested stand are relatively untried. Where stands have been harvested and disturbance has occurred, regeneration patterns were unclear. No sites were observed where stands were harvested, prepared for planting, and planted with any systematic silvicultural approach. Occasional sites have large quantities of boulders and surface rock that severely limit treatment options, and many of these sites should not be considered suitable for timber production.

Species composition, stand structure, and yields in these late seral stands is felt to reflect site capability. The open nature of these stands indicates that regeneration is a lengthy and variable process under most circumstances. Limited opportunities exist for salvage as it occurs, but on these open sites it would appear the sparse woody debris that accumulates would better serve as part of the nutrient pool and as wildlife habitat. Recommendations for treatment at the present time would be to enter stands in this type with caution and expect that results can be uncertain. Management emphasis should provide for existing wildlife habitat, plant species richness, and the landscape level diversity such stands provide.

Lodgepole Pine Association

Pinus contorta
PICO
CPLCPL13
Sample size: 8

Distribution

The lodgepole pine plant association is widespread at higher elevations in the Sierra Nevada. These are the stands that are found at the highest elevations of the upper montane. They often share this position with the red fir-western white pine-lodgepole pine and lodgepole pine/sagebrush associations, and in combination they straddle the crest at higher elevations. The association was sampled only on the Inyo and Toiyabe National Forests, but it has been observed throughout the range as the upper montane transitions into the subalpine above. Stands can cover extensive areas, but most are less than 100 acres because of natural patchiness in the landscape.

Environment

Elevations lie predominantly above 8,500 feet, and average elevations are the highest of any association in the upper montane. The lowest stand sampled, for example, was at 8,300 feet on the Toiyabe National Forest. Aspects are varied. Northeast and northwest facing slopes are typical, and solar radiation levels are commonly low due to the northerly aspects; however, south facing aspects are not uncommon. Slopes are substantially less than most other associations in the upper montane, and stands commonly occupy slopes less than 20 percent. Stands are typically found at the bottom of slopes or on benches where they join open alpine or subalpine vegetation above. This association has considerably higher levels of surface gravel compared to other sites, although litter cover is generally high as well. Stress indexes tend to be lower, reflecting the effects of higher elevation settings.

Variable	Mean	Range
Elevation (feet)	8,877	8,300-9,320
Slope (pct.)	16	4-30
Solar radiation index	0.471	0.381-0.527
Bare ground (pat.)	3	0-5
Surface gravel (pct.)	11	2-36
Surface rock (pct.)	2	0-5
Litter (pct.)	85	64-99
Litter depth (inches)	1.0	0.6-1.4
Stress index	0.45	0.38-0.57

Aspect: All.

Range: All.

Position: Lower slopes.

Range: Ridgetops, upper, middle, and lower slopes, benches.

Vegetation

Stands are moderately dense forests with open understories. Tree cover is moderate, but it is substantially less than many of the forested associations that lie at lower elevations. On most sites lodgepole pine is the only member of the overstory. This association marks the transition into the subalpine forests at higher elevations in the Sierra Nevada, and red fir occurs as widely scattered remnants in otherwise lodgepole pine dominated forests. Western white pine is rarely a member of the stand. These communities are often interspersed with the red fir-western white pine-lodgepole pine, lodgepole pine/sagebrush, and lodgepole pine//woodland associations in higher elevation settings. They are mesic sites as indicated by the presence of both lodgepole pine and red fir.

A shrub layer is essentially absent, although Sierra gooseberry occurs to indicate mesic conditions in rare cases. Forb cover is among the lowest in the upper montane forested plant associations, but the species present indicate a mix of moderate to dry conditions. Thus, broad seeded rock cress usually indicates drier sites, and white veined wintergreen indicates more moderate conditions and Fendler's meadow rue indicates moist sites. Grass cover is moderate, and the mix of species present also indicate moderate to dry sites. Ross' sedge indicates the mesic conditions occurring in most stands, but western stipa, generally a dry site indicator, is frequently present as well.

Conifer regeneration is moderate to low. The average number of seedlings is over 500 per acre, and sites usually had more than 250 per acre. Whitebark pine, red fir, and western white pine are present on occasion, but the regeneration layer is dominated by lodgepole pine; it carries substantially higher numbers of regeneration than any other species. Lodgepole pine is regenerating significantly more often on these sites compared to others in the upper montane. Red fir is regenerating at significantly lower levels when compared to other plant associations.

Plant species diversity is extremely low. It has few species overall, and most sites are dominated by a single tree species. The shrub layer is essentially absent, and the tree cover far outweighs cover values of the shrub, forb, and grass layers. Abundant species are relegated to little more than a single species in most stands.

The oldest trees in these stands are generally older than 250 years. This includes the lodgepole pine which is smaller in diameter than most associated species but not significantly different in age. Average stand age of these stands is also not substantially different from most others in these forests. Most stands have a uniform size distribution since lodgepole pine rarely attains large diameters, and many trees cluster in size classes between 18 and 30 inches. However, age differences among the individuals in a stand are often considerable, and ages of dominant trees commonly differ by more than 100 years in a ±300 year old stand. The oldest tree sampled in this association was a lodgepole pine at ±377 years.

Stand replacing events undoubtedly occur in this association, but they do not appear to be frequent or cover large areas. Fire would be the most likely cause of large scale mortality, and lodgepole pine is highly susceptible to fire damage. However, the setting of many stands on lower slopes with gentle topography, cooler north aspects, at high elevations, the isolation of many stands on the landscape, and the structure of the stands with open understories, tend to mitigate against large fires. These stands probably experience infrequent, patchy burns with some portion of the stand being completely consumed, while others are left with little damage. Avalanche can replace stands located on lower and middle slope positions. Most of these appear to be infrequent and occur at scattered locations across the landscape. Understories, including smaller trees, generally remain intact. Other disturbance elements such as windthrow, insects, disease, and lightning do not appear to cause stand replacement over large areas. It is likely that disturbance occurs continuously at various scales in these stands, and this results in the creation of various size gaps that constantly change structure.

Reproductive strategies such as reasonably constant seed production are present in the tree species on these sites. Lodgepole pine in the Sierra Nevada appears to be a prolific seeder, and in most cases the species composition of future stands is largely determined by the occurrence of this species in the overstory. Stand development is not fully understood in this association. It appears to, be sporadic as opportunities for regeneration and growth arise in response to disturbance. Many stands have an even-aged structure with the implication of a common regeneration event; however, as noted, several widely separated age classes are often present, and when several stands are viewed collectively, an irregular structure is apparent that suggests gap processes are important. Stands apparently do not go through a prolonged early successional period in a grass/forb or shrub phase, but in most cases conifer establishment is a process that can occupy a considerable period of time. It is likely that regeneration becomes established in gaps, grows, self-thins, and develops to maturity similar to other associations in the upper montane, but the narrower distribution of diameters in lodgepole pine gives the appearance of uniform ages in late seral stands. In time, several size and tree classes are represented, and the stand exhibits an irregular structure. As stands occupy sites for longer periods, successive disturbances continue to develop and maintain stand structures until an infrequent stand replacing event occurs and a new stand emerges.

Cover (percent)	*Mean*	*Range*
Total vegetative	67	42-90
Tree cover	59	39-73
Shrub	0.4	0-1
Forb	3	1-9
Grass	10	0-61
Moss	0.1	0-1
Stand age (years)	250	186-328

Cover (percent)	Mean	Range
Diversity index		
Simpson	0.71	0.38-0.94
Hill numbers		
N0	8.1	3.0-11.0
N1	1.97	1.15-3.24
N2	1.50	1.06-2.60

Characteristic Vegetation

	Code	Common name	Constancy	Percent cover Mean	Percent cover Range
I.	Overstory trees				
	PICO	Lodgepole pine	100	57	31-73
	ABMA	Red fir	25	6	4-8
II.	Understory trees				
	PICO	Lodgepole pine	100	3	1-16
	PIAL	Whitebark pine	62	1	1-2
	ABMA	Red fir	37	1	1-1
	PIMO3	Western white pine	37	1	1-1
III.	Shrubs				
	RIMO	Sierra gooseberry	25	1	1-1
IV.	Forbs				
	ARPL	Broad seeded rock cress	75	1	1-1
	PYPI	White veined wintergreen	50	1	1-1
	PESE3	Pine woods lousewort	25	3	1-5
	THFE	Fendler's meadow rue	25	1	1-1
V.	Grasses and grass-like				
	CARO1	Ross' sedge	75	1	1-1
	STOC1	Western needlegrass	62	1	1-60
	CAR-1	Sedge	25	1	1-1
	PONE1	Hooker's bluegrass	25	1	1-2
	SIHY	Bottle brush squirreltail	25	1	1-1
	STCO1	Columbia needlegrass	25	1	1-1
	STEL1	Elmer's needlegrass	25	1	1-1

Soils

Soil are Entisols, Inceptisols, and Mollisols. The Entisols and Inceptisols occur in equal abundance, but this association contains significantly higher proportions of Entisols and Mollisols than most other sites. Within these taxonomic groupings, Umbrepts, Orthents, and Borolls are encountered most frequently. Particle size classes show similar variation indicating soil profiles with significant differences in rock fragment content compared to most other sites. Some are skeletal but loamy, medial, ashy, cindery and contrasting size classes also occur, and collectively they are more common than the skeletal size classes. Parent materials also come from a variety of sources. They are commonly volcanic and derived from tephra deposits and andesitic and rhyolitic flow rocks reflecting the location of sample sites in the north and on the eastside. Granitic and mixed parent materials also occur, and throughout much of the range such bedrock material probably occupies more of the landscape where this association occurs. Regardless of parent materials, however, most of these soils are formed from alluvial deposits reflecting locations on lower slope positions.

Soils in this association are deep. Samples were commonly deeper than 40 inches, and seldom were they less than 35. Textures in the topsoils were usually sandy loams with some gravelly sands and a few loams and clay loams. Subsoil textures were similar except they contain fewer sandy loams and more sandy clay loams and clays. Subsoils differed significantly from those in other plant associations in containing higher proportions of finer textures such as clay loams, and clays. Topsoil coarse fragment content is variable, but it tends to be high. Coarse fragments in these horizons are among the highest in the upper montane on average, and some sites contain more than 65 percent coarse fragments in the topsoil.

The AWC in these sites is moderately high, but it is not substantially different from most other forested sites in the range. Although soils are deep in general, the effect of sites with coarse soil textures and high coarse fragments moderates the water holding capacity in general. Parent materials were commonly fractured and rootable thereby increasing the available moisture supply to these stands. Sites are typically well drained, but they can be excessively drained on occasion. Erodibility is low to moderate due to coarse soil textures and moderate slopes. Even though these stands occur at higher elevations, soil temperatures are moderately warm. Typical stands have soil temperatures that exceed 49° Fahrenheit, reflecting the more open stand conditions and occasional south aspects of some sites.

Variable	*Mean*	*Range*
Depth of soil sample (inches)	39	31-40+
Topsoil		
Depth (inches)	11	4-23
Coarse fragments (pct.)	33	8-95
pH	5.8	4.5-6.5
Subsoil		
Coarse fragments (pct.)	38	8-85
pH	5.9	5.2-6.9
AWC (inches)	3.4	1.2-5.8
Temp (20 inches) (Fahrenheit)	51	46-60

Productivity

Site indexes are low. Pacific Southwest Region (Region 5) site indexes for all stands sampled were 4 or 5. Stand densities, on the other hand, were moderately high. Based on average stand density indexes these sites carry nearly 85 percent of the stocking that can be carried by the red fir-white fir plant association, which is one of the densest in the upper montane; stand density indexes commonly exceed 400 in these stands. Tree heights, however, are substantially shorter than those in other dense forested plant associations. This reflects the presence of large numbers of lodgepole pine, which is generally a shorter tree in the Sierra Nevada. The tallest tree in the association was a lodgepole pine which measured 95 feet. Quadratic mean diameters are among the lowest in upper montane forests, reflecting the abundance of lodgepole pine in these stands. The combination of low site indexes and proportionately shorter trees overrides the effect of higher stand densities, resulting in cubic and board foot yields that are about 30 percent of those in the red fir or red fir-white fir associations.

When some stands are viewed in the field they often have the appearance of an even-aged or two-storied structure with very scattered predominant red fir over an even-aged stand of lodgepole pine; however, others exhibit different structures, and taken collectively the distribution approximates that of an uneven-aged stand *(fig. 38)*. When compared to uneven-aged structures in stands with similar stocking and balanced diameter distributions, these stands generally carry too many trees in size classes below 40 inches. The number of trees in size classes between 18 and 30 inches approximates an even-aged distribution. Viewed as a separate component of the stand, distributions in these size classes impart a characteristic even-aged appearance to many stands. When compared to an even-aged distribution, however, stands carry too many trees in size classes below 18 inches and more trees in size classes larger than 30 inches than would be appropriate.

Variable	*Mean*	*Range*
Region 5 site index	4	4-5
Forest survey site class	5	5-6
Stand density index	448	341-606
Quadratic mean diameter	14.4	8.7-21.8
Softwood volume (mcf/ac)	4.6	2.8-5.7
Softwood volume (mbf/ac)	22.8	9.9-28.3
Softwood basal area (sq ft/ac)	275	208-360
Hardwood volume (mcf/ac)	0	0
Hardwood basal area (sq ft/ac)	0	0

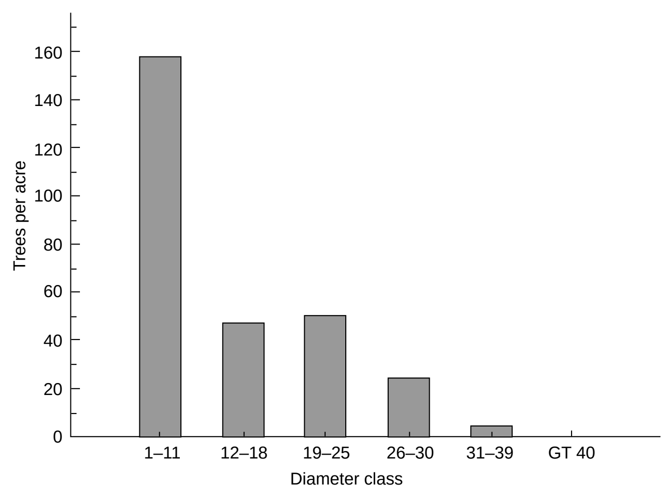


Figure 38—Number of trees by diameter class in the lodgepole pine plant association.

Tree species composition by percent of basal area

Species	ABMA	ABCO	PICO	PIJE	PIM03	TSME
Percent	1	-	93	-	-	-
Species	JUOC	PILA	LIDE3	PIAL	POTR	OUKE
Percent	-	-	-	6	-	-

Coarse Woody Debris

Snag numbers are moderate. They are comparable to those found in other dense stands such as the red fir association. Snags are concentrated in size classes less than 25 inches, which reflects continued thinning of suppressed individuals and the presence of lodgepole pine. Snags are distributed among all height classes; however, they are typically less than 50 feet tall. Snags taller than 50 feet are indicative of the tendency of lodgepole pine snags to topple rather than break apart from the top with the passage of time. Snags are distributed among all decay classes, but commonly they occur in classes 1 to 3. Most logs are smaller than 30 inches in large end diameter. Log lengths are commonly less than 50 feet, but a high proportion also occur between 50 and 100 feet indicating the presence of lodgepole pine that have fallen as complete trees. Decay classes between 3 and 5 predominate in these logs.

Snags

	Breast Height Diameter Class (inches)						
	<11	***11-17.9***	***18-24.9***	***25-29.9***	***30-39.9***	***>40***	***Total***
Snags per acre	4.0	2.8	4.1	0.4	0.4	0	11.7
Snag height (feet)							
<20	2.5	-	4.1	-	-	-	6.6
20-50	1.5	1.1	-	0.1	-	-	2.7
>50	-	1.7	-	0.3	0.4	-	2.4
Snag decay class							
1	0.6	-	-	0.1	0.4	-	1.1
2	0.9	1.2	-	0.1	-	-	2.2
3	1.9	1.6	1.6	0.1	-	-	5.2
4	0.3	-	2.5	0.1	-	-	2.9
5	0.3	-	-	-	-	-	0.3

Logs

	Large End Diameter Class (inches)				
	11-20	***21-30***	***31-40***	***>40***	***Total***
Logs per acre	7.3	8.7	2.7	1.3	20.0
Log length (feet)					
<20	5.3	2.0	-	0.6	7.9
20-50	2.0	4.0	-	0.7	6.7
51-100	-	2.7	2.7	-	5.4
>100	-	-	-	-	-
Log decay class					
1	-	0.7	-	-	0.7
3	2.0	4.0	1.4	-	7.4
4	3.3	0.7	1.3	0.6	5.9
5	2.0	3.3	-	0.7	6.0

Wildlife

These stands may offer hiding and thermal cover to large game, but presence is probably transitory in nature as animals move to areas with more abundant forage. Forage is concentrated in the grass layer. Hooker's bluegrass is a preferred large game species that occurs in low cover on a few sites, but Ross' sedge, other sedge species, bottle brush squirreltail, western needlegrass, and Columbia needlegrass are staples that also occur with low cover on these sites. Collectively these species may constitute a substantial amount of available forage. Other forage species occurring in these stands are of such low frequency or cover value that they are not important components of the large game diet. Evidence of deer and pocket gopher presence was commonly observed on these sites.

Range

Stands are transitional range sites that are used by livestock to access primary range sites, such as meadows and other moist habitats. Cattle use was generally observed in these stands. Hooker's bluegrass is a primary range species, and western needlegrass is a secondary species that occurs with relatively high frequency. Columbia needlegrass, and bottle brush squirreltail are secondary species that collectively occur with reasonable frequency and probably also contribute to range forage values.

Management Recommendations

Few stands in this association have been harvested. These have occurred primarily on the eastside where an even-aged silvicultural system was applied consistent with lodgepole pine management elsewhere in the West. Establishment of planted Jeffrey pine and lodgepole pine, however, has generally been poor. In some cases, 15 years elapsed before natural seedlings began to establish, but after more than 25 years several of these sites appear to have at least moderate stocking. The species regenerating in most cases is lodgepole pine and red fir. Successional patterns are not well understood, but high levels of shrub competition do not seem to be a factor in past regeneration efforts.

Stands have low productive capacity, and they should not be considered for traditional forest management in most cases. If harvested, options for silvicultural systems and cutting methods can vary to take advantage of differences in stand structure and density. Natural regeneration can be a viable option, but long time periods may be involved in obtaining success. Stand openings should be kept small and seed sources near to encourage natural regeneration. These stands do not regenerate abundantly soon after disturbance as do most other lodgepole pine stands in the Sierra. On north facing aspects small clearcuts can be utilized, but on south aspects shelterwood cutting or a silvicultural system that maintains constant seed source is recommended.

Harvesting at the present time should be conducted with caution and the knowledge that results are uncertain. Limited opportunities exist for salvage when it occurs, but on these sites it would appear that woody debris left in the form of snags and logs for wildlife or part of the nutrient pool would be better direction. Management emphasis should provide for existing wildlife habitat, plant species richness, and the landscape diversity this association provides to upper montane forests.

Red Fir-Lodgepole Pine/White Flowered Hawkweed Association

Abies magnifica-pinus contorta/hieracium albiflorum

ABMA-PICO/HIAL
CFRCPL11
Sample size: 48

Distribution

The red fir-lodgepole pine/white flowered hawkweed plant association occurs throughout the central and southern Sierra Nevada. Although it was sampled primarily in the central portion of the study area, it occurred in every National Forest and Park in the range except for the Lake Tahoe Basin Management Unit. It is a common associate of the lodgepole pine/Gray's lovage association. Stands often cover extensive areas in gentle terrain along drainage bottoms.

Environment

In general, lodgepole pine exhibits a wide elevational range in the Sierra Nevada. This association reflects that distribution, and it can be found at all elevations of the upper montane. The lowest elevation occurred on the Eldorado National Forest, and the highest was on the Inyo. Stands reflect the increase in elevation with decreasing latitude that is characteristic of these forests, and those that occur in the south will generally occupy higher elevations than those in the north. Aspects are varied, but frequently northeast and northwest facing slopes are encountered, resulting in solar radiation levels that are significantly lower than most other sites. Slopes are shallow. Characteristically, they are less than 20 percent, and often they are less than 10 percent. Stands typically lie on benches, lower slopes, and in bottom positions adjacent to and somewhat upslope from flat areas such as meadow complexes or drainage bottoms. Stands in this association have considerably less bare ground and surface gravel compared to most others, and microrelief is usually smooth and uniform to gently undulating. Stress indexes are among some of the lowest in the upper montane and reflect the generally moderate conditions encountered on these sites.

Variable	Mean	Range
Elevation (feet)	7,831	6,540-9,520
Slope (pct.)	13	2-40
Solar radiation index	0.479	0.359-0.561
Bare ground (pct.)	2	0-40
Surface gravel (pct.)	4	0-37
Surface rock (pct.)	3	0-33
Litter (pct.)	90	45-99
Litter depth (inches)	1.6	0.1-7.0
Stress index	0.44	0.29-0.61

Aspect: NE,NW,SW.

Range: All.

Position: Lower slopes, benches.

Range: All.

Vegetation

Stands are dense multi-layered forests with understories composed of patches of dense conifer regeneration. Average tree cover is one of the highest in the upper montane. The overstory is dominated by red fir in mix with lodgepole pine. Rarely does lodgepole pine equal or exceed the stocking levels of red fir, but together these two species occupy most of the growing space in late seral stands. White fir is an occasional member of some stands indicating lower elevation sites. All of the overstory tree species present are adapted to moderate and moist sites. This association often lies adjacent to, and upslope from, lodgepole pine/ Gray's lovage sites. Conditions in these two associations are similar, except the red fir-lodgepole pine/white flowered hawkweed plant association generally occupies drier habitats. Often the two occur adjacent to each other as conditions change from moist to drier sites.

Understories are sparse. Shrub cover is among the lowest in upper montane forests, and shrubs often occur as isolated patches and individuals scattered in the understory. Sierra gooseberry and alpine prickly currant are moist site indicators that are present in a few cases. The forb layer, on the other hand, usually has an assemblage of moderate site indicators. White flowered hawkweed and mountain violet, for example, are mesic site indicators. Mountain sweet cicely, Kellogg's bedstraw, and Bolander's bluegrass are indicators of moderate to moist habitats. Although white flowered hawkweed does not carry the high frequency usually attributed to indicator species for which an association is named, it is a constant but widely scattered member of most stands. It becomes absent with increase in elevation or in most eastside stands, but it is used in the name to aid in distinguishing the central concept of this association from others with mixed red fir and lodgepole pine.

Conifer regeneration is high in these stands. Late seral stands average over 1,200 seedlings per acre, and they often carry more than 500 per acre. White fir and lodgepole pine are usually present in the regeneration layer, but natural regeneration is dominated by red fir, and the number of natural lodgepole pine seedlings is far fewer than red fir in most instances. The high numbers of red fir seedlings often impart a characteristic appearance to many stands in which an overstory of mixed red fir and lodgepole pine occur over a dense understory of red fir seedlings and saplings. Red fir, white fir, and lodgepole pine are all regenerating more frequently than in other associations.

Plant species diversity is moderately high for upper montane forests. Compared to other plant associations the total number of species is moderate. This results from the lack of forb and grass species that are able to frequent the dense forested cover. Shrub species are also sparse. Sites are dominated by a few tree species that outweigh the cover values in the forb and grass layers. Abundant species are few in number, and they are concentrated in the tree layer.

The oldest trees in these stands are commonly greater than 200 years. These stands are essentially the same average age as other forested associations in the upper montane, and lodgepole pine, although smaller in diameter, is not substantially different in age from the larger red and white fir. The oldest tree sampled in this type was a red fir at ±470 years. The oldest lodgepole pine encountered was estimated at ±364 years, and the oldest white fir was estimated at ±375 years.

Stand replacing events probably occur in this association, but they do not appear to be frequent or large scale phenomenon. The setting of many stands on cooler north aspects or along drainage bottoms with gentle topography, and the structure of the stands with open understories and the presence of large individuals tend to preclude fire caused stand replacement. Other disturbance elements such as windthrow, insects, disease, lightning, or avalanche also do not appear to affect large areas in these stands. It is likely that disturbance from several elements occur continuously on various scales, and this results in the creation of various sized gaps with constantly changing structures through time.

Reproductive strategies such as reasonably constant seed production is present in most of the tree species in these stands. Lodgepole pine, at the elevations commonly encountered in this association, is a prolific seeder with rapid early height growth. Red fir is a shade tolerant species that can assume dominance in these stands as they develop; however, lodgepole pine, which is shade intolerant, is undoubtedly maintained by disturbances that open stands and provide seed beds. In most cases the species composition of future stands is largely determined by species presently on the site.

After disturbance these stands do not go through a prolonged period in a grass/forb or shrub phase. Often lodgepole pine occupies sites in abundance soon after disturbance. Once regeneration is established it grows, self thins, and matures, and other portions of the stand continue to be affected by disturbance. As patches close and tree cover increases, shade tolerant species such as red and white fir become established. These species continue to seed in and grow in height until they overtop the lodgepole pine. In time, and without further disturbance, they can dominate the overstory. Generally, however, disturbance will occur before the stand is completely dominated by fir, and this allows an increase in the lodgepole component once again. In time, several size classes, including a substantial portion of larger trees and mixed species, are represented, and the stand exhibits an irregular structure with many small relatively even-aged patches. As stands occupy sites for longer periods, multiple disturbances continue to be important in maintaining structures and species composition until an infrequent stand replacing disturbance occurs, and a new stand emerges.

Cover (percent)	*Mean*	*Range*
Total vegetative	80	47-99
Tree	73	43-95
Shrub	2	0-40
Forb	8	0-95
Grass	2	0-25
Moss	1	0-10)
Stand age (years)	198	102-318
Diversity index		
Simpson	0.48	0.17-0.76

Cover (percent)	*Mean*	*Range*
Hill numbers		
N0	10.4	5.0-24.0
N1	3.31	1.78-7.36
N2	2.37	1.32-5.77

Characteristic Vegetation

			Percent cover	
Code	*Common name*	*Constancy*	*Mean*	*Range*
I. Overstory trees				
PICO	Lodgepole pine	100	20	5-83
ABMA	Red fir	98	49	6-99
ABCO	White fir	27	23	5-53
II. Understory trees				
ABMA	Red fir	96	6	1-46
PICO	Lodgepole pine	67	1	1-2
ABCO	White fir	38	2	1-23
III. Shrubs				
None				
IV. Forbs				
PESE3	Pine woods lousewort	65	1	1-4
HIAL	White flowered hawkweed	46	3	1-20
VIPU	Mountain violet	35	1	1-2
COTOW	Wright's blue eyed mary	27	1	1-2
ARPL	Broad seeded rock cress	23	1	1-1
KEGA	Kellogg's bedstraw	23	1	1-4
OSCH	Mountain sweet cicely	21	3	1-20
COMA4	Spotted coral root	21	1	1-1
V. Grasses and grass-like				
POBO1	Bolander's bluegrass	44	1	1-2
CARO1	Ross' sedge	33	2	1-8
CAR-1	Sedge	31	2	1-10

Soils

Common soils in this association are Inceptisols, and they occur in the Xerumbrept and Xerochrept great groups with almost equal frequency. Occasional Entisols, and rare Alfisols, and Mollisols are also encountered. Particle size classes are distributed between skeletal and loamy and indicate relatively moderate levels of rock fragments in the profile. These soils are usually derived from granitic parent materials although occasional soils are derived from volcanic substrates such as the flow rocks and lahars of the Mehrten formation, and the tephra deposits of the eastside. A few sites developed from metamorphic parent materials. Soils are usually formed in place from bedrock, but occasionally they are formed from glacial till or alluvial deposits.

Soils are deep. Typically, they exceed 40 inches, and rarely are they less than 25 inches. These are medium to moderately coarse textured soils. Textures in both the topsoil and subsoil exhibit similar distributions. They are usually sandy loams, although occasional loams and a few sands can be encountered.

The average AWC of these soils is among the highest in the upper montane. It reflects the deep soils present in most stands. Bedrock conditions below lithic contacts are commonly fractured and rootable thereby increasing the available water supply to these sites. Soils are typically well drained, and erodibility ranges from moderate to high, reflecting differences in soil texture on individual sites. Soil temperatures are somewhat wide ranging, but overall averages are cooler than most other associations in the upper montane, and they often lie below 49° Fahrenheit.

Variable	*Mean*	*Range*
Depth of soil sample (inches)	37	24-40+
Topsoil		
Depth (inches)	9	2-28
Coarse fragments (pct.)	20	1-95
pH	5.6	4.5-6.8
Subsoil		
Coarse fragments (pct.)	30	4-87
pH	5.7	4.7-6.5
AWC (inches)	3.7	1.0-6.0
Temp (20 inches) (Fahrenheit)	47	36-64

Productivity

Site indexes are wide ranging. Typically, however, Pacific Southwest Region (Region 5) site indexes are 2 or better, and only rarely are they less than 3. Average stand densities are among the highest of the upper montane forested associations. Stocking levels based on average stand density indexes are as high as fully stocked stands in the red fir or red fir-white fir associations, and they usually exceed 500 in late seral stands. Average tree heights are somewhat lower due to the presence of lodgepole pine, which is generally a shorter tree in the Sierra Nevada. This is counterbalanced to large degree, however, by red fir heights that are quite tall due to higher site indexes. The tallest tree in the association was a red fir which measured 182 feet compared to the tallest white fir of 177 feet and the tallest lodpepole pine of 130 feet. Quadratic mean diameters for stands in this association are also lower compared to those in other late seral forested stands, and this reflects the presence of smaller lodgepole pine in the stands. The combination of higher site indexes, high proportions of the stocking in red fir, and high densities result in stands that are among the most productive in the upper montane.

