United States Department of Agriculture

Forest Service

R5

Reply To: 2060

Date: JUN 1 9 1992

Subject: Old Growth Definitions/Descriptions for Forest Cover Types

To: Forest Supervisors and Station Director, PSW-Albany

Enclosed for your use in forest planning and your resource management program is a copy of each old growth definition/characteristics for eleven forest cover types, all of which occur in Region 5. Each of these OG definitions was written by a team of resource specialists having ecology, silviculture and wildlife expertise and were subject to reviews at various levels of the organization including research. Some individuals from public groups participated in the review process as did FS employees from Region 6.

These old growth definitions/characteristics were written using the best information/data available to the teams. The data used included the FIA database and the data collected by forest ecologists during the ecological classification sampling. These definitions are final at this time. However, as we continue to learn more about the ecological characteristics of the forest types, we will want to revisit these definitions. For now use these definitions/characteristics as appropriate. Should you have any question concerning this work please contact the authors directly, Mike Srago (in Timber Management) or David Diaz (in Range and Watershed). Enclosed is the list of cover types and principle authors.

for Andrew A. Leven

RONALD E. STEWART
Regional Forester

Enclosures

Old Growth Definitions/Characteristics for Eleven Forest Cover Types
Pacific Southwest Region, California
San Francisco, CA

1. SAF 207. Ecological Characteristics of Old Growth Red Fir in California. 1992. Potter, Don, Zone 5 Ecologist, Stanislaus National Forest, Sonora, CA and others

2. SAF 211. Preliminary Ecological Old-Growth Definitions for White Fir. 1991. Fites, Jo Ann, Zone 4 Ecologists, Eldorado National Forest, Placerville, CA, and others.

3. SAF 218. Ecological Characteristics of Old Growth Lodgepole Pine in California. 1992. Potter, Don, Zone 5 Ecologist, Stanislaus National Forest, Sonora, CA and others.

4. SAF 229. Ecological Definition for Old-growth Pacific Douglas-fir. 1991. Jimerson, Tom, Zone 1 Ecologist, Six River National Forest, Eureka, CA and others.

5. SAF 232. Interim Guidelines Defining Old Growth Stands: Coast Redwood (SAF 232) of Southern Monterey County California. 1991. Borchert, Mark, Zone 7 Ecologist, Los Padres National Forest, Santa Barbara, CA and others.

6.SAF 234. Ecological Definition for Old-growth Douglas-fir/Tanoak/Madrone. 1991. Jimerson, Tom, Zone 1 Ecologist, Six Rivers National Forest, Eureka, CA. and others.

7. SAF 237. Revised Interim Old Growth Definitions for Interior Ponderosa Pine (SAF237) in Northeast California. 1991. Smith, Sydney, Zone 2 Ecologist, Modoc National Forest, Alturas, CA and others.

8. SAF 243. Preliminary Ecological Old-Growth Definitions for Mixed Conifer (SAFTYPE 243) in California. 1992. Fites, Jo Ann, Zone 4 Ecologist, Eldorado National Forest, Placerville, CA and others.

9. SAF 245. Interim Guidelines Defining Old Growth Stands: Pacific Ponderosa Pine (SAF 245) Pacific Southwest Region. 1991. Smith, Sydney, Zone 2 Ecologist, Modoc National Forest, Alturas, CA and others.

10. SAF 247. Ecological Characteristics of Old Growth Jeffery Pine in California. 1992. Potter, Don, Zone 5 Ecologist, Stanislaus National Forest, Sonora, CA and others.

11. SAF 256. Ecological Characteristics of Old Growth in California Mixed Subalpine Forests. 1992. Potter, Don, Zone 5 Ecologist, Stanislaus National Forest, Sonora, CA and others.

Ecological Characteristics of Old Growth Jeffrey Pine in California

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INTRODUCTION

The Chief, Forest Service has directed all Regions to prepare quidelines which define old growth for major forest types. These guidelines have been prepared in response to that direction. In Region 5 of the Forest Service an effort is also underway to classify forested areas into Ecological Types for purposes of management and research. Since many of the samples taken for this project were in late seral stands of Jeffrey pine (Pinus Jeffreyii), they were examined to determine which characteristics could be used to describe old growth stands in these forests. This paper describes the features of these forests useful in such a characterization, and it provides guidelines that can be used to define old growth stands that lie in the Jeffrey pine cover type (247) recognized by the Society of American Foresters (1980). Results are summarized in Table 1 on page 14.

DISTRIBUTION

In California, Jeffrey pine lies in 5 broad geographic regions. In the northern portion of the state, in the Klamath Mountains, the northern Coast Ranges, and west of the Modoc Plateau it is commonly found on xeric sites with ultramafic soils or at elevations generally above 5,000 feet. In the eastern portion of the Cascades, and on the Modoc Plateau it lies on xeric sites often in mixture with ponderosa pine (Pinus ponderosa) where stands are collectively referred to as eastside pine. Further south on the eastside of the Sierra Nevada it forms a distinct zone between the higher red fir forests and the pinyon-juniper,sage forests to the east. On the westside of the Sierra Nevada it is often found at higher elevations in open stands on glaciated sites which lie on south to southwest slopes or on ultramafic outcrops at lower elevations. In the Transverse and Penninsular Ranges of southern california stands are open and almost pure on south slopes and xeric uplands.

METHODS

Samples came from two sources. One hundred fifty nine samples were collected as part of the Ecological Type Classification being conducted by Region 5 of the Forest Service (Allen, 1987). They were intended to be used for classification purposes. The basic unit of sample was a stand, and no limits were placed on size of stand for sampling purposes. Stands were selected based on their appearance as relatively undisturbed habitats with homogeneous species composition in late seral condition. The concept used to select stands was to sample from a range of aspects. elevations, species composition, soil types, community structure, and site index. No attempt was made to include or exclude sample stands because of features suspected of describing old growth characteristics. For this reason, the samples selected are felt to represent conditions in the majority of Jeffrey pine stands in these forests. Variation in species composition, cover values, structural diversity, and habitat was sought rather than indications of the aging process. An additional 76 samples were obtained from forest inventory records for the National Forests in Southern California. Since these stands were generally lightly disturbed by logging, if at all, it was felt changes in species composition or stand structures would be minor. Visual examination of these stands verified this conclusion. The total data set from which the descriptions were developed was 235 samples.

Data collection followed the procedures described in the Region 5 Ecosystem Classification Handbook and the Region 5 Timber Management Plan Inventory Handbook. At each sample site a 1/10 acre circular plot was used to gather information on species composition, cover values, abundance and environmental setting. One tenth acre and 1/2 acre circular plots were used to obtain information on snags and logs. A 3 point "cluster" was used to establish variable radius plot centers as the basis for determining tree species composition, stand structure, basal area, and volume. Determination of site index came from a sample of height and age of dominant and codominant trees on each point in the cluster. Diameters were recorded in classes for purposes of data analysis. The diameter classes used were: 1-5.9", 6-10.9", 11-17.9", 18-24.9", 25-29.9", 30-39.9", and 40"+.

Throughout its range Jeffrey pine is associated with several other species. These species include ponderosa pine, sugar pine (Pinus lambertiana), white fir (Abies concolor), red fir (Abies magnifica and Abies magnifica var. shastensis), noble fir (Abies procera), incense cedar (Calocedrus decurrens), western white pine (Pinus monticola), lodgepole pine (Pinus contorta var. murrayana), and western juniper (Juniperus occidentalis). Quaking aspen (Populus tremuloides) is a commonly associated hardwood in the Sierra Nevada. To meet the criteria for the Jeffrey pine type, stands must contain a majority of the basal area stocking in Jeffrey pine. The stands sampled here contained more than 50% of the basal area in Jeffrey pine. The following National Forests and National Parks were represented in the sample: the Klamath, Shasta-Trinity, Modoc, Lassen, Plumas, Tahoe, Eldorado, Stanislaus, Sierra, Sequoia, Inyo, Lake Tahoe Basin Management Unit, Angeles, Cleveland, San Bernardino, Los Padres, and Toiyabe National Forests and Yosemite and Sequoia-Kings Canyon National Parks.

Stand ages were based on the age of the oldest tree measured on each site. samples used for classification purposes usually had three dominant or codominant trees measured per site. In many cases, because of species or size differences, additional trees were measured. Forest inventory plots generally had 5 trees measured per site. No attempt was made; however, to fully age each stand through a complete sample of all size classes. Furthermore, to attempt to report average stand ages from stands with skewed and irregular structures, as many of these are, could also be misleading. Therefore it was decided to use the age of the oldest tree. This is in agreement with investigators doing work in other types (Schumacher 1928, Veblen 1985).

Forty nine variables were examined. They centered around 4 areas of concern: the effects of species composition, changes in cover values, stand structure, and biomass accumulation over time. The analysis proceeded in two parts. First, information on stand structure, trees and snags per acre by diameter group, species composition and site index were determined for each sample using R5*FA.FIA-SUMMARY and R5*FS.FIA-MATRIX a series of Region 5 timber inventory and data expansion programs known as Forest Inventory and Analysis (FIA). Each plot was also processed through PROGNOSIS, a stand growth and yield simulation model developed by Stage and others (Stage 1973) to determine values for quadratic mean diameter, stand density index, and total cubic foot volume. Values from these programs were combined into a single data set for further analysis. Cover values for shrubs, forbs, and grasses were obtained from data sets developed for the classification projects where available. A subset of 105 samples where snag information was collected was used to develop the snag values reported. Insufficient data has been collected for an analysis of log and other downed woody material; so, no values are reported. Samples were then aggregated into two site index groups: Region 5 site index 0 to 3 representing high sites, and Region 5 site index 4 and 5 representing low sites.

Variables were tested for normality and transformed as necessary for statistical analysis. The analysis used regression techniques to explore diameter, height, and age relationships of individual trees by species and site group. This was followed by examining survivorship curves for individual species and stands. Scatter plots and linear regression were used to explore relationships among variables over time, and time series and regression was then used to look in detail at the data through time. The results of this analysis became the framework for which an Analysis of Variance to isolate variables correlated with differences in age was performed. Finally, the ability of those variables to differentiate between age groupings were tested using Discriminant Analysis techniques.

RESULTS

The data set for Jeffrey pine is not large for younger stands. Consequently, clear patterns of early stand development could not be fully examined. However, based on work in other types, it would appear that similar patterns of stand development through time are present. For example, red fir, an associate on many Jeffrey pine stands on the westside of the Sierra Nevada, develops features characteristic of older stands in approximately 150 years on sites 0 to 3 and 200 years on sites 4 to 5. The analysis performed for Jeffrey pine indicates similar patterns.

Height-diameter relationships indicate that Jeffrey pine usually reaches 30 inches in diameter and 100 feet in height in 150 years on sites 0 to 3, and 30 inches in diameter and 68 feet in height in 200 years on sites 4 to 5. The oldest Jeffrey pine trees sampled were 663 years on sites 0 to 3 and 587 years on sites 4 to 5. Suvivorship curves show substantial loss of trees beginning around 80 years and continuing until nearly 400 years. This would appear to indicate that losses later in the life of a stand are due to more than inter-tree competition. While early losses are probably due to natural thinning, environmental factors such as fire, drought, insects, disease, or wind eventually become major contributors to mortality. A final, prolonged period of mortality begins around 400 and continues until nearly 700 years. Losses during this time appear to reflect the effects of both environment and physiological failure.

Time series analysis showed consistent and large variation in biomass accumulation by site class in older stands. This was correlated with changes in the distribution of trees by size class, and reflected a steady mortality in large trees with concurrent recruitment of small trees through time. Examination of stand structures over time illustrated these patterns well. They showed that in most of the stands sampled many size classes are occupying sites simultaneously. Older stands are characterized by a high number of small trees, a substantial number of trees in the middle size class (25-30 inches DBH), and a significantly higher component of trees larger than 30 inches DBH.

On undisturbed sites with high site index the picture that emerges from the data is one of large numbers of small trees occupying stands at some point after a major stand replacing event. This is followed by significant losses due to thinning early in the life of the stand, a mature phase in which trees in the 24 to 30" DBH range are common, and it is followed still later by a stabilized condition characterized by a constantly changing structure in which many size classes are present on a site simultaneously. This last condition results as small gaps and openings are created in a mature overstory in response to environmental conditions such as fire, wind, or drought. Regeneration then establishes in these openings, grows, self thins, and matures. In time, several size classes, including a substantial portion of larger trees, are represented,and the stand exhibits an irregular structure. For example, on sites 4 to 5 in stands younger than 200 years, trees between 2 and 18 inches in diameter constiute 74% of the total number of trees. In stands older than 200 years they consitute 77% of the total. On sites 0 to 3 these conditions seem to occur around 150 years. It also occurs on many, but not all, low sites around 200 years. This corresponds with structures found to be representative of old growth conditions in red fir, lodgepole pine, and the California mixed subalpine type (256) in the Sierra Nevada (Potter, unpublished). It supports the hypothesis that as stands occupy sites for longer and longer periods environmental factors become more important in developing stand structures that characterize old growth conditions. These same factors continue to be important in maintaining old growth conditions until the site suffers a stand replacing event, and the cycle renews.

