KINGS RIVER PROJECT
HISTORIC FOREST CONDITION

By Ramiro Rojas, Sierra National Forest

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This description of historic forest conditions was assembled to guide restoration of historic forest structures and process within the Kings River Project (KRP). No one source can capture the variability or describes the historic conditions of the Kings River Project. Several data sources are typically used in the literature to identify the historic condition: historic oblique photos, written accounts, historic reconstructions of forest structure, (analogous relic) mixed conifer and pine forests, data sets representative of the historic condition, early aerial photographs, dendrochronology (fire scars and past growth), and repeat photography (Stephenson 1999. SNEP 1996). Descriptions, photographs and data sets are examined and compared to give a context. Specific descriptions and photographs of the Kings River Project are used when possible. Where data is lacking or incomplete that is specific to the KRP sources from other areas are used.

Sources of quantitative data

This description uses various quantitative and qualitative data sources to describe the historic condition within the KRP. Historic conditions were examined at the landscape scale and the stand scale. The landscape scale represents how stand tree canopy varied across the KRP. Landscape scale data is not available for the 1850 forest. The analysis of the landscape variability relied on literature that describes the processes that likely controlled stand structure. Canopy cover varied across the KRP landscape based on aspect, site quality, slope, forest type and fire return interval. Determinations of historical canopy were made using potential natural vegetation, site quality, historical descriptions, early photographs of KRP, aerial photographs (1940), early cruise data 1914 to 1926 (USDA 1926), and historical data sets. These determinations were inherently subjective

The stand scale examines the variability of individual stand characteristics (trees per acre, basal area, and tree distribution). The analysis of historical conditions examined quantitative data sets to determine historical conditions: existing **unmanaged** stands at the Teakettle Experimental Forest (adjacent to the KRP), **Historical** data from the turn 19th century and the 1930s (Bouldin 1999, Hasel 1931, Minnich 1995, Sudworth 1900a, Sudworth 1900b Stephens and Fiske 1998), **reconstructed** stands (North et al 2006, Taylor 2003, Covington et al 1997), analogous **relic** mixed conifer forests at the Sierra San Pedro Martir in Baja California (Stephens and Gill 2005, Minnich 2000), and existing **relic** Sierra Nevada forests not subject to fire suppression (Oliver 2001) at the Beaver Creek Pinery. In addition, the analysis compared the data sets listed above to data sets for **reconstructed** ponderosa pine found in Montana (Arno et al 1995) and the Southwest (Covington et al 1997).

Each type of data has limitations and short comings discussed in the literature (Swetnam et al 1999, Stephenson 1999). Unmanaged stands can be useful in describing the changes that have occurred in the absence of processes such as frequent low intensity fire, but are also the result of the changes that have occurred over time (e.g. density induced mortality) (North et al 2006). Historical data sets are limited by geography, unknown collection methods, or by poor coverage. Reconstructed historical conditions by nature suffer from the decay of stand structures over time, especially small trees that died shortly after the last major disturbance (Fule et al 1997).

Analogous or relic forests by nature are often small or distant from the comparison stands making direct comparisons difficult.

1) The historic forests of the Kings River Project were dominated by large trees.

Descriptions of the Sierra Nevada by observers in the late 1800's and early 1900's (Lieberg 1902, Sudworth 1900a, Sudworth 1900b, Flintham 1904, Show and Kotok 1924) indicate that the forest was dominated by trees greater than 24" in diameter at breast height. In addition, trees greater than 50 inches occurred commonly. While large trees dominated, trees less than 10 inches diameter at breast height were found infrequently (Taylor 2003, Bouldin 1999, McKelvey 1992). Examination of data collected by Sudworth in 1899 and Dunning in 1910 indicate that trees less than 11 inches occurred at a low frequency. Sudworth's data collected in 1899 within the Sierra National Forest indicate mean diameters in excess of 39" (Stephenson and Elliot-Fiske 1998).

Examinations of the VTM data collected in 1935 (Bouldin 1999) indicate that while large trees dominated, there was also great variability in tree size. This is consistent with other studies of presettelment forests that found a range in age and tree size (Bonickson and Stone 1982). This variability occurred within forest types and between forest types (Bouldin 1999, Taylor 2003, North et al 2004).

Reconstructions of historic forests in the Sierra Nevada support that trees greater than 24 inches at breast height dominated Sierra Nevada forests (Taylor 2003, North et al 2006). Reconstructions of ponderosa pine forests in the intermountain west (Arno 1995) support that large trees dominated ponderosa pine forests. Recent reconstruction of forests in the Lake Tahoe Basin and the Teakettle Experimental Forest (adjacent to the KRP) also support the conclusion that forests were dominated by large trees and less than 60 trees per acre smaller than 11 inches were present. This literature is supported by a review of the VTM data set that found 60 trees per acre smaller than 11inches in mixed conifer, 35 trees per acre were smaller than 11 inches in Jeffrey pine and 54 trees per acre smaller than 11 inches in red fir dominated stands. A similar review of historical data on the San Bernardino National Forest 1935 (Minnich 1995) also supports that large trees dominated. Figure H5 compares the numbers of trees larger than 11" dbh for several data sets. Most of the data sets have fewer than 35 trees per acre. This is especially true for ponderosa pine in the relic ponderosa pine stands in the 1910 historical data set (Hasel 1933) and Oliver (2001)

An examination of the Sierra San Pedro Martir Forest in Baja California indicates that forests disturbed by frequent fire perpetuate stands dominated by large trees (Minnich 2000).

Finally, an examination of photos taken of undisturbed forests indicates that forests in the Sierra National Forest were dominated by trees > 20 inches at breast height. Photos show very few pole size or smaller trees. Photos taken in the early 1900s do indicate a dramatic increase in conifer regeneration following the removal of fire. This flush of in-growth is observed in other areas across the Sierras (Taylor 2003, Kilgore and Taylor 1979, Vankat and Major 1978, Gruell 2001) and in the Teakettle Experimental Forest (North et al 2004, North et al 2006).

2) The historic yellow pine and mixed-conifer forests of the Kings River Project had relatively low tree densities.

Of the many descriptions of the historic 1850 mixed conifer stands of the Sierra Nevada the clearest and most succinct is by Duncun Dunning, silviculturist for California from 1910 to 1940:

> *"The situation confronting the forester was a very difficult one. As a result of early fires, insect attacks and grazing the forest were usually understocked with a preponderance of mature and decadent timber, a deficiency of intermediate classes from which to select thrifty reserves, younger trees poorly distributed or stagnating in groups and reproduction frequently absent or composed of undesirable species"(Dunning 1923).*

Other early observers noted the openness of the pine and mixed-conifer stands. Sudworth's field notes collected in 1898-1900 indicate the open nature of the pine and mixed conifer forests, noting several times that trees per acre ranged from 30 to 50 trees (Sudworth 1900a). This would agree with his representative ¼ acre plots in the Kings River drainage that range for 16 to 36 trees per acre. Flintham was charged with surveying the Sierra Reserve for the potential of regeneration of conifers in 1904. Flintham (1904) noted the open character of pine dominated stands:

> *"In this belt the forest presents a rather open stand in which the yellow pine occurs pure or predominant. The timber is often of large dimensions and very merchantable, but it stands rather scattered, reducing the acreage cut."*

Flintham noted the increase in density with more fir and sugar pine:

> "*This belt, marked by greater density, and by the presence of a heavier stand of merchantable pine timber, is the type in which the best timber in the Sierras is lumbered*."