Many individual stands have the appearance of a two storied structure; however, they commonly exhibit other structures, and taken collectively they can be considered irregular (*fig. 39*). The distribution of stems overall actually approximates those of an uneven-aged structure to some degree. Compared to uneven-aged structures in stands with similar stocking and balanced diameter distributions, however, they usually contain too many trees in smaller size classes, and too many trees in size classes larger than 35 inches. Compared to an even-aged distribution, there are far too many trees in size classes below 24 inches and more trees in size classes larger than 30 inches than would be appropriate. Red fir carries the largest portion of trees in size classes smaller than 24 inches, conveying their characteristic uneven-age structure. Lodgepole pine between seedling size and 10 inches are largely absent.

Variable	*Mean*	*Range*
Region 5 site index	2	0-5
Forest survey site class	3	1-6
Stand density index	531	272-953
Quadratic mean diameter	18.3	7.4-35.5
Softwood volume (mcf/ac)	11.6	4.4-23.4
Softwood volume (mbf/ac)	73.6	22.0-165.6
Softwood basal area (sq ft/ac)	354	187-560
Hardwood volume (mcf/ac)	0	0
Hardwood basal area (sq ft/ac)	0	0

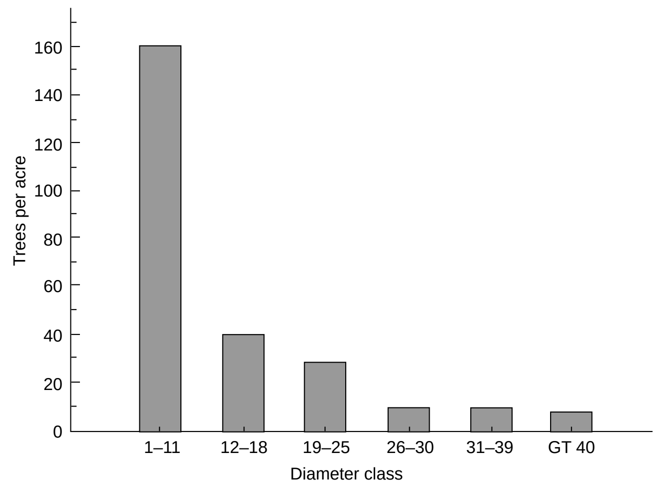


Figure 39—Number of trees by diameter class in the red fir-lodgepole pine/white flowered hawkweed plant association.

Tree species composition by percent of basal area

Species	ABMA	ABCO	PICO	PIJE	PIMO3	TSME
Percent	63	8	28	1	-	-
Species	JUOC	PILA	LIDE3	PIAL	POTR	QUKE
Percent	-	-	-	-	-	-

Coarse Woody Debris

Snag numbers are quite high. In particular, the number of snags less than 11 inches in diameter is large. Snags are distributed across all size classes, but those between 18 and 25 inches are significantly higher in number than most other stands. Small snags occur primarily in the lodgepole pine component, while snags larger than 25 inches are generally the result of mortality in red fir. Snag heights are often higher than 50 feet, reflecting both the taller heights of red fir and the tendency of lodgepole pine to topple as an entire tree rather than break off. These snags are quite sound and decay classes are generally either 1 or 2. Logs are typically less than 30 inches in large end diameter reflecting the effects of thinning of suppressed individuals and the presence of lodgepole pine in the stands. Lengths are commonly less than 50 feet although logs longer than this are well represented. Logs evidence higher levels of decay than snags. The majority of logs occur in decay classes between 3 and 5.

Snags

	Breast Height Diameter Class (inches)						
	<11	*11-17.9*	*18-24.9*	*25-29.9*	*30-39.9*	*>40*	*Total*
Snags per acre	13.2	2.6	2.3	0.8	0.9	0.9	20.7
Snag height (feet)							
<20	6.6	-	-	0.4	0.6	0.3	7.9
20-50	-	-	0.4	0.3	-	0.2	0.9
>50	6.6	2.6	1.9	0.1	0.3	0.4	11.9
Snag decay class							
1	-	-	-	0.5	-	-	0.5
2	13.2	2.6	1.5	-	0.2	0.4	17.9
3	-	-	0.4	0.1	0.3	0.4	1.2
4	-	-	0.4	0.1	0.2	0.1	0.8
5	-	-	-	0.1	0.2	-	0.3

Logs

	Large End Diameter Class (inches)				
	11-20	*21-30*	*31-40*	*>40*	*Total*
Log length (feet)					
<20	4.8	2.4	4.0	0.4	11.6
20-50	7.6	3.6	3.6	2.4	17.2
51-100	2.0	4.8	0.4	0.8	8.0
>100	0.4	1.2	0.4	-	2.0
Log decay class					
1	0.4	0.4	-	0.4	1.2
2	2.8	2.0	0.4	-	5.2
3	4.4	2.4	1.6	1.2	9.6
4	5.6	5.6	3.6	0.8	15.6
5	1.6	1.6	2.8	1.2	7.2

Wildlife

These stands may offer some hiding and thermal cover to large game, but forage possibilities appear transitory. Bolander's bluegrass is a staple in the diet as is Ross' sedge and other sedges occurring in these stands. Other species occurring on these sites are sparse or of low value for forage. The dense nature of these stands and their location in bottom type situations, often near meadows or streams, probably makes them valuable as hiding and thermal cover. Evidence of deer and pocket gopher is common in these stands.

Range

These are transitional range sites that are used by livestock to access primary forage sites such as meadows and other moist habitats. None of the more commonly occurring species in these stands are primary or secondary forage species, and it appears that range forage potential is low in these late seral stands. On the other hand, signs of cattle presence is common probably due to locations adjacent to more suitable range habitat.

Management Recommendations

Many stands in this plant association have been harvested throughout the study area. Both even-aged and uneven-aged silvicultural systems have been tried. Although successional sequences have not been studied in detail, a notable pattern has emerged from these past cuttings: the establishment of abundant lodgepole pine natural regeneration after harvest. Clearcutting, heavy improvement cuttings, or heavy selection cutting can all create the open conditions that favor natural regeneration of lodgepole pine. Seed cone periodicity in lodgepole pine throughout the Sierra Nevada appears to be frequent and regular, and a steady supply of lodgepole pine seed is provided these sites. Seed cone periodicity for other conifers, notably red and white fir, are less frequent and probably more irregular thereby reducing the number of seed from these species reaching a site in a given period. If residual stand densities are kept high red fir can establish on these sites more rapidly than lodgepole pine, and in these cases successional sequences seem to favor dominance by red fir; however, for periods of less than 100 years lodgepole pine can often be dominant.

Many stands harvested in the past were planted to Jeffrey pine. Results are varied and use of this practice has diminished in recent years, but Jeffrey pine can never carry the density nor match the yields of these stands in the mix of species usually encountered. Reforestation practices designed to regenerate these stands with a heavier component of red fir have not been developed in detail at this time. Most likely, strategies designed to increase the abundance of red fir would involve planting red fir early in the reforestation sequence with thinning at an early age to release both natural and planted red fir and control stocking of lodgepole pine.

These stands have tremendous productive capacity and flexibility for stand management. Stand structures are variable, and options for silvicultural systems and cutting methods can vary to take advantage of differences in shade tolerance and the high stand densities attainable in these stands. Natural regeneration can be a viable option. Stand openings should be kept small and seed source near. On north facing slopes small clearcuts can be utilized, but on south aspects shelterwood cutting or a silvicultural system that maintains constant tree cover is recommended. High levels of shrub, forb and grass competition are not anticipated in most cases; however, high levels of lodgepole pine natural regeneration should be anticipated in openings.

These sites also have the potential to contribute to wildlife values. In their present condition they are an important source of snags especially in smaller size classes, and through proper management, they can probably continue to provide high levels of snags for a period of time after harvest and plantation establishment.

Red Fir-White Fir Association

Abies magnifica-abies concolor

ABMA-ABCO
CFRCFW11
Sample size: 69

Distribution

The red fir-white fir plant association is widespread in the central and southern Sierra Nevada. Latitudes and longitudes span the study area, and samples were located on all National Forests and Parks in the central and southern Sierra Nevada. Stands can cover extensive areas. Individual stands can range in size from smaller than 5 acres to a few hundred acres.

Environment

This association is located at middle and lower elevations. Average elevations are among the lowest in these forests, and the association often identifies the transition into the upper montane as one ascends from lower elevations. Stands typically occur between 6,500 feet and 8,000 feet. This association reflects the increase in elevation with decreasing latitude that is characteristic of these forests, and stands in the south will lie at substantially higher elevations than in the north. Aspects are varied, but northeast to northwest facing slopes are common. The average SRI is among the lowest in these forests. Slopes range from very gentle to quite steep, but generally they are less than 40 percent. Stands are located on all slope positions; however, upper and middle slopes are more common. Microrelief also varies considerably from relatively uniform surfaces to those that are broken and hummocky. Most are somewhat uniform. This association has significantly less bare ground and surface gravel than most other sites. Litter cover and litter depths are substantially higher and reflect the higher levels of tree cover and debris on the forest floor that is characteristic of these stands.

Variable	Mean	Range
Elevation (feet)	7,319	5,780-8,800
Slope (pct.)	26	4-57
Solar radiation index	0.469	0.351-0.575
Bare ground (pct.)	1	0-12
Surface gravel (pct.)	2	0-63
Surface rock (pct.)	5	0-45
Litter (pct.)	91	44-99
Litter depth (inches)	2.0	0.5-5.3
Stress index	0.49	0.36-0.63

Aspect: All.
Range: All.
Position: Upper and middle slopes.
Range: All.

Vegetation

Stands are dense, multilayered forests with somewhat open understories. Total vegetative cover is high due to substantial tree cover. Overstories are characterized by the presence of white fir in mix with red fir, and together these two species dominate the stands.

Red fir generally was more abundant in the stands sampled, but white fir is a prominent species that indicates the moderate site conditions found, and it can dominate individual stands. These stands are often adjacent to and interspersed with the white fir-sugar pine-red fir and red fir-white fir-Jeffrey pine associations on mesic sites.

Understory shrub cover is considerably lower than most other associations in late seral stands. Creeping snowberry and Sierra gooseberry are occasional indicators of the moderate to moist conditions on these sites, and Sierra chinquapin is an infrequent indicator of drier habitats. Mountain whitethorn is an uncommon but important member of the understory due to its ability to rapidly occupy sites after disturbance. The forb layer is composed of an assemblage of species that normally occupy moderate to moist habitats. Thus, white veined wintergreen, white flowered hawkweed, Kellogg's bedstraw, and mountain violet are indicators of middle to lower elevation mesic sites. Mountain sweet cicely and western bracken fern frequent moist habitats. The grass layer is sparse, but it occasionally contains Bolander's bluegrass which also indicates the mesic conditions on these sites.

Conifer regeneration is moderately high. Stands averaged 785 seedlings per acre in late seral conditions, and sites regularly have more than 250 seedlings per acre. These are typically clumped together as patches in openings. Red fir is present on the majority of sites, and it dominates the regeneration layer. White fir is typically present as well, but numbers are less than one-third those of red fir. Both red fir and white fir are regenerating with significantly higher frequency than in other associations.

Plant species diversity is moderate to low. Compared to other associations in these forests, the total number of species is only moderate, and diversity is influenced by the relatively low cover of shrubs, forb, and grass species that occurs in these dense forests. Sites are dominated by two tree species that far outweigh the cover values of the shrub, forb, and grass layers. Abundant species are few in number and concentrated in the tree layer.

The oldest trees in these stands are commonly older than 200 years, but only occasionally were individual trees greater than 250 years. The average age of stands in this association is significantly younger than most others in these forests. The oldest tree sampled was a red fir at ±422 years, and the oldest white fir was an estimated ±383 years. These ages are typical of upper montane forests in general. The reason for the relatively younger average stand ages is unclear, but they are comparable to other low elevation plant associations. Higher numbers of younger trees in the overstory obviously contributes to this, but the origin of these younger trees remains somewhat obscure. It is possible that historically higher fire frequency associated with lower elevations maintained a substantial number of young trees in these stands.

Since stands often lie adjacent to lower montane forests where fire frequency and intensity are considered higher, stand replacing disturbance events probably occur more frequently than many others in the upper montane. Conversely, the setting of many stands in this association on cooler north aspects, the structure of the stands with open understories, and the presence of relatively large, somewhat fire resistant individuals tend to preclude the large scale loss of all individuals from fire. Observation of stand distributions and structure indicate stands probably experience both small scale patchy burns and occasional large scale stand replacing events.

Avalanche is not a common feature of most of these stands. Other disturbance elements such as windthrow, insects, disease, and lightning are more common, but mortality from these factors often occurs in localized situations or select species. Disturbance from all elements appears to occur continuously on various scales in these stands, and this results in the creation of various sized gaps with constantly changing structures through time.

Stand development appears to be sporadic as opportunities for regeneration and growth arise in response to disturbance. After disturbance the most likely successional sequence involves early dominance by shrubs, forbs, and grass. These early communities can be quite persistent on the landscape, and replacement by trees can be a prolonged process. Once conifer regeneration is established, however, it grows, self-thins, and matures while other portions of the stand continue to undergo disturbance. In time, a patchy distribution of trees emerges with several size and tree classes, including a substantial portion of larger trees. The stand eventually exhibits an irregular structure with many small relatively even-aged patches distributed throughout. As stands occupy sites for longer periods, successive disturbances continue to develop and maintain these stand structures until an infrequent stand replacing event occurs and a new stand emerges.

Cover (percent)	*Mean*	*Range*
Total vegetative	85	52-99
Tree	78	48-97
Shrub	3	0-32
Forb	13	0-80
Grass	2	0-35
Moss	0.2	0-3
Stand age (years)	192	77-319
Diversity index		
Simpson	0.47	0.15-0.87
Hill numbers		
N0	11.3	2.0-22.0
N1	3.36	1.32-8.56
N2	2.46	1.15-6.47

Characteristic Vegetation

Code	Common name	Constancy	Percent cover Mean	Percent cover Range
I. Overstory trees				
ABMA	Red fir	100	55	14-90
ABCO	White fir	94	25	2-71
II. Understory trees				
ABMA	Red fir	97	2	1-20
ABCO	White fir	71	2	1-10
III. Shrubs				
RIRO	Sierra gooseberry	29	1	1-3
SYAC	Creeping snowberry	29	4	1-25
CASE3	Sierra chinquapin	22	5	1-30
IV. Forbs				
PYPI	White veined wintergreen	49	1	1-3
HIAL	White flowered hawkweed	48	2	1-30
COMA4	Spotted coral root	43	1	1-1
KEGA	Kellogg's bedstraw	43	1	1-4
PESE3	Pine woods lousewort	43	1	1-3
PHHY	Waterleaf phacelia	42	1	1-8
VIPU	Mountain violet	39	2	1-30
CHBR3	Brewer's golden aster	33	3	1-25
MOOD	Mountain pennyroyal	30	1	1-5
OSCH	Mountain sweet cicely	28	1	1-2
COTOW	Wright's blue eyed mary	23	2	1-10
PTAQ	Western bracken fern	22	9	1-75
V. Grasses and grass-like				
POBO1	Bolander's bluegrass	26	1	1-1

Soils

Soils are predominantly Inceptisols. Entisols, Alfisols, and Mollisols are also encountered as rare occurrences. Inceptisols are typically Xerumbrepts with some Xerochrepts. Particle size classes are normally loamy, and indicate the lower levels of coarse fragments in these profiles. Infrequent sites are skeletal. Typical parent materials are granitic rocks, but occasional sites contain soils that are derived from volcanic materials and reflect locations in the north. These soils are commonly formed in place from bedrock. Glacial or alluvial and colluvial deposits are encountered in few instances.

Soils in these stands are deep. Nearly 75 percent of the samples had soil depths that exceeded 40 inches, and rarely were depths less than 35 inches. Soil textures in both the topsoil and subsoil are usually sandy loams with occasional loams but few sands. Subsoil textures are more often cobbly or gravelly; however, the average coarse fragment content in both topsoil and subsoil are among the lowest of the forested soils in the upper montane. Topsoil coarse fragments are typically less than 15 percent, and subsoil coarse fragments are commonly less than 35 percent.

The average AWC of these sites is one of the highest in the upper montane. It is substantially higher than most other sites, and it reflects the deep soils and lower coarse fragments that are common to these stands. Bedrock materials are typically fractured and rootable thereby providing access to additional stored water. The majority of stands are well drained. Those with excess drainage are commonly coarse textured soils on steeper slopes. Erodibility is moderate to high in response to loamy textures or steeper slopes. Summertime soil temperatures are cool. They are substantially lower than most other plant associations. Typical summertime temperatures are less than 49° Fahrenheit.

Variable	*Mean*	*Range*
Depth of soil sample (inches)	39	19-40+
Topsoil		
Depth (inches)	10	2-36
Coarse fragments (pct.)	15	1-65
pH	5.8	5.0-7.0
Subsoil		
Coarse fragments (pct.)	26	5-75
pH	5.8	5.0-6.8
AWC (inches)	4.1	0.6-6.9
Temp (20 inches) (Fahrenheit)	47	37-56

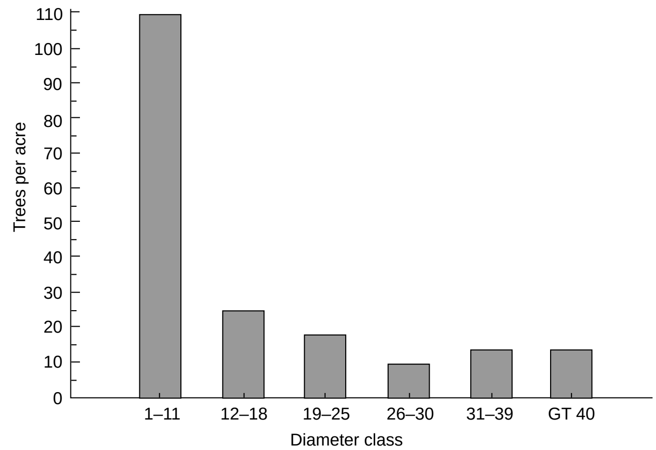
Productivity

Site indexes are among the highest in the upper montane. Pacific Southwest Region (Region 5) site indexes are typically 1 or better, and rarely are they lower than site 2. Stand densities are also extremely high. On average, this association has among the highest stand densities in these forests. They are exceeded only by stands in the red fir and quaking aspen/California corn lily associations. Tree heights are substantially higher than those in most other stands as well. This reflects both better site indexes and the presence of white fir, which attains heights similar to the tallest red fir. The tallest white fir in this association, for example, was measured at 202 feet compared to the tallest red fir of 207 feet. The combination of high site index, dense stands, and tall trees result in the highest cubic and board foot volumes of all forested plant associations in the upper montane.

Individual stands often have the appearance of an even-aged distribution; however, they frequently exhibit other distributions, and taken collectively stand structures can be considered irregular. Distributions in many stands approach those of an uneven-aged stand (*fig. 40*). Compared to an uneven-aged stand with comparable stocking and a balanced diameter distribution, however, they carry too few trees in size classes between approximately 14 and 30 inches, and they carry too many trees in size classes larger than 30 inches. When compared to even-aged distributions with equivalent stocking, both smaller and larger size classes are over-represented. They closely parallel distributions of late seral stands in the red fir plant association.

Variable	*Mean*	*Range*
Region 5 site index	1	0-3
Forest survey site class	2	1-4
Stand density index	520	200-948
Quadratic mean diameter	22.0	9.3-38.9
Softwood volume (mcf/ac)	15.1	5.5-29.7
Softwood volume (mbf/ac)	106.5	34.7-224.5
Softwood basal area (sq ft/ac)	372	150-627
Hardwood volume (mcf/ac)	0	0
Hardwood basal area (sq ft/ac)	0	0

Figure 40—Number of trees by diameter class in the red fir-white fir plant association.



Tree species composition by percent of basal area

Species	ABMA	ABCO	PICO	PIJE	PIMO3	TSME
Percent	65	33	1	1	-	-
Species	JUOC	PILA	LIDE3	PIAL	POTR	QUKE
Percent	-	-	-	-	-	-

Coarse Woody Debris

Snag numbers are moderate to high. Snags in size classes below 25 inches are abundant, and snags in size classes larger than 25 inches are substantially more numerous than many other associations. Mortality is concentrated most heavily in trees between 6 and 18 inches in diameter and appears related to thinning of smaller suppressed individuals. Mortality in larger size classes appears to be related to senescence, and it is randomly distributed among all species. Snags are generally shorter than 50 feet indicating a tendency of large standing snags to break off over time. They lie predominantly between decay classes 1 and 3. Logs are uniformly distributed between size classes. Most are shorter than 50 feet and show higher levels of decay than snags. Decay classes 4 and 5 predominate.

Snags

	Breast Height Diameter Class (inches)						
	<11	***11-17.9***	***18-24.9***	***25-29.9***	***30-39.9***	***>40***	***Total***
Snags per acre	11.0	8.8	2.2	0.7	1.3	2.2	26.2
Snag height (feet)							
<20	7.0	2.3	0.4	0.6	0.8	0.7	11.8
20-50	4.0	2.9	0.4	-	0.3	0.2	7.8
>50	-	3.6	1.4	0.1	0.2	1.3	6.6
Snag decay class							
1	2.0	2.6	1.1	-	-	0.3	6.0
2	1.0	3.4	0.4	0.2	0.2	0.5	5.7
3	8.0	2.2	0.4	0.1	0.3	0.7	11.7
4	-	0.5	-	-	0.8	0.5	1.8
5	-	0.1	0.3	0.4	-	0.2	1.0

Logs

	Large End Diameter Class (inches)				
	11-20	*21-30*	*31-40*	*>40*	*Total*
Logs per acre	3.3	6.7	3.3	0.7	14.0
Log length (feet)					
<20	2.6	3.0	1.3	0.4	7.3
20-50	0.7	2.4	1.0	-	4.1
51-100	-	1.0	0.7	0.3	2.0
>100	-	0.3	0.3	-	0.6
Log decay class					
1	-	-	-	-	-
2	-	0.7	-	-	0.7
3	-	-	1.3	-	1.3
4	1.3	3.7	1.7	0.3	7.0
5	2.0	2.3	0.3	0.4	5.0

Wildlife

Stands may offer hiding and thermal cover to large game, but forage possibilities appear limited. Of the species occurring on these sites, only western bracken fern and Bolander's bluegrass are staples in the large game diet, and frequency of occurrence for these species are low. Grass that comprises a major part of the large game diets is essentially missing from this association. On the other hand, deer presence was usually observed on these sites. Pocket gopher presence was also common.

Range

These are transitional range sites that are used by livestock to access primary range sites such as meadows and other moist habitats. Cattle were present in the majority of stands, but none of the more commonly occurring species on these sites are primary or secondary range forage species. It appears range forage potential is low in these late seral stands.

Management Recommendations

Many stands in this association have been harvested. Early harvests were directed at improvement cuttings, but more recently harvests in the form of clearcutting or shelterwood to develop even-age stands have been practiced. Except in shelterwoods, little reliance has been placed on obtaining natural regeneration. Most sites have been planted to Jeffrey pine. Results are varied, and this practice has diminished in recent years. Many well stocked and growing plantations are present, but a high number of sites with low stocking and poor growth are present as well. Poor establishment appears to result from a variety of factors not the least of which is the role of Jeffrey pine in reforesting these sites. In the southern portion of the study area, Jeffrey pine plantations in the range of 10 to 15 years appear to be well stocked and growing at acceptable rates. Scattered examples are also present elsewhere in the range; however, as one travels north, success rates appear to drop and stocking levels and growth rates become variable. Many stands exhibit high levels of shrub and forb cover after harvest.

Original cover values for competing species are low, but through resprouting and germination of stored seed early succession can be dominated by persistent shrubs, such as squaw currant and bitter cherry in the south, snowbrush on the eastside, and mountain whitethorn and Sierra chinquapin elsewhere. Bracken fern, Anderson's lupine, and Drew's silky lupine within the forb component can also dominate some of these sites. In many instances natural red and white fir regeneration is becoming established even in plantations that are larger than 30 acres. Time periods for such regeneration may exceed 20 years, however.

These stands have very high productive capacity and flexibility for stand management. Options for silvicultural systems and cutting methods can vary to take advantage of the shade tolerance and high stand densities attainable in these stands. Natural regeneration can become a viable option with proper vegetation management practices. Stand openings should be kept small, and reductions in stand density should anticipate an increase in shrub cover. Most reforestation prescriptions in this type should plan for vigorous vegetation control early in the life of any plantation. Reforestation and stand treatment such as thinning should maintain species composition expressed in late seral stands.

Late seral stands also have the potential to contribute to wildlife values. In their present condition they are an important source of snags especially in smaller size classes, and through management, they can continue to provide snags for a period of time after harvest and plantation establishment. Many of the species that compete with conifer seedlings are also preferred or secondary large game food sources. Thus, mountain whitethorn and bitter cherry are preferred forage, and snowbrush is a staple in the large game diet. Careful vegetation management early in the life of plantations can substantially increase wildlife forage and not seriously impact reforestation efforts.

Red Fir/Pinemat Manzanita Association

Abies magnifica/arctostaphylos nevadensis

ABMA/ARNE2
CFRCFR12
Sample size: 28

Distribution

The red fir/pinemat manzanita plant association is common in the upper montane, but it appears to be primarily a westside community. It was sampled throughout the study area except for the Inyo National Forest. Other eastside locations were few. Most eastside stands that are observed are the red fir-western white pine/pinemat manzanita association that resembles red fir/pinemat manzanita to a large degree but generally lies at higher elevations. In some areas, as near Trout Creek on the Lake Tahoe Basin Management Unit stands can cover large acreages; however, in most cases stands are smaller than 10 acres, and many cover areas of less than an acre.

Environment

Environments in the red fir/pinemat manzanita plant association are not substantially different from many other forested communities in the upper montane. Elevations are wide ranging, and stands lie almost equally above and below 8,000 feet. The lowest stand sampled was on the Eldorado National Forest, and the highest was on the Sequoia, reflecting a characteristic rise in elevation for these plant communities as one travels south in the range. Aspects are varied and essentially evenly distributed across the landscape. Slopes are commonly less than 35 percent. This association is located on all slope positions except toeslopes; however, stands are typically found on ridge tops and upper and middle slopes. Litter depths are significantly less than most other associations. The association is closely related to red fir-western white pine/pinemat manzanita plant communities in species composition, but the environments of the two, primarily elevation, soil coarse fragment content, and soil textures, differ enough that they are classified separately at this time.

Variable	*Mean*	*Range*
Elevation (feet)	7,983	7,050-8,800
Slope (pct.)	24	2-47
Solar radiation index	0.498	0.361-0.584
Bare ground (pct.)	3	0-12
Surface gravel (pct.)	4	0-25
Surface rock (pct.)	10	0-45
Litter (pct.)	82	5-99
Litter depth (inches)	1.0	0.2-3.0
Stress index	0.54	0.40-0.64

Aspect: All.

Range: All.

Position: Ridges, upper slopes.

Range: Ridgetops, upper, middle, and lower slopes, benches.

Vegetation

Stands are characteristically open woodlands with a distinctive understory of pinemat manzanita. Total vegetative cover is high due to the generally abundant cover of pinemat manzanita, but tree cover is considerably lower than most other associations, and trees tend to occur as scattered clumps and individuals. The overstory is predominantly red fir; occasionally Jeffrey pine, lodgeple pine, and white fir are present, and western white pine is sometimes present as widely scattered individuals. Some stands in the association are actually dominated by Jeffrey pine although red fir is typically present in these situations as well. The presence of Jeffrey pine and white fir are indicative of the lower elevations of the association, and they often serve to distinguish stands from the higher elevation red fir-western white pine/pinemat manzanita association.

The shrub layer is typified by pinemat manzanita, but Sierra chinquapin is also a consistent member of the association. Both species indicate dry conditions in general. The forb component is often sparse and contains a mix of dry and moderate site species. Thus, broad seeded rock cress and mountain pennyroyal are generally indicative of drier conditions, and white veined wintergreen and mountain violet often inhabit mesic sites. A grass layer is essentially absent.

Conifer regeneration is moderate to low, and it is usually clumped rather than evenly distributed in the stand. Stands average 420 seedlings per acre, and most sites contain more than 100. Occasional stands have more than 500 seedlings per acre. Red fir dominates the regeneration layer. White fir is occasionally present, and Jeffrey pine and western white pine are encountered in a few cases. Red fir is regenerating significantly more often compared to other plant associations.

Plant species diversity is moderate to low for upper montane forests. The association has a relatively low number of species overall. Stands are dominated by relatively few tree species and essentially a single shrub species. Together they outweigh the cover values of the forb and grass layers. The number of abundant species is among the lowest of any in the upper montane.

The oldest trees in these stands are generally older than 250 years. Stands contain high proportions of older trees, and average stand ages are substantially older than dense, forested stands in the upper montane. The oldest tree sampled was a Jeffrey pine at ±663 years, and the oldest red fir was estimated at ±440 years.

Although stand replacing events probably occur in this association, they do not appear to be frequent or large scale phenomenon. The moderate slopes and the open structure of the stands with a discontinuous, low shrub cover and conifer stocking concentrated in relatively large, widely spaced, somewhat fire resistant individuals, would tend to preclude stand replacing fires. Shrub layers favor larger more intense fires, but the low growing habit of pinemat manzanita often results in patchy burns of relatively low intensity with some portions of the stand being consumed and others left with little damage. Isolated large trees probably escape damage in most cases. Disturbance elements such as windthrow, insects, disease, lightning, or avalanche do not appear to affect large areas in these stands.

Reproductive strategies such as consistent seed production, sprouting, or delayed germination of seed until scarified by fire is present in species on these sites. Pinemat manzanita sprouts from stems, but it does not crown sprout. Patchy burns would ensure survival of at least some stems and allow reoccupation of disturbed sites. The wide spacing of existing trees would result in uneven coverage of sites by most disturbance elements.