Often on many low sites the patterns appear to be different. Many of these stands are very open with low tree densities. Except for sites with a high shrub component, it is difficult to imagine enough fuel load to carry a stand replacing fire. Nor does experience indicate that other events such as insects or disease would replace entire stands. Avalanche would appear to be the one environmental factor capable of such an event, and while common in certain areas in the Sierra Nevada, they are not widespread in the range of Jeffrey pine. This implies that these stands do not cycle through a stand initiation phase in which high numbers of trees originate more or less simultaneously and progress through time as cohorts. Rather, stand development appears to be sporadic as opportunities arise in response to disturbance levels. Small patches or stands may react similar to better sites with simultaneous stand origin, followed by crown closure, self thinning, and stand opening as gaps are created. However, in most cases, it appears stand initiation is a prolonged process with many aborted attempts. Stand development occupies considerable periods of time, and during these long periods the probability is high that an environmental event will impact the stand and recycle portions back to an earlier period. Inevitably, some individuals escape environmental damage and mature into larger members of the stand. In time, the stand takes on a very open appearance with an irregular stand structure dominated by large trees which are the survivors of several stand altering events. Thus, these stands arrive at an overall structure similar to better sites but with lower densities, a greater proportion of large trees, and through a different process of development. Other than in early stages of stand initiation, mortality appears to be responding to environmental circumstance more than competition.

Variables that could be used to distinguish between age groups were examined by One-way Analysis of Variance and Discriminant Analysis techniques. Several variables were identified, and those that would be useful in field applications were incorporated into the descriptions In most cases snag numbers were highly variable with skewed distributions, and reliable comparisons with Analysis of Variance techniques could not be developed.

When comparing stands less than 150 years with those over 150 years on sites 0 to 3 and those less than 200 with those over 200 on sites 4 to 5 several variables were found to be significantly different at the 95% probability level. These results are summarized as follows:

Variables significantly higher by age group

Sites 0-3

<150 Years	>150 Years
Trees per acre 18-24" DBH	Stand Density Index
	Cubic Foot Volume
	Total Basal Area
	Height of Dominant Trees
	Trees per acre >30" DBH

Sites 4-5

<200 Years	>200 Years
Trees per acre 18-24" DBH	Total Basal Area
	Quadratic Mean Diameter
	Cubic Foot Volume
	Height of Dominant Trees
	Trees per acre >30" DBH

These variables were then examined by Stepwise Discriminant Anlaysis. On sites 0 to 3, a 95% correct classification function was attained using Stand Density Index and height of dominant trees. In essence, this means the presence of denser stands and the attainment of most of the height growth potential of the site by dominant trees could be used to discriminate older stands on sites 0 to 3.

On sites 4 to 5 an 82% correct classification function was attained using the number of trees between 18 and 24" and the number of trees between 30 and 40 inches. Theoretically, the higher numbers of trees per acre between 18 and 24 inches could be used to differentiate stands less than 200 years, while the number of trees per acre between 30 and 40 inches could be used to differentiate stands older than 200 years.

In actual practice, the use of several variables is preferred to a paired down list. The variability of many characteristics of these stands is often wide, and if more variables can be used in concert to distinguish between older and younger stands a better solution on the ground is likely. On the other hand, some of the variables identified in the analysis are impractical for field use. Stand Density Index, Quadratic Mean Diameter and Total Cubic Foot Volume are examples. For this reason, variables which were felt to be more easily observed on the ground are included.

DISCUSSION

Models of stand dynamics in old growth forests are not abundant. Foresters commonly use the culmination of mean annual increment to define the point at which stands are considered mature. In California, yield tables have not been developed for Jeffrey pine. The only commonly associated species for which such work has been done is red fir. In red fir forests, available yield tables (Schumacher, 1928) indicates the culmination of mean annual increment to be around 140 years. The age at which stands assume old growth characteristics is unclear using this guide.

The Society of American Foresters cover types provide a description of vegetation existing on sites at the moment. They convey little insight into the change of vegetation over time. Conceptual models such as successional change, climax conditions, or potential natural vegetation that may be useful in gaining insights into old growth conditions are not a part of such descriptions. They do not, for example, explore the variation in species composition, stand structure, or ecosystem functioning that links particular plant communities to specific habitats over time. They do, however, provide a practical tool that can be used in large scale inventory and for cross regional comparisons.

Vegetation in the forests occupied by Jeffrey pine has been stabilizing over long periods of time. In the Sierras, for example, the last major glacial advance appears to have ended around 10,000 years ago, and the vegetaion on vacated sites has been sorting itself out ever since. In other areas, volcanism or climatic shifts have been creating similar conditions. Time in these forests is a continum of which human perception catches only a glimpse. Relatively few stands of Jeffrey pine originate within a specific period, develop as cohorts, and die simultaneously. Stand destroying fires do occur in Jeffrey pine. Except under eastside conditions, however, this does not appear to be a widespread or large scale phemomenon. Neither do blowdown, insects, disease, lightning, or avalanche appear to be the type of impacts which replace entire stands of Jeffrey pine. Records (Potter, unpublished) indicate that all of these factors are operating in these forests continuously, but generally on a small scale. This results in a constantly changing species composition and structure within a stand as individuals and small groups of trees and other vegetation are cycled into and out of the stand in different amounts at different times. This makes it difficult to define the age of a stand other than in a general sense, but it does focus attention on charactersitics other than age which are suggestive of the passing of time within a particular stand.

A model felt to be applicable to better sites and some low sites, and one which seems to fit observations in the field, is that outlined by Peet and Christiansen (1987) and developed initially by Oliver (1981). Under this model four phases of stand development are recognized: establishment, thinning, transition, and the steady state. Competition induced mortality is a key feature of stands in the thinning phase, which can last for relatively long time periods depending on species; however, the transition and steady state phases are of most interest here. During the transition phase mortality becomes independent of stand density, gaps in the canopy occur, and these are filled with young age classes. This phase may last for several decades. The steady state forest is then typified by an uneven age or irregular structure composed of relatively small even age patches. This pattern cycles over time as younger patches become established, thin themselves, and form gaps. All three of the earlier phases are present simultaneously. This stage can be terminated by a stand replacing disturbance such as fire. As noted earlier, this model does not fit all cases on lower sites. The model described in the Results section seems to provide better agreement with field observations in these cases; nevertheless, the steady state forest does seem to develop essentially the same general structure over time. It appears this form can be used to define old growth forests of Jeffrey pine, and that is the approach used here.

The distinction between transition and steady state is not sharp. It may cover several decades. Therefore, attention was focused on identifying variables that could be used to approximate the age at which stands developed features typical of a transition phase. Once this age was identified it was assumed that older stands would be in a transition or steady state condition if they continued to exhibit characteristics such as an irregular or uneven age structure, presence of larger trees, and relatively high stand density for the site. No attempt was made to differentiate between the transition and steady state phases since forests in both phases have similar characteristics.

The point at which a period of increasing Quadratic Mean Diameter in younger developing stands is followed by a significant decrease was one feature that might suggest the beginning of the transition phase. A decrease in Quadratic Mean Diameter would imply the stand was breaking up. It would be expected to coincide with an increase in regeneration and smaller size classes (saplings and poles). This would indicate the formation of gaps in the canopy that could not be filled by crown closure and became available for regeneration. The presence of large numbers of these smaller trees reduces the quadratic mean diameter. Stand density index usually increases at this time as well. As noted earlier, the data set for Jeffrey pine forests contains few samples in early seral condition, and the point at which Quadratic Mean

Diameter increases substantially and is followed by a sharp decline was not obvious. What is clear from the data is that most of these stands have apparently already arrived at a condition that can be described as old growth. Considerable variation in productivity, Quadratic Mean Diameter, and density is occuring, and this variation is reflected in the structure of the stands. Many size classes are present including regeneration and small trees. This indicates the opening of the stand and establishment of younger age classes has occurred.

Development of larger size trees is a trait that progresses over time, and this can often be used to indicate advancing stand age. Generally, at the point of transition the number of larger trees increases to levels that are typical from that point on. This is usually further substantiated when the number of trees in the smaller size class decreases significantly at the same time. This decrease results from both growth of smaller size classes into larger classes as well as a response to competition-induced mortality which tends to thin suppressed individuals of smaller size classes. As noted above, the data set for Jeffrey pine does not provide a clear picture of early stand development, and most of the stands in the sample are felt to already be in an old growth condition. What can be observed is that trees larger than 30 inches are present in somewhat larger numbers. They vary over time in response to environmental conditions, but they have essentially become permanent features of the stand.

Generally, mortality becomes independent of density as stands age. This does seem to be the case for these forests. Survivorship curves on both high and low sites show a steady decline in individuals punctuated by periods of increased mortality. Losses in young stands are obviously density related and represent competition induced mortality. Higher mortality rates in older stands are also apparent. These are less obviously related to stand density, and presumably they reflect higher losses due to environmental conditions. Time series show low correlation between numbers of large snags and stand density index. These conditions would seem to indicate that at least some mortality is occuring which is independent of density.

Under the model presumed to describe these forests, an irregular or uneven age structure would be present in stands past the transition phase. This structural pattern has been noted elsewhere as characteristic of "old growth" (Assman, 1978; Baker, 1962; Veblen, 1985; Parker, 1985; Taylor, 1991). Profiles of diameter distributions indicate structures skewed to the right with high numbers of trees less than 11 inches during the thinning phase. Large size classes are few. Past the thinning phase, few of the samples fit an ideal "reverse J" pattern of an optimally distributed uneven age stand, but an irregular or somewhat bimodal structure in which regeneration is low, trees less than 12 inches are overrepresented, and those between 25 and 30 inches are also overrepresented is common. In most stands at least 3 size classes appear to be present. While there are many patches that exhibit the "normal" distribution of even age stands, they generally do not cover large, continuous areas. Trees from different size classes tend to be distributed randomly or in small patches within a stand. If the general structure was irregular or uneven age in appearance with dominants in at least 3 size classes then it was presumed this condition had been satisfied and the stands were in the transition or steady state phase. The stands in this data set do reflect such a structure.

Probably the single most obvious characteristic of older Jeffrey pine trees is the attainment of a "platy" and yellowed bark structure. Generally, trees younger than those proposed in these descriptions have darker, fissured bark, while older individuals have a plate like bark structure which is quite yellow or bright orange. Decadence as reflected in broken and missing tops, scars, the presence of bole, root, and foliage disease, group kills, and lack of crown vigor is an important, but not widespread, component of these older forests. Equally important is the presence of decay fungi, and other organisms involved in the decomposition of woody material. The occurance of broken and multiple tops or the frequency and severity of disease related mortality as stands age may have important ramifications in seed production and dissemination and eventual species compostion and site occupancy. These characteristics were not sampled in the initial phases of the classification project, however, and they must remain as general observations at this time.

The Jeffrey pine forest cannot be viewed apart from its general setting. The characteristics used to describe these forests are representative of only a portion of the forest. Specifically, only stands with greater than 10% crown cover are described. The Jeffrey pine forest is an ecosystem, however, wherein non-forested areas are equally a part of the landscape and fulfill important roles in the overall functioning of that ecosystem. To describe only older stands of trees neglects the "totality" of the Jeffrey pine forest. Thus, when using these guides it must be realized that only forested areas are described. The old growth Jeffrey pine forest is larger than a simple summary of older stands.

Linked to the general view of the Jeffrey pine forest outlined above is the consideration of stand size. The size of stands that function as ecological units is important in understanding Jeffrey pine ecosystems. Whatever our preconceptions are as to the "optimal" size they must fit with the patterns these forests have evolved over a long period of time. Field observation indicates the Jeffrey pine forest is spatially complex with a range of stand sizes. It is not uncommon to observe undisturbed stands smaller than 5 acres, and stands smaller than 1 acre are not uncommon in these forests. Such stands appear to be complete components of the surrounding ecosystem with full complements of flora and fauna. On the other hand, stands covering large areas are not common. Seldom do stands exceed 100 acres. In most cases a change in relief, topography, aspect, soil, history, or some other environmental condition will cause a corresponding change in species and stand structure. The guides presented here are intended to be used in stands of all sizes.

Another important consideration in old growth Jeffrey pine forests is the amount of disturbance these stands have undergone. The stands sampled for this analysis were late seral with as little disturbance as possible. However, timber harvest has been increasing for the past 40 years, and several stands sampled had logging adjacent to them. Grazing also has been a factor of these forests since the middle to late 1800's. This activity peaked in the early part of the 1900's, but most stands continue to be grazed. Fire suppression activities started to become effective in the 1930's, and mining activity has been important in localized situations. More recently, air quality is being reduced over many areas by the current activities of man. Of course wind, fires, insects and disease, cutting by indigeneous pre-European populations, and browsing by herbivores has been present over long periods. The point is that old growth Jeffrey pine forests are not in an undisturbed condition, nor have they been necessarily free of broad ranging effects of man for many decades. For practical purposes, however, the stands described have been undisturbed except for natural phenomenon, fire suppression, and grazing. In most cases timber harvest has not been a part of the stand history.