Flintham also noted the increased density of fir dominated forest:

> "*The dense fir forests present the typical virgin condition, in which all ages and stages of development may be noted as younger growth pushes up to take a place in the forestcrown. (sic) The stand of red fir is generally very dense, …."*

Show and Kotok (1924) noted the open character of pine and mixed-confer stands as it related to frequent fire:

> *"The virgin forest is uneven-aged, or at best even-aged by small groups, and is patchy and broken; hence it is fairly immune from extensive devastating crown fire."*
>
> *"Local crown fires may extend over a few hundred acres, but stands in general are so uneven-aged and broken and have such a varied cover type that a continuous crown fire is practically impossible."*

Figure H1: The rendering on the left displays data collect by Sudworth in 1899. The photo on the right is located generally were the data used for the rendering was taken. A man is at the base of the large sugar pine in the center of the photo. A large 75" sugar pine is part of the rendering on the left.

Sudworth collected six ¼ plots within the Sierra National Forest that can be considered mixed-conifer. In addition, Sudworth collected notes and photographs of the areas he visited. The plots are subjective plots collected with bias and likely expanded to the full acre narrowly represent only the sampled areas (Stephens and Fiske 1998, Bouldin 1999). Sudworth indicated that plots were representative of entire drainages or large areas (Sudworth 1900b). That is to say that the ¼ acre plots represented the average condition and were not statistical samples. Used as representative or subjective samples these plots reflect the descriptions and photos (Figure H1). The comparison in figure H5 with other data sets of the historical forest clearly show that at the full acre the plots were not representative of average conditions. The plots indicate a range in basal area in square feet from 152 to 358 at the ¼ acre. This range indicates open to moderately dense forest. These basal area ranges are consistent with his descriptions and photographs. Sudworth's photos of the Kings River Project are consistent with open to moderately dense mixed conifer forest and open and scattered pine type (see photos H3 and H4).

Another data set that depicts historic condition of the Sierra National forest is from five ten acre plots and one six acre plot collected by Dunning and Show in 1914 and remeasured by Hasel in 1930. Trees per acre across the six acre plot averaged 45. Basal area was determined using the mid point and the upper limit of each diameter class. The basal area of the plot calculated using the mid point of the stand table was 148 square feet per acre and 208 square feet per acre using the upper limit of each diameter class. This would indicate a rather open mixed-conifer forest. This data set can also be compared with other ponderosa pine and mixed conifer forest data and yields similar results as relic stands in the Beaver creek pinery.

Addition illustrations of the nature of presettlement stand densities is contained in Sudworth's 1898-1900 plots. A rendering of Sudworth's data and a photo of mix-conifer forest on the Sierra National Forest are shown side by side to display similarities (*Figure H1*). The rendering and the photo both represent the same mixed conifer stand. The plot in *Figure H1* had several conifers that exceeded 75" in diameter at breast height. It contained 358 ft2/acre of basal area and represented 52 percent of maximum stand density index. A stand density less than 35 percent of maximum is consider below full site occupancy, while a stand density above 60 is considered at risk of density induced mortality (Long 1985, Drew and Fleweling 1979). The following table (H1) shows several plots had relative stand densities below or near full site occupancy.

PLOT	*TREES PER ACRE*	*PERCENT SDI*	*QMD*	*BA*	*CANOPY COVER*	*CROWN BULK DENSITY*
10	36	*52*	*42.7*	*358*	*57*	*0.047*
20	25	*35*	*42.6*	*247*	*45*	*0.037*
22	34	*48*	*39.8*	*293*	*51*	*0.038*
23	27	*34*	*40.6*	*242*	*41*	*0.033*
26	16	*22*	*41.8*	*152*	*35*	*0.018*
27	21	*40*	*47.1*	*254*	*47*	*0.027*

Reconstructed forests across the Sierra Nevada display a similar range in basal area per acre. At Lake Tahoe reconstruction showed a range that varied by forest type (Taylor 2003). Jeffrey pine-white fir type ranged in density from 12 to 46 trees per acre and 48 to 166 square feet of basal area with a mean of 111 square feet per acre for trees over 11 inches in diameter. Red fir-western white pine stands contained 48 to 84 trees per acre and 129 to 398 square feet per acre and a mean of 243 square feet per acre. This is similar to reconstructed forests at the Teakettle Experimental Forest measured by North et al 2006. However, North et al (2006) measured more basal area in the Teakettle forests (224 square feet) with a similar number of trees per acre (27 trees per acre)

Bouldin's review of the 1935 VTM data set indicated that basal area varied between forest types and gave the following: mixed conifer 368, Jeffrey pine 223 and red fir 384 square feet of basal area per acre. The VTM trees per acre data would also generally agree with the Tahoe data in terms of trees per acre large than 11 inches in diameter: 62 in mixed conifer, 37 in Jeffrey pine and 76 red fir.

Examinations of change in forest structure in Sequoia National Park indicate that tree densities in yellow pine stands and mixed-confer stands have generally increased (Vankat and Major 1978). The increase in density is attributed to changes in fire return intervals and grazing (Vankat and Major 1978).

The open and moderately dense character of historic mixed conifer and pine tree densities would also account for the high frequency of very large diameter trees (Poage and Tappiener 2002). They concluded that rapid and sustained diameter growth in the first fifty years was significantly correlated with large old growth trees in western Oregon. Large diameter trees may require a period early in life were tree growth is not limited by stand density. Since diameter growth and density are highly correlated (Oliver and Larson 1996), large trees would need to grow during a period when stands were near or below full site occupancy. The open stand character and low tree density is consistent between data from reconstructed presettelment stands and densities of stands in existing mixed-conifer forests with frequent fire return intervals (Minnich 2000). White fir-Jeffrey pine forests currently subject to frequent fire without fire suppression in Baja California exhibit similar stand densities (Minnich 2000). Open forests conditions are also found in relic west-side ponderosa pine stands at the Beaver Creek Pinery on the Lassen National Forest (approximately 25 greater than 11" dbh) (Oliver 2001).

3) The historic forest had high variability within forest types and between forest types.