Stand development appears to be sporadic as opportunities for regeneration and growth arise in response to disturbance. Disturbance creates opportunities for regeneration, but many microhabitats are unsuitable for conifer regeneration, and it appears conifer establishment is a prolonged process. Disturbance provides opportunities for surviving individuals to increase growth. Isolated patches of conifers that escape repeated disturbance proceed through a period of crown closure and self-thinning. Other portions of the stand continue to undergo disturbance although there are probably always isolated trees and small patches that escape disturbance and mature into larger individuals. In time, stands develop an irregular structure with several age classes reflecting numerous disturbances, and containing widely spaced large trees that are the survivors of multiple events.

Cover (percent)	*Mean*	*Range*
Total vegetative	84	60-98
Tree	51	17-95
Shrub	52	2-90
Forb	6	0-70
Grass	2	0-40
Moss	0.4	0-9
Stand age (years)	268	106-523
Diversity index		
Simpson	0.44	0.11-0.84
Hill numbers		
N0	9.5	4.0-18.0
N1	3.57	1.34-9.72
N2	2.86	1.19-8.85

Characteristic Vegetation

	Code	*Common name*	*Constancy*	*Percent cover* *Mean*	*Range*
I.	Overstory trees				
	ABMA	Red fir	93	44	5-90
	ABCO	Jeffrey pine	29	22	3-62
	PIJE	White fir	21	6	1-10
II.	Understory trees				
	ABMA	Red fir	89	1	1-5
	ABCO	White fir	25	1	1-1
III.	Shrubs				
	ARNE2	Pinemat manzanita	100	43	1-89
	CASE3	Sierra chinquapin	43	11	1-60
IV.	Forbs				
	ARPL	Broad seeded rock cress	64	1	1-30
	PESE3	Pine woods lousewort	57	1	1-80
	MOOD	Mountain pennyroyal	43	1	1-2
	CHBR3	Brewer's golden aster	32	1	1-2
	PYPI	White veined wintergreen	29	1	1-1
	APMEF	Western dogbane	25	1	1-1
	VIPU	Mountain violet	21	1	1-70
V.	Grasses and grass-like				
	None				

Soils

Typical Soils are Inceptisols. In rare cases Entisols and Alfisols are encountered. The Inceptisols usually occur as Xerumbrepts with some Xerochrepts. Entisols are typically Orthents. Particle size classes are commonly skeletal, indicative of higher levels of coarse fragments in the profiles. Granitic parent materials are commonly encountered, and volcanic and metamorphic substrates are found in rare instances. The majority of these soils are formed in place over bedrock.

Soils are moderately deep. Occasional sites have depths that exceed 40 inches, but typically depths lie between 25 and 40 inches. Coarse fragment content in the subsoils are substantially higher than most other sites in the upper montane. Typically they exceed 35 percent, and some are higher than 65 percent. Topsoil textures are commonly sandy loams with occasional sands and a few loams. Subsoil textures are more variable with a higher proportion of sands than the topsoil and textures that are usually cobbly sandy loams with some sands and a few loams and clay loams.

The AWC of these soils is variable. In general, sites are not substantially different from most others. Many sites do, however, have low water holding capacities, reflecting differences in soil textures and coarse fragment contents within individual stands. Commonly, parent materials under these sites are fractured and rootable, but almost as often stands occur on formations that were massive and unrootable. These soils are excessively drained, reflecting the coarse textures and location on slopes for most sites. Erodibility is moderate as a consequence of the coarse soil textures and moderate to gentle slopes. Stress indexes are characteristically high, indicative of lower AWC as well as locations on upper slopes.

Variable	*Mean*	*Range*
Depth of soil sample (inches)	30	(11-40+)
Topsoil		
Depth (inches)	8	2-17
Coarse fragments (pct.)	25	2-75
pH	5.8	4.6-6.5
Subsoil		
Coarse fragments (pct.)	49	6-80
pH	5.6	4.8-6.1
AWC (inches)	2.3	0.4-4.9
Temp (20 inches) (Fahrenheit)	51	44-62

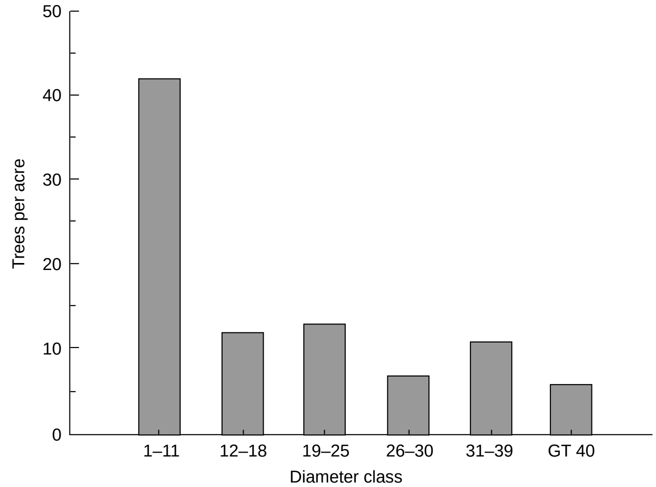
Productivity

Site indexes vary considerably, but they are significantly lower than dense well stocked stands elsewhere in the study area. Usually Pacific Southwest Region (Region 5) site indexes were 4 and 5. Stand density is also considerably lower than other forested stands in the area. Stand density indexes are typically less than 300, and average stocking levels based on stand density index are about 55 percent of values reached in the red fir-white fir association, which is one of the densest in these forests. Stocking also resides in the larger individuals of the stand. The average quadratic mean diameter is among the largest in forested associations of the upper montane. Tree heights are substantially lower than most other sites reflecting overall lower site quality. The tallest tree measured in this association was a Jeffrey pine at 157 feet. The tallest red fir encountered was estimated at 152 feet, and typically heights of the tallest trees were less than 150 feet. These factors result in less basal area stocking and moderate cubic and board foot yields for this association.

Stand structures are irregular. Stands tend to be open with few total trees per acre, and stocking is sometimes concentrated in a few large trees (*fig. 41*). Stands often appear to have an even-aged structure in the field; however, when compared to an even-aged distribution, they have an excess of trees in both smaller and larger size classes. Compared to an uneven-aged structure with a balanced diameter distribution and similar stocking levels, these stands have too few trees in size classes smaller than 18 inches, and an excess of trees in size classes larger than 30 inches.

Variable	*Mean*	*Range*
Region 5 site index	3	1-5
Forest survey site class	4	2-6
Stand density index	290	118-750
Quadratic mean diameter	24.9	9.4-38.1
Softwood volume (mcf/ac)	7.1	2.9-15.7
Softwood volume (mbf/ac)	47.1	17.3-98.9
Softwood basal area (sq ft/ac)	221	72-493
Hardwood volume (mcf/ac)	0	0
Hardwood basal area (sq ft/ac)	0	0

Figure 41—Number of trees by diameter class in the red fir/pinemat manzanita plant association.



Tree species composition by percent of basal area

Species	ABMA	ABCO	PICO	PIJE	PIMO3	TSME
Percent	81	4	3	9	2	-
Species	JUOC	PILA	LIDE3	PIAL	POTR	QUKE
Percent	1	-	-	-	-	-

Coarse Woody Debris

Snag numbers are among the lowest in the upper montane. Snags in size classes smaller than 25 inches DBH are particularly sparse, but mortality is distributed among species in proportion to their stocking levels. Snags are distributed among all height classes, but typically they are shorter than 50 feet reflecting a tendency for standing snags to break off as they age. Decay classes are between 1 and 3 in the majority of these snags. Logs are distributed among all size classes. Often they are less than 30 inches in large end diameter, but size classes larger than 30 inches are also well represented. Logs are characteristically less than 50 feet in length, and they indicate higher levels of decay than snags. The majority lie in decay classes between 3 and 5.

Snags

	Breast Height Diameter Class (inches)						
	<11	*11-17.9*	*18-24.9*	*25-29.9*	*30-39.9*	*>40*	*Total*
Snags per acre	0	0	0.5	0.1	1.7	0.5	2.8
Snag height (feet)							
<20	-	-	0.2	0.1	0.3	-	0.6
20-50	-	-	0.1	-	0.8	0.5	1.4
>50	-	-	0.2	-	0.6	-	0.8
Snag decay class							
1	-	-	0.1	-	0.6	-	0.7
2	-	-	-	-	0.3	0.5	0.8
3	-	-	0.2	0.1	0.6	-	0.9
4	-	-	0.1	-	-	-	0.1
5	-	-	0.1	-	0.2	-	0.3

Logs

	Large End Diameter Class (inches)				
	11-20	*21-30*	*31-40*	*>40*	*Total*
Logs per acre	3.0	11.5	3.0	6.5	24.0
Log length (feet)					
<20	2.5	6.3	1.5	3.0	13.3
20-50	0.5	3.1	1.5	3.0	8.1
51-100	-	2.1	-	0.5	2.6
>100	-	-	-	-	-
Log decay class					
1	-	0.5	-	0.5	1.0
2	0.5	-	-	-	0.5
3	2.0	5.0	0.5	0.5	8.0
4	0.5	5.5	1.0	4.0	11.0
5	-	0.5	1.5	1.5	3.5

Wildlife

These appear to be transitional forage sites as large game seek preferred habitats. Forage values appear to be low. None of the more common shrub and forb species occurring on these sites contribute to the large game diet, and the grass component is essentially absent. Nevertheless, evidence of deer and pocket gophers were common in this association.

Range

Range forage potential appears to be transitory as livestock move to primary range sites such as meadows and other moist habitats. The majority of sites did show signs of cattle presence, but none of the shrub and forb species occurring on these sites are primary or secondary range species, and the grass component is essentially absent. It appears range forage potential is low in late seral stands of this association.

Management Recommendations

Relatively few stands in this type have been harvested. As a result, silvicultural systems, cutting methods, successional sequences, and stocking levels important in the management of any forest type are relatively unknown. Where disturbance from logging has occurred, regeneration success has been mixed. On small scales, some success has been noted with red fir natural regeneration, but over larger areas this is not the case. A portion of this apparent failure may result from not applying vegetation control for pinemat manzanita or bush chinquapin. Regeneration strategies involving planting have not been determined for this association, and no cases were observed where stands were harvested and planted with any systematic approach.

These stands have limited productive capacity and flexibility for stand management. The open nature of stands indicates that regeneration and establishment is a lengthy and variable process under most conditions. Recommendations for harvesting at the present time would be to treat stands in this association with caution and the expectation that results can be uncertain. A broad base of experience in treating these stands does not exist in the field.

Limited opportunities exist for salvage when it occurs, but on these open sites it would appear that woody debris left in the form of snags and logs for wildlife or part of the nutrient pool would be better direction for this association. Management emphasis should provide for existing wildlife habitat, plant species richness, and the landscape level diversity these plant communities provide to upper montane forests.

Red Fir Association

Abies magnifica

ABA
CFRCFR11
Sample size: 16

Distribution

The red fir plant association is widespread. It was sampled on all National Forests and Parks in the study area. Latitudes and longitudes span the range of upper montane forests in the central and southern Sierra Nevada. Red fir can be considered the species that defines the location of upper montane forests in this region. It appears at elevations above the white fir-sugar pine communities that occur at the upper edge of the lower montane; it becomes dominant within the upper montane, and it disappears gradually into the subalpine zone above. Stands in this association are those that reflect optimum sites and maximum development of red fir. Individual stands range from smaller than 5 acres to extensive tracts covering large areas. Usually, however, changes in aspect, topography, geologic formation, soil conditions, and slope position occur frequently enough in these forests that single stands are of moderate size with most occupying less than 100 acres.

Environment

This association can occur at all elevations of the upper montane. The lowest stand sampled was on the Eldorado National Forest at 6,660 feet, and the highest was at 9,240 feet on the Sequoia National Forest. Eastside stands generally occur between elevations of 8,000 to 9,200 feet. Aspects are varied, but often northeast and northwest aspects are encountered, and average solar radiation levels are among the lowest in the upper montane. Slopes range from gentle to steep, but the majority of stands occur on slopes of less than 40 percent. Stands are located on all slope positions; however, upper, middle, and lower slopes are favored, and seldom do they occur on ridgetops. Site microrelief varies from relatively uniform surfaces to those that are broken and hummocky, although most are smooth and uniform. This association has significantly lower levels of bare ground and surface gravel than most other sites, and litter cover and litter depth are correspondingly higher. These features reflect the substantially higher levels of tree cover and debris on the forest floor that is characteristic of these stands. Stress indexes are mid-range among all of the upper montane forests.

Variable	*Mean*	*Range*
Elevation (feet)	8,017	6,660-9,240
Slope (pct.)	24	2-60
Solar radiation index	0.475	0.293-0.587
Bare ground (pct.)	3	0-45
Surface gravel (pct.)	4	0-84
Surface Rock (pct.)	5	0-70
Litter (pct.)	87	5-99
Litter depth (inches)	1.6	0.2-5.0
Stress index	0.49	0.33-0.62

Aspect: NE, NW.

Range: All.

Position: Upper and middle slopes.

Range: All.

Vegetation

Stands are characteristically dense forests with open understories. Total tree cover is one of the highest in the upper montane. The overstory is dominated by a single species—red fir—and on these sites the high cover of red fir indicates the moderate site conditions frequently encountered.

Understories are sparse. Shrub and grass layers are essentially absent. In rare cases Sierra chinquapin, pinemat manzanita, huckleberry oak, and mountain whitethorn may be present in substantial amounts to indicate drier site conditions. Mountain whitethorn, often low in constancy, is an important member of the understory due to its ability to rapidly occupy sites after disturbance. The forb layer usually contains spotted coral root, but this is a difficult species to recognize to an untrained eye. Occasionally white veined wintergreen, mountain violet, or white flowered hawkweed are scattered throughout the understory. They are also indicators of the moderate site conditions that prevail in these stands.

Conifer regeneration is moderately high. The average number of seedlings per acre is about 870, and most sites carry more than 100 per acre. These are typically clumped together as patches in openings. Rare sites will have over 2,000 seedlings per acre. Red fir is the major species regenerating although white fir, Jeffrey pine, western white pine, and lodgepole pine are infrequent members in the regeneration layer. Red fir is regenerating on these sites with significantly higher frequency than in other plant associations.

Plant species diversity is quite low. Stands have few species overall, and these are concentrated in the overstory tree layer. Most sites are dominated by a single tree species and little else. The shrub and grass layers are essentially absent, and the tree cover far outweighs the cover values of most forb species. Abundant species are relegated to slightly more than a single species in most stands.

The oldest trees in these stands are commonly greater than 200 years. Almost 50 percent of the dominant trees sampled were older than 250 years. The oldest tree sampled was a red fir at ±531 years. Scattered individuals of other species show ages that are comparable to ages attained in these forests in general. Thus, the oldest white fir sampled was ±341 years; the oldest Jeffrey pine was measured at ±308 years; and the oldest lodgepole pine was measured at ±231years.

Stand replacing disturbances probably occur in this association, but they do not appear to be a frequent or large scale phenomenon. The setting of many stands on cooler north aspects, the structure of the stands with open understories, the presence of relatively large, somewhat fire resistant individuals, and the natural patchiness of the landscape tend to preclude large scale stand replacement. Observation of stand distributions and structure indicate stands probably experience both small scale patchy burns and infrequent large scale stand replacing events.

Avalanche can replace stands on middle and lower slopes in the association, but most appear to be infrequent and occur at scattered locations across the landscape. Understories, including trees, generally remain intact. Other disturbance elements such as windthrow, insects, disease, and lightning do not appear to affect large areas in these stands. It is likely that disturbances occur continuously on various scales, and this results in the creation of various sized gaps with constantly changing structures through time that are quite characteristic of these stands.

Stand development appears to be sporadic as opportunities for regeneration and growth arise in response to disturbance. It does not appear these stands go through a prolonged period in a grass/forb or shrub phase, although lower elevation sites on south facing slopes can experience early dominance by persistent shrubs and forbs such as squaw currant, mountain whitethorn, bitter cherry, and lupine, and sometimes lodgepole pine occupies sites in abundance after disturbance. Once regeneration is established, however, it grows, self-thins, and matures while other portions of the stand continue to undergo disturbance. In time, a patchy distribution of trees emerges with several size and tree classes present including a substantial portion of larger trees. The stand eventually exhibits an irregular structure with many small relatively even-aged patches. As stands occupy sites for longer periods, multiple disturbances are important in developing and maintaining structures until the site does encounter a stand replacing event, and a new stand emerges.

Cover (percent)	***Mean***	***Range***
Total vegetative	82	40-90
Tree	77	29-96
Shrub	2	0-26
Forb	6	0-90
Grass	1	0-46
Moss	0.2	0-8
Stand age (years)	219	79-446
Diversity index		
Simpson	0.78	0.16-1.00
Hill numbers		
N0	7.9	1.0-20.0
N1	1.88	1.00-8.26
N2	1.42	1.00-6.41

Characteristic Vegetation

	Code	Common name	Constancy	Percent cover Mean	Percent cover Range
I.	Overstory trees				
	ABMA	Red fir	100	76	28-99
II.	Understory trees				
	ABMA	Red fir	95	4	0-75
III.	Shrubs				
	None				
IV.	Forbs				
	COMA4	Spotted coral root	48	1	1-2
	PESE3	Pine woods lousewort	47	1	1-20
	PHHY	Waterleaf phacelia	43	1	1-80
	PYPI	White veined wintergreen	36	1	1-5
	VIPU	Mountain violet	32	1	1-30
	ARPL	Broad seeded rock cress	30	1	1-6
	HIAL	White flowered hawkweed	29	1	1-3
	CHBR3	Brewer's golden aster	26	2	1-10
V.	Grasses and grass-like				
	None				

Soils

Soils are typically Inceptisols, and usually classified as Xerumbrepts with occasional Xerochrepts. Occasional Entisols and rare Alfisols are also encountered. Entisols are evenly distributed between Orthents and Psamments at the suborder level, and the few Alfisols are represented by Xeralfs. Particle size classes are usually skeletal, reflective of somewhat higher levels of rock fragments throughout the profile. Occasional sites are classified as loamy. Granitic parent materials occur most often, but volcanic substrates are not uncommon, and represent samples from the northern portion of the study area. Soils derived from metamorphic, sedimentary, and mixed lithology are rare. Soils in this association are typically formed in place from bedrock although occasional soils are developed from deposited materials such as glacial till, colluvium, or alluvium.

Soils are quite deep. Average depths are considerably deeper than most other sites. Depths exceeded 40 inches on over two-thirds of the sample sites. Rare sites had depths less than 35 inches. Topsoil and subsoil textures are nearly identical. They are usually sandy loams. Occasional sands or loams occurred that differed from this modal texture, and subsoils had a tendency toward higher levels of sand. In general, these soils can be considered moderately coarse textured throughout the profile. Coarse fragment contents in the topsoil are generally less than 35 percent. Subsoils contain higher levels overall, but they are often less than 35 percent as well.

The AWC of these stands is somewhat variable, but it can be considered moderate in most cases. This reflects coarser textures in many of these soils contrasting with the deeper soils commonly encountered. Bedrock conditions below lithic contacts show variable rooting conditions, but they are usually fractured and rootable, thereby increasing the available water supply. Typically, these soils are well drained, although sites with coarser textured soils and steeper slopes can sometimes be excessively drained. Erodibility ranges widely from low to high, reflecting differences in soil texture and slope on individual sites. Summertime soil temperatures are cool. They are significantly lower than in most other plant associations in the upper montane, and typically they lie below 49° Fahrenheit.

Variable	*Mean*	*Range*
Depth of soil sample (inches)	38	18-40+
Topsoil		
Depth (inches)	8	2-25
Coarse fragments (pct.)	20	0-98
pH	5.9	4.5-7.0
Subsoil		
Coarse fragments (pct.)	38	0-99
pH	5.8	4.5-7.5
AWC (inches)	3.3	0.7-6.5
Temp (20 inches) (Fahrenheit)	47	36-60

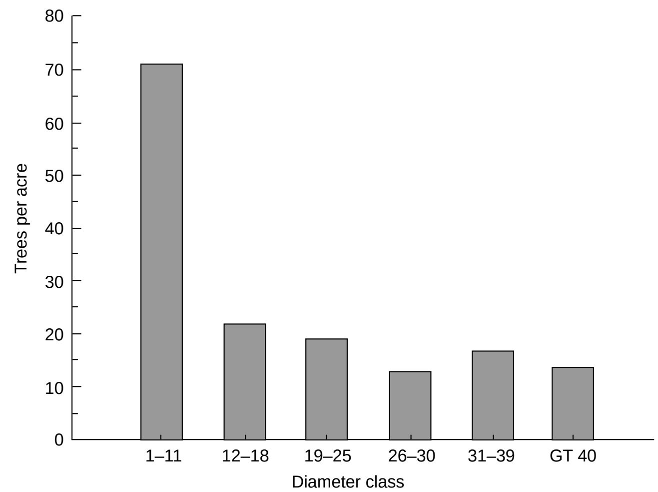
Productivity

Pacific Southwest Region (Region 5) site indexes average 2 in these stands, but they show considerable variation, reflecting the range of environments occupied. Typically, however, site indexes are 2 or better, and only rarely are they as low as 4. Stand density is quite high. Stands regularly have stand density indexes that exceed 500. Index values in the densest stands measured were over 1,100, which corresponds to values from earlier studies (Reineke 1933). On average, these are some of the densest stands in the upper montane. Quadratic mean diameters are also among the largest in these forests and reflect substantial stocking in large trees. Tree heights are substantially taller than those in most other stands as well. On the best sites, red fir can attain impressive heights. The tallest red fir was measured at 232 feet in this association. Yields are also high. The combination of relatively high site index, dense stands, and tall trees results in average cubic and board foot yields in these late seral stands that are among the highest of the upper montane forests.

Many individual stands appear to be even-aged; however, on any scale larger than a few acres structures approach the irregular distributions characteristic of other dense late seral stands in upper montane forests (*fig. 42*). Considered collectively, structures approach those of uneven-aged stands. Compared to an uneven-age distribution with similar stocking levels and a balanced diameter distribution, these stands generally contain too few trees in size classes smaller than 24 inches and too many in size classes larger than 30 inches. When compared to an even-age distribution, they carry too many trees in both smaller and larger size classes.

Variable	*Mean*	*Range*
Region 5 site index	2	0-4
Forest survey site class	3	1-5
Stand density index	517	136-1104
Quadratic mean diameter	24.7	8.4-39.4
Softwood volume (mcf/ac)	15.0	2.8-30.5
Softwood volume (mbf/ac)	105.9	17.9-225.1
Softwood basal area (sq ft/ac)	402	93-693
Hardwood volume (mcf/ac)	0	0
Hardwood basal area (sq ft/ac)	0	0

Figure 42—Number of trees by diameter class in the red fir plant association.



Tree species composition by percent of basal area

Species	ABMA	ABCO	PICO	PIJE	PIMO3	TSME
Percent	96	2	1	-	1	-
Species	JUOC	PILA	LIDE3	PIAL	POTR	QUKE
Percent	-	-	-	-	-	-

Coarse Woody Debris

Snag numbers are moderate when compared to other associations. Snags less than 18 inches DBH are abundant, and those in size classes larger than 25 inches are substantially more numerous than in most other stands. Mortality in smaller individuals represents losses to thinning of suppressed individuals; whereas in the larger members of the stand it is probably related to senescence, and it is distributed rather uniformly among the larger size classes. The majority of snags occurring in this association are red fir. Snag heights are distributed among all classes, but typically they are shorter than 50 feet, reflecting a tendency of large standing snags to break off with the passage of time. They are relatively sound and generally lie in decay classes between 1 and 3. Logs are commonly smaller than 30 inches in large end diameter, although logs larger than 30 inches are also well represented. Lengths are predominantly less than 50 feet, and logs evidence more decay than snags. The majority lie in decay classes between 3 and 5.

Snags

	Breast Height Diameter Class (inches)						
	<11	***11-17.9***	***18-24.9***	***25-29.9***	***30-39.9***	***>40***	***Total***
Snags per acre	4.4	3.1	2.5	1.3	1.4	1.9	14.6
Snag height (feet)							
<20	1.4	0.8	1.1	0.4	0.7	1.0	5.4
20-50	2.7	1.3	0.4	0.6	0.4	0.3	5.7
>50	0.3	1.0	1.0	0.3	0.3	0.6	3.5
Snag decay class							
1	0.9	0.7	0.3	0.3	0.2	0.2	2.6
2	2.7	1.3	0.5	0.1	0.3	0.5	5.4
3	0.8	1.0	1.3	0.7	0.8	0.6	5.2
4	-	0.1	0.4	0.2	0.1	0.4	1.2
5	-	-	-	-	-	0.2	0.2

Logs

	Large End Diameter Class (inches)				
	11-20	*21-30*	*31-40*	*>40*	*Total*
Logs per acre	12.3	12.2	6.6	5.1	36.2
Log length (feet)					
<20	6.5	5.7	2.9	1.8	16.9
20-50	5.0	4.3	2.5	2.1	13.9
51-100	0.8	2.2	1.0	0.9	4.9
>100	-	-	0.2	0.3	0.5
Log decay class					
1	-	0.1	-	0.1	0.2
2	2.1	0.6	0.3	0.3	3.3
3	5.6	4.3	1.8	1.0	12.7
4	3.9	4.0	2.6	2.6	13.1
5	0.7	3.2	1.9	1.1	6.9

Wildlife

Stands may offer some hiding and thermal cover to large game, but forage possibilities appear sparse. Of the species commonly occurring on these sites only waterleaf phacelia appears to be a staple that occurs with sufficient constancy to contribute to the large game diet. Shrubs and grass that comprise a major part of large game diets are essentially missing from this plant association. On the other hand, deer and pocket gopher presence was commonly observed in these stands.

Range

These are transitional range forage sites that are used by livestock to access primary forage areas such as meadows and other moist habitats. None of the more commonly occurring species on these sites, however, are of value as primary or secondary range forage; and grass, which forms a major portion of the range diet, is essentially missing from this association. Signs of cattle use were present in the majority of cases, but forage potential for livestock is generally low in late seral stands.

Management Recommendations

Many stands have been harvested in the study area. Early harvests were directed at improvement cuttings, but more recently harvests in the form of clearcutting and shelterwood to develop even-age stands have been practiced. One observation can be made from this early cutting. If seed sources are left on or adjacent to these sites, they will eventually regenerate naturally with red fir. In past cases involving clearcutting, most sites were planted with Jeffrey pine. Results in general from this approach are mixed, and this practice has diminished in recent years. Stocking levels were erratic and growth rates were low. On the other hand, many of these sites have regenerated naturally with red fir, apparently because of erratic seed production from residual trees and adjacent stands. This can take some time, perhaps as long as 25 years. Rather sizeable clearcuts (25+ acres) appear to have been regenerated in this way. In cases involving shelterwood cutting, good results have been observed in some cases, but this practice is still new in this portion of the Sierra Nevada, and broad patterns are not well established at this time. More recently, regeneration strategies involving planted red fir are being used. Nursery practices and planting techniques have been developed, but survival rates are somewhat erratic at this point, and more time must pass before judgments can be made about this practice.

Late seral stands on these sites generally do not carry high levels of shrub and forb cover, particularly on north aspects or at higher elevations; however, in individual cases shrub, forb, and grass competition can become significant after treatment. The ability to predict these situations at this time is not good; however, south aspects should be approached with caution. Early successional sequences in these stands are not well understood at present.

These stands have high productive capacity and flexibility for stand management. Options for silvicultural systems and cutting methods can vary to take advantage of the shade tolerance and high stand densities attainable in these stands. Natural regeneration can be a viable option. Stand openings should be kept small and seed source near. On north facing slopes small clearcuts can be used, but on south aspects shelterwood cutting or a silvicultural system that maintains constant tree cover is recommended. If shelterwood cutting is used, care must be directed to selection of seed trees. In many cases in the past, shelterwood residuals were composed of trees too young to bear many cones, or trees with damaged and unproductive crowns. High levels of shrub, forb and grass competition are not anticipated in most cases; however, individual sites, particularly at lower elevations and south aspects, can become occupied with species such as mountain whitethorn that offer serious competition to new seedlings.

Stands in this association also have the potential to contribute to wildlife values. In their present condition they are an important source of snags especially in smaller size classes, and through management, they can continue to provide snags for a period of time after harvest and plantation establishment.