These guides were developed from and intended for use in stands that became established and developed for long periods under naturally occuring processes (except for grazing). These processes include: natural fires, insect and disease activity, browsing by indigeneous herbivores, wind, avalanches, climatic cycles, lightning, competition, and species selection processes. Establishment has been the result of natural distribution of seed from parents generally in close proximity to a stand. Stand density, diameter distribution, spacing, growth patterns, and vertical arrangement are generally the result of these naturally occuring processes.

CONCLUSION

From the analysis it appears Jeffrey pine stands begin to assume old growth characteristics around 150 to 200 years. Since old growth forests are too complex for simple descriptions to be useful, multiple characteristics are used in the descriptions. Variables which were felt to be readily observed on the ground but could not be statistically compared are also included. Numbers of snags and stand structure are examples. Most have been used by others in describing old growth forests. However, judgement will be necessary when using the guides since overlaps occur, and not all characteristics will be present in any one stand or area at any one time. The general setting and characteristics of surrounding stands must be considered as well as the stand under examination. The variables that are used to describe old growth characteristics in this type are: species composition, age, height of dominant trees in the stand, stand structure, canopy layering, stems and basal area per acre of live trees in larger size classes, and stems and basal area per acre of dead trees in larger size classes.

DESCRIPTIONS

The following outlines the characteristics and significant observations of old growth forests in the Jeffrey pine cover type. They are arranged by site and summarized in Table 1 (page 14). To many, the variation in some of the basic attributes may seem unsettling. They would prefer simpler, more concrete definition. Such definition, however, often raise more questions than it answers. Variation is a fundamental feature of nature and certainly of old grwoth stands, and it must be recognized. Consequently, the mean, standard deviation, and range are shown where appropriate. In addition, where possible, probability statements are included which define minimums expected at a specified level of probability. It was felt this would be more useful to a variety of users in different settings and give a clearer picture of the characteristic over a range of samples. The mean ± one standard deviation will capture the expected values in most situations, and the range will alert one to extreme values that may be outliers. Probability values can be used to assess realistic minimum values. Interpretations can then legitimately be made by users. Regeneration layers are not used in stand structure descriptions. All values are given on a per acre basis.

Jeffrey Pine - SAF Cover Type (247)

Sites 0 to 3

1.Species composition: Conifer tree cover is moderate on these sites. The mean tree cover is 54%. The standard deviation is 18%. Values range from 3 to 85%. Jeffrey pine constitutes more than 50% of the basal area stocking.

2.Age: Stands on these sites assume old growth characteristics at approximately 150 years.

3.Tree height: Dominant Jeffrey pine on the site will have attained 100 feet.

4.Stand Structure: An irregular structure is most common on these sites. Different size classes are distributed in patches throughout the stand. At least 3 size classes must be present. Trees ≥30"DBH or ≥150 years old are present as indicated below.

5.Canopy Layering: canopy layers coincide with diameter distributions. In those stands which approach an even age structure, a single canopy layer predominates. In stands with several diameter classes, several canopy layers are present.

6.Live Trees:

Conifer trees ≥30"DBH

Number of trees - The average number of trees per acre in these size classes is 9.4. The standard deviation is 6.2. Values range from 0 to 25.2. At the 80% probability level more than 4.3 trees per acre ≥30" DBH will be present.

Basal Area - The average basal area per acre in these size classes is 75.4. The standard deviation is 61.9. Values range from 0 to 226.8. At the 80% probability level more than 23.4 square feet per acre will be present in trees ≥30" DBH.

7.Snags:

Conifer snags $\geq$30"DBH

Number of snags	The average number of snags per acre in these size classes is 0.4. The standard deviation is 0.9. Values range from 0 to 3.6.
Basal Area	The average basal area per acre in these size classes is 3.5. The standard deviation is 9.0. Values range from 0 to 40.0

Sites 4 to 5

1.Species composition: Conifer tree cover is moderate on these sites. The mean tree cover is 48%. The standard deviation is 17%. Values range from 4 to 72%. Jeffrey pine constitutes more than 50% of the basal area stocking.

2.Age: Stands on these sites assume old growth characteristics at approximately 200 years.

3.Tree height: Dominant trees on the site will have attained 68 feet.

4.Stand Structure: An irregular structure is most common on these sites. Different size classes are distributed in patches or singly throughout the stand. At least 3 size classes must be present. Trees $\geq$30"DBH or $\geq$200 years old are present as indicated below.

5.Canopy Layering: canopy layers coincide with diameter distributions. In those stands which approach an even age structure, a single canopy layer predominates. In stands with several diameter classes, several canopy layers are present.

6.Live Trees:

Conifer trees $\geq$30"DBH

Number of trees -	The average number of trees per acre in these size classes is 5.6. The standard deviation is 4.2. Values range from 0 to 17.6. At the 75% probability level more than 2.2 trees per acre $\geq$30" DBH will be present.
Basal Area -	The average basal area per acre in these size classes is 43.9. The standard deviation is 33.5. Values range from 0 to 160.0. At the 75% probability level more than 4.2 square feet per acre will be present in trees $\geq$30" DBH.

7.Snags:

Conifer snags >30"DBH

Number of snags	The average number of snags per acre in these size classes is 0.2. The standard deviation is 0.8. Values range from 0 to 4.0.
Basal Area	The average basal area per acre in these size classes is 1.9. The standard deviation is 6.8. Values range from 0 to 40.0.

TABLE 1

CHARACTERISTICS OF OLD GROWTH
JEFFREY PINE FORESTS

	R5 SITE CLASS 0-3	R5 SITE CLASS 4-5
1. SPECIES COMPOSITION	BASAL AREA STOCKING $\geq$50% JEFFREY PINE	BASAL AREA STOCKING $\geq$50% JEFFREY PINE
2. AGE	$\geq$150 YEARS	$\geq$200 YEARS
3. HEIGHT OF DOMINANTS	JEFFREY PINE DOMINANTS $\geq$100 FEET	JEFFREY PINE DOMINANTS $\geq$68 FEET
4. STAND STRUCTURE	IRREGULAR. AT LEAST 3 DIAMETER CLASSES PRESENT	IRREGULAR. AT LEAST 3 DIAMETER CLASSES PRESENT
5. CANOPY LAYERING	MULTILAYERED. LAYERS CORRESPOND TO DIAMETER DISTRIBUTION	MULTILAYERED. LAYERS CORRESPOND TO DIAMETER DISTRIBUTION
6. LIVE TREES >30" DBH		
NUMBER	9.4 ± 6.2 80% OF STANDS: $\geq$4.3	5.6 ± 4.2 75% OF STANDS: $\geq$2.2
BASAL AREA (SQ FT)	75.4 ± 61.9 80% OF STANDS: $\geq$23.4	43.9 ± 33.5 75% OF STANDS: $\geq$4.2
7. SNAGS >30" DBH		
NUMBER	0.4 ± 0.9	0.2 ± 0.8
BASAL AREA (SQ FT)	3.5 ± 9.0	1.9 ± 6.8

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Ecological Characteristics of
Old Growth Red Fir
in California

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INTRODUCTION

The Chief, Forest Service, has directed all Regions to prepare quidelines which define old growth for major forest types. These guidelines have been prepared in response to that direction. In Region 5 of the Forest Service an effort is currently underway to classify these forests into Ecological Types for purposes of management and research. Since many of the samples taken for this project were in late seral stands, they were examined to determine which characteristics could be used to describe older California red fir (Abies magnifica and Abies magnifica var. shastensis) forests. This paper describes the features of these forests useful in such a characterization, and it provides guidelines that can be used to define old growth stands that lie in the red fir cover type (207) recognized by the Society of American Foresters (1980). Results are summarized in Table 1 on page 15.

DISTRIBUTION

California red fir occurs from the vicinity of Crater Lake Oregon south through the Cascades and Sierra Nevada into northern Kern County at Sunday Peak. An arm of the range also extends south through the Coast Ranges to Snow Mountain in Lake County. It is limited to higher elevations. The lower elevational limits lie near 5,300 feet in the north and increase to the south. Lower limits reach 7,000 feet in the southern Sierra Nevada. The Red Fir Type covers these same geographic regions.

METHODS

Samples came from data collected as part of the Ecological Type Classification being conducted by Region 5 of the Forest Service (Allen, 1987). They were intended to be used for classification purposes. The basic unit of sample was a stand, and no limits were placed on the size of stand for sampling purposes. Stands were selected based on their appearance as relatively undisturbed habitats with a homogeneous species composition in late seral condition. The concept used to select stands was to sample from a range of aspects, elevations, species composition, soil types, community structure, and site index. No attempt was made to include or exclude stands because of features suspected of describing old growth characteristics. For this reason, the stands selected are felt to represent conditions on the majority of red fir stands in these forests. Variation in species composition, cover values, structural diversity, and habitat was sought rather than indications of the aging process.

Data collection followed the procedures described in the Region 5 Ecosystem Classification Handbook and the Region 5 Timber Management Plan Inventory Handbook. At each stand a 1/10 acre circular plot was used to sample information on species composition, cover values, abundance and environmental setting. One tenth acre and 1/2 acre circular plots were used to obtain information on snags and logs. A 3 point "cluster" was used to establish variable radius plot centers as the basis for determining tree species composition, stand structure, basal area, and volume. Determination of site index came from a sample of height and age of dominant and codominant trees on each point in the cluster. Diameters were recorded in classes for purposes of analysis. The diameter classes used were: 1-5.9", 6-10.9", 11-17.9", 18-24.9", 25-29.9", 30-39.9", and 40"+.

To meet the criteria for the red fir cover type, stands must contain greater than 50% of the basal area stocking in red fir. Although many stands in the type are almost pure red fir several species are often found in mixture with red fir. Thus, white fir (Abies concolor), Jeffrey pine (Pinus Jeffreyii), lodgepole pine (Pinus contorta var. murrayana), western white pine (Pinus monticola), mountain hemlock (Tsuga mertensiana), western juniper (Juniperus occidentalis), and quaking aspen (Populus tremuloides) are common associates of red fir. It is known from classification work in these forests (Potter, unpublished) that the presence of these species above a threshold level often indicates different environmental conditions. This classification was therefore used as the basis for selecting samples that were used to describe the type. For purposes of old growth description, samples were screened and separated in three steps. First, samples containing more than 50% of the basal area stocking in red fir were identified in the data set. Next, from this list those containing more than 25% lodgepole pine were removed and assigned to the Lodgepole Pine Type (218). Finally, samples containing more than 10% western white pine, whitebark pine, mountain hemlock, western juniper, and quaking aspen were removed and assigned to the California mixed subalpine type (256).

To date 740 stands have been sampled for classification purposes in the region from Lake Tahoe south to the Sequoia National Forest. Among them a subset of 340 stands met the minimum criteria for the red fir type and were selected as the data set from this source. The following National Forests and National Parks were represented in the sample: the Eldorado, Stanislaus, Sierra, Sequoia, Inyo, Lake Tahoe Basin Management Unit, and Toiyabe National Forests and Yosemite and Sequoia-Kings Canyon National Parks. In addition, a data set containing many younger stands was provided by Leroy Dolph of the PSW Research Station in Redding. Forty nine plots from the Klamath, Lassen, Six Rivers, Plumas, Shasta-Trinity, Tahoe, Eldorado, Stanislaus, Sierra, and Sequoia National Forests were contained in this set. The final data set contained 389 samples.

Stand ages were based on the age of the oldest tree measured on each site. Samples used for classification purposes usually had three dominant or codominant trees measured per site. In many cases, because of species or size differences, additional trees were sampled. No attempt was made; however, to fully age each stand through a complete sample of all size classes. Cases supplied by Dolph did have a complete sample of ages. However, to attempt to develop a combined average from the ages supplied by each data set would be meaningless. Furthermore, to attempt to report on stand age from stands with skewed and irregular structures as many of these are, could also be misleading, and it was therefore decided to use the age of the oldest tree. This is in agreement with investigators doing work in Red Fir (Schumacher, 1928) as well as other types.

Forty nine variables were examined. They centered around 5 areas of concern: the effects of species composition, changes in cover values, stand structure, and biomass accumulation over time, and stand size. The analysis proceeded in two parts. First, information on stand structure, trees and snags per acre by diameter group, species composition and site index were determined for each sample using R5*FS.FIA-SUMMARY and R5*FS.FIA-MATRIX, a series of Region 5 timber inventory and data expansion programs. Each plot was also processed through PROGNOSIS, a stand growth and yield simulation model developed by Stage and others (Stage 1973) to determine values for quadratic mean diameter, stand density index, mean annual increment, and total cubic foot volume. Values from these programs were combined into a single data set for further analysis. Cover values for shrubs, forbs, and grasses were obtained from data sets developed for the classification project. A separate data set for logs had been developed for the classification effort, and it was used to derive values reported for logs. Samples were then aggregated into two site index groups: Region 5 site index 0 to 3 representing high sites, and Region 5 site index 4 and 5 representing low sites. To examine stand size, existing data bases on each of the National Forests in the study area were queried for number of stands that existed in certain size classes. The size classes examined were: 0-10 acres, 10-20 acres,20-30 acres,30-50 acres,50-100 acres, and those exceeding 100 acres.