Descriptions by Sudworth in his "Notes on Regions in the Sierra Forest Reserve" in 1900 describe the density and nature of the timber in the Sierra Reserve. He often described the change in density from north aspects to south aspects and on the basis of site quality:

> "*The north slope of this canyon bears a generally heavier stand of timber than the south slope. The commercial stand of timber on the latter slope is of a less valuable type, ranging from 2,000 to 5.000 feet, and very inaccessible on account of the rocky nature of the slope."*
>
> "*Passing from the head of Stevenson Creek, which is heavily timbered with Sugar Pine, Jeffrey and Yellow Pines, White Fir and Incense Cedar, the same heavy stand of timber prevails on the head of Dinky Creek*"

Sudworth often described the density of stands in terms of board feet:

> *"The canyon of Dinky Creek, below Dinky Meadow, is narrow and slopes to the rocky channel, but is timbered throughout. The prevailing timber is Sugar Pine and White Fir. The estimated yield is 4 to 7 million feet per 160 acres (estimate of mill cutting)."*

In addition, Sudworth's notes and photos supplement his ¼ acre plots. In his published paper covering the Stanislaus Forest Reserve he describes his ¼ acre plots as representative and displays the data unexpanded to the full acre (Sudworth 1900b). Reviews of Sudworth's 1898-1900 notes have concluded that his ¼ acre plots are problematic when expanded to the full acre (Stephens and Fiske 1998, McKelvey 1992, and Bouldin 199). His method of representative plots is similar to the subjective sampling scheme described by Lund and Thomas (1989). Using Sudworth's ¼ acre plots as representative of the average condition it becomes reasonable to examine the mixed-conifer forest structure. Two of these plots fall in the Kings River Project area. In addition to plot data, Sudworth took photographs and notes of each plot or area. The notes describe the general character of stands and watersheds. His notes include descriptions on the variability of volume and stand density. Even though Sudworth's plots seem uncharacteristically high for the KRP a review reveals some information on stand structure for mixed conifer stands. Data displayed in Table H1 indicates that even though mixed-conifer stands had high volume per acre, plots are hovering near the lower limit of full site occupancy based on stand density index (Long 1985). The lower limit of full site occupancy would indicate open to moderately dense stands.

Sudworth's descriptions of volume and density for the Dinkey watershed covers land later cruised by the Forest Service in 1914 and 1926. Volumes per acre described in the Forest Service cruise of 1914 seem to agree with Sudworth's descriptions. This cruise data was gathered by section for each township and range. Only those sections with little or no harvest activity were examined. It indicates a range in volume from 13,000 board feet to 41,000 board feet per acre across the Dinkey watershed. This is consistent with Gowen's 1922 cruise of the same watershed and the Pine Logging cruise of 1926. Gowen measured volume ranges from 11 MBF to 35 MBF. The 1926 data is by section. Sections dominated by fir have higher densities than those dominated by pine and sections on north aspects have higher volumes than those on southwest aspects.

A comparison of the PNV polygons developed from an ecological unit inventory of the Kings River Project and the 1926 Pine Logging cruise data indicates volume varied greatly by PNV. This cruise volume indicated that sections dominated by ponderosa pine PNV had stand volumes less than 11,000 board feet. Sections dominated by mixed conifer PNV had volumes as much as 3 times that of the ponderosa pine PNV.

Another data set that describes stand structures on the Sierra National Forest prior to logging was collected by Show and Dunning in 1914 and later examined by Hasel in 1931in the" methods of cut study" (Table H2). The data represents conditions in 1910 and 1911. Data for stand density in Table H2 were developed assuming all trees were at the upper limit in each diameter class. Even using this assumption that is sure to exaggerate stand density, the data describes an open stand below full site occupancy. The data is also consistent with other data sets in describing stands dominated by large trees with few trees below 11 inches DBH (Sudworth 1900a, McKelvey and Johnston 1992, Lieberg 1902). The stand has 50 percent of the site occupied by trees larger than 35 inches DBH. Photos of the sites following logging indicate that trees were clumped. Hasel describes the arrangement within the stand as "grouped or clumped". Again looking at figure H5 indicates that these plots are similar in tree number to several of the other data sets shown. However, ponderosa pine data has a lower range of trees per acre than mixed conifer data.

Upper diameter class	Trees per acre	Stand Density Index (sdi)	Volume weighted max sdi	Percent of max sdi
11	18.2	21.20		
17	7.5	17.53		
23	3.9	14.79		
29	4	21.97		
35	4	29.69		
50	7.9	103.75		
Total	45.5	208.92	618	33.80

Species	Board ft volume	Trees per acre	Volume per tree
PP	27510	14	1965.00
SP	8820	2.5	3528.00
WF	4500	2.7	1666.67
IC	4680	8.1	577.78
Total	Volume	per acre	= 45510

Table H2: 1914 data from the Sierra N.F. The data represents a ponderosa pine stand on high site. Slopes are less than 20%. Stand density are below full site occupancy assuming all trees fall at the upper range of the diameter class. Hasel 1931 (original sample by Show and Dunning 1904)

The VTM data set from 1935 is the most descriptive of the Sierra Nevada at a landscape scale. The VTM data would

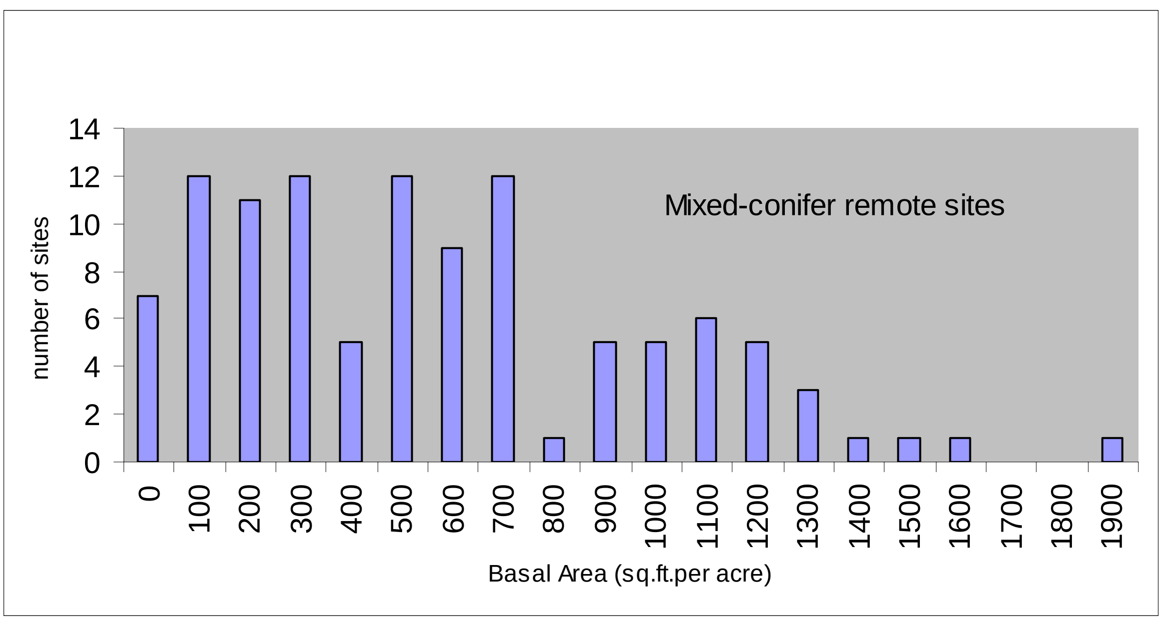


Figure H2: Bouldin (1999) displays the range in variability for two unlogged mixed-conifer areas with 1935 VTM plots.

indicate a wide range of stand structure and density (Bouldin 1999). Bouldin's review of this extensive data set indicates that stands varied greatly within forest types and between forest types. While mixed-conifer pine averaged 368 square feet per acre across the Sierras with 3 percent of the plots exceeding 1000 square feet per acre, the mean and the range changed depending on the location. The average mixed conifer stand was dense, while the average Jeffrey pine stand was relatively open. Bouldin identified two areas on the Stanislaus that were remote and not likely to have been logged prior to the VTM data collection. He suggests that these areas are representative of presettlement Sierran forests. An examination of Bouldin's Figure 71a (Figure H2) indicates that plots for these two remote areas on the Stanislaus Forest Reserve showed 54 percent of the plots located in open to moderately dense stands (0 to 500 square feet per acre). The VTM data set has more trees greater than 11" than any of the other data sets with known collection methods.