Appendix A

Classification Hierarchy of Plant Associations

Plant Association	*Subseries*	*Series*
Bolander's Locoweed (*Astragalus bolanderii*) ASBO[1], FBLFBL11[2]	Bolander's Locoweed	Bolander's Locoweed
Red Fir/Mountain Mule Ears (*Abies magnifica/Wyethia mollis*) ABMA/WYMO, CFRFME11	Red Fir/MountainMule Ears	Red Fir
Quaking Aspen/California Corn Lily (*Populus tremuloides/Veratrum Californicum*) POTR/VECA1, HQAHQA11	Quaking Aspen	Quaking Aspen
Quaking Aspen/Mountain Pennyroyal (*Populus tremuloides/Monardella odoratissima*) POTR/MOOD, HQAHQA12	Quaking Aspen	Quaking Aspen
Western Juniper/Sagebrush (*Juniperus occidentalis/Artemisia tridentata*) JUOC/ARTR, CJOCJO12	Western Juniper	Western Juniper
Western Juniper (*Juniperus occidentalis*) JUOC, CJOCJO11	Western Juniper	Western Juniper
Mountain Hemlock//Steep (*Tsuga mertensiana//steep*) TSME//STEEP, CHMCHM11	Mountain Hemlock	Mountain Hemlock
Mountain Hemlock (*Tsuga mertensiana*) TSME, CHMCHM12	Mountain Hemlock	Mountain Hemlock
Jeffrey Pine/Huckleberry Oak (*Pinus Jeffreyii/Quercus vaccinifolia*) PIJE/QUVA, CPJCPJ12	Jeffrey Pine	Jeffrey Pine

Plant Association	***Subseries***	***Series***
Jeffrey Pine/Greenleaf Manzanita-Snowbrush (*Pinus Jeffreyii/ Arctostaphylos patula-Ceanothus velutinus*) PIJE/ARPA9-CEVE3, CPJCPJ13	Jeffrey Pine	Jeffrey Pine
Jeffrey Pine/Mountain Whitethorn-Sagebrush (*Pinus Jeffreyii/Ceanothus cordulatus-Artemisia tridentata*) PIJE/CECO2-ARTR, CPJCPJ14	Jeffrey Pine	Jeffrey Pine
Jeffrey Pine-Red Fir (*Pinus Jeffreyii-Abies magnifica*) PIJE-ABMA, CPJCPJ11	Jeffrey Pine	Jeffrey Pine
Lodgepole Pine/Gray's Lovage (*Pinus contorta/Ligusticum grayii*) PICO/LIGR1, CPLCPL11	Lodgepole Pine	Lodgepole Pine
Lodgepole Pine/Sagebrush (*Pinus contorta/Artemisia tridentata*) PICO/ARTR, CPLCPL14	Lodgepole Pine	Lodgepole Pine
Lodgepole Pine//Woodlands (*Pinus contorta//woodlands*) PICO//WOODLANDS, CPLCPL12	Lodgepole Pine	Lodgepole Pine
Lodgepole Pine (*Pinus contorta*) PICO, CPLCPL13	Lodgepole Pine	Lodgepole Pine
Red Fir-Western WhitePine/Sierra Chinquapin (*Abies magnifica-Pinus monticola/ Castanopsis sempervirens*) ABMA-PIMO3/CASE3, CFRCPW14	Red Fir-Western White Pine	Red Fir
Red Fir-Western WhitePine/Pinemat Manzanita (*Abies magnifica-Pinus monticola/ Arctostaphylos nevadensis*) ABMA-PIMO3/ARNE2, CFRCPW12	Red Fir-Western White Pine	Red Fir

Plant Association	*Subseries*	*Series*
Red Fir-Western WhitePine-Lodgepole Pine (*Abies magnifica-Pinus monticola-Pinus contorta*) ABMA-PIMO3-PICO, CFRCPW13	Red Fir-Western White Pine	Red Fir
Red Fir-Western WhitePine (*Abies magnifica-Pinus monticola*) ABMA-PIMO3, CFRCPW11	Red Fir-Western White Pine	Red Fir
White Fir-Sugar Pine-Red Fir (*Abies concolor-Pinus lambertiana-Abies magnifica*) ABCO-PILA-ABMA, CFWCPR11	White Fir-Sugar Pine	White Fir
Red Fir-White Fir-Jeffery Pine (*Abies magnifica-Abies concolor-Pinus Jeffreyii*) ABMA-ABCO-PIJE, CFRCFW12	Red Fir-White Fir	Red Fir
Red Fir-White Fir (*Abies magnifica-Abies concolor*) ABMA-ABCO, CFRCFW11	Red Fir-White Fir	Red Fir
Red Fir-Lodgepole Pine/White Flowered Hawkweed (*Abies magnifica-Pinus contorta/Hieracium albiflorum*) ABMA-PICO/HIAL, CFRCPL11	Red Fir-Lodgepole Pine	Red Fir
Red Fir/Pinemat Manzanita (*Abies magnifica/Arctostaphylos nevadensis*) ABMA/ARNE2, CFRCFR12	Red Fir	Red Fir
Red Fir (*Abies magnifica*) ABMA, CFRCFR11	Red Fir	Red Fir

[1] See *appendix I* for the key to species codes. See "Using the Classification" in the text for an explanation of the use of slashes and hyphens.

[2] Assigned by the U.S. Department of Agriculture, Forest Service, Pacific Southwest Region Ecology Program.

Appendix B

Soil Taxonomy by Plant Association

Soil Taxonomy		*Plant Association*[1]						
Order	Great Group	ASBO (10)[2]	POTR/ MOOD (19)	POTR/ VECA1 (16)	JUOC/ ARTR (17)	JUOC (12)	ABMA/ WYMO (14)	TSME// STEEP (17)
Inceptisols	Xerumbrepts	6	8	11	10	2	8	5
	Cryumbrepts	3	4		5	4	4	2
	Haplumbrepts							
	Xerochrepts		3		1	4		3
	Cryochrepts							3
	Durochrepts							
	Dystrandepts							
	Vitrandepts							
	Humaquepts							
Entisols	Xerorthents							
	Cryorthents							2
	Cryofluvents							
	Udifluvents			1				
	Xeropsamments	1				2		
	Cryopsamments							
	Cryaquents							
Mollisols	Cryoborolls		1					
	Paleborolls							
	Haploxerolls			2				
Alfisols	Haploxeralfs		1	2			2	
	Cryoboralfs		2		1			2

Soil Taxonomy		Plant Association[1]						
Order	Great Group	TSME (32)	ABMA-PIMO3/ ARNE2 (31)	ABMA-PIMO3/ CASE3 (11)	ABMA-PIMO3-PICO (25)	ABMA-PIMO3 (35)	ABCO-PILA-ABMA (33)	PIJE/ QUVA (32)
Inceptisols	Xerumbrepts	8	6	1	2	10	16	19
	Cryumbrepts	5	2		5	2		
	Haplumbrepts	3						
	Xerochrepts	5	7	1	2	13	10	3
	Cryochrepts	3	1		2	1		
	Durochrepts							
	Dystrandepts				1			
	Vitrandepts							
	Humaquepts							
Entisols	Xerorthents		2	4	5	5	2	3
	Cryorthents	1	5	2	3	1		2
	Cryofluvents	1						
	Udifluvents							
	Xeropsamments	3	6	3	1	2	1	3
	Cryopsamments		1		3			1
	Cryaquents							
Mollisols	Cryoborolls		1					
	Paleborolls							
	Haploxerolls							
Alfisols	Haploxeralfs	3			1	1	4	1
	Cryoboralfs							

Soil Taxonomy		Plant Association[1]						
Order	Great Group	PIJE/ ARPA9- CEVE3 (32)	PIJE/ CECO2- ARTR (18)	ABMA- ABCO- PIJE (31)	PIJE- ABMA (8)	PICO/ ARTR (11)	PICO/ LIGR1 (23)	PICO/ / WDLNDS (10)
Inceptisols	Xerumbrepts	12	8	16		4	7	1
	Cryumbrepts		2			1	2	1
	Haplumbrepts						1	
	Xerochrepts	3	2	10		1	6	2
	Cryochrepts							
	Durochrepts							
	Dystrandepts							
	Vitrandepts							
	Humaquepts						1	
Entisols	Xerorthents	7	1	4	1	1	1	
	Cryorthents	2	1		2		2	1
	Cryofluvents							
	Udifluvents							
	Xeropsamments	5	3	1	4			4
	Cryopsamments	1			1			1
	Cryaquents						1	
Mollisols	Cryoborolls					1		
	Paleborolls							
	Haploxerolls	2	1				1	
Alfisols	Haploxeralfs					2	1	
	Cryoboralfs					1		

Soil Taxonomy		*Plant Association*[1]						
Order	Great Group	PICO (8)	ABMA-PICO/HIAL (48)	ABMA-ABCO (69)	ABMA/ARNE2 (28)	ABMA (167)		
Inceptisols	Xerumbrepts	1	16	35	12	84		
	Cryumbrepts	1	1	1		2		
	Haplumbrepts							
	Xerochrepts	1	15	22	9	45		
	Cryochrepts		1					
	Durochrepts					1		
	Dystrandepts	1						
	Vitrandepts		1					
	Humaquepts							
Entisols	Xerorthents		1	3	5	11		
	Cryorthents	2	4			7		
	Cryofluvents							
	Udifluvents							
	Xeropsamments	1	5	4	1	11		
	Cryopsamments		1	1		4		
	Cryaquents							
Mollisols	Cryoborolls	1						
	Paleborolls		1	1				
	Haploxerolls		1	1				
Alfisols	Haploxeralfs		1	1	1	2		
	Cryoboralfs							

1 See *appendix A* for a list of associations and codes.

2 Number of samples.

Appendix C

Variables Used in the Classification

Definitions of variables may be found in the list of references. Definitions for location, environment, soil, and vegetation can be found in the Ecosystem Classification and Inventory Handbook, FSH 2090.11 (U.S. Department ofAgriculture 1991). Definitions for productivity can be found in this same reference and the Forest Inventory and Analysis User's Guide (U.S. Department of Agriculture 1992).

Location:

- Plot identification
- Forest map number
- Township
- Section
- National Forest or Park and Ranger District
- Local planning compartment
- Range

Environment:

- Elevation (feet)
- Slope (percent)
- Slope position
- Vertical microrelief
- Percent of gravel
- Total vegetative cover (percent)
- Percent of moss
- Litter thickness (inches)
- Latitude (degrees and minutes)
- Fire evidence (presence/absence)
- Grazing (presence/absence)
- Wildlife (presence/absence)
- Aspect (Azimuth)
- Landform
- Horizontal microrelief
- Percent of bare ground
- Percent of surface rock
- Age of vegetation
- Percent litter
- Total tree basal area (square feet per acre)
- Longitude (degrees and minutes)
- Insects and disease (presence/absence)
- Logging (presence/absence)

Soil:

- Type of parent material
- Total soil depth (inches)[1]
- Topsoil thickness (inches)
- Topsoil coarse fragment content (percent)
- Subsoil texture
- Subsoil color
- Available water holding capacity (AWC) (inches)
- Topsoil pH
- Soil temperature (degrees Fahrenheit)[2]
- Parent material origin
- Rootability
- Topsoil texture
- Topsoil color
- Subsoil coarse fragment content (percent)
- Soil drainage class
- Soil name
- Subsoil pH

[1]Soil depth was measured from the mineral surface to bedrock, or a layer of material that is impenetrable to roots, or a maximum of 40 inches—whichever was deepest.

[2]Summertime temperature measured at 20-inch depth.

Tree Layer:

- Overstory tree species
- Total tree cover (percent)
- Dominant height (feet)
- Canopy position of tree species
- Understory cover by species (percent)
- Overstory cover by species (percent)
- Diameter group
- Stand age (years)[3]
- Understory tree species
- Understory density by species

Shrub Layer:

- Shrub species
- Total shrub cover (percent)
- Shrub cover by species (percent)
- Average height of shrubs by species

Herbaceous Layer:

- Forb species
- Total forb cover (percent)
- Forb cover by species (percent)
- Forb abundance by class

Grass and Grass-like Layer:

- Grass and grass-like species
- Total grass and grass-like cover (percent)
- Grass and grass-like cover by species (percent)
- Grass and grass-like abundance by class.

Productivity:

- Pacific Southwest Region site index
- Number of trees per acre
- Quadratic mean diameter
- Cubic foot volume (MCF)
- Forest survey site class
- Stand density index[4]
- Basal area (square feet per acre)
- Board foot volume (MBF-Scribner)

Coarse Woody Debris:

- Species of snag
- Snag height
- Species of log
- Log diameter at small end
- Log decay class
- Snag diameter at breast height
- Snag decay class
- Log diameter at large end
- Log length

Derived Variables:

- Solar radiation index (SRI)
- Hill diversity numbers
- Simpson's index of diversity.
- Stress index = ((SRI)*0.25)+((AWC/10)*0.25)+((10000-ELEV/9000)* 0.25)+((POSN)* 0.25) in which position was assigned an ordinal value based on seven slope positions from ridgetop to draw including benches.

[3]Stand ages are the average ages of three or more dominant trees at each sample site.

[4]Reinecke 1993.

Appendix D

Autecological Relationships of Selected Plants

Plant species on a site are often referred to as indicator or characteristic species because of their particular relationship to environmental conditions. In many studies these relationships are established from published documents(Abrams and Ferris 1975, Burns and Honkala 1990, Hickman 1993, McMinn 1939, Minore 1979, Munz and Keck 1959) or from observations made in the field during sampling. Such relationships were explored in further detail in this study by using information obtained from the samples to establish the autecological status of many plants in the upper montane.

The observations offered here are not intended to fully describe the environmental relationships of all species sampled. Rather, they emphasize most of the indicator species used in the classification and a few others that are characteristic of particular settings. The table highlights the environmental differences on sites containing each of the selected species. Environmental settings that are not substantially different from the distributions obtained on other sites in the upper montane are not described. These observations are intended to assist those using the classification in understanding and interpreting site conditions based upon floristic composition. Species have been stratified on the basis of moisture relationships that may be useful in management, and entries under each moisture regime are listed in order of life form: trees, shrubs, forbs, and grass.

Autecological Relationships of Selected Plants

Feature	Dry Site Indicators — Trees		
	Juniperus occidentalis	*Pinus Jeffreyii*	*Pinus monticola*
Physiognomy of typical community	open, shrubby woodland	open, shrubby forest	~
Distribution	north, eastside	~	~
Elevation	middle, high	~	high
Solar radiation index	high	~	low
Aspect	se, sw	se, sw	ne, nw
Position	~	~	upper slopes, ridges
Slope	~	~	~
Microrelief	hummocky, broken	hummocky, broken	hummocky, undulating
Litter thickness	~	~	~
Bare ground	high	high	~
Gravel	high	high	~
Rock	high	~	high
Tree cover	low	low	moderately low
Shrub cover	high	high	~
Forb cover	high	~	high
Grass cover	high	~	~
Total basal area	low	low	~
Stand density	low	low	~
R-5 Site class	low	low	~
Parent material	~	granite, ash, tephra	~
Parent material origin	~	glacial outwash, alluvium	~
Total soil depth	moderately shallow	shallow	~
Surface horizon depth	deep	~	shallow
Surface horizon texture	~	coarse	~
Subsoil texture	~	coarse: gravelly	~
Surface coarse fragments	high	~	~
Subsoil coarse fragments	high	~	high
Rootability	~	hard, fractured, massive	~
Drainage	~	excessive	excessive
Available water holding capacity	low	low	low
Moisture stress	high	high	~
Soil acidity	~	~	~
Soil temperature	high	high	~
Soil taxonomy	~	~	entisols
Soil particle size class	~	~	~

Feature	Dry Site Indicators — Shrubs		
	Arctostaphylos nevadensis	*Arctostaphylos patula*	*Castanopsis sempervirens*
Physiognomy of typical community	open, shrubby forest	open, shrubby forest	shrubby forest
Distribution	north	~	south
Elevation	~	~	~
Solar radiation index	high	high	high
Aspect	se, sw	se, sw	se, sw
Position	~	~	upper, middle slopes
Slope	~	~	steep, >40 percent
Microrelief	~	~	hummocky, broken
Litter thickness	shallow	~	~
Bare ground	high	high	low
Gravel	high	high	~
Rock	high	~	high
Tree cover	low	low	~
Shrub cover	~	high	~
Forb cover	low	~	~
Grass cover	~	~	~
Total basal area	low	low	low
Stand density	~	~	~
R-5 Site class	low	low	low
Parent material	~	~	Granite
Parent material origin	~	~	~
Total soil depth	shallow	~	~
Surface horizon depth	~	~	shallow
Surface horizon texture	~	moderately coarse, coarse	~
Subsoil texture	~	moderately coarse, coarse	coarse: sandy
Surface coarse fragments	~	high	high, gravelly, cobbly
Subsoil coarse fragments	high	high, gravelly, stoney	~
Rootability	hard, fractured, massive	~	~
Drainage	excessive	excessive	excessive
Available water holding capacity	low	low	low
Moisture stress	high	high	high
Soil acidity	~	~	~
Soil temperature	high	high	~
Soil taxonomy	~	entisols	entisols
Soil particle size class	skeletal	skeletal, sandy	skeletal, sandy

Autecological Relationships of Selected Plants

Feature	***Dry Site Indicators*** / ***Shrubs***		
	Quercus vaccinifolia	*Ceanothus velutinus*	*Prunus emarginata*
Physiognomy of typical community	open, shrubby forest	open, shrubby forest	open, shrubby forest
Distribution	north, westside	north, eastside	~
Elevation	middle, low	~	~
Solar radiation index	high	~	high
Aspect	se, sw	~	se, sw
Position	~	~	upper, middle slopes
Slope	~	steep, >40 percent	moderately steep
Microrelief	hummocky, broken	~	~
Litter thickness	~	~	~
Bare ground	high	high	high
Gravel	high	high	high
Rock	high	~	high
Tree cover	low	low	low
Shrub cover	high	high	high
Forb cover	~	~	~
Grass cover	~	~	~
Total basal area	low	low	low
Stand density	~	~	~
R-5 Site class	low	~	~
Parent material	granite	~	~
Parent material origin	~	alluvium, colluvium	~
Total soil depth	~	~	moderately shallow
Surface horizon depth	~	~	~
Surface horizon texture	~	coarse: sandy	~
Subsoil texture	~	coarse: sandy	~
Surface coarse fragments	high, gravelly, cobbly	~	~
Subsoil coarse fragments	gravelly, cobbly	gravelly, cobbly	high, cobbly
Rootability	~	~	~
Drainage	excessive	excessive	excessive
Available water holding capacity	low	low	low
Moisture stress	high	~	high
Soil acidity	~	neutral	~
Soil temperature	~	high	high
Soil taxonomy	~	entisols	~
Soil particle size class	~	sandy	~

Autecological Relationships of Selected Plants

Feature	Dry Site Indicators		
	Forbs		
	Eriogonum nudum	*Arabis platysperma*	*Monardella odoratissima*
Physiognomy of typical community	open, shrubby forest	open forest	open, shrubby forest
Distribution	~	~	~
Elevation	high	high	~
Solar radiation index	high	~	high
Aspect	se, sw	~	se, sw
Position	~	upper slopes, ridges	~
Slope	~	~	~
Microrelief	undulating	undulating	~
Litter thickness	shallow	shallow	shallow
Bare ground	high	high	high
Gravel	high	high	high
Rock	~	moderately high	~
Tree cover	low	low	low
Shrub cover	high	low	high
Forb cover	high	~	high
Grass cover	high	low	high
Total basal area	low	low	low
Stand density	~	~	low
R-5 Site class	~	low	~
Parent material	volcanics	~	~
Parent material origin	~	~	~
Total soil depth	~	moderately shallow	moderately shallow
Surface horizon depth	~	shallow	~
Surface horizon texture	coarse: sandy	coarse: sandy	~
Subsoil texture	coarse: sandy	coarse: sandy	~
Surface coarse fragments	high, gravelly, cobbly	moderately high	high, gravelly, cobbly
Subsoil coarse fragments	~	high	high, gravelly, cobbly
Rootability	~	fractured	~
Drainage	excessive	excessive	~
Available water holding capacity	low	low	~
Moisture stress	~	high	high
Soil acidity	~	~	~
Soil temperature	high	~	high
Soil taxonomy	entisols	~	inceptisols
Soil particle size class	~	~	~

Autecological Relationships of Selected Plants

	Dry Site Indicators		
Feature	Forbs		Grass and Grass-like
	Calyptridium umbellatum	*Gayophytum eriospermum*	*Sitanion hystrix*
Physiognomy of typical community	open forest	open forest	open forest
Distribution	~	~	~
Elevation	~	~	high
Solar radiation index	high	high	high
Aspect	se, sw	se, sw	se, sw
Position	upper slopes, ridges	upper slopes, ridgetops	upper slopes, ridgetops
Slope	~	~	~
Microrelief	undulating	hummocky	undulating
Litter thickness	shallow	shallow	shallow
Bare ground	high	high	high
Gravel	high	high	high
Rock	~	~	high
Tree cover	moderately low	low	low
Shrub cover	~	moderately high	high
Forb cover	moderately high	high	high
Grass cover	moderately high	moderately high	high
Total basal area	low	low	low
Stand density	low	~	low
R-5 Site class	low	~	low
Parent material	~	~	~
Parent material origin	~	~	~
Total soil depth	~	~	moderately shallow
Surface horizon depth	~	~	deep
Surface horizon texture	coarse: sandy	~	~
Subsoil texture	coarse: sandy	~	~
Surface coarse fragments	~	gravelly, cobbly	moderately high
Subsoil coarse fragments	~	gravelly, cobbly	~
Rootability	~	~	hard, fractured, massive
Drainage	excessive	excessive	excessive
Available water holding capacity	~	excessive	low
Moisture stress	high	high	~
Soil acidity	~	acid	~
Soil temperature	high	high	high
Soil taxonomy	~	~	mollisols
Soil particle size class	sandy	~	~

Autecological Relationships of Selected Plants

Feature	Dry Site Indicators	Moderate Site Indicators	
	Grass and Grass-like	Trees	
	Stipa occidentalis	*Abies magnifica*	*Abies concolor*
Physiognomy of typical community	~	dense forest	dense forest
Distribution	eastside	~	~
Elevation	high	~	middle, low
Solar radiation index	~	~	~
Aspect	~	~	~
Position	upper slopes, ridges, benches	~	~
Slope	~	~	~
Microrelief	undulating	uniform, undulating	~
Litter thickness	shallow	~	deep
Bare ground	~	low	low
Gravel	~	low	low
Rock	~	~	~
Tree cover	low	high	high
Shrub cover	high	low	~
Forb cover	high	low	~
Grass cover	high	low	low
Total basal area	low	high	~
Stand density	~	high	~
R-5 Site class	low	high	~
Parent material	~	~	~
Parent material origin	alluvium	bedrock	~
Total soil depth	moderately shallow	deep	deep
Surface horizon depth	~	~	~
Surface horizon texture	coarse: sandy	moderately coarse: loamy	moderately coarse: loamy
Subsoil texture	~	moderately coarse: loamy	loamy
Surface coarse fragments	~	~	~
Subsoil coarse fragments	~	~	low
Rootability	fractured	~	~
Drainage	excessive	well	well
Available water holding capacity	low	high	high
Moisture stress	~	~	~
Soil acidity	~	~	acid
Soil temperature	high	~	~
Soil taxonomy	entisols	inceptisols	~
Soil particle size class	skeletal, sandy	~	~

Autecological Relationships of Selected Plants

Feature	Moderate Site Indicators		
	Trees		Shrubs
	Pinus contorta	*Tsuga mertensiana*	*Ceanothus cordulatus*
Physiognomy of typical community	open to dense forest	dense forest	open, shrubby forest
Distribution	~	north	~
Elevation	middle, high	high	low
Solar radiation index	~	low	high
Aspect	~	ne, nw	se, sw
Position	lower slopes, toeslopes, benches	upper slopes	~
Slope	shallow	moderately steep	moderate
Microrelief	~	~	~
Litter thickness	shallow	~	shallow
Bare ground	~	low	high
Gravel	high	~	high
Rock	~	~	~
Tree cover	moderately low	high	moderately low
Shrub cover	low	low	high
Forb cover	high	low	high
Grass cover	high	low	~
Total basal area	~	high	low
Stand density	~	~	~
R-5 Site class	~	~	~
Parent material	~	~	~
Parent material origin	~	~	~
Total soil depth	~	~	~
Surface horizon depth	~	~	deep
Surface horizon texture	~	~	~
Subsoil texture	~	~	~
Surface coarse fragments	~	gravelly, cobbly, stoney	gravelly
Subsoil coarse fragments	low	~	~
Rootability	~	~	~
Drainage	~	~	~
Available water holding capacity	~	low	~
Moisture stress	low	low	~
Soil acidity	acid	~	~
Soil temperature	~	low	high
Soil taxonomy	~	ochrepts	~
Soil particle size class	~	~	~

Feature	Moderate Site Indicators — Shrubs		
	Artemesia tridentata	*Symphoricarpos acutus*	*Symphoricarpos vaccinoides*
Physiognomy of typical community	open, shrubby forest	moderately dense forest	open forest
Distribution	north, eastside	north	north
Elevation	high	low	middle, high
Solar radiation index	high	~	~
Aspect	se, sw	~	~
Position	~	~	~
Slope	~	~	~
Microrelief	~	~	~
Litter thickness	shallow	~	~
Bare ground	high	~	high
Gravel	high	~	high
Rock	~	~	~
Tree cover	moderately low	~	low
Shrub cover	high	high	high
Forb cover	high	high	high
Grass cover	high	~	high
Total basal area	low	low	low
Stand density	~	~	~
R-5 Site class	~	~	~
Parent material	volcanic, mixed	~	volcanic
Parent material origin	~	~	glacial till, outwash, colluvium, alluvium
Total soil depth	moderately shallow	~	~
Surface horizon depth	deep	shallow	shallow
Surface horizon texture	~	medium	~
Subsoil texture	moderately fine: loamy	~	moderately coarse to moderately fine
Surface coarse fragments	high, gravelly, cobbly	~	high, gravelly
Subsoil coarse fragments	~	~	~
Rootability	fractured	~	~
Drainage	~	~	~
Available water holding capacity	high	~	~
Moisture stress	~	~	~
Soil acidity	~	acid	~
Soil temperature	high	~	high
Soil taxonomy	inceptisols	inceptisols	~
Soil particle size class	~	~	~

Autecological Relationships of Selected Plants

Feature	Moderate Site Indicators		
	Shrubs		Forbs
	Chrysothamnus viscidiflorus	*Wyethia mollis*	*Hieracium albiflorum*
Physiognomy of typical community	open forest	open woodlands	dense forest
Distribution	eastside	north	westside
Elevation	high	middle	middle, low
Solar radiation index	~	high	low
Aspect	~	se, sw	~
Position	~	~	lower slopes, toeslopes, benches
Slope	~	~	~
Microrelief	uniform , undulating	~	~
Litter thickness	shallow	shallow	moderately deep
Bare ground	high	high	low
Gravel	high	high	low
Rock	low	~	low
Tree cover	low	low	high
Shrub cover	high	~	low
Forb cover	high	high	~
Grass cover	high	high	low
Total basal area	low	low	high
Stand density	~	~	~
R-5 Site class	~	~	~
Parent material	volcanic	~	~
Parent material origin	~	~	~
Total soil depth	~	~	~
Surface horizon depth	~	~	~
Surface horizon texture	~	~	~
Subsoil texture	~	~	moderately coarse, medium: loamy
Surface coarse fragments	~	~	~
Subsoil coarse fragments	~	~	~
Rootability	~	~	~
Drainage	~	~	well
Available water holding capacity	~	~	high
Moisture stress	~	~	~
Soil acidity	~	~	~
Soil temperature	high	high	~
Soil taxonomy	entisols, mollisols	inceptisols	~
Soil particle size class	~	ashy, medial skeletal	~

Autecological Relationships of Selected Plants

Feature	**Moderate Site Indicators — Forbs**		
	Viola purpurea	*Pyrola picta*	*Kelloggia galioides*
Physiognomy of typical community	dense forest	dense forest	dense forest
Distribution	westside	~	north, westside
Elevation	middle,low	middle, low	middle, low
Solar radiation index	high	low	~
Aspect	se, sw	ne,nw	~
Position	~	~	~
Slope	moderate, shallow	moderate	~
Microrelief	~	~	~
Litter thickness	deep	~	deep
Bare ground	low	low	~
Gravel	low	low	~
Rock	~	~	~
Tree cover	high	high	high
Shrub cover	low	low	~
Forb cover	~	~	~
Grass cover	~	low	~
Total basal area	high	high	~
Stand density	~	high	~
R-5 Site class	~	high	~
Parent material	~	~	volcanic
Parent material origin	bedrock	bedrock	~
Total soil depth	~	~	~
Surface horizon depth	~	~	deep
Surface horizon texture	~	~	moderately coarse, medium
Subsoil texture	moderately coarse, medium	moderately coarse, medium: loamy	moderately coarse, medium: loamy
Surface coarse fragments	~	~	~
Subsoil coarse fragments	cobbly, stoney	cobbly, stoney	~
Rootability	~	~	~
Drainage	well	~	well
Available water holding capacity	high	high	high
Moisture stress	~	~	~
Soil acidity	acid	acid	acid
Soil temperature	low	~	~
Soil taxonomy	inceptisols	inceptisols	inceptisols
Soil particle size class	skeletal	skeletal	coarse loamy, fine loamy

Autecological Relationships of Selected Plants

Feature	***Moderate Site Indicators — Grass and Grass-like***		
	Poa Bolanderi	*Carex rossii*	*Elymus glaucus*
Physiognomy of typical community	dense forest	open to dense forest	open to dense forest
Distribution	north, westside	north	north
Elevation	middle, low	high	middle, low
Solar radiation index	~	~	high
Aspect	~	~	se, sw
Position	lower slopes, toeslopes, benches	lower slopes, toeslopes, benches	upper, middle, lower slopes
Slope	shallow	shallow	~
Microrelief	~	broken, hummocky	~
Litter thickness	~	shallow	~
Bare ground	low	high	high
Gravel	~	high	~
Rock	low	~	~
Tree cover	~	~	~
Shrub cover	high	high	high
Forb cover	high	high	high
Grass cover	high	high	high
Total basal area	~	low	low
Stand density	high	low	low
R-5 Site class	high	low	low
Parent material	volcanic	~	volcanic
Parent material origin	colluvium, alluvium	~	glacial till, outwash, colluvium
Total soil depth	deep	moderate	~
Surface horizon depth	deep	~	shallow
Surface horizon texture	medium, moderately fine: loamy	medium, moderately fine	medium, moderately fine, loamy
Subsoil texture	moderately coarse, medium	medium, moderately fine	medium, moderately fine, fine: loamy
Surface coarse fragments	~	~	~
Subsoil coarse fragments	low	~	high, gravelly, cobbly
Rootability	~	hard	~
Drainage	well	~	well
Available water holding capacity	high	~	high
Moisture stress	~	~	~
Soil acidity	~	~	~
Soil temperature	low	~	~
Soil taxonomy	inceptisols	entisols	inceptisols
Soil particle size class	~	~	medial skeletal