Variables were tested for normality and transformed as necessary for statistical analysis. The analysis then proceeded using regression techniques to explore diameter, height, and age relationships of individual trees by species and site group. This was followed by examining survivorship curves for individual species and stands. Scatter plots and linear regression were used to explore relationships among variables over time, and time series was also used to look in detail at the data through time. The results of this analysis became the framework for which an Analysis of Variance to isolate variables correlated with broad differences in age was performed. The ability of those variables to differentiate between age groupings were tested using Discriminant Analysis techniques. Finally, Chi square was used to evaluate differences in stand size.

RESULTS

The analysis indicated patterns that emerge through time in these forests. Height-Diameter relationships indicate red fir on sites 0 to 3 can reach 112 feet in height in 120 years and over 135 feet in 200 years. Diameters can exceed 30 inches in 120 years and 40 inches in 200 years on these same sites. On sites 4 to 5 trees can reach 89 feet in height and 31 inches in diameter in 200 years. The oldest tree sampled was 531 years on sites 0 to 3 and 586 years on sites 5 to 5. Survivorship curves showed high loss of trees in young stands between 50 and 110 years due to mortality related to natural thinning. Mortality rates moderate until about 160 years when they increase again until nearly 325 years. This would appear to indicate that losses later in the life of a stand are due to more than inter-tree competition. While early losses in stands are due to natural thinning, environmental factors such as fire, drought, insects, disease, or wind appear to become major contributors to mortality in later years. A final, prolonged period follows in which reduced but steady mortality indicates loss to both environment and physiological failure.

Time series analysis showed considerable variation in biomass accumulation by site class in older stands. This was correlated with changes in the distribution of trees by size class, and reflect steady mortality of large trees with concurrent recruitment of small trees through time. An initial drop in small trees was indicative of the early mortality mentioned above. From that point forward in time, small trees cycle in and out of stands at a relatively constant rate. Large trees, on the other hand, start at low numbers and increase steadily to a point. They too then die and are replaced through time. Often during this stage, large tree numbers are high, when small tree numbers are low, and large tree numbers are low, when small tree numbers are high. This suggests that mortality in later periods is opening stands up and allowing establishment of regeneration and young trees. Examination of stand structures over time illustrated these patterns well. Young stands are characterized by little regeneration, a high number of small trees, and few large trees. At some point in time stands assume an irregular structure and many size classes are occupying sites simultaneously. Older stands are then characterized by higher levels of regeneration, substantially fewer small trees, significant numbers of trees in several size classes, and a significant component of large trees.

On high sites the picture that emerges from the data is one of high numbers of trees occupying stands at some point after a major stand replacing event. This is followed by significant losses due to thinning early in the life of the stand, and it is followed still later by a stabilized condition characterized by a constantly changing structure in which many size classes are present on a site simultaneously. This last condition results as small gaps and openings are created in a mature overstory in response to environmental conditions such as fire, wind, or drought. Regeneration then becomes established in these openings, grows, self thins, and matures. In time, several size classes, including a substantial portion of larger trees, are represented,and the stand exhibits an irregular structure. On sites 0 to 3 this seems to occur around 150 years. It also occurs on many, but not all, low sites around 200 years. These patterns support the hypothesis that as stands occupy sites for longer and longer periods environmental factors become more important in developing stand structures that characterize old growth conditions. These same factors continue to be important in maintaining old growth conditions until the site suffers a stand replacing event, and the cycle renews.

On many low sites the patterns are different. First, many of these stands are very open with low tree densities. Except for sites with a high shrub component, it is difficult to imagine enough fuel to carry a stand replacing fire. Nor is it reasonable to expect that other events such as insects or disease would replace entire stands. Avalanche would appear to be the one environmental factor capable of such an event, and while common in certain areas, they are not widespread. Second, in the Red Fir Type few stands on low sites were found that were less than 200 years old. This carries the implication that few stands less than 200 years old are present on low sites.

Apparently, these stands do not cycle through a stand initiation phase in which high numbers of trees originate more or less simultaneously and progress through time as cohorts. Rather, stand development appears to be sporadic as opportunities arise in response to disturbance levels. Small patches or stands may react similarly to better sites with simultaneous stand origin, followed by crown closure, self thinning, and stand opening as gaps are created. However, in most cases, it appears stand initiation is a prolonged process with many aborted attempts. Stand development occupies considerable periods of time, and during these long periods the probability is high that an environmental event will impact the stand and recycle portions back to an earlier period. Inevitably, some individuals escape environmental damage and mature into larger members of the stand. In time, the stand takes on a very open appearance with an irregular stand structure dominated by large trees which are the survivors of several stand altering events. Thus, these stands arrive at a structure similar to better sites but with lower densities and through a different process of development. Other than in early stages of stand initiation, mortality appears to be responding to environmental circumstance more than competition.

Variables that could be used to distinguish between age groups were examined by One-way Analysis of Variance and Discriminant Analysis techniques. In most cases snag and log numbers were highly variable with skewed distributions, and reliable comparisons could not be made. Reliable transformations of the data could not be developed except for the larger snags and logs on sites 0 to 3. Several variables were identified in each association, and those that would be useful in field applications were incorporated into the descriptions.

When comparing stands less than 150 years with those over 150 years on sites 0 to 3 and those less than 200 years with those over 200 years on sites 5 to 5, several variables were found to be significantly different at the 95% probability level. These results are summarized below:

Variables significantly higher by age group

Sites 0-3

<150 Years	>150 Years
Total trees per acre	Quadratic Mean Diameter
Trees per acre <30" DBH	Total cubic foot volume
Logs per acre <30"	Height of the tallest tree
	Trees per acre >30" DBH
	Snags per acre >30" DBH
	Logs per acre >30"
	Total basal area
	Trees per acre in regeneration
	Diversity index

Sites 4-5

<200 Years	>200 Years
Total trees per acre	Quadratic Mean Diameter
Stand Density Index	Total cubic foot volume
Trees per acre <18" DBH	Height of the tallest tree
	Trees per acre >30" DBH
	Trees per acre in regeneration

These variables were then examined by Stepwise Discriminant Anlaysis. On sites 0 to 3, a 94.4% correct classification function was attained using number of trees in size classes smaller than 30 inches DBH, number of trees larger than 30 inches DBH, and snags larger than 30 inches in diameter. In essence, this means the presence of higher numbers of trees smaller than 30 inches can be used to discriminate younger stands, while number of trees larger than 30 inches and the higher number of logs larger than 30 inches diameter can be used to discriminate older stands on sites 0 to 3.

On sites 4 to 5 a 90.3% correct classification function was attained using the number of trees between 11 and 18 inches, the Quadratic Mean Diameter, and the number of trees larger than 30 inches DBH. It appears then, that the high number of trees per acre between 11 and 18 inches can be used to differentiate stands less than 200 years. The presence of larger diameters, generally expressed in trees larger than 30 inches diameter are the characteristics which best discriminate stands older than 200 years.

In actual practice, the use of several variables is preferred to a paired down list. The variability of many features of these stands is often wide, and if more variables can be used in concert to distinguish between older and younger stands a better solution on the ground is likely. On the other hand, some of the variables identified in the analysis are impractical for field use. Quadratic Mean Diameter, Stand Density Index, and Trees per acre in regeneration are examples. For this reason, variables which are felt to be readily observed on the ground are included.

Chi Square analysis of the distribution by size class confirms what had been observed in the field: the red fir forest is a mosiac of different size stands intertwined with non-forested areas. Distributions toward smaller size stands were significant. Thus, the number of stands smaller than 20 acres is higher than might be expected, and the number of stands greater than 100 acres is smaller than might be expected. This would probably also be true in smaller sizes except that most forest data bases do not track stands smaller than 10 acres. Comparisons were made with roaded and unroaded areas and between forested and non-forested areas (shrub stands) with similar results. Thus, the red fir forest appears as a spatially complex ecosystem with a general pattern of relatively small to middle size stands.

DISCUSSION

Models of stand dynamics in old growth forests are not abundant. Foresters commonly use the culmination of mean annual increment to define the point at which stands are considered mature. In red fir forests, available yield tables (Schumacher, 1928) indicates this point to be around 140 years. The age at which stands assume old growth characteristics is unclear using this guide.

The Society of American Foresters cover types provide a description of vegetation existing on sites at the moment. They convey little insight into the change of vegetation over time. Conceptual models such as successional change, climax conditions, or potential natural vegetation that may be useful in gaining insights into old growth conditions are not a part of these descriptions. They do not, for example, explore the variation in species composition, stand structure, or ecosystem functioning that links particular plant communities to specific habitats over time. They do, however, provide a practical tool that can be used in large scale inventory and cross regional comparisons.

Vegetation in the forests occupied by red fir has been stabilizing over long periods of time. In the Sierras, for example, the last major glacial advance appears to have ended around 10,000 years ago, and the vegetaion on vacated sites has been sorting itself out ever since. In other areas of red fir, volcanism or climatic shifts have been creating similar conditions. Time in these forests is a continum of which human perception catches only a glimpse. Relatively few stands of red fir originate within a specific period, develop as cohorts, and die simultaneously. Stand replacing fires do occur in red fir, but this does not appear to be a widespread or large scale phemomenon. Neither are blowdown, insects, disease, lightning, or avalanche. Records (Potter, unpublished) indicate that all of these factors are operating in these forests continuously, but on a small scale. This results in a constantly changing species composition and structure within a stand as individuals and small groups of trees and other vegetation are cycled into and out of the stand in different amounts at different times. This makes it difficult to define the age of a stand other than in a general sense, but it does focus attention on characteristics other than age which are suggestive of the passing of time within a particular stand.

A model felt to be more applicable to red fir forests, and one which seems to fit observations in the field, is that outlined by Peet and Christiansen (1987) and developed initially by Oliver (1981). Under this model four phases of stand development are recognized: establishment, thinning, transition, and the steady state. Competition-induced mortality is a key feature of stands in the thinning phase, which can last for relatively long time periods; however, the transition and steady state phases are of most interest here. During the transition phase mortality becomes independent of stand density, gaps in the canopy occur, and these are filled with young age classes. This phase may last for several decades. The steady state forest is then typified by an uneven age or irregular structure composed of relatively small even age patches. This pattern cycles over time as younger patches become established, thin themselves, and form gaps. All three of the earlier phases are present simultaneously. This stage is most likely terminated by a stand replacing disturbance such as fire. As noted earlier, this model does not fit all cases on lower sites. The model described in the Results section seems to provide better agreement with field obseravtions; nevertheless, the steady state forest does seem to develop essentially the same general structure over time. It appears this form can be used to define old growth forests of red fir, and that is the approach used here.

The distinction between transition and steady state is not sharp, and as noted, may cover several decades. Therefore, attention was focused on identifying variables that could be used to approximate the age at which stands developed features typical of a transition phase. Once this age was identified it was assumed that older stands would be in the transition or steady state condition if they continued to exhibit characteristics such as an irregular or uneven age structure or the presence of larger trees. No attempt was made to differentiate between the transition and steady state phases since forests in both phases have similar characteristics.

The point at which a period of increasing Quadratic Mean Diameter in younger, developing stands is followed by a significant decrease is thought to be a feature that would suggest the beginning of the transition phase. Such decreases were observed around 150 years on sites 0 to 3 and 200 years on sites 4 and 5, but the relationships were not strong. There was considerable variation in Quadratic Mean Diameter before and after these ages, and this tended to obscure the correlations. Typically, however, around these ages a decrease in Quadratic Mean Diameter was associated with an increase in regeneration and smaller size classes (saplings and poles). This indicated the formation of gaps in the canopy that could not be filled by crown closure and became available for regeneration. The presence of large numbers of these smaller trees reduced the Quadratic Mean Diameter. Stand density index usually increased as well, and this appeared to further indicate the opening of the stand and establishment of younger age classes with high densities. This pattern of changing size classes reflecting changes in Quadratic Mean Diameter became a more or less permanent characteristic in stands past these ages.

Development of larger size trees is a trait that progresses over time, and this can often be used to indicate advancing stand age. Generally, at the point of transition the number of larger trees had increased to levels that were typical from that point on. This was further substantiated when the number of trees in the smaller size class had decreased significantly at the same time. This decrease seems to result both from growth of smaller size classes into the larger class as well as a response to competition-induced mortality which thins suppressed individuals of this size class. The analysis shows a substantial drop in small trees up to ages of 150 years on sites 0 to 3 and 200 years on sites 4 and 5. The feature that emerges at this time is an increase in the number of large trees.

Generally, mortality becomes independent of density as stands age. This does not seem to be the case for these forests. The time series for snags illustrated a high correlation between the number of smaller snags and the number of small trees up to 150 years on sites 0 to 3 and 200 years on sites 4 and 5. This is to be expected as the result of heavy thinnings during this period. However, stands past the thinning phase on sites 0 to 3 also show mortality to be somewhat correlated with density . From the beginning of the Transition phase and continuing, an increase in stand density is usually accompanied by higher numbers of small snags. This reflects continuing thinning in patches of younger trees. Large snags, however, show a somewhat different pattern. From the beginning of the Transition phase until approximately 300 years on sites 0 to 3, an increase in density is usually accompanied by an increase in large snags. After 300 years a decrease in density generally results in an increase in large snags. This appears to suggest that some competition induced mortality is still occuring in stands up to nearly 300 years, and it would account for a portion of the increased levels of mortality indicated by the survivorship curves during this period. Mortality on sites 4 and 5 does appear to be independent of density.