Reconstruction of historic forests at landscape scale indicate that stands were generally open and patchy (Bonickson and Stone 1982). This patchy nature was made of groups that were either homogenous in age (Bonickson and Stone 1981) or heterogeneous in age (North et al 2004). These patches were not uniformly distributed. This general description of the variability within mixed-conifer stands is supported by descriptions of the McKinely Grove of giant sequoias within the Kings River Project (Gutherie 1906). Gutherie's description of Mckinely Grove indicates it was affected by low intensity fire. Clumps of trees are interspersed with small openings created from higher severity fire. Gutherie (1906) describes one opening formed by the mortality of a dozen understory fir 100 feet tall. Research based on limited data indicates that group sizes within mixed-conifer forests ranged from .08 acres to 100s of acres (Keeley and Stephenson 2000). The highest frequency group size was those less than .49 acres (Keeley and Stephenson 2000). While 2/3 of mixed conifer presettlement groups were less than .49 acres they accounted for only one-third of the area. These ranges in gap size have been suggested for restoration of mixed conifer (Piirto and Rogers 2002). Within the Teakettle experiment forest, in contrast to Bonickson and Stones reconstruction of Redwood Creek, presettlement groups were not composed of even-aged trees but rather of many cohorts (North et al 2004). Within Teakettle trees were also clumped and that the clumped arrangement was dependent upon the soil depth and rock. Both studies would indicate that mixed conifer forests were composed of a randomly arranged widely variable distribution of tree ages and sizes. This distribution occurred at a very fine scale. This fine grained mosaic of age/size class has been noted in the reconstruction of presettlement pine forests of the interior-west with a frequent fire interval similar to the Sierra Nevada (Arno 1995). The structure on moist sites in the interior-west tended towards even-aged as a result of the catastrophic intensity of fires and tended towards coarse grained. Reconstruction of the Teakettle Forest by North et al (2004) indicates that the clustered pattern occurred at a very fine scale with the clustering pattern *occurring within a 160 foot circle.*

Flintham surveyed the Sierra Reserve in 1904. His descriptions of density by forest type, aspect and landscape position are consistent with other observation of the time (Sudworth 1900b, Lieberg 1902). In addition he describes a change in density relative to a stands position on the landscape. Pine stands adjacent to chaparral were more scattered in canopy density than those higher in elevation. In addition, fir dominated stands adjacent to pine stands or above steeper slopes were more prone to fire mortality and fragmentation. Using descriptors such as "scattered", "open", "dense", and heavy Flintham described the range of variability across the Sierra Reserve.

Other descriptions of the early 1900 Sierra are also helpful in setting limits on canopy density. Descriptions by many observers indicate that trees in the yellow pine and mixed conifer were spaced so far apart that a sustained crown fire was unlikely (Show and Kotok 1924). Flintham noted that he observed no sign of crown fire in the ponderosa pine and sugar pine stands. Flintham made special note of the mortality from fire in the dense fir stands. These descriptions while broad provides some insight on canopy density resulting from frequent low intensity fire and the less frequent higher intensity or variable intensity fire. Research by Van Wagner (1978) and modeling by Van Wagtendonk (1996) and Hollenstien (2001) indicate that crown canopies below a range of 40% offer little opportunity for active crown fire. In addition, crown bulk density figures less than 0.1 Kg/m^3 cannot support active crown fire (Scott 2003, Scott and Rienhardt 2001). One-quarter acre plots gathered by Sudworth in the Sierra National Forest all have crown bulk densities below .1 kg/m^3. Thus the historic descriptions by Show and Kotok and Flintham provide limits as described by contemporary research. The limited data also would support the low crown bulk density. The majority of the stands dominated by ponderosa pine or Jeffrey pine must have been near or below 40% canopy cover. In addition, the descriptions by Flintham of dense stands dominated by fir indicate that canopy covers often exceeded 40 % canopy cover for fir stands. Otherwise mortality as described by him would not have been observed in the fir. This is consistent with Sudworth's 1900 data set shown in Table H1.

The historic fire pattern and forest structure was the result of climate, topography, fuel load and fire frequency (Heyerdahl, Brubaker and Agee 2001, Caprio and Swetnam 1995, Arno 1995, North et al 2004, others). Reconstruction of the historic forest pattern done in the Sequoia/Kings National Park found a pattern of fire return interval strongly related to the aspect and elevation (Caprio and Swetnam 1995). Reconstruction of the presettlement Teakettle Forest indicates a strong influence in age structure, micro-site conditions and soil depth. This same variability in forest structure and pattern for presettlement forest has been documented in other parts of the Sierra Nevada and western coniferous forests (Heyerdahl et al 2001). These findings are consistent with the descriptions by early observers and would indicate that forest structure in Kings River Project would also have had a high degree of variability dependent upon climate, topography, fuel load and fire frequency.

Surveys of mixed conifer forest types which have sustained frequent fire show mean canopy cover for all trees less than 50%. The highest tree canopy density measured was 60% (Minnich1995).

4) Historic forest stand structures were uneven-aged.

Late 19th century and early 20th century descriptions of the pre-settlement mixed conifer and pine stands in the Sierra Nevada indicate that structures were dominated by uneven-aged tree distribution (Dunning 1923, Show and Kotok 1924) . Dunning (1933) concluded succinctly "The virgin stands are not even-aged". He also states the nature of the mixed conifer forest type:

> *"In relatively few sections of this large region are the stands uniform in age. All age classes are not present, as they would be in a true selection forest. Stands are usually made up of small even-aged groups, the ages of the groups differing by periods of 10 to 20 years."*

Observations of the early 1900s of the Sierra National Forest and the Kings River Project area in general would also indicate that the uneven-aged structure was dominant (Flintham 1904, Sudworth 1900a). Meyers (1934) in his description of ponderosa pine forests of the west coast including California noted the uneven-aged character and the general more open nature of the Sierra Nevada. Little data on presettlement forests was collected. What little data exists would indicate that the structure was uneven-aged but many tree distributions were present.