Autecological Relationships of Selected Plants

	— Moderate Site Indicators —	Moist Site Indicators	
Feature	***----- Grass and Grass-like -----***	***--------- Trees ---------***	***------ Shrubs ------***
	Bromus marginatus	*Populus tremuloides*	*Ribes roezlii*
Physiognomy of typical community	open forest	dense forest	dense forest
Distribution	north	north, eastside	north, westside
Elevation	~	~	middle, low
Solar radiation index	high	~	~
Aspect	se, sw	~	~
Position	~	lower slopes, toeslopes, bottoms, benches	lower slopes, toeslopes, benches
Slope	~	shallow	~
Microrelief	broken, hummocky	~	~
Litter thickness	~	low	deep
Bare ground	high	~	~
Gravel	high	~	~
Rock	~	~	~
Tree cover	low	~	high
Shrub cover	~	~	~
Forb cover	high	high	high
Grass cover	high	high	high
Total basal area	low	~	high
Stand density	low	~	high
R-5 Site class	low	~	high
Parent material	volcanic	~	~
Parent material origin	~	glacial outwash, colluvium, alluvium	~
Total soil depth	~	~	~
Surface horizon depth	shallow	~	deep
Surface horizon texture	medium, moderately fine, loamy	medium, moderately fine, loamy	medium, moderately fine, loamy
Subsoil texture	medium, moderately fine, fine, loamy	moderately fine, fine, loamy	medium, moderately fine, loamy
Surface coarse fragments	high, gravelly, cobbly	~	~
Subsoil coarse fragments	~	~	~
Rootability	~	~	~
Drainage	~	well drained	well drained
Available water holding capacity	~	high	high
Moisture stress	~	low	low
Soil acidity	~	~	~
Soil temperature	~	~	~
Soil taxonomy	alfisols, mollisols,	alfisols, mollisols,	inceptisols
Soil particle size class	~	~	medial, loamy, ashy

Autecological Relationships of Selected Plants

Feature	**Moist Site Indicators**		
	Shrubs	**Forbs**	
	Ribes montigenum	*Ligusticum Grayii*	*Osmorhiza chilensis*
Physiognomy of typical community	dense forest	dense forest	dense forest
Distribution	north, eastside	north, westside	~
Elevation	high	~	middle, low
Solar radiation index	~	~	~
Aspect	~	~	~
Position	lower slopes, toeslopes, benches	lower slopes, toeslopes, benches	lower slopes, toeslopes, benches
Slope	~	shallow	~
Microrelief	~	~	~
Litter thickness	~	~	~
Bare ground	~	low	low
Gravel	~	low	low
Rock	~	low	low
Tree cover	~	high	high
Shrub cover	low	low	low
Forb cover	high	high	high
Grass cover	high	high	high
Total basal area	~	high	high
Stand density	~	~	~
R-5 Site class	~	~	~
Parent material	~	~	~
Parent material origin	alluvium	~	glacial till, alluvium
Total soil depth	~	~	deep
Surface horizon depth	~	medium: loamy	~
Surface horizon texture	~	medium, moderately fine: loamy	medium, moderately fine, fine: loamy
Subsoil texture	~	~	medium, moderately fine, fine: loamy
Surface coarse fragments	~	low	low
Subsoil coarse fragments	~	low	low
Rootability	~	~	~
Drainage	~	well drained	well drained
Available water holding capacity	high	high	high
Moisture stress	low	low	low
Soil acidity	~	~	~
Soil temperature	~	~	~
Soil taxonomy	entisols	inceptisols	inceptisols
Soil particle size class	loamy, ashy	loamy, loamy skeletal	loamy

Autecological Relationships of Selected Plants

Feature	Moist Site Indicators — Forbs		
	Pyrola secunda	*Thalictrum fendlerii*	*Pteridium aquilinum*
Physiognomy of typical community	dense forest	dense forest	dense forest
Distribution	~	north, westside	north, westside
Elevation	~	~	low
Solar radiation index	~	~	~
Aspect	~	~	sw, nw
Position	lower slopes, toeslopes, benches	lower slopes, toeslopes, benches	toeslopes, benches
Slope	shallow	shallow	~
Microrelief	~	~	~
Litter thickness	~	~	deep
Bare ground	~	~	low
Gravel	~	low	low
Rock	~	low	~
Tree cover	high	high	high
Shrub cover	low	low	high
Forb cover	high	high	~
Grass cover	high	~	~
Total basal area	high	high	high
Stand density	~	~	high
R-5 Site class	~	~	high
Parent material	~	~	granitic
Parent material origin	~	~	glacial till
Total soil depth	~	~	~
Surface horizon depth	~	~	~
Surface horizon texture	medium, moderately fine	medium, moderately fine: loamy	~
Subsoil texture	medium, moderately fine	medium, moderately fine: loamy	medium, loamy
Surface coarse fragments	low	~	~
Subsoil coarse fragments	low	high	~
Rootability	~	~	~
Drainage	well to poorly drained	well drained	well drained
Available water holding capacity	high	high	high
Moisture stress	low	low	low
Soil acidity	~	~	~
Soil temperature	~	~	~
Soil taxonomy	~	inceptisols	~
Soil particle size class	~	loamy, medial skeletal	loamy

Appendix E

Environmental Summary by Plant Association

Plant Association	*Elevation (ft) mean/range*	*Slope (pct) mean/range*	*Aspect mode*	*Slope Position mode*	*Bare Ground (pct) mean/range*	*Surface Gravel (pct) mean/range*	*Surface Rock (pct) mean/range*	*Litter Depth (in) mean/range*
ASBO	7962 (7060-8800)	19 (8-31)	NE, NW	Upper	43 (21-80)	24 (6-42)	3 (0-15)	0.4 (0.1-1.0)
POTR/MOOD	8046 (6920-9100)	18 (3-33)	SE, SW, NW	Middle, lower	4 (0-12)	7 (0-55)	3 (0-25)	1.0 (0.2-1.9)
POTR/VECA1	7417 (6500-8600)	12 (2-31)	All	Lower	2 (0-12)	2 (0-15)	3 (0-10)	1.1 (0.2-2.9)
JUOC/ARTR	8117 (7600-8720)	26 (8-42)	SE, SW	Upper	15 (3-30)	24 (5-50)	13 (0-62)	0.6 (0.2-1.1)
JUOC	8133 (7560-8960)	32 (19-58)	SE, SW	Upper	6 (1-20)	13 (2-65)	27 (1-65)	0.9 (0.3-2.9)
ABMA/WYMO	7899 (6940-8340)	22 (5-38)	SE, SW	Upper	10 (0-30)	23 (0-99)	4 (0-14)	0.6 (0.1-1.5)
TSME//STEEP	8241 (7120-9360)	45 (30-60)	NE, NW	Upper	1 (0-3)	5 (1-20)	13 (0-49)	1.8 (0.2-8.0)
TSME	8390 (7380-9160)	18 (2-29)	NE, NW	Upper, middle, lower	1 (0-32)	4 (0-32)	9 (0-43)	1.3 (0.4-3.0)
ABMA-PIMO3/ARNE2	8364 (7200-9120)	28 (6-59)	SE, SW	Upper, middle	6 (0-25)	5 (0-40)	11 (0-65)	1.0 (0.2-3.5)
ABMA-PIMO3/CASE3	8696 (8000-9200)	39 (25-65)	NE, NW	Upper, middle	3 (0-10)	6 (0-15)	18 (1-60)	1.3 (0.5-2.7)
ABMA-PIMO3-PICO	8602 (7360-9640)	24 (3-65)	NE, NW	Upper, middle	2 (0-12)	10 (0-55)	9 0-50)	1.1 (0.6-2.2)
ABMA-PIMO3	8465 (7140-9520)	25 (2-60)	NE, NW	Upper, middle	4 (0-36)	7 (0-75)	8 (0-63)	1.2 (0.2-3.8)
ABCO-PILA-ABMA	6881 (5860-7880)	27 (3-60)	All	Middle, lower	0.8 (0-3)	0.9 (0-10)	3 (0-20)	1.9 (0.2-5.5)
PIJE/QUVA	7320 (6300-8320)	27 (4-58)	SE, SW	Upper	3 (0-15)	4 (0-20)	13 (1-46)	1.2 (0.2-2.4)
PIJE/ARPA9-CEVE3	8255 (6660-9520)	30 (4-64)	SE, SW	Upper	8 (1-49)	9 (0-43)	7 (0-30)	1.1 (0.3-2.2)
PIJE/CECO2-ARTR	7967 (6820-9360)	20 (1-51)	SE, SW	Upper, middle, lower	12 (1-35)	14 (1-40)	3 (0-12)	0.8 (0.2-1.6)
ABMA-ABCO-PIJE	7507 (6300-8800)	25 (0-57)	SE, SW	Upper	5 (0-40)	2 (0-10)	4 (0-20)	1.9 (0.2-6.0)
PIJE-ABMA	8607 (7340-9120)	33 (12-47)	SE, SW	Upper	10 (0-43)	11 (1-35)	5 (0-24)	1.5 (0.2-2.2)
PICO/ARTR	8510 (7560-9480)	22 (11-40)	SE, SW	Middle, lower	10 (2-25)	13 (2-30)	3 (0-20)	0.6 (0.2-1.0
PICO/LIGR1	7973 (6660-8920)	11 (3-32)	NE, NW	Lower	1 (0-4)	1 (0-6)	4 (0-25)	1.4 (0.4-2.4)
PICO//WOODLANDS	8174 (7360-9080)	12 (5-30)	All	All	28 (3-80)	15 (1-55)	10 (0-53)	0.6 (0.1-1.0)
PICO	8877 (8300-9320)	16 (4-30)	All	Lower, benches	3 (0-5)	11 (2-35)	2 (0-5)	1.0 (0.6-1.4)
ABMA-PICO/HIAL	7831 (6540-9520)	13 (2-40)	NE, NW, SW	Lower, benches	2 (0-40)	4 (0-37)	3 (0-33)	1.6 (0.5-7.0)
ABMA-ABCO	7319 (5780-8800)	26 (4-57)	All	Upper	1 (0-12)	2 (0-63)	5 (0-45)	2.0 (0.5-5.3)
ABMA/ARNE2	7983 (7050-8800)	24 (2-47)	All	Upper, middle	3 (0-12)	4 (0-25)	10 (0-45)	1.0 (0.2-3.0)
ABMA	8017 (6660-9240)	24 (2-60)	NE, NW	Upper, middle	3 (0-45)	4 (0-84)	5 (0-70)	1.6 (0.2-5.0)

Appendix F

Vegetation Summary by Plant Association

Plant Association	*Vegetation Total cover (pct) mean/range*	*Tree Cover (pct) mean/range*	*Shrub Cover (pct) mean/range*	*Forb Cover (pct) mean/range*	*Grass Cover (pct) mean/range*
ASBO	64 (25-90)	4 (0-15)	6 (0-55)	44 (9-85)	14 (0-41)
POTR/MOOD	94 (70-100)	71 (33-85)	13 (0-55)	50 (8-90)	43 (1-90)
POTR/VECA1	94 (82-99)	78 (49-96)	12 (0-60)	36 (0-95)	18 (0_80)
JUOC/ARTR	74 (35-99)	31 (4-75)	30 (1-92)	33 (8-70)	16 (2-60)
JUOC	66 (24-99)	33 (3-79)	31 (3-65)	24 (1-80)	13 (1-80)
ABMA/WYMO	79 (52-99)	25 (0-89)	5 (0-45)	54 (6-98)	19 (1-98)
TSME//STEEP	68 (38-85)	65 (37-81)	1 (0-2)	2 (0-5)	1 (0-8)
TSME	77 (23-97)	68 (22-88)	1 (0-15)	7 (0-35)	5 (0-45)
ABMA-PIMO3/ARNE2	69 (30-100)	43 (11-79)	31 (2-82)	3 (0-25)	2 (0-9)
ABMA-PIMO3/CASE3	70 (40-95)	51 (26-81)	29 (2-85)	9 (0-40)	1 (0-4)
ABMA-PIMO3-PICO	73 (48-99)	63 (37-91)	1 (0-12)	9 (1-40)	5 (0-33)
ABMA-PIMO3	75 (24-99)	66 (20-91)	2 (0-35)	7 (0-47)	2 (0-13)
ABCO-PILA-ABMA	85 (62-98)	76 (37-93)	12 (0-66)	7 (0-41)	0.5 (0-2)
PIJE/QUVA	83 (38-99)	36 (8-67)	55 (13-90)	10 (0-80)	1 (0-8)
PIJE/ARPA9-CEVE3	74 (30-99)	40 (10-79)	41 (1-82)	7 (0-53)	4 (0-40)
PIJE/CECO2-ARTR	76 (30-97)	36 (1-63)	28 (1-77)	19 (1-65)	15 (1-55)
ABMA-ABCO-PIJE	76 (39-97)	65 (30-90)	10 (0-78)	13 (0-90)	2 (0-40)
PIJE-ABMA	72 (18-98)	54 (17-83)	10 (0-50)	19 (1-83)	5 (0-30)
PICO/LIGR1	94 (82-99)	76 (61-95)	4 (0-30)	40 (1-90)	17 (2-45)
PICO/ARTR	83 (70-90)	44 (18-68)	26 (3-52)	37 (2-70)	25 (4-75)
PICO//WOODLANDS	49 (18-72)	33 (16-48)	1 (0-2)	12 (1-30)	7 (0-30)
PICO	67 (42-90)	59 (39-73)	0.4 (0-1)	3 (1-9)	10 (0-61)
ABMA-PICO/HIAL	80 (47-99)	73 (43-95)	2 (0-40)	8 (0-95)	2 (0-25)
ABMA-ABCO	85 (52-99)	78 (48-97)	3 (0-32)	13 (0-80)	2 (0-35)
ABMA/ARNE2	84 (60-98)	51 (17-95)	52 (2-90)	3 (0-70)	2 (0-40)
ABMA	82 (40-90)	77 (29-96)	2 (0-26)	5 (0-50)	1 (0-15)

Appendix G

Soil Summary by Plant Association

Plant Association	*Total soil depth (in) mean/range*	*Topsoil depth (in) mean/range*	*Topsoil coarse fragments (pct) mean/range*	*Topsoil texture mode*	*Subsoil coarse fragments(pct) mean/range*	*Subsoil texture) mode*	*AWC (") mean/range*
ASBO	38 (30-40+)	17 (4-40+)	13 (7-20)	sdl,l	18 (6-30)	sdl,l	3.7 (2.1-6.5)
POTR/MOOD	36 (26-40+)	12 (4-38)	22 (5-80)	sdl,l,sdcl	38 (5-98)	sdl,sdcl	3.4 (0.5-5.1)
POTR/VECA1	37 (27-40+)	12 (2-37)	15 (1-55)	l,sdl	27 (7-55)	l,sdl	4.7 (1.7-6.3)
JUOC/ARTR	26 (7-40+)	12 (4-28)	32 (14-60)	sdl,l	47 (15-79)	gsdl,l	2.3 (0.4-5.7)
JUOC	30 (11-40+)	11 (3-16)	25 (10-46)	sd,sdl	49 (13-75)	sd,sdl	2.1 (0.5-3.8)
ABMA/WYMO	34 (15-40+)	11 (3-22)	19 (3-46)	sdl,l	40 (6-92)	sdl,l	3.2 (0.8-5.9)
TSME//STEEP	35 (22-40+)	6 (1-20)	32 (1-75)	gsd,gsdl,gl	48 (1-88)	sd,sdl,l	2.3 (0.5-5.4)
TSME	32 (14-40+)	8 (0-60)	19 (2-65)	sdl,l	32 (2-70)	sd,sdl,l	2.8 (0.7-5.3)
ABMA-PIMO3/ARNE2	31 (8-40+)	6 (2-11)	19 (5-38)	sd,sdl	45 (10-86)	sd,sdl	2.1 (0.3-4.4)
ABMA-PIMO3/CASE3	33 (25-40+)	6 (2-8)	24 (2-60)	sd	43 (7-75)	sd	2.0 (0.9-2.8)
ABMA-PIMO3-PICO	35 (19-40+)	6 (3-16)	28 (5-95)	gsd	38 (1-87)	gsd	2.7 (0.6-5.5)
ABMA-PIMO3	34 (16-40+)	7 (3-15)	22 (2-55)	sdl	49 (10-98)	gsdl	2.5 (0.4-5.0)
ABCO-PILA-ABMA	37 (26-40+)	10 (3-24)	23 (5-75)	sdl,l	38 (5-80)	sdl,l	3.4 (0.8-6.6)
PIJE/QUVA	32 (13-40+)	9 (2-38)	25 (3-65)	gsd,sdl	46 (5-85)	stsd,sdl	2.4 (0.6-5.4)
PIJE/ARPA9-CEVE3	32 (5-40+)	8 (2-23)	22 (2-55)	sd,sdl	43 (3-92)	sd,sdl	2.2 (0.2-5.2)
PIJE/CECO2-ARTR	35 (17-40+)	10 (3-22)	20 (2-80)	sd,sdl	37 (4-90)	sd,sdl,l	2.8 (0.1-5.3)
ABMA-ABCO-PIJE	39 (28-40+)	8 (3-20)	13 (1-52)	sdl	26 (5-80)	sdl	3.8 (1.2-6.4)
PIJE-ABMA	38 (17-40+)	9 (4-16)	36 (6-80)	gsd	36 (5-85)	gsd	2.2 (0.5-3.9)
PICO/LIGR1	35 (22-40+)	9 (3-31)	14 (1-42)	l	32 (1-86)	l	3.8 (1.7-5.7)
PICO/ARTR	37 (26-40+)	12 (8-20)	30 (10-75)	sdl,l	38 (15-55)	sdl,l	3.3 (1.9-4.6)
PICO//WOODLANDS	33 (13-40+)	7 (2-15)	15 (2-45)	sd,sdl	18 (2-40)	sd,sdl	2.7 (1.3-4.6)
PICO	39 (31-40+)	11 (4-23)	33 (8-95)	sd,sdl	38 (8-85)	sd,sdl	3.4 (1.2-5.8)
ABMA-PICO/HIAL	37 (24-40+)	9 (2-28)	20 (1-95)	sdl,l	30 (10-87)	sdl,l	3.7 (1.0-6.0)
ABMA-ABCO	39 (19-40+)	10 (2-36)	15 (1-65)	sdl,l	26 (5-75)	sdl,l	4.1 (0.6-6.9)
ABMA/ARNE2	30 (11-40+)	8 (2-17)	25 (2-75)	sdl	49 (6-80)	csdl	2.3 (0.4-4.9)
ABMA	38 (18-40+)	8 (2-25)	20 (0-98)	sdl	38 (0-99)	sdl	3.3 (0.7-6.5)

Appendix H

Productivity Summary by Plant Association

Plant Association	*Region 5 Site Index mean/range*	*Forest Survey Site Class mean/range*	*Stand Density Index mean/range*	*Cubic Foot Volume mean/range*	*Total Basal Area mean/range*
ASBO	3 (1-4)	4 (2-5)	76 (0-167)	2.1 (0-4.8)	48 (0-140)
POTR/VECA1	1 (0-3)	2 (1-4)	519 (119-1124)	11.5 (5.6-28.8)	229 (20-547)
POTR/MOOD	3 (1-5)	4 (2-6)	401 (163-711)	6.4 (1.9-10.6)	117 (7-240)
JUOC/ARTR	4 (3-5)	5 (4-6)	242 (117-438)	4.5 (1.6-7.7)	159 (48-267)
JUOC	4 (2-5)	5 (3-6)	225 (44-464)	4.2 (1.7-8.8)	129 (40-320)
ABMA/WYMO	3 (1-5)	4 (2-6)	171 (50-401)	5.4 (1-16.6)	122 (32-344)
TSME//STEEP	3 (3-5)	4 (3-6)	523 (95-816)	10.0 (4.2-16.5)	353 (213-507)
TSME	3 (1-5)	4 (2-6)	541 (141-1239)	10.2 (1.3-21.0)	364 (116-680)
ABMA-PIMO3/ARNE2	4 (2-5)	5 (3-6)	274 (124-482)	6.1 (2.5-12.9)	196 (5-400)
ABMA-PIMO3/CASE3	3 (1-5)	4 (2-6)	287 (196-417)	7.3 (3.5-10.6)	229 (120-320)
ABMA-PIMO3-PICO	4 (2-5)	5 (3-4)	425 (114-659)	7.0 (2.0-15.2)	287 (88-453)
ABMA-PIMO3	3 (1-5)	4 (2-6)	411 (135-723)	10.3 (2.8-25.7)	316 (80-600)
ABCO-PILA-ABMA	1 (0-3)	2 (1-4)	458 (99-824)	13.5 (1.1-24.3)	347 (88-587)
PIJE/QUVA	3 (2-5)	4 (3-6)	224 (50-592)	5.2 (1.2-14.2)	155 (40-320)
PIJE/ARPA9-CEVE3	3 (2-4)	4 (3-5)	177 (50-324)	4.3 (1.6-12.9)	122 (27-307)
PIJE/CECO2-ARTR	3 (2-4)	4 (3-5)	252 (106-491)	5.5 (2.5-8.7)	157 (56-280)
ABMA-ABCO-PIJE	2 (0-4)	3 (1-5)	386 (101-870)	12.0 (4.7-25.5)	287 (56-560)
PIJE-ABMA	3 (2-3)	4 (3-4)	324 (92-647)	8.0 (3.4-12.8)	234 (88-413)
PICO/LIGR1	3 (1-5)	4 (2-6)	489 (223-951)	8.6 (3.0-21.2)	333 (220-600)
PICO/ARTR	4 (2-5)	5 (3-6)	225 (99-429)	4.3 (1.5-9.8)	154 (56-240)
PICO//WOODLANDS	4 (3-5)	5 (4-6)	212 (53-390)	3.8 (1.4-9.0)	139 (32-248)
PICO	4 (4-5)	5 (5-6)	448 (341-606)	4.6 (2.8-5.7)	275 (208-360)
ABMA-PICO/HIAL	2 (0-5)	3 (1-6)	531 (272-953)	11.6 (4.4-23.4)	354 (187-560)
ABMA-ABCO	1 (0-3)	2 (1-4)	520 (200-948)	15.1 (5.5-29.7)	372 (150-627)
ABMA/ARNE2	3 (1-5)	4 (2-6)	290 (118-750)	7.1 (2.9-15.7)	221 (72-493)
ABMA	2 (0-4)	3 (1-5)	517 (136-1104)	15.0 (2.8-30.0)	402 (93-693)

Appendix I

Common Plants of the Upper Montane

Species Code	*Scientific Name*	*Common Name*	*Constancy*
Tree Overstory			
ABCO	*Abies concolor*	White fir	25
ABMA	*Abies magnifica*	Red fir	81
JUOC	*Juniperus occidentalis*	Western juniper	4
LIDE3	*Calocedrus decurrens*	Incense cedar	<1
PIAL	*Pinus albicaulis*	Whitebark pine	<1
PICO	*Pinus contorta*	Lodgepole pine	24
PIJE	*Pinus jeffreyii*	Jeffrey pine	21
PILA	*Pinus lambertiana*	Sugar pine	2
PIMO3	*Pinus monticola*	Western white pine	21
POTR	*Populus tremuloides*	Quaking aspen	3
QUKE	*Quercus kelloggii*	Black oak	1
QUWI	*Quercus wislizenii*	Interior live oak	1
TSME	*Tsuga mertensiana*	Mountain hemlock	6
Tree Understory			
ABCO	*Abies concolor*	White fir	29
ABMA	*Abies magnifica*	Red fir	82
JUOC	*Juniperus occidentalis*	Western juniper	5
LIDE3	*Calocedrus decurrens*	Incense cedar	2
PIAL	*Pinus albicaulis*	Whitebark pine	2
PICO	*Pinus contorta*	Lodgepole pine	23
PIJE	*Pinus jeffreyii*	Jeffrey pine	12
PILA	*Pinus lambertiana*	Sugar pine	2
PIMO3	*Pinus monticola*	Western white pine	21
POTR	*Populus tremuloides*	Quaking aspen	5
QUKE	*Quercus kelloggii*	Black oak	1
TSME	*Tsuga mertensiana*	Mountain hemlock	8
Shrubs			
ACGLT	*Acer glabrum torreyi*	Mountain maple	<1
ALTE	*Alnus tenuifolia*	Mountain alder	<1
AMPA2	*Amelanchier pallida*	Pallid service berry	1
AMPU3	*Amelanchier pumila*	Service berry	<1
ARNE2	*Arctostaphylos nevadensis*	Pinemat manzanita	15
ARPA9	*Arctostaphylos patula*	Greenleaf manzanita	6
ARAR	*Artemisia arbuscula*	Dwarf sagebrush	<1
ARCA8	*Artemisia cana*	Hoary sagebrush	<1
ARRO3	*Artemisia rothrockii*	Timberline sagebrush	<1
ARTR	*Artemisia tridentata*	Sagebrush	7
BESO	*Berberis sonnei*	Truckee barberry	<1
CAME3	*Cassiope mertensiana*	White heather	<1
CASE3	*Castanopsis sempervirens*	Sierra chinquapin	15

Species Code	*Scientific Name*	*Common Name*	*Constancy*
Shrubs, continued			
CECO2	*Ceanothus cordulatus*	Mountain whitethorn	10
CEDI3	*Ceanothus diversifolius*	Trailing ceanothus	<1
CEFR	*Ceanothus fresnensis*	Creeping ceanothus	<1
CEPI	*Ceanothus pinetorum*	Kern ceanothus	1
CEVE3	*Ceanothus velutinus*	Snowbrush	3
CELE3	*Cercocarpus ledifolius*	Curlleaf mountain mahogany	<1
CHNA2	*Chrysothamnus nauseosus*	Common rabbit brush	<1
CHPA9	*Chrysothamnus parryi*	Parry's rabbit brush	<1
CHR9	*Chrysothamnus sp. (woody shrub)*	Rabbit brush	<1
CHVI4	*Chrysothamnus viscidiflorus*	Sticky-leaved rabbit brush	1
CONU2	*Cornus nuttallii*	Mountain dogwood	<1
COST3	*Cornus stolonifera*	American dogwood	<1
COCOC	*Corylus cornuta californica*	California hazelnut	<1
ERPR5	*Eriogonum prattenianum*	Eriogonum	<1
HABL	*Haplopappus bloomeri*	Bloomer's goldenbush	<1
HOBO2	*Holodiscus boursieri*	Oceanspray	1
HOMI2	*Holodiscus microphyllus*	Rock sprirea	<1
KAPOM	*Kalmia polifolia microphylla*	Alpine laurel	<1
LEDA	*Leucothoe davisiae*	Sierra laurel	<1
LOCO3	*Lonicera conjugialis*	Double honeysuckle	2
LOIN4	*Lonicera involucrata*	Black twinberry	<1
PERO	*Penstemon rothrockii*	Rothrock's penstemon	<1
PHBR4	*Phyllodoce breweri*	Red mountain heather	<1
PREM	*Prunus emarginata*	Bitter cherry	5
PUTR	*Purshia tridentata*	Bitter brush	2
QUVA	*Quercus vaccinifolia*	Huckleberry oak	10
RHOC	*Rhododendron occidentale*	Western azalea	<1
RICE	*Ribes cereum*	Squaw currant	7
RIDI	*Ribes divaricatum*	Straggly gooseberry	<1
RIMO	*Ribes montigenum*	Alpine prickly currant	5
RINE	*Ribes nevadense*	Sierra Nevada currant	<1
RIRO	*Ribes roezlii*	Sierra gooseberry	12
RIB	*Ribes sp. (woody shrub)*	Currant	1
RIVE	*Ribes velutinum*	Plateau gooseberry	<1
RIVE3	*Ribes viscosissimum*	Sticky currant	7
ROPI1	*Rosa pinetorum*	Pinerose	<1
RUPA2	*Rubus parviflorus*	Thimble berry	<1
SAEA	*Salix eastwoodiae*	Eastwood's willow	<1
SALU	*Salix lutea*	Yellow willow	<1
SAL11	*Salix sp. (woody shrub)*	Willow	<1
SACA4	*Sambucus caerulea*	Blue elderberry	<1
SAME5	*Sambucus melanocarpa*	Black elderberry	<1
SAMI4	*Sambucus microbotrys*	Mountain red elderberry	1
SOCA3	*Sorbus californica*	Western mountain ash	<1
SOSC	*Sorbus scopulina*	Mountain ash	<1
SPDES	*Spiraea densiflora splendens*	Mountain spirea	1
SYAC	*Symphoricarpos acutus*	Creeping snowberry	13