Under the model presumed to describe these forests, an irregular or uneven age structure would be present in stands past the transition phase. This structural pattern has been noted elsewhere as characteristic of "old growth" (Assman,1970; Baker,1962; Veblen,1985; Parker,1985; Taylor,1991). Profiles of diameter distributions in these stands indicate structures skewed to the right. High numbers of trees less than 11 inches are present during the thinning phase. Regeneration at this time, however, is sparse, and large size classes are missing. Past the thinning phase, few of the samples fit an ideal "reverse J" pattern of an optimally distributed uneven age stand, but an irregular structure in which large size classes are overrepresented and regeneration is generally underrepresented is common. In over 90% of the stands at least 3 size classes appeared to be present. While there are many patches that exhibit the "normal" distribution of even age stands, they generally do not cover large, continuous areas. An important structural feature of red fir forests is that different size classes are often aggregated into patches. That is, small patches of fairly uniform size trees are distributed in a mosaic throughout the stand. Trees from different size classes tend not to be distributed randomly or uniformly within a stand. If the general structure was irregular or uneven age in appearance with dominants in at least 3 size classes then it was presumed this condition had been satisfied and the stands were in the transition or steady state phase.

Decadence as reflected in broken and missing tops, scars, the presence of bole, root, and foliage disease, group kills, and lack of crown vigor is an important component of these forests. Equally important is the presence of decay fungi, and other organisms involved in the decomposition of woody material. The occurance of broken and multiple tops or the frequency and severity of disease related mortality as stands age may have important ramifications in seed production and dissemination and eventual species compostion and site occupancy. These characteristics were not sampled in the initial phases of the classification project, however, and they must remain as general observations at this time.

The red fir forest cannot be viewed apart from its general setting. The characteristics used to describe these forests are representative of only a portion of the forest. Specifically, only stands with greater than 10% crown canopy were sampled and described. The red fir forest is an ecosystem, however, wherein non-forested areas are equally a part of the landscape and fulfill important roles in the overall functioning of that ecosystem. To describe only older stands of trees neglects the "totality" of the red fir forest. Thus, when using these guides it must be realized that only forested areas are described. The old growth red fir forest is larger than a simple summary of old growth stands.

Linked to the general view of the red fir forest outlined above is the consideration of size. Size of stands that function as ecological units is important in understanding red fir ecosystems. Whatever our preconceptions are as to the "optimal" size they must fit with the patterns these forests have evolved over long periods of time. Obviously, these forests are spatially complex, with a range of stand sizes. It is not uncommon to observe undisturbed stands smaller than 5 acres in the field, and stands smaller than 1 acre are not uncommon in these forests. Such stands appear to be complete components of the surrounding ecosystem with full complements of flora and fauna. The guides presented here are intended to be used in stands of all sizes.

Another important consideration in old growth red fir forests is the amount of disturbance these stands have undergone. The stands sampled for this analysis were late seral with as little disturbance as possible. Only two showed signs of logging within 10 years; however, as noted earlier, timber harvest has been increasing for the past 40 years, and many stands sampled had logging adjacent to them. Grazing also has been a factor of these forests since the middle to late 1800's. This activity peaked in the early part of the 1900's, but most stands continue to be grazed. Fire suppression activities started to become effective in the 1930's, and mining activity was important in localized situations. More recently, air quality is being reduced over many areas by the current activities of man. Of course wind, fires, insects and disease, cutting by indigeneous pre-European populations, and browsing by herbivores has been present over long periods. The point is made that old growth red fir forests are not in an undisturbed condition, nor have they been particularly free of broad ranging effects of man for many decades. For practical purposes, however, the stands described have been undisturbed except for natural occurances, fire suppression, and grazing. Timber harvest has not been a part of the stand history.

Thus, these guides were developed from and intended for use in stands that became established and developed for long periods under naturally occuring processes (except for grazing). These processes include: natural fires, insect and disease activity, browsing by indigeneous herbivores, wind, avalanches, wet and dry climatic cycles, lightning, competition, and species selection processes. Establishment has been the result of natural distribution of seed from parents generally in close proximity to a stand. Stand density, diameter distribution , spacing, growth patterns, and vertical arrangement are generally the result of these naturally occuring processes.

CONCLUSION

From the analysis it appears red fir stands begin to assume old growth characteristics around 150 to 200 years. The descriptions that follow are based on these characteristics. Since old growth forests are too complex for simple descriptions to be useful, multiple characteristics are necessary to describe them. Variables which were felt to be readily observed on the ground but could not be statistically compared are also included in the descriptions. Numbers of snags, number of logs, and stand structure are examples. Most have been used by others in describing old growth forests. Judgement will be necessary when using the guides since overlaps occur, and not all characteristics will be present in any one stand or area at any one time. The general setting and characteristics of surrounding stands must be considered as well as the stand under examination. The variables that are used to describe old growth characteristics in this type are: species composition, age, height of dominant trees in the stand, stand structure, canopy layering, stems and basal area per acre of live trees in larger size classes, stems and basal area per acre of dead trees in larger size classes, and number of logs in larger size classes.

DESCRIPTIONS

The following outlines the characteristics and significant observations of old growth forests in the red fir cover type. They are summarized in Table 1 (page 15). To many, the variation in some of the basic attributes may seem unsettling. They would prefer simpler, more concrete definition. Such definition, however, often raises more questions than it answers. Variation is a fundamental feature of nature, and it must be recognized. Consequently, the mean, standard deviation, and range are shown where appropriate. In addition, where possible, probability statements are included which define expected minimums at a specified level of probability. It was felt this would be more useful to a variety of users in different settings and give a clearer picture of the characteristic over a range of samples. The mean ± one standard deviation will capture the expected values in most situations, and the range will alert one to extreme values that may be outliers. Interpretations can then legitimately be made by users. Regeneration layers are not used in stand structure descriptions. All values are given on a per acre basis.

Red Fir - SAF Cover Type (207)

Sites 0 to 3

1. Species composition: Conifer tree cover is high on these sites. The mean tree cover is 75%. The standard deviation is 14%. Values range from 21 to 97%. Red fir constitutes 90% of the stand. Other conifer species constitute 10%.

2. Age: Stands on these sites assume old growth characteristics at approximately 150 years.

3.Tree height: Dominant red fir trees on the site will have attained 108 feet.

4.Stand Structure: An irregular structure is most common on these sites. Different size classes are distributed in patches throughout the stand. At least 3 size classes are present. Trees ≥30"DBH or ≥150 years old are present as indicated below.

5.Canopy Layering: canopy layers coincide with diameter distributions. In those stands which approach an even age structure, a single canopy layer predominates. In stands with several diameter classes, several canopy layers are present.

6.Live Trees:

Conifer trees ≥30"DBH

Number of trees -	The average number of trees per acre in these size classes is 29.0. The standard deviation is 13.6. Values range from 2.9 to 65.4. At the 90% probability level more than 11.6 trees per acre ≥30" DBH will be present.
Basal Area -	The average basal area per acre in these size classes is 255.1. The standard deviation is 127.2. Values range from 30.0 to 586.7. At the 90% probability level more than 92.3 square feet will be present in trees ≥30" DBH.

7.Snags:

Conifer snags ≥30"DBH

Number of snags	The average number of snags per acre in these size classes is 3.0. The standard deviation is 3.7. Values range from 0 to 25.8
Basal Area	The average basal area per acre in these size classes is 25.9. The standard deviation is 28.3. Values range from 0 to 146.7

8.Logs:

Conifer logs ≥30"

Number of logs	The average number of logs in these size classes is 5.4. The standard deviation is 5.3. Values range from 0 to 20.

Sites 4 to 5

1.Species composition: Conifer tree cover is moderate on these sites. The mean tree cover is 51%. The standard deviation is 23%. Values range from 11 to 90%. Red fir constitutes 89% of the stand. Other conifer species constitute 11%.

2.Age: Stands on these sites assume old growth characteristics at approximately 200 years.

3.Tree height: Dominant red fir trees on the site will have attained 84 feet.

4.Stand Structure: An irregular structure is most common on these sites. Different size classes are distributed in patches or singly throughout the stand. At least 3 size classes must be present. Trees ≥30"DBH or ≥200 years old are present as indicated below.

5.Canopy Layering: canopy layers coincide with diameter distributions. In those stands which approach an even age structure, a single canopy layer predominates. In stands with several diameter classes, several canopy layers are present.

6.Live Trees:

Conifer trees ≥30"DBH

Number of trees -	The average number of trees per acre in these size classes is 16.8. The standard deviation is 7.4. Values range from 6.9 to 33.4. At the 90% probability level more than 7.3 trees per acre ≥30" DBH will be present.
Basal Area -	The average basal area per acre in these size classes is 137.6. The standard deviation is 63.6. Values range from 48.0 to 293.4. At the 90% probability level more than 56.2 square feet per acre will be present in trees ≥30" DBH.

7.Snags:

Conifer snags ≥30"DBH

Number of snags	The average number of snags per acre in these size classes is 1.1. The standard deviation is 1.8. Values range from 0 to 6.3.
Basal Area	The average basal area per acre in these size classes is 10.5. The standard deviation is 16.0. Values range from 0 to 53.4.

8.Logs:

Conifer logs $\geq$30" Number of logs	The average number of logs in these size classes is 2.7. The standard deviation is 2.1. Values range from 0 to 6.

TABLE 1

CHARACTERISTICS OF OLD GROWTH RED FIR FORESTS

	R5 SITE CLASS 0-3	R5 SITE CLASS 4-5
1. SPECIES COMPOSITION	BASAL AREA STOCKING IS ≥50% RED FIR. PERCENT COVER IN RED FIR IS 90% ± 15%.	BASAL AREA STOCKING IS ≥50% RED FIR. PERCENT COVER IN RED FIR IS 89% ± 17%.
2. AGE	≥150 YEARS	≥200 YEARS
3. HEIGHT OF DOMINANTS	RED FIR DOMINANTS ≥108 FEET	RED FIR DOMINANTS ≥84 FEET
4. STAND STRUCTURE	IRREGULAR. AT LEAST 3 DIAMETER CLASSES PRESENT	IRREGULAR. AT LEAST 3 DIAMETER CLASSES PRESENT
5. CANOPY LAYERING	MULTILAYERED. LAYERS CORRESPOND TO DIAMETER DISTRIBUTION	MULTILAYERED. LAYERS CORRESPOND TO DIAMETER DISTRIBUTION
6. LIVE TREES >30" DBH		
NUMBER	29.0 ± 13.6 90% OF STANDS: ≥12	16.8 ± 7.4 90% OF STANDS: ≥7
BASAL AREA (SQ FT)	255.1 ± 127.2 90% OF STANDS: ≥92	137.6 ± 63.6 90% OF STANDS: ≥56
7. SNAGS >30" DBH		
NUMBER	3.0 ± 3.7	1.1 ± 1.8
BASAL AREA (SQ FT)	25.9 ± 28.3	10.5 ± 16.0
8. LOGS >30" LARGE END		
NUMBER	5.4 ± 5.3	2.7 ± 2.1

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Ecological Characteristics of Old Growth in California Mixed Subalpine Forests

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INTRODUCTION

The Chief, Forest Service, has directed all Regions to prepare quidelines which define old growth for major forest types. These guidelines have been prepared in response to that direction. In Region 5 of the Forest Service an effort is also currently underway to classify these forests into Ecological Types for purposes of management and research. Since many of the samples taken for this project were in late seral stands of the mixed subalpine type, they were examined to determine which characteristics could be used to describe older mixed subalpine forests. This paper describes the features of these forests useful in such a characterization, and it provides guidelines that can be used to define old growth stands that lie in the California mixed subalpine cover type (256) recognized by the Society of American Foresters (1980). Results are summarized in Tables 1 to 5 beginning on page 24.

DISTRIBUTION

The California mixed subalpine type occurs primarily in the Sierra Nevada, but it is found from the Klamath mountains through the Cascades and into the Penninsular Ranges of southern California. It lies at elevations above 7,500 feet in the north to nearly 8,500 feet in the south, and it is characterized by several species growing singly or in mixture in small to moderate sized, open stands. Species commonly associated in the type are western white pine (Pinus monticola), whitebark pine (Pinus albicaulis), mountain hemlock (Tsuga mertensiana), red fir (Abies magnifica and Abies magnifica var. shastensis), western juniper (Juniperus occidentalis), Jeffrey pine (Pinus Jeffreyii), and white fir (Abies concolor). Quaking aspen (Populus tremuloides) is the most commonly associated hardwood. Foxtail pine (Pinus Balfouriana) is a component of this type in a fairly restricted region around the upper South Fork of the Kern River Drainage in the Sierra Nevada and further to the north in scattered stands in the Klamath Mountains. Jeffrey pine, white fir, and aspen communities are common on the east side of the Sierra Nevada, and mountain hemlock does not occur south of northern Tulare county.