Several tree distributions have been suggested as representative of this historical condition. North (2005) has suggested the rotated sigmoid. Reconstruction of 1865 forest structures in the Teakettle Experimental Forest (adjacent to KREW-bull management unit) indicates that a relatively flat tree distribution existed after the last major fire (North et al 2006). Mckelvey and Johnston (1992) display data collect by Sudworth in 1900 showing a highly skewed distribution with more small trees than larger trees. Bouldin's (1999) review of the earliest sierra wide data set (VTM 1935) suggests that distributions with decreasing numbers with increasing size were dominant. Minnich's (1999) review of similar VTM data in Southern California mixed conifer forest showed flat and inverse J-shaped distributions. Data from un-harvested mixed conifer and ponderosa pine stands on the Sierra Forest Reserve measured by Dunning and Show (circa 1910) indicate an inverse-j shape was prevalent. Data from relic forest in Baja California Sierra San Pedro Martir (Stephans and Gill 2004) indicate that the dominant tree distribution was inverse-j shaped. Relic ponderosa pine forest in the Sierra Nevada structures had a flat distribution following high intensity fire (Oliver 2000), but had an inverse-j distribution prior to high intensity fire (Knapp 2006, presentation R5 fuels vegetation conference). Ponderosa pine stands across the western United States also show this variability (Arno et al 1995, Covington et al 1997). Figures H6 and H7 display the tree distribution of several reconstructed forests, historical data sets with known data collection methods and historical data with unknown methods. The table and figure indicate that eleven of the fifteen data sets have an inverse-j shaped curve or a highly skewed distribution.

An important factor in creating the uneven-aged distribution was the episodic nature of regeneration in mixed-conifer and true fir forests (Taylor 1991, Taylor 2003, North et al 2004, Battles 2000). This is similar to the episodic regeneration patterns in ponderosa pine forests of the Southwest (White 1985). Regeneration occurred after disturbances and when conditions were suitable for establishment. Regeneration patterns differed by species and between ridge tops and riparian areas (North et al 2004). Seedling survival was dependent on fire free intervals (Vankat and Major 1978, Kilgore and Taylor 1979). However, there is some evidence that in red fir dominated stands regeneration occurred independent of fire and was dependent on sufficient moisture (Taylor 1991, Taylor 1993, North et al 2004).

5) The historic mixed-conifer and pine forest had a lower frequency of shade intolerant individuals.

Several studies comment on the increased density and increased abundance and frequency of shade tolerant species in California conifer forests (Vankat and Major 1978, Minnich 1995, Bouldin 1999, others). The higher frequency of shade tolerant species is attributed by several authors to the decreased fire return interval (Skinner and Chang 1996). With the removal of fire from the landscape, white fir and incense cedar, present in drainages and on cooler aspects, seeded the open forest floor. North et al (2004) indicates that initiation of shade tolerant cohorts coincided with cessation of fire in 1865 in the Teakettle Forest. This increased establishment of shade tolerant incense cedar and white fir coincided with an increased logging of pine species and the removal of fire as a landscape process. North et al (2006) found that reconstructed mixed conifer forests at 7000 feet in elevation had a nearly 50/50 split between shade intolerant pine and shade tolerant fir and incense cedar. Measured data from the 1910's (Hasel 1931) indicates slightly higher amounts of pine. These shade tolerant incense cedar and white fir now occur at a higher frequency and at higher densities than presettlement forests(North et al 2006, Taylor 2003, Vankat and Major 1978).

6) The historic forest was greatly affected by frequent low intensity fire.

Flintham in his survey of the regeneration potential of the Sierra Reserve in 1904 wrote several sections on the influence of fire on different forest types. His conclusions were that fire varied by forest type in intensity and severity of effects. His observations were that frequent fire in the ponderosa pine and mixed-conifer types resulted in more open stands and that damage was largely confined to individual tree scaring and the mortality of seedlings and saplings. This last observation was also generally described by Show and Kotok for the Sierra Nevadas. Sudworth 1899 notes on the Sierra Reserve make mention of the ubiquitous nature of fire in all forest types. Flintham, however, makes special notes on the catastrophic nature of fire in the dense fir stands. He noted in particular the greater injury and introduction of stem rots from frequent ground fires as well as more extensive damage that resulted in the creation of brush fields.

The frequency of fire in the historic forest has often been attributed to native Indian burning (Weaver 1974). Interviews by historians with local native people also indicate that native people burned on a regular basis (Anderson 1992). In addition, cattlemen and sheepherders were responsible for lighting fires on the Sierra Reserve (Rose 1993).

Fire return intervals are generally shorter with decreasing elevation (Kilgore and Taylor 1979). Increasing amounts of white fir are found in areas with longer fire return intervals (North et al 2004). Examinations of fire return intervals within the Kings River Project have found some variation among mixed-conifer forest types with differences in the abundance of white fir and red fir. A study by Drum (1996) in the Kings River Project mixed-conifer–white fir type determined a mean pre-1900 fire return interval of less than 8 years on all sites prior to fire removal. Four of the six sites measured by Drum had mean fire return intervals less than 5 years.

Recent studies of fire return intervals in the mixed-confer forest in the Teakettle Experimental Forest in the mixed-conifer-red fir type indicate a fire return interval of 11.4 years (North et al 2004). The Teakettle Experimental Forest are located at higher elevations than the mixed-conifer forests in Drum's study. Widespread fire ceased after 1865 in the Teakettle experimental forest (North et al 2004). This lack of wide spread fire could be the result of increased grazing. Both Drum (1996) and North et al (2004) would indicate a fire return interval with in the range observed by others for the Southern Sierra Nevada (Wagner 1961, Kilgore and Taylor 1979, Skinner and Chang 1996). However, others have found an increase in fire return interval with changing aspect and elevation (Caprio and Swetnam 1995, Kilgore and Taylor 1979).

A fire return study in the ponderosa pine forest type in the Big Creek drainage found a mean fire return interval that ranged from 3.8 years to 2.2 years from 1770 to 1850 (Phillips 1998 unpublished results)

While fire scar evidence without stand structure reconstruction, such as Drum (1996) or Wagner (1961), may over estimate the fire return interval (Baker and Ehle 2001). Short fire return intervals and stand reconstruction measured by Taylor (1991, 2003) and North et al (2004), would support both descriptions of frequent fire by native people, early observers and other fire history reconstructions for the Sierras and the Kings River Project (Skinner and Chang 1996).

Some evidence of longer more intense fire return intervals does exist in dry forest types in the Southwest similar to forest types found in the Sierra (Baker and Ehle 2001).

The result of this frequent low intensity fire on the Kings River landscape was variable on stand structure and species composition. Within the stands dominated by ponderosa pine the effect was to maintain a seral pine type that was composed of irregularly spaced individuals at low density. While at higher elevations along main ridges or on north aspects the frequent fire produced vegetation that was a fine mosaic of small irregularly spaced groups. The fine scale mosaic of groups was determined by both soil depth, fuel bed and landscape location (North et al 2004). The frequent low intensity fire maintained the uneven-aged distribution. Areas of rock, lingering snow pack and low ground fuels provide barriers to fire that affected the coarse large scale pattern of vegetation. The effects of frequent fire and site conditions produce a vegetation mosaic that can be explained at the coarse scale by the Potential Natural Vegetation.

Figure H3:Picture of mixed conifer stand in the Kings River Project area 1900 taken by George Sudworth. The photo is taken within the area close to the KREW_Prov1 management unit. Sudworth's caption follows: "Yellow pine forest on north side of Big Creek toward south slope - top of ridges. Timber similar to measurements taken on Little Kern River at Shot Gun Creek camp. Chiefly yellow pine, white Fir and incense cedar. Shows the bare forest floor subject to frequent surface fires which have scarred tree trunks, see blackoned portions. Very little reproduction except in occasional small patches in open spaces."