Species Code	Scientific Name	Common Name	Constancy
Shrubs, continued			
SYPA	*Symphoricarpos parshii*	Parish's snowberry	7
SYM3	*Symphoricarpos sp. (woody shrub)*	Snowberry	<1
SYVA	*Symphoricarpos vaccinioides*	Mountain snowberry	5
TECA	*Tetradymia canescens*	Gray horsebrush	1
VANI	*Vaccinium nivictum*	Dwarf huckleberry	<1
Forbs			
ACLA2	*Achillea lanulosa*	Common yarrow	3
ACCO2	*Aconitum columbianum*	Columbia monkshood	<1
ADBI	*Adenocaulon bicolor*	Trail plant	1
AGUR	*Agastache urticifolia*	Nettle-leaved horsemint	<1
AGUT	*Agave utahensis*	Utah agoseris	<1
AGEL2	*Agoseris elata*	Tall agoseris	<1
AGGLL	*Agoseris glauca laciniata*	Short-beaked agoseris	<1
AGRE2	*Agoseris retrorsa*	Spear-leaved agoseris	<1
AGO3	*Agoseris sp. (herb-longevity unk)*	Agoseris	<1
ALCA2	*Allium campanulatum*	Sierra onion	6
ALFIA	*Allium fimbriatum abramsii*	Fringed onion	<1
ALOB	*Allium obtusum*	Red sierra onion	4
ALPA3	*Allium parvum*	Dwarf onion	<1
ALL2	*Allium sp. herbaceous perennial*	Onion	2
ALTR2	*Allium tribracteatum*	Three-bracted onion	<1
ALVA	*Allium validum*	Swamp onion	<1
ALDI2	*Allophyllum divaricatum*	Pink false gilia	<1
ALIN2	*Allophyllum integrifolium*	Allophyllum	<1
ALVI1	*Allophyllum violaceum*	Allophyllum	<1
ALVI2	*Allotropa virgata*	Sugar stick	<1
ANMA1	*Anaphalis margaritacea*	Pearly everlasting	<1
ANBR2	*Angelica breweri*	Brewer's angelica	3
ANLI	*Angelica lineariloba*	Sierra angelica	1
ANCO1	*Antennaria corymbosa*	Meadow everlasting	<1
ANRO	*Antennaria rosea*	Rosy everlasting	2
APMEF	*Apocynum medium floribundum*	Western dogbane	7
APPU	*Apocynum pumilum*	Mountain dogbane	1
AQFO	*Aquilegia formosa*	Northwest crimson columbine	<1
ARBR	*Arabis breweri*	Brewer's rock cress	<1
ARDI5	*Arabis divaricarpa*	Bent-pod rock cress	2
ARDR2	*Arabis drummondii*	Drummond's rock cress	<1
ARHIG	*Arabis hirsuta glabrata*	Hairy rock cress	<1
ARHOR	*Arabis holboellii retrofracta*	Holboell's rock cress	4
ARHOP	*Arabis holboellii pinetorum*	Holboell's rock cress	1
ARIN1	*Arabis inyoensis*	Inyo rock cress	<1
ARLE	*Arabis lemmonii*	Lemmon's rock cress	<1
ARLY	*Arabis lyallii*	Lyal's rock cress	<1
ARMI2	*Arabis microphylla*	Small-leaved rock cress	<1
ARPL	*Arabis platysperma*	Broad-seeded rock cress	35
ARPLH	*Arabis platysperma howellii*	Howell's rock cress	<1

Species Code	*Scientific Name*	*Common Name*	*Constancy*
Forbs, continued			
ARPU4	*Arabis pulchra*	Beautiful rock cress	<1
ARRE1	*Arabis rectissima*	Bristly-leaved rock cress	1
ARRE2	*Arabis repanda*	Repand rock cress	8
ARA2	*Arabis sp. (herb-ann or bien)*	Rock cress	1
ARA3	*Arabis sp. (herb-peren)*	Rock cress	<1
ARSPA	*Arabis sparsiflora arcuata*	Elegant rock cress	<1
ARSU3	*Arabis suffrutescens*	Woody rock cress	<1
ARCOS	*Arenaria congesta subcongesta*	Capitate sandwort	<1
ARNUG	*Arenaria nuttallii gracilis*	Nuttall's sandwort	<1
ARKIG	*Arenaria kingii glabrescens*	King's sandwort	1
ARMO2	*Arnica mollis*	Cordilleran arnica	<1
ARPAS	*Arnica parryi sonnei*	Nodding arnica	<1
ARLUI	*Artemisia ludoviciana incompta*	Western mugwort	<1
ASC1	*Asclepias sp. (herb-peren)*	Milkweed	<1
ASAD	*Aster adscendens*	Long-leaved aster	<1
ASCAB	*Aster campestris bloomerii*	Western meadow aster	<1
ASEA	*Aster eatonii*	Eaton's aster	<1
ASFO	*Aster foliaceus*	Leafy aster	<1
ASIN1	*Aster integrifolius*	Entire-leaved aster	<1
ASOCI	*Aster occidentalis intermedius*	Western mountain aster	<1
ASOCY	*Aster occidentalis yosemitanus*	Western mountain aster	<1
AST2	*Aster sp. (herb-peren)*	Aster	1
ASBO	*Astragalus bolanderi*	Bolander's locoweed	1
ATALA	*Athyrium alpestra americanum*	Alpine lady fern	<1
BASA1	*Balsamorhiza sagittata*	Arrow-leaved balsam root	<1
BEER	*Berula erecta*	Cut-leaved water parsnip	<1
BREL	*Brodiaea elegans*	Harvest brodiaea	<1
BRLU2	*Brodiaea lutea*	Yellow brodiaea	6
CAER	*Calliandra eriophylla*	Hairy-leaved calliandra	<1
CAIN5	*Calochortus invenustus*	Plain mariposa lily	<1
CALE6	*Calochortus leichtlinii*	Leichtlin's mariposa lily	1
CAL5	*Calochortus sp. (herb-peren)*	Mariposa lily	1
CAHO2	*Caltha howellii*	White marsh marigold	<1
CAUM2	*Calyptridium umbellatum*	Pussy paws	10
CAPR6	*Campanula prenanthoides*	California harebell	<1
CABR8	*Cardamine breweri*	Brewer's bitter cress	<1
CAAP	*Castelleja applegatei*	Wavy-leaved indian paint brush	7
CADI3	*Castelleja disticha*	Eastwood's indian paint brush	<1
CALI3	*Castelleja linariaefolia*	Linear-leaved indian paint brush	<1
CAMI4	*Castelleja miniata*	Great red indian paint brush	<1
CAPR7	*Castelleja pruinosa*	Pruinose indian paint brush	<1
CHDO1	*Chaenactis douglasii*	Hoary chaenactis	3
CHNE2	*Chaenactis nevadensis*	Northern sierra chaenactis	<1
CHAL3	*Chenopodium album*	Lambs quarters	<1
CHAT	*Chenopodium atrovirens*	Pigweed	<1
CHDE1	*Chenopodium desiccatum*	Narrow-leaved pigweed	<1
CHME2	*Chimaphila menziesii*	Little prince's pine	3

Species Code	Scientific Name	Common Name	Constancy
Forbs, continued			
CHUMO	*Chimaphila umbellata occidentalis*	Western prince's pine	3
CHUBR3	*Chrysopsis breweri*	Brewer's golden aster	25
CIAN1	*Cirsium andersonii*	Anderson's thistle	5
CIDR	*Cirsium drummondii*	Dwarf thistle	<1
CLRH	*Clarkia rhomboidea*	Rhomboid clarkia	<1
CLLAS	*Claytonia lanceolata sessilifolia*	Western spring beauty	<1
COGR1	*Collinsia grandiflora*	Large-flowered blue eyed mary	<1
COPA2	*Collinsia parviflora*	Small-flowered blue eyed mary	1
COTO1	*Collinsia torreyi*	Torrey's blue eyed mary	4
COTOW	*Collinsia torreyi wrightii*	Wright's blue eyed mary	16
COGR3	*Collomia grandiflora*	Large-flowerd collomia	<1
COLI2	*Collomia linearis*	Narrow-leaved collomia	3
COTI2	*Collomia tinctoria*	Yellow-staninining collomia	<1
COMA3	*Convolvulus malacophyllus*	Sierra morning glory	<1
COMA4	*Corallorhiza maculata*	Spotted coral root	21
COST1	*Corallorhiza striata*	Striped coral root	<1
CORAS	*Cordylanthus ramosus setosus*	Much branched bird's beak	<1
CRAC2	*Crepis acuminata*	Long-leaved hawksbeard	<1
CRBA1	*Crepis bakeri*	Baker's hawksbeard	<1
CRIN1	*Crepis intermedia*	Intermediate hawksbeard	<1
CRMOS	*Crepis modocensis subacaulis*	Low hawksbeard	<1
CROC	*Crepis occidentalis*	Western hawksbeard	<1
CRE2	*Crepis sp. (herb-peren)*	Hawksbeard	<1
CRY2	*Cryptantha sp. (herb-ann or bien)*	Cryptantha	6
CRY3	*Cryptantha sp. (herb-peren)*	Cryptantha	<1
CRTO	*Cryptantha torreyana*	Torrey's cryptantha	<1
CRAC1	*Cryptogramma acrostichoides*	American parsley fern	<1
CYOC	*Cynoglossum occidentale*	Western hounds tongue	1
DENU2	*Delphinium nuttallianum*	Nuttalls larkspur	1
DEPR	*Delphinium pratense*	Meadow larkspur	<1
DEL1	*Delphinium sp. (longevity unk)*	Larkspur	2
DEL2	*Delphinium sp. (herb-peren)*	Larkspur	<1
DEPA3	*Dentaria pachystigma*	Stout-beaked toothwort	<1
DECA5	*Descurainia californica*	Sierra tansy mustard	<1
DERII	*Descuraninia richardsonnii incisa*	Mountain tansy mustard	2
DIUM	*Dicentra uniflora*	Steer's head	<1
DIHO2	*Disporum hookeri*	Hooker's fairy bell	1
DOJE	*Dodecatheon jeffreyi*	Jeffrey's shooting star	<1
DRCR1	*Draba crassifolia*	Draba	<1
DRSTN	*Draba stenoloba*	Alaska Whitlow grass	<1
DRAR	*Dryopteris arguta*	Coastal wood fern	<1
EPAN2	*Epilobium angustifolium*	Fireweed	2
EPBR	*Epilobium brevistylum*	Slender willow herb	<1
EPEX	*Epilobium exaltatum*	Elevated willow herb	<1
EPGL1	*Epilobium glaberrimum*	Glaucous willow herb	<1
EPLA1	*Epilobium lactiflorum*	White-flowered willow herb	<1
EPPA	*Epilobium paniculatum*	Panicled willow herb	<1

Species Code	Scientific Name	Common Name	Constancy
Forbs, continued			
EPI2	*Epilobium sp. (herb-peren)*	Willow herb	<1
EQFU	*Equisetum funstoni*	California horsetail	<1
EQU	*Equisetum sp. (herb-peren)*	Horsetail	<1
ERBR2	*Erigeron breweri*	Brewer's daisy	10
ERCO5	*Erigeron coulteri*	Coulter's daisy	<1
ERIN2	*Erigeron inornatus*	California rayless daisy	<1
ERPEA	*Erigeron peregrinus angustifolius*	Wandering daisy	5
ERI6	*Erigeron sp. (herb-peren)*	Daisy	2
ERBR3	*Eriogonum brachyanthum*	Short-flowered eriogonum	<1
ERIN6	*Erigonum incanum*	Hoary erigonum	2
ERLAN	*Eriogonum latifolium nudum*	Coast eriogonum	2
ERMA3	*Eriogonum marifolium*	Marum-leaved eriogonum	3
ERNU3	*Eriogonum nudum*	Naked-stemmed eriogonum	<1
ERNUN	*Eriogonum nudum nudum*	Naked-stemmed eriogonum	1
ERNUD	*Eriogonum nudum deductum*	Naked-stemmed eriogonum	13
ERPO2	*Eriogonum polypodum*	Eriogonum	<1
ERI11	*Eriogonum sp. (herb-longevity unk)*	Eriogonum	<1
ERSP2	*Eriogonum spergulinum*	Spurry eriogonum	5
ERUM	*Eriogonum umbellatum*	Sulphur-flowered eriogonum	1
ERUMP	*Eriogonum umbellatum polyanthum*	Sulphur-flowered eriogonum	2
ERWRS	*Eriogonum wrightii subscaposum*	Wright's eriogonum	<1
ERLA6	*Eriophyllum lanatum*	Common wooly sunflower	<1
ERLAM	*Eriophyllum lanatum monoense*	Common wooly sunflower	1
ERCA3	*Erysimum capitatum*	Douglas' wallflower	<1
ERPE3	*Erysimum perenne*	Sierra wallflower	17
EUOC1	*Eupatorium occidentale*	Western eupatorium	<1
FRCA1	*Fragaria californica*	California strawberry	<1
FRPL1	*Fragaria platypetala*	Broad-petaled strawberry	1
FRVIP	*Fragaria virginiana*	Mountain strawberry	<1
FRSP	*Frasera speciosa*	Deer tongue	1
FRTU	*Frasera tubulosa*	Kern swertia	<1
GAAS	*Galium asperrimum*	Tall rough bedstraw	1
GABI	*Galium bifolium*	Low mountain bedstraw	<1
GABO1	*Galium bolanderi*	Bolander's bedstraw	<1
GAL2	*Galium sp. (herb-ann or bien)*	Bedstraw	<1
GAL5	*Galium sp. (semiwoody herb)*	Bedstraw	<1
GASP1	*Galium sparsiflorum*	Sequoia bedstraw	<1
GATRS	*Galium trifidum subbiflorum*	Trifid bedstraw	<1
GADE	*Gayophytum dicepiens*	Gravel gayophytum	<1
GADI2	*Gayophytum diffusum*	Diffuse gayophytum	2
GAER	*Gayophytum eriospermum*	Covilles's gayophytum	20
GAHU1	*Gayophytum humile*	Low gayophytum	<1
GANU1	*Gayophytum nuttallii*	Nuttall's gayophytum	2
GARA1	*Gayophytum racemosum*	Black-foot gayophytum	1
GARA2	*Gayophytum ramosissimum*	Much-branched gayophytum	1
GAY	*Gayophytum sp. (herb-ann or bien)*	Gayophytum	<1
GEHO	*Gentiana holopetala*	Sierra gentian	<1

Species Code	Scientific Name	Common Name	Constancy
Forbs, continued			
GECA3	*Geranium californicum*	California geranium	<1
GERI	*Geranium richardsonii*	Richardson's geranium	<1
GEMA	*Geum macrophyllum*	Large-leaved avens	<1
GICA3	*Gilia capillaris*	Smooth-leaved gilia	<1
GILE1	*Gilia leptales*	Bridge's gilia	<1
GOOB	*Goodyera oblongifolia*	Rattlesnake plantain	1
HADIL	*Habenaria dilatata leucostachys*	Boreal bog orchid	<1
HAEL	*Habenaria elegans*	Elegant piperia	<1
HAUN1	*Habenaria unalascensis*	Alaska piperia	<1
HACA1	*Hackelia californica*	California stickseed	5
HAFL	*Hackelia floribunda*	Many-flowered stickseed	<1
HAJE	*Hackelia jessicae*	Jessica's stickseed	3
HALO	*Hackelia longituba*	Velvety stickseed	<1
HAMU	*Hackelia mundula*	Pink stickseed	1
HANE	*Hackelia nervosa*	Sierra stickseed	<1
HAC1	*Hackelia sp. (herb-peren)*	Stickseed	<1
HAVE	*Hackelia velutina*	Velvety stickseed	6
HAWH	*Haplopappus whitneyi*	Whitney's haplopappus	<1
HEHO	*Helenium hoopesii*	Tall mountain helenium	<1
HELA2	*Heracleum lanatum*	Cow parsnip	<1
HERUA	*Heuchera rubescens alpicola*	Pink heuchera	<1
HIAL	*Hieracium albiflorum*	White-flowered hawkweed	22
HIGR1	*Hieracium gracile*	Alpine hawkweed	<1
HIHO	*Hieracium horridum*	Shaggy hawkweed	1
HUBR	*Hulsea brevifolia*	Short-leaved hulsea	<1
HYOC	*Hydrophyllum occidentale*	California waterleaf	1
IPAG	*Ipomopsis aggregata*	Scarlet gilia	2
IVSA	*Ivesia santolinoides*	Mouse-tail ivesia	<1
KEGA	*Kelloggia galioides*	Kellogg's bedstraw	18
LALA2	*Lathyrus lanszwertii*	Nevada pea	<1
LAGL4	*Layia glandulosa*	White layia	<1
LEVIP	*Lepidium virginicum pubescens*	Wild peppergrass	<1
LELE4	*Lewisia leana*	Lee's lewisia	<1
LETR2	*Lewisia triphylla*	Three-leaved lewisia	<1
LIGR1	*Ligusticum grayi*	Gray's lovage	6
LIKE1	*Lilium kelleyanum*	Kelley's lily	<1
LIPA1	*Lilium paradalinum*	Leopard lily	<1
LIPA3	*Lilium parvum*	Small tiger lily	<1
LIL2	*Lilium sp. (herb-peren)*	Lily	<1
LICI	*Linanthus ciliatus*	Bristly-leaved linanthus	4
LIHA	*Linanthus harknessii*	Harkness' linanthus	<1
LIMO2	*Linanthus montanus*	Mustang clover	<1
LINU2	*Linanthus nuttallii*	Nuttall's linanthus	1
LIN2	*Linanthus sp. (herb-ann or bien)*	Linanthus	1
LIPEL	*Linum perenne lewisii*	Western blue flax	<1
LIBU	*Lithophragma bulbiferum*	Rock star	<1
LIHE	*Lithophragma heterophyllum*	Hill star	<1

Species Code	Scientific Name	Common Name	Constancy
Forbs, continued			
LIT2	*Lithospermum sp. (herb-ann or bien)*	Stoneseed	<1
LODIM	*Lomatium dissectum multifidum*	Fern-leaved lomatium	<1
LOMA3	*Lomatium macrocarpum*	Large-fruited lomatium	<1
LOPL	*Lomatium plummerae*	Plummer's lomatium	<1
LORI1	*Lomatium rigidum*	Inyo lomatium	<1
LOM2	*Lomatium sp. (semiwoody herb)*	Lomatium	<1
LOTO2	*Loamtium toreyi*	Torrey's lomatium	<1
LOCU	*Lotus cupreus*	Copper-flowered bird's-foot trefoil	<1
LONE3	*Lotus nevadensis*	Sierra nevada trefoil	<1
LOOB	*Lotus oblingifolius*	Narrow-leaved trefoil	<1
LUADU	*Lupinus adsurgens undulatus*	Drew's silky lupine	6
LUAL1	*Lupinus albicaulis*	Sickle-keeled lupine	3
LUAN2	*Lupinus andersonii*	Anderson's lupine	7
LUAL3	*Lupinus arbifrons*	Silver lupine	<1
LUAR4	*Lupinus arbustus*	Douglas' spurred lupine	<1
LUBR2	*Lupinus breweri*	Brewer's lupine	<1
LUCA2	*Lupinus caudatus*	Kellogg's spurred lupine	<1
LUDU	*Lupinus duranii*	Lupine	<1
LUEX	*Lupinus excubitus*	Interior bush lupine	<1
LUFU	*Lupinus fulcratus*	California green-stipuled lupine	2
LUGR1	*Lupinus gracilentus*	Greene's slender lupine	<1
LULAC	*Lupinus latifolius columbianus*	Broad-leaved lupine	4
LULO1	*Lupinus lobbii*	Dwarf lupine	<1
LULY	*Lupinus lyallii*	Lyall's lupine	<1
LUME	*Lupinus meionanthus*	Gray's many-flowered lupine	<1
LUBO	*Lupinus obtusilobus*	Ornate lupine	<1
LUPOS	*Lupinus polyphyllus superbus*	Large-leaved lupine	<1
LUSE1	*Lupinus sellulus*	Torrey's lupine	<1
LUP3	*Lupinus sp. (longevity unk)*	Lupine	<1
LUP2	*Lupinus sp. (herb-peren)*	Lupine	3
LUST	*Lupinus stiversii*	Stiver's annual lupine	<1
LUSU5	*Lupinus sublanatus*	Lupine	<1
MACA1	*Machaeranthera canescens*	Hoary aster	<1
MASHM	*Machaeranthera shastensis montana*	Shasta aster	<1
MAEX1	*Madia exigua*	Small tarweed	<1
MAGL1	*Madia glomerata*	Mountain tarweed	<1
MAMI1	*Madia minima*	Hemizonella	<1
MEAR3	*Mentha arvensis*	Field mint	<1
MEAL2	*Mentzelia albicaulis*	White-stemmed stick leaf	<1
MECIS	*Mertensia ciliata stomatechoides*	Ciliate lungwort	<1
MINU1	*Microseris nutans*	Nodding scorzonella	<1
MIGR1	*Microsteris gracilis*	Slender phlox	<1
MIAR1	*Mimulus arenarius*	Sand-loving monkey flower	<1
MICO1	*Mimulus coccineus*	Sierra monkey flower	<1
MIFL1	*Mimulus floribundus*	Floriferous monkey flower	1
MIGU	*Mimulus guttatus*	Common large monkey flower	<1
MILE1	*Mimulus leptaleus*	Least-flowered monkey flower	<1

Species Code	Scientific Name	Common Name	Constancy
Forbs, continued			
MIME	*Mimulus mephiticus*	Skunky monkey flower	<1
MINA2	*Mimulus nasutus*	Snouted monkey flower	<1
MIPR	*Mimulus primuloides*	Primrose monkey flower	<1
MIM1	*Mimulus sp. (herb-ann or bien)*	Monkey flower	<1
MIM2	*Mimulus sp. (herb-peren)*	Monkey flower	<1
MIWH2	*Mimulus whitneyi*	Varicolored monkey flower	<1
MIBR6	*Mitella breveri*	Brewer's mitrewort	1
MOOD	*Monardella odoratissima*	Mountain pennyroyal	22
MOODP	*Monardella odoratissima pallida*	Mountain pennyroyal	3
MOPE2	*Montia perfoliata*	Miner's lettuce	<1
MOSIH	*Montia sibirica heterophylla*	Candy flower	<1
MYMI2	*Myosurus minimus*	Common mouse tail	<1
NEM3	*Nemophila sp. (herb-ann or bien)*	Nemophila	<1
NESP	*Nemophila spatulata*	Sierra nemophilla	<1
NOAL	*Nothocalais alpestris*	Alpine lake agoseris	<1
ONDE	*Onychium densum*	Indian's dream	<1
ORCAC	*Orobanche californica corymbosa*	California broomrape	<1
ORUNP	*Orobanche uniflora purpurea*	Naked broomrape	<1
ORTH	*Orochaenactis thysanocarpha*	Orochaenactis	<1
ORCOC	*Orthocarpus copelandii cryptanthus*	Copeland's orthocarpus	1
ORT	*Orthocarpus sp. (herb-ann or bien)*	Orthocarpus	<1
OSCH	*Osmorhiza chilensis*	Mountain sweet-cicely	12
OSOC	*Osmorhiza occidentalis*	Western sweet-cicely	1
OSM	*Osmorhiza sp. (herb-peren)*	Sweet-cicely	<1
PABR	*Paeonia brownii*	Western peony	1
PESE3	*Pedicularis semibarbata*	Pine-woods lousewort	45
PEBR3	*Pellaea bridgeii*	Bridge's cliff brake	<1
PEAZ	*Penstemon asureus*	Azure penstemon	<1
PEBR4	*Penstemon bridgesii*	Bridge's penstemon	1
PECA5	*Penstemon caesius*	Cushion penstemon	3
PEGR3	*Penstemon gracilentus*	Slender penstemon	<1
PEHE2	*Penstemon heterodoxus*	Sierran penstemon	<1
PELA2	*Penstemon laetus*	Gay penstemon	2
PENE3	*Penstemon newberryi*	Mountain pride	3
PEOR1	*Penstemon oreocharis*	Meadow penstemon	<1
PEPA8	*Penstemon parvulus*	Small azure penstemon	<1
PERY	*Penstemon rydbergii*	Rydberg's meadow penstemon	<1
PEN2	*Penstemon sp. (herb-peren)*	Penstemon	<1
PEN3	*Penstemon sp. (semiwoody-herb)*	Penstemon	<1
PESP1	*Penstemon speciosus*	Showy penstemon	<1
PEBO	*Perideridia bolanderi*	Bolander's yampah	<1
PEPA5	*Perideridia parishii*	Parish's yampah	2
PHFR2	*Phacelia frigida*	Timberline phacelia	<1
PHHA	*Phacelia hastata*	Silverleaf phacelia	<1
PHHE1	*Phacelia heterophylla*	Virgate phacelia	5
PHHY	*Phacelia hydrophylloide*	Waterleaf phacelia	24
PHIM	*Phacelia imbricata*	Imbricate phacelia	1

Species Code	Scientific Name	Common Name	Constancy
Forbs, continued			
PHMU2	*Phacelia mutablis*	Changeable phacelia	5
PHPU1	*Phacelia purpusii*	Purpus phacelia	<1
PHQU	*Phacelia quickii*	Persistent-flowered phacelia	<1
PHRA1	*Phacelia racemosa*	Racemose phacelia	<1
PHRA2	*Phacelia ramosissima*	Branching phacelia	5
PHA4	*Phacelia sp. (herb-ann or bien)*	Phacelia	<1
PHCO4	*Phlox covillei*	Coville's phlox	<1
PHDI4	*Phlox diffusa*	Spreading phlox	5
PHSPO	*Phlox speciosa occidentalis*	Showy phlox	<1
PHBR4	*Phyllodoce breweri*	Brewer's mountain heather	<1
PLFI	*Pleuricospora fimbriolata*	Fringed pine-sap	1
POCAA	*Polemonium caeruleum amygdalinum*	Western polemonium	<1
POCA4	*Polemonium californica*	Low polemonium	2
POBI3	*Polygonum bistortoides*	Western bistort	<1
PODA	*Polygonum davisiae*	Davis' knotweed	<1
PODO3	*Polygonum douglasii*	Douglas' knotweed	3
POKE2	*Polygonum kelloggii*	Kellogg's knotweed	1
POPH	*Polygonum phytolaccaefolium*	Alpine knotweed	<1
PODR	*Potentilla drummondii*	Drummond's cinquefoil	<1
POFL1	*Potentilla flabellifolia*	Mount Ranier cinquifoil	<1
POGL2	*Potentilla glandulosa*	Sticky cinquefoil	2
POGR4	*Potentilla gracilis*	Slender cinquefoil	1
POPES	*Potentilla pennsylvanica strigosa*	Pennsylvania cinquefoil	<1
POT2	*Potentilla sp. (herb-ann or bien)*	Cinquefoil	<1
PRVUL	*Prunella vulgaris lanceolata*	Self-heal	<1
PTAQL	*Pteridium aquilinum lanuginosum*	Western bracken fern	<1
PTAQP	*Pteridium aquilinum pubescens*	Western bracken fern	6
PTE1	*Pteridium sp. (herb-peren)*	Bracken fern	<1
PTAN	*Pterospora andromedea*	Pinedrops	4
PTTEC	*Pteryxia terebinthina californica*	Terebinth pteryxia	<1
PYMI	*Pyrola minor*	English wintergreen	<1
PYPI	*Pyrola picta*	White-veined wintergreen	18
PYPIA	*Pyrola picta aphylla*	White-veined wintergreen	1
PYPID	*Pyrola picta dentata*	White-veined wintergreen	<1
PYPII	*Pyrola picta integra*	White-veined wintergreen	7
PYSE	*Pyrola secunda*	Serrated wintergreen	3
RASC3	*Raillardella scaposa*	Green-leaved raillardella	<1
RAAL1	*Ranunculus alismaefolius*	Water plantain buttercup	<1
RAOC	*Ranunculus occidentalis*	Western buttercup	<1
RAN1	*Ranunculus sp. (herb-ann or bien)*	Buttercup	<1
RONA	*Rorippa nasturtium*	Water cress	<1
ROSU2	*Rorippa subumbellata*	Tahoe water cress	<1
RUAN	*Rumex angiocarpus*	Sheep sorrel	<1
RUPA1	*Rumex paucifolius*	Alpine sheep sorrel	<1
SAGR1	*Sanicula graveolens*	Sierra sanicle	<1
SATU	*Sanicula tuberose*	Tuberous sanicle	<1
SASA3	*Sarcodes sanguinea*	Snow plant	6

Species Code	Scientific Name	Common Name	Constancy
Forbs, continued			
SABR1	*Saxifraga bryophora*	Bud saxifrage	<1
SANI1	*Saxifraga nidifica*	Peak saxifrage	<1
SAPUA	*Saxifraga punctata arguta*	Brook saifrage	<1
SCR1	*Scrophularia sp. (herb-peren)*	Figwort	<1
SEOB	*Sedum obtusatum*	Sierra gormania	<1
SESP2	*Sedum spathuliforium*	Pacific stonecrop	<1
SEWA2	*Selaginella watsoni*	Alpine selaginella	<1
SEAR	*Senecio aronicoides*	California butterweed	10
SECA3	*Senecio canus*	Woody butterweed	<1
SECL1	*Senecio clarkianus*	Clark's butterweed	<1
SECY	*Senecio cymbalarioides*	Rocky mountain butterweed	<1
SEIN2	*Senecio integerrimus*	Single-stemmed butterweed	4
SEINM	*Senecio integerrimus major*	Single-stemmed butterweed	1
SESE1	*Senecio serra*	Tall butterweed	<1
SEN3	*Senecio sp. (herb-longevity unk)*	Butterweed	<1
SESP3	*Senecio spartioides*	Narrow-leaved butterweed	<1
SETR	*Senecio triangularis*	Arrowhead butterweed	3
SIGL	*Sidalicea glaucescens*	Glaucous checker	3
SIOR1	*Sidalicea oregana*	Oregon checker	1
SIAP	*Silene aperta*	Naked campion	<1
SIBR	*Silene bridgesii*	Bridge's campion	<1
SIDO1	*Silene douglasii*	Douglas' campion	<1
SIIN	*Silene invisa*	Short-petaled campion	<1
SILE	*Silene lemmonii*	Lemmon's campion	7
SIMED	*Silene menziesii dorrii*	Menzies' campion	<1
SIMO	*Silene montana*	Mountain campion	<1
SIOC	*Silene occidentalis*	Western campion	<1
SISA	*Silene sargentii*	Sargent's campion	<1
SIL1	*Silene sp. (herb-ann or bien)*	Campion	<1
SIVEP	*Silene verecunda platyota*	Dolores' campion	<1
SIOF	*Sisymbrium officinale*	Hedge mustard	<1
SMRA	*Smilacina racemosa*	False Solomon's seal	2
SMRAA	*Smilacina racemosa amplexicaulis*	False Solomon's seal	1
SMRAG	*Smilacina racemosa glabra*	False Solomon's seal	2
SMST	*Smilacina stellata*	Nuttall's Solomon's seal	<1
SOXA	*Solanum xantii*	Purple nightshade	<1
SOMU	*Solidago multiradiata*	Alpine goldenrod	<1
SPRU	*Spergularia rubra*	Purple sand spurry	<1
SPCA	*Sphenosciadium capitellatum*	Swamp white-heads	1
STAL	*Stachys albens*	White hedge nettle	<1
STJA	*Stellaria jamesiana*	Sticky starwort	3
STLO1	*Stellaria longipes*	Long-stalked starwort	<1
STME	*Stellaria media*	Common chickweed	<1
STE4	*Stellaria sp. (herb-longevity unk)*	Starwort	<1
STLA2	*Stephanomeria lactucina*	Large-flowered stephanomeria	1
STTE	*Stephanomeria tenuifolia*	Narrow-leaved stephanomeria	4
STCO4	*Streptanthus cordatus*	Perennial streptanthus	<1