METHODS

Samples came from data collected as part of the Ecological Type Classification being conducted by Region 5 of the Forest Service (Allen, 1987). They were intended to be used for classification purposes. The basic unit of sample was a stand, and no limits were placed on size of stand for sampling purposes. Stands were selected based on their appearance as relatively undisturbed habitats with homogeneous species composition in late seral condition. The concept used to select stands was to sample from a range of aspects, elevations, species composition, soil types, community structure, and site index. No attempt was made to include or exclude stands because of features suspected of describing old growth characteristics. For this reason, the samples selected are felt to represent conditions on the majority of stands in the California mixed subalpine type. Variation in species composition, cover values, structural diversity, and habitat was sought rather than indications of the aging process.

Data collection followed the procedures described in the Region 5 Ecosystem Classification Handbook and the Region 5 Timber Management Plan Inventory Handbook. In each stand a 1/10 acre circular plot was used to sample information on species composition, cover values, abundance and environmental setting. One tenth acre and 1/2 acre circular plots were used to obtain information on snags and logs. A 3 point "cluster" was used to establish variable radius plot centers as the basis for determining tree species composition, stand structure, basal area, and volume. Determination of site index came from a sample of height and age of dominant or codominant trees on each point in the cluster. Diameters were recorded in classes for purposes of data analysis. The diameter classes used were: 1-5.9", 6-10.9", 11-17.9", 18-24.9", 25-29.9", 30-39.9", and 40"+.

In the California mixed subalpine type, different species may occur in pure stands almost next to each other or in intimate mixtures within a stand. It is known from classification work in these forests (Potter, unpublished) that the presence of each of these species above a threshold level generally indicates different environmental conditions. This classification was therefore used as the basis for selecting samples that were used to describe the type. For purposes of old growth description samples were screened and separated in three steps. First, those containing more than 10% of the basal area stocking in western white pine, whitebark pine, mountain hemlock, western juniper, and quaking aspen were selected from the data set. These samples were screened again, and those containing more than 25% lodgepole pine, or more than 50% Jeffrey pine, or more than 50% white fir were removed and assigned to other types. A final screen removed samples which contained only red fir in combination with Jeffrey pine or white fir. The remainder were assigned to the California mixed subalpine type and arranged into the following associations for analysis: western white pine, mountain hemlock, white fir-Jeffrey pine, western juniper, and quaking aspen.

To date, 740 stands have been sampled for classification purposes in the region from Lake Tahoe south to the Sequoia National Forest. Among them a subset of 191 stands met the criteria for California mixed subalpine type and were selected as the data set to be used in the analysis. The mountain hemlock association contained 43 samples; western white pine contained 52 samples; western juniper contained 21 samples; the Jeffrey pine-white fir association contained 44 samples, and quaking aspen contained 31 samples. The following National Forests and National Parks were represented in the sample: the Eldorado, Stanislaus, Sierra, Sequoia, Inyo, Lake Tahoe Basin Management Unit, and Toiyabe National Forests and Yosemite and Sequoia-Kings Canyon National Parks. As noted, these samples were taken on undisturbed sites.

Stand ages were based on the age of the oldest tree measured on each site. Samples used for classification purposes usually had three dominant or codominant trees measured per site. In many cases, because of species or size differences, additional trees were measured. No attempt was made; however, to fully age each stand through a complete sample of all size classes. To attempt to report on ages from stands with skewed and irregular structures, as many of these are, could also be misleading. Therefore it was decided to use the age of the oldest tree. This is in agreement with investigators doing work in associated red fir (Schumacher 1928) as well as other types.

Forty nine variables were examined. They emphasized 5 areas of concern: the effects of species composition, changes in cover values, stand structure, biomass accumulation over time, and stand size. The analysis proceeded in two parts. First, information on stand structure, trees and snags per acre by diameter group, species composition and site index were determined for each sample using R5*FS.FIA_SUMMARY and R5*FS.FIA-MATRIX part of a series of Region 5 timber inventory and data expansion programs. Each sample was also processed through PROGNOSIS, a stand growth and yield simulation model developed by Stage and others (Stage 1973) to determine values for quadratic mean diameter, stand density index, mean annual increment, and total cubic foot volume. Values from these programs were combined into a single data set for further analysis. Cover values for shrubs, forbs, and grasses were obtained from data sets developed for the classification project. A separate data set for logs had been developed for the classification effort, and it was used to derive values reported for logs. Samples were then aggregated into two site index groups: Region 5 site index 0 to 3 representing high sites, and Region 5 site index 4 and 5 representing low sites. To examine stand size, existing data bases on each of the National Forests in the study area were queried for number of stands that existed in certain size classes in these forested areas. The size classes examined were 0-10 acres, 10-20 acres, 20-30 acres, 30-50 acres, 50-100 acres, and those exceeding 100 acres.

Variables were tested for normality and transformed as necessary for statistical analysis. The analysis then proceeded using regression techniques to explore diameter, height, and age relationships of individual trees by species and site group. This was followed by examining survivorship curves for individual species and stands. Scatter plots and linear regression were used to explore relationships among variables over time, and time series was also used to look in detail at the data through time. The results of this analysis became the framework for which an Analysis of Variance to isolate variables correlated with broad differences in age was performed. The ability of those variables to differentiate between age groupings were tested using Discriminant Analysis techniques. Finally, Chi square was used to evaluate differences in stand size.

RESULTS

The data set for the California mixed subalpine type is not large for younger stands. Consequently, clear patterns of stand development over long time periods could not be fully determined. However, based on work in red fir, which is a common associate in these forests, it would appear that similar patterns of stand development through time are present. Red fir develops features characteristic of older stands in approximately 150 years on sites 0 to 3 and 200 years on sites 4 to 5. The analysis done for this type indicates similar patterns.

Height-diameter relationships indicate that western white pine, and mountain hemlock are smaller in diameter and shorter in height than associated species such as red fir at comparable ages. While stands may appear younger due to smaller diameters, they are not necessarily different in age. The oldest western white pine sampled was 726 years while the oldest mountain hemlock was 496 years. This compares with the oldest Jeffrey pine sampled of 660 years, and the oldest red fir of 586 years. Survivorship curves show steady but sustained mortality over a relatively long period in each of the associations. This would appear to indicate that early losses in stands are due to natural thinning, but eventually environmental factors such as fire, drought, insects, disease, or wind become major contributors to mortality.

Time series analysis showed consistent variation in biomass accumulation by site class in older stands. This was correlated with changes in the distribution of trees by size class, and reflected steady mortality in large trees with concurrent recruitment of small trees through time. Examination of stand structures over time illustrated these patterns well. They showed that at some point in time stands assume an irregular structure and many size classes are occupying sites simultaneously. Older stands are characterized by moderate regeneration, the presence of trees in several size classes, and a significant component of large trees. These same patterns have been observed in associated types such as red fir and lodgepole pine.

Quaking aspen and western juniper are two species that do not fit the general picture above. Both of these species are difficult to age in the field; however, from sanded cores and cutoff ends it was possible to establish a general picture of ages. Aspen appears to be a very short lived species, at least as far as individual trees are concerned. Clones may be able to persist for long periods. Individual tree ages above 120 to 130 years are doubtful, and survivorship curves indicates substantial mortality in trees beginning around 60 to 70 years. The oldest aspen measured was 135 years old. Diameters and heights are generally smaller than conifer species in this association. Aspen stands usually have high densities, and they have an irregular structure which results from the presence of conifers that are predominant residuals from an earlier stand or individuals that are currently invading the stand. The aspen component by itself often appears to have a normal distribution characteristic of an even-aged structure.

Western juniper appears to be a long lived species. Several samples in excess of 700 to 800 years were encountered, and it may be ages can exceed 1000 to 1500 years. Western juniper is a short tree, with a large diameter. Stands generally have low densities, and they tend to be quite open. These stands also have an irregular structure due to the presence of a substantial number of large, very old juniper.

On high sites the picture that emerges from the analysis is similar to that of red fir. In red fir stands relatively high numbers of trees occupy stands at some point after a major stand replacing event. This is followed by significant losses due to natural thinning early in the life of the stand, and it is followed still later by a stabilized condition characterized by a constantly changing structure in which many size classes are present on a site simultaneously. This last condition results as small gaps and openings are created in a mature overstory in response to environmental conditions such as fire, wind, or drought. Regeneration becomes established in these openings, grows, self thins, and matures. In time, several size classes, including a substantial portion of larger trees, are represented,and the stand exhibits an irregular structure. The hypothesis forwarded here, is that as stands occupy sites for longer and longer periods, environmental factors become increasingly important in developing stand structures that characterize old growth conditions. These same factors continue to be important in maintaining old growth conditions until the site suffers a stand replacing event, and the cycle renews. By ages of 150 years on sites 0 to 3, these patterns appear to be established in the California mixed subalpine type.

On low sites the same patterns do not emerge. First, many of these stands are very open with low tree densities. Except for sites with a high shrub component, it is difficult to imagine enough fuel to carry a stand replacing fire. Nor is it reasonable to expect that other events such as insects or disease would replace entire stands. Avalanche would appear to be the one environmental factor capable of such an event, and while common in certain areas, they are not widespread. Second, in all of the California mixed subalpine type no stand on low sites was found that was less than 200 years old. This confirms similar results in red fir and lodgepole pine stands associated with these mixed subalpine stands. Very few stands less than 200 years old are present on low sites. This implies that many of these stands do not cycle through a stand initiation phase in which high numbers of trees originate more or less simultaneously and progress through time as cohorts. Rather, stand development appears to be sporadic as opportunities arise in response to disturbance levels. Small patches or stands may react similar to better sites with simultaneous stand origin, followed by crown closure, self thinning, and stand opening as gaps are created. However, in most cases, it appears stand initiation is a prolonged process with many aborted attempts. Stand development occupies considerable periods of time, and during these long periods the probability is high that an environmental event will impact the stand and recycle portions back to an earlier period. Inevitably, some individuals escape environmental damage and mature into larger members of the stand. In time, the stand takes on a very open appearance with an irregular stand structure dominated by large trees which are the survivors of many stand altering events. Thus, these stands arrive at a structure similar to better sites but with lower densities and through a different process of development. Other than in early stages of stand initiation, mortality appears to be responding to environmental circumstance more than competition.

Variables that could be used to distinguish between age groups in each of the associations were examined by One-way Analysis of Variance and Discriminant Analysis techniques. In most cases small numbers of samples in younger age stands that were further subdivided by site made meaningful comparisons between age groups difficult. For example, in the western white pine association there were only 2 samples less than 150 years old on sites 0 to 3, and there were no samples less than 200 years old on sites 4 to 5. Snag and log numbers were also highly variable and reliable transformations of the data could not be made for comparison using analysis of variance and Discriminant Analysis. The analysis that was made using regression, suvivorship curves, examination of stand structures, and time series indicated the stands in the California mixed subalpine type are behaving similarly to older stands in red fir, lodgepole pine, and Jefrey pine for which analysis of variance and Discriminant Analysis could be used. Knowledge of the environmental factors acting on these sites allows development of a hypothesis of stand dynamics that fits the information developed and stand patterns in other associated forest types. Therefore, the descriptions report on values that have been used in describing old growth conditions in other types and that can be easily applied in the field.

Chi Square analysis of the distribution by size class confirms what had been observed in the field: the California mixed subalpine forest is a mosiac of different size stands intertwined with non-forested areas. Distributions toward smaller size stands were significant. Thus, the number of stands smaller than 20 acres is higher than might be expected, and the number of stands greater than 100 acres is smaller than might be expected. This would probably also be true in smaller sizes except that most forest data bases do not track stands smaller than 10 acres. Comparisons were made with roaded and unroaded areas and between forested and non-forested areas (shrub stands) with similar results. Thus, the California mixed subalpine forest appears as a spatially complex ecosystem with a general pattern of relatively small to middle size stands.

DISCUSSION

Models of stand dynamics in old growth forests are not abundant. Foresters commonly use the culmination of mean annual increment to define the point at which stands are considered mature. In California yield tables have not been developed for most of the species in the California Mixed Subalpine Type. The only associated species for which such work has been done is red fir. In red fir forests, available yield tables (Schumacher, 1928) indicates the culmination of mean annual increment to be around 140 years. The age at which stands assume old growth characteristics is unclear using this guide.

The Society of American Foresters cover types provide a description of vegetation existing on sites at the moment. They convey little insight into the change of vegetation over time. Conceptual models such as successional change, climax conditions, or potential natural vegetation that may be useful in gaining insights into old growth conditions are not a part of these descriptions. They do not, for example, explore the variation in species composition, stand structure, or ecosystem functioning that links particular plant communities to specific habitats over time. They do, however, provide a practical tool that can be used in large scale inventory and cross regional comparisons.

Vegetation in the forests occupied by the California mixed subalpine type have been stabilizing over long periods of time. In the Sierras, for example, the last major glacial advance appears to have ended around 10,000 years ago, and the vegetaion on vacated sites has been sorting itself out ever since. In other areas volcanism or climatic shifts have been creating similar conditions. Time in these forests is a continum of which human perception catches only a glimpse. Few stands originate within a specific period, develop as cohorts, and die simultaneously. Stand destroying fires do occur in this type, but this does not appear to be a widespread or large scale phemomenon.