Figure H4 Photo of ponderosa pine forest at lower elevations of Big Creek, "Interior of yellow pine forest on so. Slope of Big Creek. Incense cedar mixed 5 to 10%." Photo taken by George Sudworth 1900.

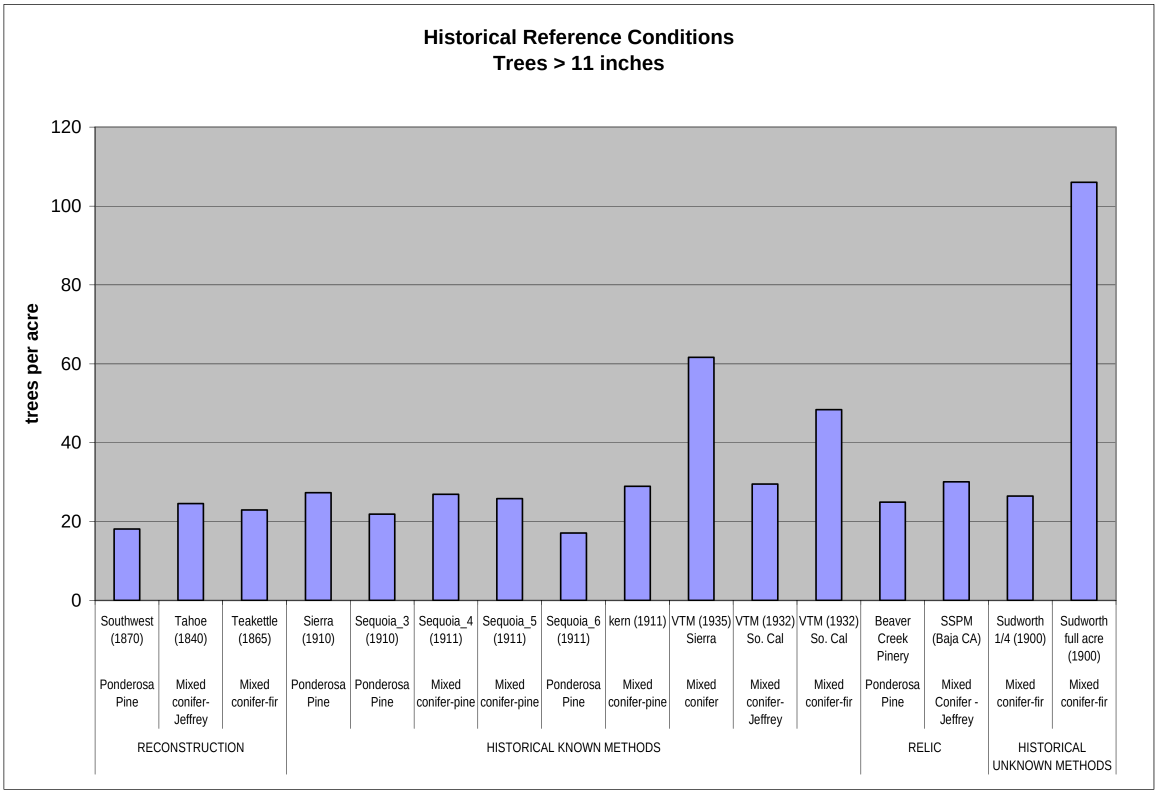
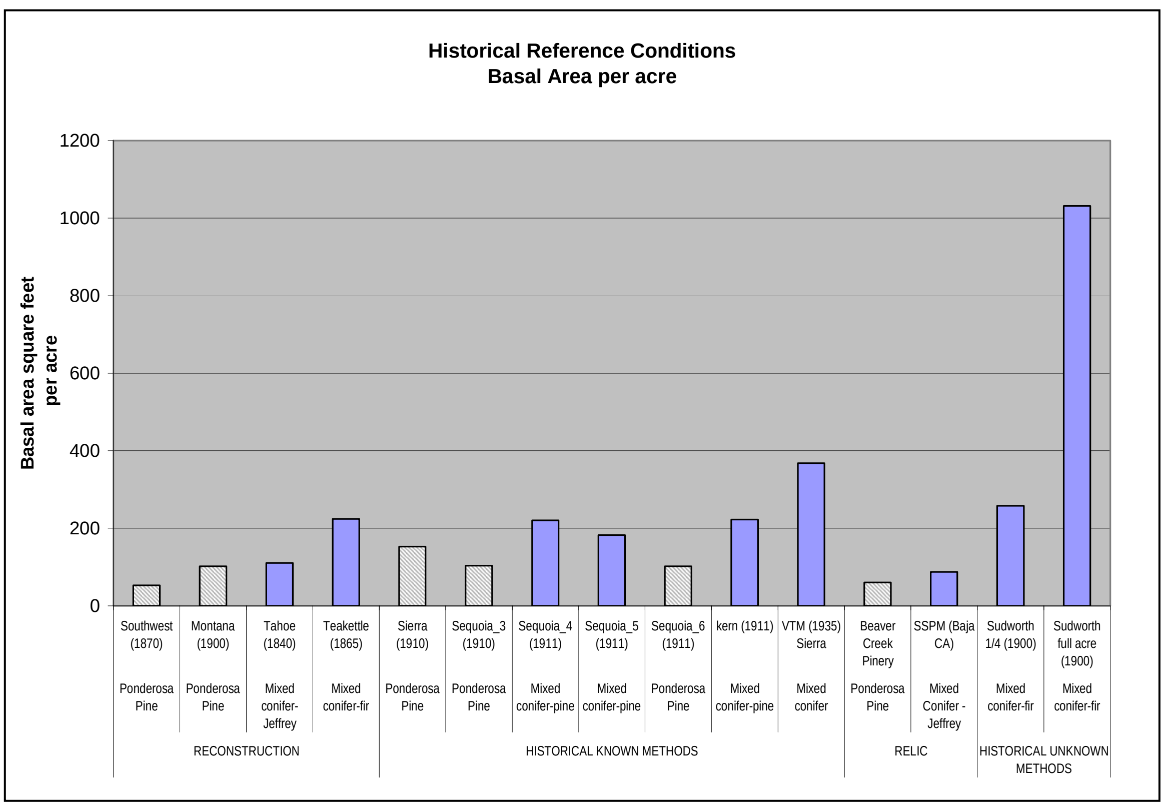


Figure H5 displays the number of trees per acre greater than 11" for reconstructed forests, relic forests in the Sierra Nevada and Baja California, and historical data sets with known and unknown collection methods. These data sets indicate that historical forest structures had relatively few trees. In addition they compare Sudworth's ¼ acre plots collected in 1900 to other data sets representing the historical condition. The comparison clearly shows that Sudworth's plots expanded to the full acre are not representative of the average historical condition. Figure H5 b below displays the basal area per acre of a subset of those in figure H5 a. Data shows the relative open nature of stands.