Species Code	Scientific Name	Common Name	Constancy
Forbs, continued			
STGR2	*Streptanthus gracilis*	Alpine streptanthus	<1
STTO	*Streptanthus tortuosus*	Mountain streptanthus	4
TAOF	*Taraxacum officinale*	Common dandelion	<1
THFE	*Thalictrum fendleri*	Fendler's meadow rue	11
TRLO	*Trifolium longipes*	Long-stalked clover	<1
TRMI2	*Trifolium microcephalum*	Small-headed clover	<1
TRMO1	*Trifolium monanthum*	Carpet clover	<1
TRI9	*Trifolium sp. (herb-ann or bien)*	Clover	1
TRVAP	*Trifolium variegatum pauciflorum*	White-tipped clover	<1
VACAC	*Valeriana capitata californica*	California valerian	<1
VECA1	*Veratrum californicum*	California corn lily	2
VETH	*Verbascum thapsus*	Wooly mullein	<1
VEALA	*Veronica alpine alterniflora*	American alpine speedwell	<1
VEAM	*Veronica americana*	American brooklime	<1
VEPEX	*Veronica peregrina xalapensis*	Purslane speedwell	<1
VESC2	*Veronica scutellata*	Marsh speedwell	<1
VESE	*Veronica serpyllifolia*	Thyme-leaved speedwell	<1
VICA1	*Vicia californica*	California vetch	<1
VIAD	*Viola adunca*	Western dog violet	1
VIGL	*Viola glabella*	Stream violet	<1
VILO	*Viola lobata*	Pine violet	1
VILO1	*Viola lobata integrifolia*	Pine violet	<1
VIMA2	*Viola macloskeyi*	Macloskey's violet	<1
VIPU	*Viola purpurea*	Mountain violet	23
VIO3	*Viola sp. (herb-longevity unk)*	Violet	<1
WOOR	*Woodsia oregana*	Oregon woodsia	<1
WYMO	*Wyethia mollis*	Mountain mule-ears	6
Grass and Grass-Like			
AGTR1	*Agropyron trachycaulum*	Slender wheatgrass	<1
AGEX1	*Agrostis exarata*	Western bent grass	<1
AGID	*Agrostis idahoensis*	Idaho bent grass	<1
AGTH	*Agrostis thurberiana*	Thurber's bent grass	2
AGVA	*Agrostis variablilis*	Ross' bent grass	<1
BRBR1	*Bromus breviaristatus*	Short brome	2
BRCA1	*Bromus carinatus*	California brome	<1
BRLA1	*Bromus laevipes*	Woodland brome	1
BRMA3	*Bromus marginatus*	Large mountain brome	9
BROR1	*Bromus orcuttianus*	Orcutt's brome	1
BRRI1	*Bromus richardsonii*	Richardson's brome	<1
BRO1	*Bromus sp. (ann or bien)*	Brome	3
BRO2	*Bromus sp. (peren)*	Brome	<1
BRSU	*Bromus suksdorfii*	Sudsdorf's brome	3
BRTE	*Bromus tectorum*	Cheatgrass	<1
CACA1	*Calamagrostis canadensis*	Blue-joint	<1
CAIN1	*Calamagrostis inexpensa*	Narrow-spiked reed grass	<1
CAAQ	*Carex aquatilis*	Water sedge	<1

Species Code	*Scientific Name*	*Common Name*	*Constancy*
Grass and Grass-Like, continued			
CAAT2	*Carex athrostachya*	Slender-beaked sedge	<1
CABR5	*Carex brevipes*	Shot sedge	<1
CABU1	*Carex buxbaumii*	Buxbaum's sedge	<1
CAEX1	*Carex exserta*	Short-grass sedge	<1
CAFE2	*Carex feta*	Green-sheathed sedge	<1
CAFI1	*Carex filifolia*	Short-grass sedge	<1
CAFR1	*Carex fracta*	Fragile-sheathed sedge	1
CAHA3	*Carex hassei*	Hasse's sedge	<1
CAHE3	*Carex heteroneura*	Various-nerved sedge	<1
CAIN3	*Carex integra*	Smooth-beaked sedge	<1
CAJE	*Carex jepsonii*	Jepson's sedge	1
CALA3	*Carex lanuginosa*	Wooly sedge	<1
CALE3	*Carex leporinella*	Sierra hare sedge	<1
CALU1	*Carex luzulaefolia*	Luzula-leaved sedge	<1
CALU2	*Carex luzulina*	Luzula-like sedge	<1
CAMA1	*Carex mariposana*	Mariposa sedge	<1
CAMI1	*Carex microptera*	Small-winged sedge	<1
CAMU2	*Carex multicostata*	Many-ribbed sedge	1
CANE2	*Carex nervina*	Sierra nerved sedge	<1
CAOC1	*Carex occidentalis*	Sedge	<1
CAPA1	*Carex pachystachya*	Thick-headed sedge	<1
CAPR2	*Carex praegracilis*	Clustered field sedge	<1
CARA1	*Carex raynoldsii*	Raynold's sedge	1
CARO1	*Carex rossii*	Ross' sedge	24
CARO2	*Carex rostrata*	Beaked-sedge	<1
CASI1	*Carex simulata*	Short-beaked sedge	<1
CASP1	*Carex specifica*	Narrow-fruited sedge	<1
CASP2	*Carex spectablis*	Showy sedge	<1
CASU2	*Carex subfusca*	Rusty sedge	<1
CATE1	*Carex teneraeformis*	Sierra slender sedge	<1
CATU	*Carex tumulicola*	Foothill sedge	<1
CAUN1	*Carex unilateralis*	One-sided sedge	<1
CAVE2	*Carex vesicaria*	Inflated sedge	<1
CAWH	*Carex whitneyi*	Whitney's sedge	<1
CAR-1	*Carex sp. (longevity unk)*	Sedge	8
DAIN	*Danthonia intermedia*	Mountain wild oatgrass	<1
DECA1	*Deschampsia caespitosa*	Tufted hairgrass	<1
DEEL	*Deschampsia elongata*	Slender hairgrass	2
ELCA1	*Elymus canadensis*	Canadian wildrye	<1
ELGL	*Elymus glaucus*	Blue wildrye	6
ELGLJ	*Elymus glaucus jepsonii*	Jepson's blue wildrye	<1
ELTR	*Elymus triticoides*	Alkali rye	<1
FES3	*Festuca sp. (longevity unk)*	Bunchgrass	<1
FEVI	*Festuca viridula*	Mountain bunchgrass	1
GLEL	*Glyceria elata*	Tall mannagrass	<1
GLST	*Glyceria striata*	Mannagrass	<1
HOJU	*Hordeum jubatum*	Squirreltail	<1

Species Code	*Scientific Name*	*Common Name*	*Constancy*
Grass and Grass-Like, continued			
JUBA	*Juncus balticus*	Baltic rush	<1
JUDR	*Juncus drummondii*	Drummond's rush	<1
JUME2	*Juncus mertensianus*	Merten's rush	<1
JUNE	*Juncus nevadensis*	Sierra rush	<1
JUOX	*Juncus oxymeris*	Pointed rush	<1
JUPA1	*Juncus parryi*	Parry's rush	2
JUN2	*Juncus sp. (peren)*	Rush	<1
LUCO1	*Luzula comosa*	Common woodrush	5
LUDI	*Luzula divaricata*	Forked woodrush	<1
LUPA1	*Luzula parviflora*	Small-flowered woodrush	<1
LUSP1	*Luzula spicata*	Spiked woodrush	<1
MEAR1	*Melica aristata*	Awned oniongrass	<1
MEBU	*Melica bulbosa*	Western oniongrass	3
MEFU	*Melica fugax*	Small oniongrasss	<1
MEHA	*Melica harfordii*	Harford's oniongrass	1
MEST	*Melica stricta*	Nodding oniongrass	<1
METO1	*Melica torreyana*	Torrey's oniongrass	<1
MUFI	*Muhlenbergia filiformis*	Slender muhlenbergia	<1
MURI1	*Muhlenbergia richardsonis*	Richardson's muhlenbegia	<1
ORHU	*Oryzopsis hymenoides*	Indian mountain rice	<1
PHAL1	*Phleum alpinum*	Mountain timothy	<1
POBO1	*Poa bolanderi*	Bolander's bluegrass	22
POGR1	*Poa gracillima*	Pacific bluegrass	9
POHA	*Poa hanseni*	Leidberg's bluegrass	<1
POIN1	*Poa incurva*	Sandberg's bluegrass	1
POLE2	*Poa leptocoma*	Bog bluegrass	<1
PONE1	*Poa nervosa*	Hooker's bluegrass	4
PONE2	*Poa nevadensis*	Nevada bluegrass	<1
POPR1	*Poa pratensis*	Kentucky bluegrass	1
POSA3	*Poa sandbergii*	Sandberg's bluegrass	<1
POA1	*Poa sp. (ann or bien)*	Bluegrass	4
SIHY	*Sitanion hystrix*	Bottle-brush squirreltail	20
SIT	*Sitanion sp. (peren)*	Squirreltail	<1
STCA1	*Stipa californica*	California needlegrass	9
STCO1	*Stipa columbiana*	Columbia needlegrass	6
STEL1	*Stipa elmeri*	Elmer's needlegrass	4
STLE1	*Stipa lemmonii*	Lemmon's needlegrass	<1
STNE	*Stipa nevadensis*	Needlegrass	<1
STOC1	*Stipa occidentalis*	Western needlegrass	18
STPI1	*Stipa pinetorum*	Letterman's needlegrass	1
STI1	*Stipa sp. (peren)*	Needlegrass	2
TRCEP	*Trisetum cernuum projectum*	Nodding oat-grass	<1
TRSP1	*Trisetum spicatum*	Downy oat-grass	4
TRSPM	*Trisetum spicatum molle*	Downy oat-grass	1
TRWO1	*Trisetum wolfii*	Beardless oat-grass	<1

Glossary

Abundance The total number of individuals of a taxon or taxa in an area or community. Often measured as cover in plants.

Available Water Holding Capacity (AWC) The capacity of soils to hold water available for use by most plants. It is commonly defined as the difference between the amount of soil water at field capacity and the amount at the wilting point. It is usually expressed as inches of water per inch of soil.

Basal Area The area of the cross section of a tree stem at 4½ feet above the ground on the high side and inclusive of the bark. Basal area per acre is the sum of the cross sections of trees at 4½ feet on an acre of land.

Batholith A large mass of granitic rock measurable by hundreds of miles long, as much as a hundred or more miles in width, and formed from the slow cooling of molten magma several miles below the surface.

Board Foot One-twelfth of a cubic foot; it represents a rough sawn board 1-foot square and 1-inch thick. Generally expressed as thousands of board feet and abbreviated "Mbf."

Climax A more or less stable biotic community that is in equilibrium with existing environmental conditions and that represents the terminal stage of an ecological succession.

Coarse Fragments Soil particles larger than 2 millimeters in diameter.

Constancy The ratio of the number of samples with a species present to the total number of samples.

Cover The proportion of ground occupied by a vertical projection of the aerial parts of individuals of the species under consideration.

Cubic Foot A volume of rough sawn lumber measuring 12 inches by 12 inches by 12 inches. Generally expressed as thousands of cubic feet and abbreviated "Mcf."

Density The number of plants per unit area such as "trees per acre."

Diameter At Breast Height (DBH) The diameter of a standing tree measured at 4½ feet above the highest ground.

Diversity A measure of the number of species and their relative abundance in a community.

Diversity Index A measure of the number of species in a community and their relative abundance. Such measures include the ratio between number of species and number of individuals.

Dominance The extent that a given species predominates in a community because of its size, abundance, or coverage and affects the fitness of associated species.

Drainage The ability of soils to retain moisture. For purposes of description, three drainage classes are used in this guide: excessive, well, and poor. Excessively drained soils are those that have high hydraulic conductivity and low water holding capacity; well drained soils are those that retain optimum amounts of moisture; poorly drained soils are those that are wet close enough to the surface for long enough periods that vegetative growth is restricted.

Forest Communities formed by trees with a canopy cover of 61 percent or more at maturity.

Habitat The locality, site, and particular type of local environment occupied by an organism.

Herbaceous Vegetation Communities dominated by grass, grass-like, or forb vegetation with or without a tree or shrub component at maturity. The tree or shrub canopy cover is 25 percent or less at maturity.

Hill Numbers A diversity index value that is used to characterize species abundance relationships in communities.

Hydric A habitat characterized by an abundance of moisture available for the support of plants.

Importance Value A measure of overall importance of a given species in a community. It is calculated as the sum of relative frequency, relative density, and relative dominance.

Life Form The characteristic structural features and method of survival of a plant species.

Mesic A habitat characterized by a moderate amount of moisture available for the support of plants. Neither hydric nor xeric.

Microrelief Small scale irregularity of the land surface.

Overstory That portion of the trees in a forest stand forming the upper crown cover. The topmost layers in a forest community.

Plant Association A potential natural plant community of definite floristic composition, representing a uniform appearance and occurring within uniform habitat conditions. Associations are groupings of plants that have attained dynamic equilibrium with local existing environmental conditions. Future plant communities are unpredictable in the absence of major disturbance. They are conventionally named for conspicuous dominant or codominant species in different vegetation layers. A diagnostic indicator species may be used in the association name to provide a clearer link between the association characteristic and the name.

Plant Community An assemblage of plants living and interacting together in a specific location. No particular ecological status is implied.

Potential Natural Community The biotic community that would be established if all successional sequences of its ecosystem were completed without additional human-caused disturbance under existing environmental conditions. Grazing by native fauna, natural disturbances such as drought, floods, wildfire, insects, and disease are inherent in the development of potential natural communities that may include naturalized non-native species.

Quadratic Mean Diameter The breast height diameter of the tree of average basal area. The average stand diameter weighted by basal area.

Regeneration Tree seedlings or saplings smaller than 1-inch DBH.

Sere A succession of plant communities in a given habitat leading to a particular climax association. A stage in a community succession.

Seral Stage The developmental stages of an ecological succession.

Series An aggregation of taxonomically related plant associations named for the late seral stage species that dominate or have the potential to dominate the principal vegetative layer in a time frame appropriate for the vegetation under consideration. Generally, in this classification, series were named for the tree species with highest average total cover.

Shrubland Communities composed of woody perennial shrubs less than 16 feet tall at maturity with 26 percent or more canopy cover. A tree canopy cover 25 percent or less may be present.

Simpson Index A diversity index value that is used to characterize species abundance relationships in communities (cf Methods).

Site A location, place, or position in respect to physical surroundings. An area considered as to its ecological factors with reference to capacity to produce forests or other vegetation.

Site Index An expression of forest site quality based on the height of the dominant trees at an arbitrarily chosen age.

Snag A standing dead tree from which the leaves have fallen.

Solar Radiation Index (SRI) The ratio of the total annual potential solar insolation on a particular slope to the maximum annual potential solar insolation at the same location. It compares total potential solar radiation at a site with the potential radiation at the same site after adjusting for latitude, aspect, and percent slope.

Stand An aggregation of trees or other vegetation occupying a specific area and sufficiently uniform in species composition, age arrangement, and condition as to be distinguishable from the forest or other vegetation on adjoining areas.

Stand Age The average age of the dominant or codominant trees that compose a stand.

Stand Density Index The ratio of the number of trees in a stand of a certain average diameter to the number of trees in a fully stocked stand of the same diameter. The Reinecke stand density index is used in this study. It is independent of species, site quality, and age. It is used as a measure of stocking for stands of similar diameter.

Stress Index An index value used to describe the moisture conditions of a site by integrating the available water holding capacity, the solar radiation index, elevation, and slope position.

Subseries An aggregation of taxonomically related plant associations within a series that takes the name of that series followed by related species that are codominant or have indicator value across multiple plant associations (Pacific Southwest Region, USDA Forest Service).

Subsoil The layers of soil beneath the topsoil and overlying the bed rock.

Succession The replacement of one community by another. The gradual process of community change and replacement leading to a stable climax community. The process of continuous colonization and extinction of species populations at a particular site.

Topsoil The upper soil layer or layers containing some organic matter.

Understory The vegetation in a forest stand below the overstory. The vegetation layers between the overstory and the ground. In this classification all trees smaller than 1-inch DBH are considered understory.

Woodland Communities composed of trees with a canopy cover of 26 to 60 percent at maturity.

Xeric A habitat characterized by low or deficient amounts of moisture available for the support of plant life.

Bibliography

Abrams, Leroy R.; Ferris, Roxana S. 1975. **Illustrated flora of the Pacific states: Washington, Oregon and California.** 4 vols. Stanford, CA: Stanford University Press; 2771 p.

Agee, James K. 1990. **The historical role of fire in Pacific Northwest forests.** In: Walstad, J.D.; Radosevich, S.R.; Sandberg, D.V., eds. Natural and prescribed fire in Pacific Northwest Forests. Corvallis, OR: Oregon State University Press; 25-38.

Agee, James K. 1993. **Fire ecology of Pacific Northwest forests.** Washington D.C.: Island Press; 493 p.

Alexander, Robert R. 1975. **Partial cutting in old-growth lodgepole pine**. Res. Paper RM-136. Fort Collins, CO: Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 16 p.

Allen, Barbara H. 1987. **Ecological type classification for California: the Forest Service approach.** Gen. Tech. Rep. PSW-98. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 8 p.

Anderson, Kat. 1993. **Indian fire-based management in the sequoia-mixed conifer forests of the central and southern Sierra Nevada.** Final report submitted to Yosemite National Park. Cooperative agreement order number 8027-2-002. National Park Service, U.S. Department of Interior; 502 p.

Anderson, Kat; Nabhan, Gary P. 1991. **Gardeners in Eden.** Wilderness Magazine: 27-30.

Anderson, M. Kat. 1990. **California Indian horticulture.** Fremontia 18(2):7-14.

Anderson, M. Kat. 1991. **California Indian horticulture: management and use of redbud by the southern Sierra Miwok.** Journal of Ethnobiology 11(1):145-157.

Anderson, M. Kat. 1993a. **The mountains smell like fire.** Fremontia 21(4):15-20.

Anderson, M. Kat. 1993b. **Native Californians as ancient and contemporary cultivators.** In: Blackburn; T.C., Anderson, M.K., eds. Before the wilderness: environmental management by native Californians. Menlo Park, CA: Ballena Press; 476 p.

Assmann, Ernst. 1970. **The principles of forest yield study.** New York: Pergamon Press; 506 p.

Bailey, James R. Fire Planning Specialist, Pacific Southwest Region, USDA Forest Service. [Personal communication with Donald Potter]. 13 November, 1994.

Bailey, Robert G. 1995. **Descriptions of the ecoregions of the United States.** Miscellaneous Publication Number 1391. Washington, DC: Forest Service, U.S. Department of Agriculture; 108 p.

Baker, Frederick S. 1944. **Mountain climates of the western United States.** Ecological Monographs 14:223-254.

Baker, Frederick S. 1950. **Principles of silviculture.** New York: McGraw-Hill Book Company, Inc; 414 p.

Baker, Frederick S. 1962. **The California region.** In: Barratt, J.W., ed. Regional silviculture of the United States. New York: The Ronald Press Company; 610 p.

Balen, Barbara J., Heritage Resource Program, Pacific Southwest Region, USDA Forest Service. [Personal communication with Donald Potter]. 21 October, 1994.

Barbour, Michael G. 1984. **Can a red fir forest be restored?** Fremontia: 18-19.

Barbour, Michael G.; Berg, Neal H.; Kittel, George F.; Kunz, Michael E. 1991. **Snowpack and the distribution of a major vegetation ecotone in the Sierra Nevada of California**. Journal of Biogeography: 18:141-149.

Barbour, Michael G.; Billings, William D., eds. 1989. **North American terrestrial vegetation**. New York: Cambridge University Press; 434 p.

Barbour, Michael G.; Major, Jack., eds. 1988. **Terrestrial vegetation of California.** Sacramento, CA: California Native Plant Society; 1030 p.

Barbour, Michael G.; Pavlik, Bruce M.; Antos, Joseph A. 1990. **Seedling growth and survival of red and white fir in a Sierra Nevada ecotone**. American Journal of Botany 77(7):927-938.

Barbour, Michael G.; Woodward, Roy A. 1984. **Stand structure and natural regeneration of undisturbed red fir forests in the southern Sierra Nevada mountains**. Final Report. Cooperative Agreement PSW-83-005CA. San Francisco, CA: Pacific Southwest Region, Forest Service, U.S. Department of Agriculture; 16 p.

Barbour, Michael G.; Woodward, Roy A. 1985. **The shasta red fir forest of California.** Canadian Journal of Forest Resources 15:570-576.

Barry, Wesley J. 1971. **The ecology of Populus Tremuloides, a monographic approach.** Davis: University of California; 730 p. Ph.D. dissertation.

Bateman, Paul C.; Wahrhaftig, Clyde. 1966. **Geology of the Sierra Nevada.** In: Bailey, Edgar H., ed. Geology of northern California. Bull. 190. San Francisco, CA: California Division of Mines and Geology Ferry Building; 107-172.

Baumgartner, David M., ed. 1975. **Management of lodgepole pine ecosystems symposium proceedings.** Pullman WA: Washington State University; 495 p.

Birkeland, Peter W. 1974. **Pedology weathering, and geomorphological research.** London: Oxford University Press, Inc; 285 p.

Biswell, Harold H. 1989. **Prescribed burning in California wildlands vegetation management.** Berkeley, CA: University of California Press; 255 p.

Bonnecksen, Thomas M. 1975. **Spatial patterns and succession within a mixed conifer-giant sequoia forest ecosystem.** Master's thesis. 239 p. Berkeley, CA: University of California.

Botkin, D.B.; Sobel, M.J. 1975. **Stability in time varying ecosystems.** American Naturalist 109:625-646.

Brower, James E.; Zar, Jerrold. H. 1984. **Field and laboratory methods for general ecology.** Dubuque, Iowa: Brown Publishers; 266 p.

Brunsfeld, Steven J.; Johnson, Frederic D. 1985. **Field guide to the willows of East-Central Idaho.** Moscow, Idaho: Forest Wildlife and Range Experiment Station, University of Idaho; 95 p.

Burcham, Levi T. 1957. **California range land: An historico-ecological study of the range resource of California.** Sacramento, CA: Division of Forestry, Department of Natural Resources, State of California; 262 p.

Burcham, L.T. 1974. **Fire and chaparral before european settlement.** In: Rosenthal, Murray., ed. Symposium on living with chaparral. San Francisco, CA: Sierra Club; 101-120.

Burns, Russell M.; Honkala, Barbara H., technical coordinators. 1990. **Silvics of North America.** Vol. 1. Conifers. Agric. Handb. 654. Washington, DC: U.S. Department of Agriculture; 675 p.

Christensen, Mark N. 1966. **Late cenozoic crustal movements in the Sierra Nevada of California.** Geological Society of America Bulletin 77:229-340.

Clements, Frederick E. 1936. **Nature and structure of the climax.** Journal of Ecology 24:252-284.

Cody, Martin L.; Diamond, Jared M., eds. 1982. **Ecology and evolution of communities.** Cambridge, MA: The Belknap Press of Harvard University Press; 545 p.

Cronquist, Arthur A.; Holmgren, Arthur H.; Holmgren, Noel H.; Reveal, James L.; Holmgren, Patricia K. 1977. **Intermountain flora: vascular plants of the intermountain West, U.S.A.** Vol. 6. New York: Columbia University Press; 548 p.

Cronquist, Arthur A.; Holmgren, Arhtur H.; Holmgren, Noel H.; Reveal, James L.; Holmgren, Patricia K.; Barneby, Rupert C. 1989. **Intermountain flora: vascular plants of the intermountain West, U.S.A.** Vol.3 Part B. Bronx, NY: The New York Botanical Garden; 279 p.

Daubenmire, R. 1952. **Forest vegetation of northern Idaho and adjacent Washington, and its bearing on concepts of vegetation classification.** Ecological Monographs 22:301-330.

DeBenedetti, Steven H.; Parsons, David J. 1979. **Natural fire in subalpine meadows. A case description from the Sierra Nevada.** Journal of Forestry 77 (8): 477-479.

Denslow, Julie S. 1985. **Disturbance-mediated coexistence of species**. In: Pickett, S.T.A.; White, P.S., eds. The ecology of natural disturbance and patch dynamics. San Diego, CA: Academic Press Inc.; 307-323.

Despain, Don G. 1983. **Nonpyrogenous climax lodgepole pine communities in Yellowstone National Park.** Ecology 64:231-234.

Dice, Lee R. 1952. **Natural communities.** Ann Arbor, Michigan: University of Michigan Press; 547 p.

Dixon, W.J., ed. 1990. **BMDP statistical software manual**. Berkeley, CA: University of California Press. Volume 1 and 2; 1385 p.

Driscoll, Richard S.; Merkel, Daniel L.; Radloff, David L.; Snyder, Dale E.; Hagihara, James S. 1984. **An ecological land classification framework for the United States.** Miscellaneous publication number 1439. Washington, DC: Forest Service, U.S. Department of Agriculture; 56 p.

Eldorado National Forest. 1912. **Grazing history on the Eldorado National Forest.** Unpublished draft supplied by author.

Eyre, Francis H., ed. 1980. **Forest cover types.** Washington, DC: Society of American Foresters; 148 p.

Ferguson, Dennis E.; Morgan, Penelope; Johnson, Frederic D., compilers. 1989. **Proceedings-land classifications based on vegetation: applications for resource management.** Gen. Tech. Rep. INT-257. Ogden, UT: Intermountain Research Station. Forest Service, U.S. Department of Agriculture; 315 p.

Ferrell, George T. 1983. **Growth classification systems for red fir and white fir in northern California.** Gen. Tech. Rep. PSW-72. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 11 p.

Ferrell, George T. 1986. **Using indicator plants to assess suseptibility of California red fir and white fir to the fir engraver beetle.** Res. Note PSW-388. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 5 p.

Ferrell, George T. 1989. **Ten-year risk-rating systems for California red fir and white fir: development and use.** Gen. Tech. Rep. PSW-115. Berkeley, CA. Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 11 p.

Ford-Robertson, F.C., ed. 1971. **Terminology of forest science, technology practice and products.** Washington, DC: Society of American Foresters; 349 p.

Fowells, Harry A., compiler. 1965. **Silvics of forest trees of the United States.** Agric. Handb. 271. Washington, DC: U.S. Department of Agriculture; 762 p.

Frank, Ernest C.; Lee, Richard. 1966. **Potential solar beam irradiation on slopes: tables for 30 to 50 degrees latitude.** Res. Paper RM-18. Fort Collins, CO: Rocky Mountain Forest and Range Experiment Station, U.S. Department of Agriculture; 116 p.

Furniss, Robert L.; Carolin, Valentine M. 1977. **Western forest insects.** Washington, DC: U.S. Government Printing Office; 654 p.

Gauch, Hugh G. Jr. 1985. **Multivariate analysis in community ecology.** New York: Cambridge University Press; 298 p.

Gordon, Donald T. 1970. **Natural regeneration of white and red fir-influence of several factors**. Res. Paper PSW-58. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 32 p.

Gordon, Donald T. 1973a. **Damage from wind and other causes in mixed white fir-red fir stands adjacent to clearcuttings**. Res. Paper PSW-90. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 22 p.

Gordon, Donald T. 1973b. **Released advance reproduction of white and red fir..growth, damage, mortality**. Res. Paper PSW-95. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 12 p.

Gordon, Donald T. 1978a. **Herbs and brush on red fir regeneration areas.** Res. Note PSW-329. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 10 p.

Gordon, Donald T. 1978b. **California red fir literature: some corrections and comments**. Forest Science 24: 52-56.

Gordon, Donald T. 1978c. **White and red fir cone production in northeastern California: report of a 16 year study**. Res. Note PSW-330. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 4 p.

Gordon, Donald T. 1979. **Successful natural regeneration cuttings in California true firs**. Res. Paper PSW-140. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 14 p.

Grace, Harry D. [Letter to Adelbert Nicholls]. 1965. 6 leaves. Located at: U.S. Department of Agriculture, Forest Service, Pacific Southwest Region. Sonora, Calif.

Greenlee, John M. 1973. **A study of the fire ecology of the Emigrant Basin Primitive Area.** Sonora, CA: Stanislaus National Forest, Forest Service, U.S. Department of Agriculture; 105 p.

Greig-Smith, Peter. 1983. **Quantitative plant ecology.** Berkeley, CA: University of California Press; 359 p.

Griffin, James R.; Crithchfield, William B. 1976. **The distribution of forest trees in California.** Res. Paper PSW-82/1972. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 118 p.

Gruell, George. Retired Research Wildlife Biologist. Carson City, Nevada. [Personal communication with Donald Potter]. 6 March, 1996.

Hall, Frederick C. 1973. **Plant communities of the Blue Mountains in eastern Oregon and southeastern Washington.** Region 6 Area Guide 3-1. Portland OR: Pacific Northwest Region, Forest Service, U.S. Department of Agriculture; 62 p.

Hall, Frederick C. 1988. **Pacific northwest ecoclass codes for plant associations.** Region 6 Ecology Technical Paper 289-87. Pacific Northwest Region, Forest Service, U.S. Department of Agriculture; 164 p.

Hallin, W.E. 1957. **Silvical characteristics of California red fir and shasta red fir.** Technical Paper PSW-16. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 8 p.