Neither are blowdown, insects, disease, lightning, or avalanche. Records (Potter, unpublished) indicate that all of these factors are operating in these forests continuously, but on a small scale. This results in a constantly changing species composition and structure within a stand as individuals and small groups of trees and other vegetation are cycled into and out of the stand in different amounts at different times. This makes it difficult to define the age of a stand other than in a general sense, but it does focus attention on characteristics other than age which are suggestive of the passing of time within a particular stand.

A model felt to be applicable to these forests, and one which seems to fit observations in the field on better sites, is that outlined by Peet and Christiansen (1987) and developed initially by Oliver (1981). Under this model four phases of stand development are recognized: establishment, thinning, transition, and the steady state. Competition-induced mortality is a key feature of stands in the thinning phase, which can last for relatively long time periods; however, the transition and steady state phases are of most interest here. During the transition phase mortality becomes independent of stand density, gaps in the canopy occur, and these are filled with young age classes. This phase may last for several decades. The steady state forest is then typified by an uneven age or irregular structure composed of relatively small even age patches. This pattern cycles over time as younger patches become established, thin themselves, and form gaps. All three of the earlier phases are present simultaneously. This stage is most likely terminated by a stand replacing disturbance such as fire. As noted earlier, this model does not fit all cases on lower sites. The model described in the Results section seems to provide better agreement with field observations; nevertheless, the steady state forest does seem to develop essentially the same general structure over time. It appears this form can be used to define old growth forests of the mixed subalpine, and that is the approach used here.

The distinction between transition and steady state is not sharp, and as noted, may cover several decades. Therefore, attention was focused on identifying variables that could be used to approximate the age at which stands developed features typical of a transition phase. Once this age was identified it was assumed that older stands would be in the transition or steady state condition if they continued to exhibit characteristics such as an irregular structure or presence of larger trees. No attempt was made to differentiate between the transition and steady state phases since forests in both phases have similar characteristics.

The point at which a period of increasing Quadratic Mean Diameter in developing younger stands is followed by a significant decrease was one feature that might suggest the beginning of the transition phase. A decrease in Quadratic Mean Diameter would imply the stand was breaking up. This decrease would be expected to coincide with an increase in regeneration and smaller size classes (saplings and poles). This would indicate the formation of gaps in the canopy that could not be filled by crown closure and therefore became available for regeneration. The presence of large numbers of these smaller trees reduces the Quadratic Mean Diameter. Stand density index would be expected to increase at this time as well. As noted earlier, the data set for these forests contains few samples in early seral condition, and the point at which Quadratic Mean Diameter increases substantially and is followed by a sharp decline was not obvious. What is clear from the data is that these stands have apparently already arrived at a condition that can be described as old growth. Considerable variation in productivity, Quadratic Mean Diameter, and density is occuring, and this variation is reflected in the structure of the stands. Many size classes are present including regeneration and small trees. This indicates the opening of the stand and establishment of younger age classes has already occurred.

Development of larger size trees is a trait that progresses over time, and this can often be used to indicate advancing stand age. Generally, at the point of transition the number of larger trees increases to levels that are typical from that point on. This is usually further substantiated when the number of trees in the smaller size class decreases significantly at the same time. This decrease results from both growth of smaller size classes into larger classes as well as a response to competition-induced mortality which thins suppressed individuals of this size class. As noted above, the data set for the California mixed subalpine type does not provide a picture of early stand development, and most of the stands in the sample are felt to already be in an old growth condition. What can be observed is that larger trees are present in somewhat stable numbers. They vary over time in response to environmental conditions, but they have essentially become permanent features of the stand.

Generally, mortality becomes independent of density as stands age. This does seem to be the case for these forests. Time series for most of the stands in the data set show mortality of larger size classes to be somewhat uncorrelated with density. Survivorship curves on both high and low sites show a steady decline in individuals over time. This would also indicate that at least some mortality is occuring which is independent of density.

Under the model presumed to describe these forests, an irregular or uneven age structure would be present in stands past the transition phase. This structural pattern has been noted elsewhere as characteristic of "old growth" (Assman,1970; Baker,1962; Veblen,1985; Parker,1985; Taylor,1991). Profiles of diameter distributions in these stands indicate structures skewed to the right. Few of the samples fit an ideal "reverse J" pattern of an optimally distributed uneven age stand, but an irregular structure in which large size classes are overrepresented and regeneration is generally underrepresented is common. The California mixed subalpine type is apparently also distinguished from associated types by having fewer trees in size classes below 25" Dbh. In most stands at least 3 size classes do appear to be present. While there are many patches that exhibit the "normal" distribution of even age stands, they generally do not cover large, continuous areas. Trees from different size classes tend to be distributed randomly or in small patches within a stand. Quaking aspen differs from the general pattern described above. It often fits and even age or two storied structure. Aspen stands will often appear to have distinctly uniform distribution of stems in the field. This pattern is obvious in diagrams of tree distribution by size class. Many aspen stands have a large component of trees between 8 and 18" Dbh. However, there are often conifer trees in size classes above 18" Dbh. This is what gives these stands the characteristic irregular structure overall, while the aspen component alone is distinctly even aged. If the general structure was irregular or uneven age in appearance with dominants in at least 3 size classes then it was presumed this condition had been satisfied and the stands were in the transition or steady state phase.

Decadence as reflected in broken and missing tops, scars, the presence of bole, root, and foliage disease, group kills, and lack of crown vigor is an important component of these forests. Equally important is the presence of decay fungi, and other organisms involved in the decomposition of woody material. The occurance of broken and multiple tops or the frequency and severity of disease related mortality as stands age may have important ramifications in seed production and dissemination and eventual species compostion and site occupancy. These characteristics were not sampled in the initial phases of the classification project, however, and they must remain as general observations at this time.

The mixed subalpine forest cannot be viewed apart from its general setting. The characteristics used to describe these forests are representative of only a portion of the forest. Specifically, only stands with greater than 10% crown cover were sampled and described. These forests are an ecosystem, however, wherein non-forested areas are equally a part of the landscape and fulfill important roles in the overall functioning of that ecosystem. To describe only older stands of trees neglects the "totality" of the california mixed subalpine forest. Thus, when using these guides it must be realized that only forested areas are described. The old growth California Mixed Subalpine Type is larger than a simple summary of old growth stands.

Linked to the general view of the California mixed subalpine forest outlined above is the consideration of size. Size of stands that function as ecological units is important in understanding these ecosystems. Whatever our preconceptions are as to the "optimal" size they must fit with the patterns these forests have evolved over a long period of time. Obviously, these forests are spatially complex with a range of stand sizes. It is not uncommon to observe undisturbed stands smaller than 5 acres in the field, and stands smaller than 1 acre are not uncommon in these forests. Such stands appear to be complete components of the surrounding ecosystem with full complements of flora and fauna. The guides presented here are intended to be used in stands of all sizes.

Another important consideration in old growth forests is the amount of disturbance these stands have undergone. The stands sampled for this analysis were late seral with as little disturbance as possible. However, as noted earlier, timber harvest has been increasing for the past 40 years, and several stands sampled had logging adjacent to them. Grazing also has been a factor in these forests since the middle to late 1800's. This activity peaked in the early part of the 1900's, but most stands continue to be grazed. Fire suppression activities started to become effective in the 1930's, and mining activity was important in localized situations. More recently, air quality is being reduced over many areas by the current activities of man. Of course wind, fires, insects and disease, cutting by indigeneous pre-European populations, and browsing by herbivores has been present over long periods. Thus, old growth forests in the California mixed subalpine type are not in an undisturbed condition, nor have they been particularly free of broad ranging effects of man for many decades. For practical purposes, however, the stands described have been undisturbed except for natural phenomenon, fire suppression, and grazing. Timber harvest has not been a part of the stand history.

These guides were developed from and intended for use in stands that became established and developed for long periods under naturally occuring processes (except for grazing). These processes include: natural fires, insect and disease activity, browsing by indigeneous herbivores, wind, avalanches, climatic cycles, lightning, competition, and species selection processes. Establishment has been the result of natural distribution of seed from parents generally in close proximity to a stand. Stand density, diameter distribution, spacing, growth patterns, and vertical arrangement are generally the result of these naturally occuring processes.

CONCLUSION

From the analysis it appears most forests in the California mixed subalpine type begin to assume old growth characteristics around 150 to 200 years. These ages correspond to the ages other associated types such as red fir and lodgepole pine assume old growth characteristics, and they are a reflection of the passage of a substantial period of time in which stands have been exposed to environmental hazards. The same ages are used in the california mixed subalpine associations except for Quaking Aspen. This species appears to be short lived by comparison with associates. Few stands were sampled less than 80 years, and an age of 100 years was simply used in the description for this species. These ages were used to separate candidate old growth stands from others.

The descriptions that follow are based on examination of older stands in these forests. Since old growth forests are too complex for simple descriptions to be useful, multiple characteristics are used. Variables which were felt to be readily observed on the ground but could not be statistically compared are also included in the descriptions. Numbers of snags, number of logs, and stand structure are examples. Most have been used by others in describing old growth forests. Judgement will be necessary when using the guides since overlaps occur, and not all characteristics will be present in any one stand or area at any one time. The general setting and characteristics of surrounding stands must be considered as well as the stand under examination. The variables that are used to describe old growth characteristics in this type are: species composition, age, height of dominant trees in the stand, stand structure, canopy layering, stems and basal area per acre of live trees in larger size classes, stems and basal area per acre of dead trees in larger size classes, and number of logs in larger size classes.

DESCRIPTIONS

The following outlines the characteristics and significant observations of old growth forests in the California mixed subalpine cover type. They are arranged by association and summarized in Tables 1 through 5 beginning on page 24. To many, the variation in some of the basic attributes may seem unsettling. They would prefer simpler, more concrete definition. Such definition, however, often raises more questions than it answers. Variation is a fundamental feature of nature, and it must be recognized. Consequently, the mean, standard deviation, and range are shown where appropriate. In addition, where possible, probability statements are included which define the lower limits at a specified level of probability. It was felt this would be more useful to a variety of users in different settings and give a clearer picture of the characteristic over a range of samples. The mean ± one standard deviation will capture the expected values in most situations, and the range will alert one to extreme values that may be outliers. Interpretations can then legitimately be made by users. Regeneration layers are not used in stand structure descriptions. All values are given on a per acre basis.

California Mixed Subalpine - SAF Cover Type (256)

Western White Pine Association

Sites 0 to 3

1.Species composition: Conifer tree cover is moderate on these sites. The mean tree cover is 53%. The standard deviation is 18%. Values range from 15 to 77%. Western white pine constitutes 30% of the stand. Red fir constitutes 61%. Other conifer species constitute 9%.

2.Age: Stands on these sites assume old growth characteristics at approximately 150 years.

3.Tree height: Dominant Western white pine on the site will have attained 75 feet.

4.Stand Structure: An irregular structure is most common on these sites. Regeneration and trees smaller than 11" are underrepresented while trees larger than 30" are overrepresented. Different size classes are distributed in patches throughout the stand. At least 3 size classes must be present. Trees ≥30"DBH or ≥150 years old are present as indicated below.

5.Canopy Layering: canopy layers coincide with diameter distributions. In those stands which approach an even age structure, a single canopy layer predominates. In stands with several diameter classes, several canopy layers are present.

6.Live Trees:

Conifer trees ≥30"DBH

Number of trees - The average number of trees per acre in these size classes is 20.8. The standard deviation is 11.9. Values range from 2.0 to 41.1. At the 90% probability level more than 5.6 trees per acre ≥30" DBH will be present.

Basal Area - The average basal area per acre in these size classes is 177.5. The standard deviation is 98.1. Values range from 13.3 to 480.0. At the 90% probability level more than 52.0 square feet per acre will be present in trees ≥30" DBH.

7.Snags:

Conifer snags ≥30"DBH

Number of snags The average number of snags per acre in these size classes is 1.2. The standard deviation is 1.6. Values range from 0 to 5.6.

Basal Area The average basal area per acre in these size classes is 14.8. The standard deviation is 21.4. Values range from 0 to 80.0.

8.Logs:

Conifer logs ≥30" large end

Number of logs The average number of logs in these size classes is 2.0. The standard deviation is 2.0. Values range from 0 to 4.0.

Sites 4 to 5

1.Species composition: Conifer tree cover is moderate on these sites. The mean tree cover is 54%. The standard deviation is 19%. Values range from 20 to 88%. Western white pine constitutes 35% of the stand. Red fir constitutes 55% of the stand; other conifer species constitute 10%.

2.Age: Stands on these sites assume old growth characteristics at approximately 200 years.

3.Tree height: Dominant trees on the site will have attained 65 feet.

4.Stand Structure: An irregular structure is most common on these sites. Regeneration and trees <11" are commonly underrepresented while trees larger than 30" are overrepresented. Different size classes are distributed in patches or singly throughout the stand. At least 3 size classes must be present. Trees $\geq$30"DBH or $\geq$200 years old are present as indicated below.

5.Canopy Layering: canopy layers coincide with diameter distributions. In those stands which approach an even age structure, a single canopy layer predominates. In stands with several diameter classes, several canopy layers are present.

6.Live Trees:

Conifer trees $\geq$30"DBH

Number of trees - The average number of trees per acre in these size classes is 16.5. The standard deviation is 7.0. Values range from 4.7 to 29.8. At the 90% probability level more than 7.6 trees per acre $\geq$30" will be present.