Data type	Forest Type	Data Set	Distribution
RECONSTRUCTION	Ponderosa Pine	Montana	modal, flat
	Mixed conifer-Jeffrey	Tahoe	skewed modal
	Mixed conifer-fir	Teakettle	flat
HISTORICAL KNOWN METHODS	Ponderosa Pine	Sierra-methods of cut	inverse j
	Ponderosa Pine	Sequoia_3-methods of cut	inverse j
	Mixed conifer-pine	Sequoia_4-methods of cut	inverse j
	Mixed conifer-pine	Sequoia_5-methods of cut	inverse j
	Ponderosa Pine	Sequoia_6-methods of cut	inverse j
	Mixed conifer-pine	Kern-methods of cut	inverse j
	Mixed conifer	Sierra VTM (1935)	various mostly invers J
	Mixed Conifer - Jeffrey	So Cal VTM (1932)	flat
	Mixed conifer-fir	So Cal VTM (1932)	inverse j
RELIC	Ponderosa	Beaver Creek Pinery	skewed modal
	Mixed Conifer - Jeffrey	SSPM (Baja CA)	various mostly inverse j
HISTORICAL UNKNOWN METHODS	Mixed conifer-fir	Sudworth 1/4	skewed modal
	Mixed conifer-fir	Sudworth full acre	skewed modal

Figure H6 displays various data that describes forest conditions prior to removal of frequent fire and logging representative of the historical condition and the tree distributions.

References

Alexander, R.R., and Edminster, C.B. 1978. Regulation and control under uneven-aged management. In Proceedings of uneven-aged silviculture and management in the United States. Washington, D.C.: Timber Management Research, Forest Service, USDA; 186-201.

Anderson, Kat. 1992. The Mountains Smell Like Fire: Indian Management of Black Oak For Acorns. Unpublished manuscript.

Arno, Stephen F and Joe H. Scott. 1995. Age-Class Structure of Old Growth Ponderosa Pine/ Douglas-Fir Stands and Its Relationship to Fire History. USDA Research Paper-481.

Baker, W. L. and D. Ehle. 2001. Uncertainty in surface-fire history: The case of ponderosa pine forests in the western United States. Canadian Journal of Forest Research 31:1205-1226.

Bonnicksen, T.M., and E.C. Stone. 1981. The giant sequoia-mixed conifer forest community characterized through pattern analysis as a mosaic of aggregations. Forest Ecology and Management 3: 307-328.

Bonnicksen, T.M., and E.C. Stone. 1982. Reconstruction of a presettlement giant sequoia-mixed conifer forest community using the aggregation approach. Ecology 63: 1134-1148.

Bouldin, J. 1999. Twentieth-century changes in Forests of the Sierra Nevada, California. Davis, CA: University of California; PhD dissertation.

Caprio A.C. and T. W. Swetnam. 1995. Historic fire regimes along an elevational gradient on the west slope of the Sierra Nevada, California. In Proceedings: Symposium on Fire in Wilderness and Park Management; 1993 March 30–April 1; Missoula, MT. General Technical Report INT-GTR-320. Ogden, UT: Intermountain Research Station, Forest Service, USDA; 173–179.

Covington W. W. and M. M. Moore.1994. Southwestern Ponderosa Forest Structure: Changes since Euro-American Settlement. Journal of Forestry 92:39–47.

Curtis, R. O. 1978. Growth and Yield in Uneven-Aged Stands. In Proceedings of uneven-aged silviculture and management in the United States. Washington, D.C.: Timber Management Research, Forest Service, USDA; 186-201.

Drew, T.J. and J.W. Flewelling. 1979. Stand density management: an alternative approach and its application to Douglas-fir plantations. Forest Service 25: 518-532.

Drumm, M K. 1996. Fire History in the Mixed Conifer Sierras of the Kings River Adaptive Management Area, Sierra National Forest. Arcata, CA: Humboldt State University; M.S. thesis.

Dunning, Duncan. 1923. Some Results of Cutting in the Sierra Forests of California. Dept. Bulletin No. 1176. Washington, D.C.: USDA.

Dunning, Duncan and L. H. Reineke. 1933. Preliminary yield tables for second-growth stands in the California pine region. Tech. Bull. No. 354. Washington, D.C.: USDA. 24 p.

Fule´, P. Z., W. W. Covington, and M. M. Moore. 1997. Determining reference conditions for ecosystem management of southwestern ponderosa pine. Ecological Applications7:895–908.

Flintham, S. J. 1904. Forest Extension in the Sierra Forest Reserve. Bureau of Forestry.

Foiles, M. W. 1978. Stand structure. In Proceedings of uneven-aged silviculture and management in the United States. Washington, D.C.: Timber Management Research, Forest Service, USDA: 176-185.

Gruell, G. E. 2001. Fire in Sierra Nevada Forests: A Photographic Interpretation of Ecological Change since 1849. Missoula, Mont.: Mountain Press.

Guldin, James M. 1991. Uneven-Aged BDq Regulation of Sierra Nevada Mixed Conifers. Western Journal of Applied Forestry 6:27-32.

Gutherie, John D. 1906. The Dinkey Grove of Big Trees: One of the little known groves of the sequoias. Forestry and Irrigation 12:454-458.

Heyerdahl, Emily K., Linda B. Brubaker and James K. Agee. 2001. Spatial Controls of Historical Fire Regimes: A Multi-scale Example from the Interior West. Ecology 82(3): 660-678.

Hollenstein, K., R.L. Graham, and W.D. Shepperd. 2001. Simulating the effects of fuel reduction and presettlement restoration treatments. Journal of Forestry 99(10): 12-19.

Keeley, Jon E. and Nathan L. Stephenson. 2000. Restoring Natural Fire Regimes to the Sierra Nevada in an Era of Global Change. In Wilderness science in a time of change conference – Volume 5: Wilderness ecosystems, threats, and management. May 23-27, 1999; Missoula, MT. Ogden, UT: Rocky Mountain Research Station, Forest Service, USDA. Proceedings RMRS-P_15_VOL-5.

Kilgore, Bruce M. and Dan Taylor. 1979. Fire History of a Sequoia-Mixed Conifer Forest. Ecology 60(1):129-142.

Lieberg, J.B. 1902. Forest conditions in the northern Sierra Nevada, California. Washington, D. C.: Government Printing Office, United States Geological Survey Professional Paper No. 8, Series H, Forestry 5.

Long, James N. 1985. A Practical Approach to Density Management College of Natural Resources. Logan, Utah: Utah State University Agricultural Experiment Station Journal Paper No. 2939.

Long, J.N. 1995. Using stand density index to regulate stocking in uneven-aged stands. *In* Uneven-aged management — opportunities,constraints, and methodologies. *Edited by* K. O'Hara.Montana Forest and Conservation Experiment Station, Missoula, Mont. Misc. Publ. 56. pp. 110–122.

Lund, G. H. and C. Thomas. 1989. A Primer on Stand and Forest Inventory Designs. Washington, D.C.: Forest Service, USDA. Gen. Tech. Rep. WO-54.

McKelvy, K.S. and J.D. Johnston. 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 The California Spotted Owl: A Technical Assessment of Its Current Status. Albany, CA: Pacific Southwest Research Station, Forest Service, USDA. PSW-GTR-133:225-246.