Heinselman, Marion L. 1981. **Fire intensity and frequency as factors in the distribution and structure of northern ecosystems.** In: Mooney, H.A.; Bonnecksen, T.M.; Christensen, N.L.; Lotan, J.E.; Reiners, W.A., eds. Fire regimes and ecosystem properties. Gen. Tech. Rep. WO-26. Washington, DC: Forest Service, U.S. Department of Agriculture; 7-75.

Helms, John A.; Standiford, Richard B. 1982. **Release of advance growth mixed conifer species in California following overstory removal.** Report of cooperative agreement. San Francisco, CA: Pacific Southwest Region, Forest Service, U.S. Department of Agriculture; 28 p.

Hickman, James C., ed. 1993. **The Jepson manual: higher plants of California.** Berkeley, CA: University of California Press; 1400 p.

Hill, Mary. 1975. **Geology of the Sierra Nevada.** Berkeley, CA: University of California Press; 232 p.

Hill, Mark O. 1979a. **Decorana, a FORTRAN program for deterended correspondence, analysis and reciprocal averaging.** Ithaca, NY: Cornell University.

Hill, Mark O. 1979b. **Twinspan, a FORTRAN program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes.** Ithaca, NY: Cornell University.

Hitchcock, Albert S. 1971a. **Manual of the grasses of the United States.** Vol.1. New York: Dover Publications Inc.; 569 p.

Hitchcock, Albert S. 1971b. **Manual of the grasses of the United States.** Vol.2. New York: Dover Publications Inc.; 1051 p.

Hitchcock, C. Leo; Cronquist, Arthur; Ownbey, Marion; Thompson, J.W. 1969. **Vascular plants of the Pacific Northwest.** Part 1. Seattle, WA: University of Washington Press; 913 p.

Holland, Robert F. 1986. **Preliminary descriptions of the terrestrial natural communities of California**. Sacramento, CA: Department of Fish and Game, The Resources Agency, State of California; 156 p.

Hutchinson, Judy L.; Stebbins, G. Ledyard. 1986. **A flora of the Wright's Lake area.** Sacramento, CA: Cal Central Press; 237 p.

Johnson, Richard A.; Wichern, Dean W. 1988. **Applied multivariate statistical analysis.** Englewood Cliffs, NJ: Prentice Hall; 607 p.

Jones, John R. 1985. **Distribution**. In: DeByle, Norbert V.; Winokur, Robert P.eds. Aspen: Ecology and management in the western United States. Gen. Tech. Rep. RM-119. Fort Collins, Co.: Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 283 p.

Jones, John R.; DeByle, Norbert V. 1985a. **Fire**. In: DeByle, Norbert V.; Winokur, Robert P., eds. Aspen: Ecology and management in the western United States. Gen. Tech. Rep. RM-119. Fort Collins, Co.: Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 283 p.

Jones, John R.; DeByle, Norbert V. 1985b. **Genetics and variation**. In: DeByle, Norbert V.; Winokur, Robert P., eds. Aspen: Ecology and management in the western United States. Gen. Tech. Rep. RM-119. Fort Collins, Co.: Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 283 p.

Jones, John R.; Schier, George A. 1985. **Growth**. In: DeByle, Norbert V.; Winokur, Robert P., eds. Aspen: Ecology and management in the western United States. Gen. Tech. Rep. RM-119. Fort Collins, Co.: Rocky Mountain Forest and Range ExperimentStation, Forest Service, U.S. Department of Agriculture; 283 p.

Jongman, Rob H.G.; ter Braak, Cajo J.F.; van Tongeren, Onno F.R., eds. 1987. **Data analysis in community and landscape ecology.** Wageningen, The Netherlands: Pudoc Wageningen; 299 p.

Kauffman, J. Boone. 1990. **Ecological relationships of vegetation and fire in Pacific Northwest Forests.** In: Walstad, J.D.; Radosevich, S.R.; Snadberg, D.V., eds. Natural and prescribed fire in Pacific Northwest forests. Corvallis, Oregon: Oregon State University Press; 39-52.

Kershaw, Kenneth A.; Looney, Johnhenry H. 1985. **Quantitative and dynamic plant ecology.** London: Edward Arnold, WC1B 3DQ; 282 p.

Kilgore, Bruce M. 1971. **The role of fire in managing red fir forests.** Thirty-Sixth North American Wildlife Conference 36:405-416.

Kilgore, Bruce M. 1973. **The ecological role of fire in Sierra conifer forests: its application to national park management**. Quaternary Research 3:496-513.

Kilgore, Bruce M. 1981. **Fire in ecosystem distribution and structure: western forests and shrublands.** In: Mooney, H.A.; Bonnecksen, T.M.; Christensen, N.L.; Lotan, J.E.; Reiners, W.A., eds. Fire regimes and ecosystem properties. Gen. Tech. Rep. WO-26. Forest Service, U.S. Department of Agriculture; 58-89.

Kilgore, Bruce M.; Briggs, George S. 1972. **Restoring fire to high elevation forests in California.** Journal of Forestry 70:266-271.

Kilgore, Bruce M.; Taylor, Dan. 1979. **Fire history of a mixed conifer forest.** Ecology 60:129-142.

Kramer, Paul J.; Kozlowski, Theodore T. 1960. **Physiology of trees.** New York: McGraw-Hill Book Company; 642 p.

Kuchler, August W. 1964. **Potential natural vegetation of the conterminous United States**. New York: American Geographical Society; 155 p.

Laacke, Robert J.; Tomascheski, Jeanne H. 1986. **Shelterwood regeneration of truefir: conclusions after 8 years.** Res. Paper PSW-184. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 7 p.

LeConte, Joseph. 1930. **A journal of ramblings through the high Sierras of California**. San Francisco, CA: The Sierra Club; 148 p.

Leiberg, John B. 1902. **Forest conditions in the northern Sierra Nevada, California.** Prof. Paper No. 8, Series H, Forestry 5. Washington, DC: U.S. Geological Survey, U.S. Department of the Interior; 194 p.

Lewis, Henry T. 1973. **Patterns of Indian burning in California: ecology and ethnohistory.** Ballena Anthropological Papers, Vol 1. Ramona CA: Ballena Press.

Lincoln, Roger J.; Boxshall, Geoffrey A.; Clark, Peter F. 1982. **A dictionary of ecology, evolution and systematics.** Great Britain: Cambridge University Press; 298 p.

Lotan, James E.; Critchfield, William B. 1990. **Lodgepole pine.** In: Burns, Russell M.; Barbara H. Honkala, technical coordinators. 1990. Silvics of North America. Vol. 1. Conifers. Agric. Handb. 654. Washington, DC: U.S. Department of Agriculture; 675 p.

Ludwig, John A.; Reynolds, James F. 1985. **Statistical ecology: A primer on methods and computing.** New York: John Wileys and Sons; 337 p.

Major, Jack. 1988. **California climate in relation to vegetation.** In: Barbour, M.G.; Major, J., eds. Terrestrial vegetation of California. Sacramento, CA: California Native Plant Society; 1030 p.

Mattson, William J.; Addy, Norton D. 1975. **Phytophagous insects as regulators of forest primary productions.** Science 190(4214): 515-522.

Mayer, Kenneth E.; Laudenslayer, William F., eds. 1988. **A guide to wildlife habitats of California.** Sacramento, CA: California Department of Forestry and Fire Protection; 166 p.

McCarthy, Helen. 1993. **Managing oaks and the acorn crop.** In: Blackburn, Thomas C.; Anderson, Kat, eds. Before the wilderness. Menlo Park, CA: Ballena Press; 213-228.

McDonald, Geral I. 1979. **Resistance of western white pine to blister rust (cronartium ribicola): a foundation for integrated control.** Res. Note INT-252. Ogden, UT: Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 5 p.

McKelvey, Kevin S.; Johnston, James D. 1992. **Historical perspectives on forests of the Sierra Nevada and the transverse ranges of southern California: forest conditions at the turn of the century.** In: U.S. Department of Agriculture. The California Spotted Owl: A technical assessment of its current status. Gen. Tech. Rep. PSW-GTR-133. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 225-246.

McMinn, Howard E. 1939. **An illustrated manual of California shrubs.** Berkeley, CA: University of California Press; 663 p.

McNab, W. Henry; Avers, Peter E., compilers. 1994. **Ecological subregions of the United States: section descriptions.** Washington, DC: Forest Service, U.S. Department of Agriculture.

Minore, Don. 1979. **Comparative autecological characteristics of northwestern tree species: a literature review.** Gen. Tech. Rep. PNW-87. Portland, OR: Pacific Northwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 72 p.

Moeck, Henry A.; Wood, David L.; Lindahl, Kenneth Q., Jr. 1981. **Host selection behavior of Bark Beetles (Coleoptera: Scolytidae) attacking *Pinus ponderosa*, with special emphasis on the Western Pine Beetle, *Dendroctonus Brevicomis*.** Journal of Chemical Ecology 7(1): 49-83.

Moratto, Michael J. 1984. **California archaeology.** San Diego, CA: Academic Press, Inc.; 757 p.

Mueller-Dombois, Dieter; Ellenberg, Heinz. 1974. **Aims and methods of vegetation ecology.** New York: John Wiley and Sons; 547 p.

Muir, John. 1894. **The mountains of California.** New York: The Century Company; 398 p.

Muir, John. 1911. **My first summer in the Sierra.** Boston, MA: Houghton Mifflin Company; 272 p.

Munz, Philip A.; Keck, David D. 1959. **A California flora.** Berkeley, CA: University of California Press; 1905 p.

Mutch, Robert W. 1970. **Wildland fire and ecosystems-a hypothesis.** Ecology 51(6): 1046-1051.

National Oceanic and Atmospheric Administration. 1982. **Monthly normals of temperature, precipitation, and heating and cooling degree days 1951-1980, California.** Asheville, NC: Environmmental Data and Information Service, National Climatic Center.

Oakeshott, Gordon B. 1971. **California's changing landscapes: A guide to the geology of the state.** New York: McGraw-Hill Book Company; 388 p.

Oliver, Chadwick D. 1981. **Forest Development in North America following major distrubances.** Forest Ecological Management 3: 153-168.

Oliver, William W. 1986. **Growth of California red fir advance regeneration after removal and thinning.** Res. Paper PSW-180. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 6 p.

Oosting, Henry J.; Billings, William D. 1943. **The red fir forest of the Sierra Nevada: *Abietum magnificae*.** Ecological Monographs 13: 259-274.

Parker, Albert J. 1982a. **Comparative structural/functional features in conifer forests of Yosemite and Glacier National Parks, U.S.A.** American Midland Naturalist 107(1): 55-68.

Parker, Albert J. 1982b. **The topographic relative moisture index-an approach to soil moisture assessment in mountain terrain.** Physical Geography 3: 160-168.

Parker, Albert J. 1984. **Mixed forests of red fir and white fir in Yosemite National Park, California.** American Midland Naturalist 112(1): 15-23.

Parker, Albert J. 1986a. **Persistence of lodgepole pine forests in the central Sierra Nevada.** Ecology 67(6): 1560-1567.

Parker Albert J. 1986b. **Environmental and historical factors affecting red and white fir regeneration in ecotonal forests.** Forest Science 32(2): 339-347.

Parker, Albert J. 1989. **Forest/environment relationships in Yosemite National Park, California, U.S.A.** Vegetatio 82: 41-54.

Parker, Albert J. 1991. **Forest/environment relationships in Lassen Volcanic National Park, California, U.S.A.** Journal of Biogeography 18: 543-552.

Parker, Albert J. 1992. **Spatial variation in diameter structures of forests in Lassen Volcanic National Park, California.** Professional Geographer 44(2): 147-160.

Parsons, David J. 1972. **The southern extensions of tsuga mertensiana (mountain hemlock) in the Sierra Nevada.** Madrono 21(8): 536-539.

Parsons, David J.; DeBenedetti, Steven H. 1979. **Impact of fire suppression on a mixed-conifer forest**. Forest Ecology and Management 2: 21-33.

Peet, Robert K. 1980. **Ordination as a tool for analyzing complex data sets.** Vegetatio 42: 171-174

Peet, Robert K.; Christensen, Norman L. 1987. **Competition and tree death.** Bioscience 37(8): 586-595.

Pianka, Eric R. 1988. **Evolutionary ecology.** New York: Harper and Row; 468 p.

Pickett, Steward T.A. 1989. **Space-for-time substitution as an alternative to long- term studies.** In: Likens, G.E., ed. Long-term studies in ecology. New York: Springer-Verlag; 110-135.

Pickett, Steward T.A.; Parker, V. Thomas.; Fieldler, Peggy L. 1992. **The new paradigm in ecology: implication for conservation biology above the species level.** In: Fiedler, Peggy L.; Join, Subodh K., eds. Conservation biology. New York: Chapman and Hall; 65-88.

Pickett, Steward T.A.; White, P.S., eds. 1985. **The ecology of natural disturbance and patch dynamics.** San Diego, CA: Academic Press Inc.; 472 p.

Pielou, E.C. 1991. **After the ice age.** Chicago: The University of Chicago Press; 366 p.

Pitcher, Donald C. 1981. **The ecological effects of fire on stand structure and fuel dynamics in red-fir forests of Mineral King, Sequoia National Park, California**. Berkeley, CA: University of California. Masters thesis.

Pitcher, Donald C. 1987. **Fire history and age structure in red fir forests of Sequoia National Park, California.** Canadian Journal of Forest Research 17: 582-587.

Potter, Donald; Smith, Mark; Beck, Thomas; Kermeen, Brian; Hance, Wayne; Robertson, Steve. 1992a. **Ecological characteristics of old growth red fir in California**. San Francisco, CA: Pacific Southwest Region, Forest Service, U.S. Department of Agriculture; 18 p.

Potter, Donald; Smith, Mark; Beck, Thomas; Kermeen, Brian; Hance, Wayne; Robertson, Steve. 1992b. **Ecological characteristics of old growth lodgepole pine in California**. San Francisco, CA: Pacific Southwest Region, Forest Service, U.S. Department of Agriculture; 17 p.

Potter, Donald; Smith, Mark; Beck, Thomas; Kermeen, Brian; Hance, Wayne; Robertson, Steve. 1992c. **Ecological characteristics of old growth Jeffrey pine in California**. San Francisco, CA: Pacific Southwest Region, Forest Service, U.S. Department of Agriculture; 17 p.

Potter, Donald; Smith, Mark; Beck, Thomas; Kermeen, Brian; Hance, Wayne; Robertson, Steve. 1992d. **Ecological characteristics of old growth California mixed subalpine forests**. San Francisco, CA: Pacific Southwest Region, Forest Service, U.S. Department of Agriculture; 31 p.

Ratliff, Raymond D. 1985. **Meadows in the Sierra Nevada of California: state of knowledge.** Gen. Tech. Rep. PSW-84. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 52 p.

Reed, Merton J.; Powell, W. Robert; Bal, Bur S. 1963. **Electronic data processing codes for California wildland plants**. Res. Note PSW-N20. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 314 p.

Reinecke, L.H. 1933. **Perfecting a stand-density index for even-aged forests.** Journal of Agricultural Research 46(7): 627-638.

Reynolds, Richard D. 1959. **Effect of natural fires and aboriginal burning upon the forests of the central Sierra Nevada.** Berkeley, CA: Department of Geography, University of California. Masters thesis.

Richards, Lucille G. 1959. **Forest densities, ground cover and slopes in the snowzone of the Sierra Nevada west-side.** Tech. Paper 40. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 21 p.

Rundle, Philip W.; Parsons, David J.; Gordon, Donald T. 1988. **Montane and subalpine vegetation of the Sierra Nevada and Cascade ranges**. In: Barbour, Michael G.; Major, Jack., eds. Terrestrial vegetation of California. Sacramento, CA: California Native Plant Society; 559-599.

Runkle, James R. 1985. **Distrubance regimes in temperate forests.** In: Pickett, S.T.A.; White, P.S., eds. The ecology of natural disturbance and patch dynamics. San Diego, CA: Academic Press Inc; 17-33.

Salman, K.A.; Bongberg, J.W. 1942. **Logging high-risk trees to control insects in the pine stands of northeastern California.** Journal of Forestry 40: 533-539.

Sawyer, John O.; Keeler-Wolf, Tom. 1995. **A manual of California vegetation.** Sacramento, CA: California Native PLant Society; 471 p.

Scharpf, Robert F. 1969. **Dwarf mistletoe on red fir: infection and control in understory stands.** Res. Paper PSW-50. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 8 p.

Scharpf, Robert F., technical coordinator. 1993. **Diseases of Pacific coast conifers.** Agric. Handb. 521. Albany, CA: U.S. Department of Agriculture; 199 p.

Scharpf, Robert F.; Parmeter Jr., J.R. 1982. **Population dynamics of dwarf mistletoe on young true firs in the central Sierra Nevada, California.** Res. Paper PSW-161. Berkeley, CA: Pacific Southwest Forest and Range ExperimentStation, Forest Service, U.S. Department of Agriculture; 9 p.

Schier, George A.; Jones, John R.; Winkour, Robert P. 1985. **Vegetative regeneration.** In: DeByle, Norbert V.; Winokur, Robert P., eds. Aspen: Ecology and management in the western United States. Gen. Tech. Rep. RM-119. Fort Collins, Co.: Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 283 p.

Schumacher, Francis X. 1926. **Yield, stand and volume tables for white fir in the California pine region**. Berkeley, CA: College of Agriculture, Agricultural Experiment Station, University of California. Bulletin 407. University of California Printing Office; 26 p.

Schumacher, Francis X. 1928. **Yield, stand and volume tables for red fir in California.** Berkeley, CA: College of Agriculture, Agricultural ExperimentStation, University of California. Bulletin 456. University of California Printing Office; 29 p.

Secretary of Agriculture [Letter in response to Senate Resolution No. 289. **A report on the western range: A great but neglected natural resource**.] 1936. United States Government Printing Office, U.S. Department of Agriculture, Washington, DC; 620 p.

Selter, C.M.; Pitts, W.D.; Barbour, M.G. 1986. **Site microenvironment and seedling survival of Shasta red fir**. American Midland Naturalist 115: 288-300.

Slemmons, David B. 1966. **Cenozoic volcanism of the central Sierra Nevada, California.** In: Bailey, E.H., ed. Geology of northern California. San Francisco, CA: Bulletin 190. California Division of Mines and Geology; 199-208.

Smith, David M. 1962. **The practice of silviculture.** 7th ed. New York: John Wiley and Sons, Inc.; 578 p.

Soil Survey Staff. 1988. **Keys to soil taxonomy.** Blacksburg VA: International Soils, Department of Crop and Soil Environmental Services, Virginia Tech; 280 p.

Soil Survey Staff. 1990. **Keys to soil taxonomy.** Blacksburg VA: International Soils, Department of Crop and Soil Environmental Services, Virginia Tech; 422 p.

State of California. 1979. **The California water atlas**. William L. Kahrl, ed. Los Altos, CA: Sacramento: The Governor's Office of Planning and Research, General Services Publications Section; 118 p.

State of California, Dept of Water Resources. 1991. **Introduction to the California data exchange center database.** Sacramento, CA: Division of Flood Management, California Data Exchange Center, Department of Water Resources; 16 p.

State of California, Dept. of Water Resources. 1993. **1993 California snow survey measurement schedule.** Sacramento, CA: California Cooperative Snow Surveys, Department of Water Resources Reprographics, Department of Water Resources; 62 p.

Steel, Robert G.D.; Torrie, James H. 1980. **Principles and procedures of statistics: a biometrical approach.** 2d ed. New York: McGraw-Hill Book Company, Inc.; 631 p.

Sudworth, George B. 1900. **Stanislaus and Lake Tahoe forest reserves, California, and adjacent territory.** In: Annual reports of the Department of the Interior, 21st. Annual Report of the U.S. Geological Survey, Part 5. Washington, DC: Government Printing Office; 505-561.

Taylor, Alan H. 1990. **Tree invasion in meadows of Lassen Volcanic National Park.** Professional Geographer 53: 457-470.

Taylor, Alan H. Assistant Professor, Department of Geography, College of Earth and Mineral Sciences, The Pennsylvania State University at University Park, PA. [Conversation with Donald Potter] 20 September 1993.

Taylor, Alan H. 1993. **Fire history and structure of red fir (Abies magnifica) forests, Swain Mountain Experimental Forest, Cascade Range, northeastern California**. Canadian Journal of Forest Resources 23: 1672-1678.

Taylor, Alan H.; Halpern, Charles B. 1991. **The structrue and dynamics of Abies magnifica forests in the southern Cascade Range, USA.** Journal of Vegetation Science 2: 189-200.

TriMetrix, Inc. 1994. **Axum: technical graphics and data analysis.** Seattle WA: TriMetrix Inc; 326 p.

U.S. Department of Agriculture. 1941. **Climate and man.** Washington, DC: Agricultural Yearbook.

U.S. Department of Agriculture. 1974. **Soil survey Tahoe Basin area California and Nevada.** Washington D.C.: Soil Conservation and Forest Service in cooperation with the Universtiy of California Agricultural Experiment Station and the Nevada Agricultural Experiment Station; 86 p.

U.S. Department of Agriculture. 1981. **Calveg - a classification of California vegetation.** San Francisco, CA: Pacific Southwest Region, Forest Service; 168 p.

U.S. Department of Agriculture, Forest Service. **Soil survey Eldorado National Forest.** Placerville, CA: U.S. Department of Agriculture, Forest Service, in cooperation with the Soil Conservation Service and the Regents of the University of California (Agricultural Experiment Station); 317 p.

U.S. Department of Agriculture, Forest Service. **Soil survey Sequoia National Forest.** Porterville, CA: U.S. Department of Agriculture, Forest Service, in cooperation with the Soil Conservation Service and the Regents of the University of California (Agricultural Experiment Station); 310 p.

U.S. Department of Agriculture, Forest Service. **Soil survey Stanislaus National Forest.** Sonora, CA: U.S. Department of Agriculture, Forest Service, incooperation with the Soil Conservation Service and the Regents of the University of California (Agricultural Experiment Station); 158 p.

U.S. Department of Agriculture, Forest Service. 1969. Forest Service Handb. 2209.21. **Range environmental analysis handbook.** San Francisco, CA.

U.S. Department of Agriculture, Forest Service. 1974. **Seeds of woody plants in the United States.** Agric. Handb. 450. Washington DC: Forest Service, U.S. Department of Agriculture; 883 p.

U.S. Department of Agriculture, Forest Service. 1986a. Forest Service Handb. 2090.11. **Ecosystem classification and inventory**. Washington DC.

U.S. Department of Agriculture, Forest Service. 1986b. Forest Service Handb.2409.21b. **Timber management plan inventory handbook**. San Francisco, CA.

U.S. Department of Agriculture, Forest Service. 1991. Forest Service Manual 2060. **Ecosystem classification, interpretation, and application.** Washington, DC.

U.S. Department of Agriculture, Forest Service. 1992a. **Forest inventory and analysis users' Guide**. San Francisco, CA.

U.S. Department of Agriculture, Forest Service. 1992b. **The California spotted owl: a technical assessment of its current status.** Gen. Tech. Rep. PSW-GTR-133. Albany, CA: Pacific Southwest Research Station, Forest Service; 285 p.

U.S. Department of Agriculture, Forest Service. 1993. **Soil survey Sierra National Forest.** Clovis, CA: U.S. Department of Agriculture, Forest Service, in cooperation with the Soil Conservation Service and the Regents of the University of California (Agricultural Experiment Station); 151 p.

U.S. Department of Agriculture, Soil Conservation Service. 1975. **Soil taxonomy: a basic system of soil classification for making and interpreting soil surveys.** Agric. Handb. 436. Washington, DC: U.S. Government Printing Office; 754 p.

U.S. Department of Agriculture, Soil Conservation Service. 1984. **Glossary of selected geomorphic terms for western soil surveys.** Portland OR: West National Technical Center, Soil Conservation Service; 41 p.

U.S. Department of Agriculture, Soil Conservation Service. 1994. **Plants of California - alphabetical listing**; 299 p.

U.S. Department of Interior. 1975. **The effects of naturally ignited fires on components of a southern Sierra forest ecosystem.** Report for the National Park Service of grant NSF-GY-11497 from the National Science Foundation; 193 p.

Ustin, Susan L.; Woodward, Roy A.; Barbour, Michael G.; Hatfield, Jerry L. 1984. **Relationships between sunfleck dynamics and red fir seedling distribution**. Ecology 65: 1420-1428.

Vankat, John L. 1970. **Vegetation change in the Sequoia National Park, California**. Berkeley, CA: University of California; 197 p. Ph.D. dissertation.

Vankat, John L. 1977. **Fire and man in Sequoia National Park.** Annals of the association of American Geographers 67: 17-27.

Vankat, John L. 1985. **General patterns of lightning ignitions in Sequoia National Park, California.** In: Lotan, James, E.; Kilgore, Bruce M.; Fischer, William C.; Mutch, Robert W., technical coordinators. Proceedings - symposium and workshop on wilderness fire. November 15-18, 1983. Missoula, MT. Gen. Tech. Rep. INT-182. Ogden, UT: Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agricultrue; 408-411.

Vankat, John L.; Major, Jack. 1978. **Vegetation changes in Sequoia National Park, California.** Journal of Biogeography 5: 377-402.

Van Wagtendonk, Jan W. 1974. **Refined burning prescriptions for Yosemite National Park.** Occasional Paper Number 2. Washington DC: National Park Service, U.S. Department of Interior; 21 p.

Van Wagtendonk, Jan W. 1985. **Fire suppression effects on fuels and succession in short-fire-interval wilderness ecosystems.** In: Lotan, James, E.; Kilgore, Bruce M.; Fischer, William C.; Mutch, Robert W., technical coordinators. Proceedings - symposium and workshop on wilderness fire; 1983 November 15-18. Missoula, MT. Gen. Tech. Rep. INT-182. Ogden, UT: Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agricultrue; 119-126.

Van Wagtendonk, Jan W. 1986. **The role of fire in the Yosemite wilderness.** In: Proceedings - National Wilderness Research Conference; 1985 July 23-26. Fort Collins, CO. Gen. Tech. Rep. Int-212. Ogden, UT: Intermountain Research Station, Forest Service, U.S. Department of Agriculture; 2-10.

Van Wagtendonk, Jan W. 1993a. **Spatial patterns of lightning strikes and fires in Yosemite Park.** In: Proceedings of the 12th conference on fire and forest meteorology. 1993 October 26-28; Jekyll Island, GA.

Van Wagtendonk, Jan W. 1993b. **Large fire in wilderness areas.** In: Symposium on fire in wilderness and park management: Past lessons and future opportunities; 1993. March 30-April 1; Missoula, MT.

Vitorsek, Peter M.; White, Peter S. 1981. **Process studies in succession.** In: West, Darrell C.; Shugart, Herman H.; Botkin, Daniel B., eds. Forest succession: concepts and application. New York: Springer-Verlag; 267-275.

Wagener, Willis W. 1961. **Past fire incidence in Sierra Nevada forests.** Journal of Forestry: 739-748.

Wahrhaftig, C.; Birman, J.H. 1965. **The quaternary of the Pacific Mountain system in California.** In: Wright, H.E. Jr.; Frey, D.G., eds. The quaternary of the United States-a review volume for the VII Congress of the International association for Quarternary Research. Princeton, NJ: Princeton University Press; 299-340.

Walstad, James D.; Radosevich, Steven R.; Snadberg, David V., eds. 1990. **Natural and prescribed fire in Pacific Northwest Forest.** Corvallis, OR: Oregon State University Press; 317 p.

Weatherspoon, Phillip C.; Husari, Susan J.; Van Wagtendonk, Jan W. 1992. **Fire and fuels management in relation to owl habitat in forests of the Sierra Nevada and southern California.** In: U.S. Department of Agriculture. The California spotted owl: A technical assessment of its current status. Gen. Tech. Rep. PSW-GTR-133. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 247-260.

Weeden, Norman F. 1975. **A Sierra Nevada flora.** Berkeley, CA: Wilderness Press; 406 p.

Wellner, Charles A. 1987. **Classification of habitat types in the western United States.** In: Proceedings-land classifications based on vegetation: applications for resource management. Gen. Tech. Rep. INT-257. Ogden, UT: Intermountain Research Station, Forest Service, U.S. Department of Agriculture; 315 p.

West, Tom C. 1935. **Fire history.** In: Bunett, L.A. A record of forest and field fires in California from the days of early explorers to the creation of the forest reserves. Unpublished draft supplied by the author.

Westman, Walter E. 1987. **Above ground biomass, surface area, and production relations of red fir (Abies magnifica) and white fir (Abies concolor).** Canadian Journal of Forest Research 17(4): 311-319.

White, Peter S. 1979. **Pattern, process, and natural disturbance in vegetation.** The Botanical Review 45: 220-299.

Whitney, Stephen. 1979. **A Sierra Club naturalist's guide to the Sierra Nevada.** San Francisco, CA: Sierra Club Books; 526 p.

Wilde, Sergius A. 1958. **Forest soils.** New York: The Ronald Press Company; 537 p.

Williams, C.B.; Azuma, D.L.; Ferrell, G.T. 1992. **Incidence and effects of endemic populations of forest pests in young mixed-conifer forests of northern Sierra Nevada.** Res. Paper PSW-RP 212. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 8 p.

Woolfenden, Wallace B. 1994. **Historical ecology and the human dimension in ecosystem management.** Draft Region 5 Ecosystem Management Guidebook. Volume 2. Appendix I-E. San Francisco, CA: Forest Service, U.S. Department of Agriuclture; 1-38.

Wykoff, William R.; Crookston, Nicholas L.; Stage, Albert R. 1982. **User's guide to the stand prognosis model**. Gen. Tech. Rep. Int-133. Ogden, UT: Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 112 p.

Zieroth, Elaine. 1978. **The vegetation and environment of red fir clearcuts in the central Sierra Nevada, California.** Fresno, CA: Department of Biology, California State University; 125 p. Masters thesis.