Mazzoni, Amie. 2002. Habitat Use by Fishers (Martes pennanti) in the Southern Sierra Nevada, CA. Fresno, CA: California State University; M.S. thesis.

Meyers, Walter H. 1934. Growth of Selectively Cut Ponderosa Pine Forests of the Pacific Northwest. Pacific Northwest Research Station, Forest Service. Technical Bulletin 407.

Minnich, R. A., M. G. Barbour, J. H. Burk and J. Sosa-Raqmirez. 2000. California mixed-conifer forests under unmanaged fires regimes in the Sierra San Pedro Martir, Baja California, Mexico Blackwell Science Ltd., Journal of Biogeography 27:105-129.

Minnich, R. A., M. G. Barbour, J. H. Burk and Robert F. Fernau. 1995. Sixty Years of Change in Californian Conifer Forest of the San Bernardino Mountains. Conservation Biology:902-914.

North, Malcolm, Jiquan Chen, Brian Oakley, Bo Song, Mark Rudnicki, Andrew Grey and Jim Innes. 2004. Forest Stand Structure and Pattern of Old-Growth Western Hemlock/Douglas-Fir and Mixed-Conifer Forests. Forest Science 50(3): 299.

North, M. , Jim I., Zald, H. 2006. Comparison fo thinning and prescribed fire restoration treatments to Sierran mixed-conifer historic conditions. In Press

O'Hara Kevin L. 1998. Silviculture for Structural Diversity: A New Look at Multiaged Systems. Journal of Forestry 96(7): 4-10.

Oliver, William W. 2001. Can We Create and Sustain Late Successional Attributes n Interior Ponderosa Pine Stands? Large-Scale Ecological Research Studies in Northeastern California. USDA Forest Service Proceedings RMRS-P-22.

Oliver, C. D. and B. C. Larson. 1996. Forest Stand Dynamics. John Wiley & Sons, Inc. New York, New York.

Piirto, Douglas D. and Robert L. Rogers. 2002. An Ecological Basis for Managing Giant Sequoia Ecosystems. Environmental Management 30(1):110-128.

Poage, Nathan J. and John C. Tappeiner, II. 2002. Long-term patterns of diameter and basal area growth of old-growth Douglas-fir trees in western Oregon. Canadian Journal of Forest Research 32:1232-1243.

Rose,Gene. 1993. Sierra centennial: One Hundred years of pioneering on the Sierra National Forest. Washington, D. C.: Forest Service, USDA. 183 pages.

Scott, Joe H. 2003. Canopy Fuel Treatment Standards for the Wildland-Urban Interface. Fort Collins, CO: Rocky Mountain Research Station, Forest Service, USDA. Proceedings RMRS-P-29.

Scott, Joe H. and Elizabeth D. Reinhardt. 2001. Assessing crown fire potential by linking models of surface and crown fire behavior. Fort Collins, CO: Rocky Mountain Research Station, Forest Service, USDA. RMRS-RP-29.

Show S. B. and E. I. Kotok. 1924. The Role of Fire in the California Pine Forests. Washington, D. C.: USDA. Dept. Bulletin No. 1294.

Skinner, C.N and Chang, C. 1996. Fire regimes, past and present. In: Sierra Nevada Ecosystem Project: Final report to Congress, Vol. II, Assessments and scientific basis for management options. Davis, CA: University of California at Davis, Centers for Water and Wildland Resources. Wildland Resources Center Report No. 37:1041-1069.

Smith, David M. 1986. The Practice of Silviculture. John Wiley & Sons Inc., New York, New York.

Smith, Mark T. and J. D. Exline. 2002. An Uneven-aged Management Strategy: Lessons Learned. In: Proceedings of a Symposium on the Kings River Sustainable Forest Ecosystems Project: Progress and Current Status. January 26, 1998; Clovis, CA. Albany, Ca.: Pacific Southwest Research Station, Forest Service, USDA. Gen. Tech. Rep. PSW-GTR-183:19-30.

Stephens, Scott L. and Deborah L. Elliott-Fisk.1998. *Sequoiadendron Giganteum*-Mixed Conifer Forest Structure In 1900-1901 From the Southern Sierra Nevada, CA. Madrono 45(3): 221-230.

Stephens, Scott L.; Gill, Samantha J. 2005. Forest structure and mortality in an old-growth Jeffrey pine-mixed conifer forest in northwestern Mexico. Forest Ecology and Management 205 (2005) 15–28

Stephenson, N. L. 1999. Reference conditions for giant sequoia forest restoration: structure, process, and precision. Ecological Applications 9:1253-1265.

Sudworth, G.B. 1900b. Stanislaus and Lake Tahoe Forest Reserves, California, and adjacent territory. Washington, D. C.: Government Printing Office, United States Geological Survey Professional Paper No. 8, Series H, Forestry 5.

Sudworth, G.B. 1900a. Notes on Regions in the Sierra Forest Reserve 1898-1900. Unpublished.

Taylor, Alan H. 2003. Climatic influences on fire regimes in the northern Sierra Nevada mountains, Lake Tahoe Basin, NV, USA. Journal of Biogeography 31:1-14.

Taylor, Alan H. and Charles B. Halpern.1991. The structure and dynamics of *Abies magnifica* forests in the southern Cascade Range, USA. Journal of Vegetation Science (2): 189-200.

Vankat, John L. and Jack Major.1978. Vegetation changes in Sequoia Nation Park, California Blackwell Scientific Publications Res. Paper, Journal of Biogeography 5:377-402.

Van Wagner, C. E. 1977. Conditions for the start and spread of crown fire. Canadian Journal of Forest Research. 7:23-34.

Van Wagtendonk, Jan W. 1996. Use of Deterministic Fire Growth Model toTest Fuel Treatments. In: Sierra Nevada Ecosystem Project: Final report to Congress, Vol. II, Assessments and scientific basis for management options. Davis, CA: University of California at Davis, Centers for Water and Wildland Resources. Wildland Resources Center Report No. 37:1155-1165.

Verner, Jared, Kevin S. McKelevy, Barry R. Noon, R. J. Gutierrez, Gordon I. Gould, Jr., and Thomas W. Beck.1992. The California Spotted Owl: A Technical Assessment of Its Current Status. Albany, CA: Pacific Southwest Research Station, Forest Service, USDA. PSW-GTR-133. 285 pages.

Verner, Jared. 2002. Proceedings of a Symposium on the Kings River Sustainable Forest Ecosystems Project: Progress and Current Status. January 26, 1998; Clovis, CA. Albany, Ca.: Pacific Southwest Research Station, Forest Service, USDA. Gen. Tech. Rep. PSW-GTR-183. 154 pages.

Wagner, Willis W. 1961. Past Fire Incidence in Sierra Nevada Forests. Journal of Forestry 59(10): 739-748.

Weaver, Harold.1974. Effects of Fire on Temperate Forests: Western United States. In Fire and Ecosystems. Academic Press, New York, New York. 542 pages.

White, Alan S. 1985. Presettlement Regeneration Patterns in a Southwestern Ponderosa Pine Stand. Ecology 66(2): 589-594.