Basal Area - The average basal area per acre in these size classes is 132.2. The standard deviation is 59.8. Values range from 40.0 to 240.0. At the 90% probability level more than 55 square feet per acre will be present in trees $\geq$30" DBH.

7.Snags:

Conifer snags $\geq$30"DBH

Number of snags The average number of snags per acre in these size classes is 1.8. The standard deviation is 1.8. Values range from 0 to 5.1.

Basal Area The average basal area per acre in these size classes is 14.9. The standard deviation is 16.1. Values range from 0 to 40.0.

8.Logs:

Conifer logs $\geq$30"

Number of logs The average number of logs in these size classes is 1.7. The standard deviation is 2.3. Values range from 0 to 6.

Mountain Hemlock Association

Sites 0 to 3

1.Species composition: Conifer tree cover is high on these sites. The mean tree cover is 73%. The standard deviation is 9%. Values range from 48 to 88%. Mountain Hemlock constitutes 44% of the stand. Red fir constitutes 41%. Other conifer species constitute 15%.

2.Age: Stands on these sites assume old growth characteristics at approximately 150 years.

3.Tree height: Dominant Mountain Hemlock on the site will have attained 85 feet.

4.Stand Structure: An irregular structure is most common on these sites. Regeneration and trees smaller than 11" are underrepresented while trees larger than 30" are overrepresented. Different size classes are distributed in patches throughout the stand. At least 3 size classes must be present. Trees ≥30"DBH or ≥150 years old are present as indicated below.

5.Canopy Layering: canopy layers coincide with diameter distributions. In those stands which approach an even age structure, a single canopy layer predominates. In stands with several diameter classes, several canopy layers are present.

6.Live Trees:

Conifer trees ≥30"DBH

Number of trees - The average number of trees per acre in these size classes is 22.3. The standard deviation is 10.6. Values range from 0 to 44.0. At the 90% probability level more than 8.7 trees per acre ≥30" DBH will be present.

Basal Area - The average basal area per acre in these size classes is 191.6. The standard deviation is 86.5. Values range from 0 to 386.7. At the 90% probability level more than 80.9 square feet per acre will be present in trees ≥30" DBH.

7.Snags:

Conifer snags ≥30"DBH

Number of snags The average number of snags per acre in these size classes is 1.7. The standard deviation is 2.0. Values range from 0 to 7.2.

Basal Area The average basal area per acre in these size classes is 17.2. The standard deviation is 21.5. Values range from 0 to 80.0.

8.Logs:

Conifer logs >25" large end

Number of logs — The average number of logs in these size classes is 3.6. The standard deviation is 5.0. Values range from 0 to 10.0

Sites 4 to 5

1.Species composition: Conifer tree cover is moderate on these sites. The mean tree cover is 49%. The standard deviation is 17%. Values range from 22 to 69%. Mountain Hemlock constitutes 41% of the stand. Western white pine constitutes 28% of the stand. Red fir constitutes 20%, and other conifer species constitute 11%.

2.Age: Stands on these sites assume old growth characteristics at approximately 200 years.

3.Tree height: Dominant trees on the site will have attained 65 feet.

4.Stand Structure: An irregular structure is most common on these sites. Regeneration and trees <11" are commonly underrepresented while trees larger than 30" are overrepresented. Different size classes are distributed in patches or singly throughout the stand. At least 3 size classes must be present. Trees >30"DBH or >200 years old are present as indicated below.

5.Canopy Layering: canopy layers coincide with diameter distributions. In those stands which approach an even age structure, a single canopy layer predominates. In stands with several diameter classes, several canopy layers are present.

6.Live Trees:

Conifer trees >30"DBH

Number of trees - The average number of trees per acre in these size classes is 13.3. The standard deviation is 7.3. Values range from 5.1 to 26.5. At the 90% probability level more than 4.0 trees per acre >30" will be present.

Basal Area - The average basal area per acre in these size classes is 112.3. The standard deviation is 65.8. Values range from 40.0 to 226.7. At the 90% probability level more than 28.1 square feet per acre will be present

7.Snags:

Conifer snags ≥30"DBH

Number of snags — The average number of snags per acre in these size classes is 1.4. The standard deviation is 1.3. Values range from 0 to 3.6.

Basal Area — The average basal area per acre in these size classes is 12.7. The standard deviation is 13.2. Values range from 0 to 40.0.

8.Logs:

Conifer logs ≥25"

Number of logs — The average number of logs in these size classes is 2.0. The standard deviation is 2.5. Values range from 0 to 6.

White fir - Jeffrey pine Association

Sites 0 to 3

1.Species composition: Conifer tree cover is moderate on these sites. The mean tree cover is 64%. The standard deviation is 22%. Values range from 16 to 93%. White fir constitutes 44% of the stand. Red fir constitutes 23%; Jeffrey pine averages 22%. Other conifer species constitute 1%.

2.Age: Stands on these sites assume old growth characteristics at approximately 150 years.

3.Tree height: Dominant White fir on the site will have attained 95 feet.

4.Stand Structure: An irregular structure is most common on these sites. Regeneration and trees smaller than 11" are underrepresented while trees 18 to 25" and 30 to 40" are overrepresented. Different size classes are distributed in patches throughout the stand. At least 3 size classes must be present. Trees ≥30"DBH or ≥150 years old are present as indicated below.

5.Canopy Layering: canopy layers coincide with diameter distributions. In those stands which approach an even age structure, a single canopy layer predominates. In stands with several diameter classes, several canopy layers are present.

6.Live Trees:

Conifer trees ≥30"DBH

Number of trees - The average number of trees per acre in these size classes is 20.6. The standard deviation is 10.6. Values range from 7.8 to 49.3. At the 90% probability level more than 7.1 trees per acre ≥30" DBH will be present.

Basal Area - The average basal area per acre in these size classes is 187.8. The standard deviation is 101.0. Values range from 64.0 to 493.3. At the 90% probability level more than 58.6 square feet per acre will be present in trees ≥30" DBH.

7.Snags:

Conifer snags ≥30"DBH

Number of snags The average number of snags per acre in these size classes is 2.8. The standard deviation is 2.7. Values range from 0 to 9.5.

Basal Area The average basal area per acre in these size classes is 24.5. The standard deviation is 24.4. Values range from 0 to 80.0.

8.Logs:

Conifer logs ≥30" large end

Number of logs The average number of logs in these size classes is 4.0. The standard deviation is 4.8. Values range from 0 to 16.0.

Sites 4 to 5

1.Species composition: Conifer tree cover is moderate on these sites. The mean tree cover is 47%. The standard deviation is 23%. Values range from 18 to 81%. White fir constitutes 33% of the stand. Red fir constitutes 36% of the stand, and Jeffrey pine averages 21%. Other conifer species constitute 10%.

2.Age: Stands on these sites assume old growth characteristics at approximately 200 years.

3.Tree height: Dominant trees on the site will have attained 75 feet.

4.Stand Structure: An irregular structure is most common on these sites. Regeneration and trees <11" are commonly underrepresented while trees in the 11 to 25" classes and 30 to 40" classes are significantly overrepresented. Different size classes are distributed in patches or singly throughout the stand. At least 3 size classes must be present. Trees ≥30"DBH or ≥200 years old are present as indicated below.

5.Canopy Layering: canopy layers coincide with diameter distributions. In those stands which approach an even age structure, a single canopy layer predominates. In stands with several diameter classes, several canopy layers are present.

6.Live Trees:

Conifer trees ≥30"DBH

Number of trees -	The average number of trees per acre in these size classes is 12.8. The standard deviation is 7.8. Values range from 5.0 to 24.9. At the 90% probability level more than 2.8 trees per acre ≥30" DBH will be present.
Basal Area -	The average basal area per acre in these size classes is 97.6. The standard deviation is 60.8. Values range from 53.3 to 200.0. At the 90% probability level more than 19 square feet per acre will be present in trees ≥30" DBH.

7.Snags:

Conifer snags ≥30"DBH

Number of snags	The average number of snags per acre in these size classes is 2.4. The standard deviation is 2.1. Values range from 0 to 5.9.
Basal Area	The average basal area per acre in these size classes is 19.2. The standard deviation is 15.0. Values range from 0 to 40.0.

8.Logs:

Conifer logs ≥30"

Number of logs	There was only 1 sample on sites 4 to 5 in this association. Values will not be reported for this variable.

Western Juniper Association

All sites combined

1.Species composition: Conifer tree cover is low on these sites. The mean tree cover is 29%. The standard deviation is 13%. Values range from 4 to 61%. Western juniper constitutes 58% of the stand. Jeffrey pine constitutes 14%, red fir averages 9%, and lodgepole pine constitutes 9%. Other species average 10%

2.Age: Stands on these sites assume old growth characteristics at approximately 200 years.

3.Tree height: Dominant western juniper on the site will have attained 30 feet.

4.Stand Structure: An irregular structure is most common on these sites. Regeneration and size classes between 11 and 25" are underrepresented while trees larger than 30" are overrepresented. Different size classes are distributed randomly throughout the stand. At least 3 size classes must be present. Trees $\geq$30"DBH or $\geq$200 years old are present as indicated below.

5.Canopy Layering: canopy layers coincide with diameter distributions. Rarely do stands approach an even age structure. In stands with several diameter classes, several canopy layers are present.

6.Live Trees:

Conifer trees $\geq$30"DBH

Number of trees - The average number of trees per acre in these size classes is 11.0. The standard deviation is 5.6. Values range from 2.6 to 23.1. At the 90% probability level more than 3.8 trees per acre $\geq$30" DBH will be present.

Basal Area - The average basal area per acre in these size classes is 102.5. The standard deviation is 49.9. Values range from 29.0 to 186.7. At the 90% probability level more than 38.7 square feet per acre will be present in trees $\geq$30" DBH.

7.Snags:

Conifer snags $\geq$30"DBH

Number of snags The average number of snags per acre in these size classes is 1.2. The standard deviation is 1.1. Values range from 0 to 3.6.

Basal Area The average basal area per acre in these size classes is 13.3. The standard deviation is 11.3. Values range from 0 to 40.0.

8.Logs:

Conifer logs

Number of logs The average number of logs is 2.0. The standard deviation is 1.9. Values range from 0 to 4.0.

Quaking Aspen Association

Sites 0 to 3

1.Species composition: Tree cover is high on these sites. The mean tree cover is 76%. The standard deviation is 10%. Values range from 49 to 91%. Quaking aspen constitutes 62% of the stand. Red fir constitutes 23%; white fir averages 10%. Other conifer species constitute 5%.

2.Age: Stands on these sites assume old growth characteristics at approximately 80 years.

3.Tree height: Dominant Aspen on the site will have attained 65 feet.

4.Stand Structure: An irregular structure is most common on these sites, but they commonly appear as even aged or 2 storied stands. The aspen component exhibits an even-aged structure with most stems centered around 10 to 18 inch diameter trees. Aspen regeneration tends to be high due to the sprouting characteristics of this species. Trees larger than 25" are generally conifers that have invaded these sites in the past. They impart a bimodal structure to the stand. Different size classes are distributed randomly throughout the stand. At least 3 size classes are present.

5.Canopy Layering: canopy layers coincide with diameter distributions. In those stands which approach an even age structure, a single canopy layer predominates. In stands with several diameter classes, several canopy layers are present.

6.Live Trees:

Aspen trees >18-25"<

Number of trees - The average number of aspentrees per acre in these size classes is 17.7. The standard deviation is 12.1. Values range from 0 to 43.6. At the 80% probability level more than 7.5 trees per acre between 18 and 25 inches DBH will be present.

Basal Area - The average basal area per acre for aspen in these size classes is 47.0. The standard deviation is 32.3. Values range from 0 to 106.7. At the 90% probability level more than 19.0 square feet per acre between 18 and 25 inches DBH will be present.

Conifer trees ≥30"DBH

Number of trees - The average number of trees per acre in these size classes is 6.4. The standard deviation is 6.6. Values range from 0 to 22.3. At the 75% probability level more than 2.0 trees per acre ≥30"DBH will be present.

Basal Area - The average basal area per acre in these size classes is 60.2. The standard deviation is 55.6. Values range from 0 to 173.4. At the 80% probability level more than 13.6 square feet per acre will be present in trees ≥30" DBH.

7.Snags:

Aspen snags >18-25"<

Number of snags — The average number of aspen snags per acre in these size classes is 2.5. The standard deviation is 4.4. Values range from 0 to 16.3.

Basal Area — The average basal area per acre for aspen in these size classes is 6.2. The standard deviation is 10.7. Values range from 0 to 40.0.

Conifer snags ≥30"DBH

Number of snags - The average number of snags per acre in these size classes is 0.8. The standard deviation is 1.1. Values range from 0 to 3.6

Basal Area - The average basal area per acre in these size classes is 8.2. The standard deviation is 12.5. Values range from 0 to 40.0.

8.Logs:

Logs all species ≥18" large end

Number of logs — The average number of logs in these size classes is 10.0. The standard deviation is 8.5. Values range from 4.0 to 16.0.

Sites 4 to 5

1.Species composition: Aspen tree cover is moderate on these sites. The mean tree cover is 64%. The standard deviation is 19%. Values range from 33 to 81%. Quaking aspen constitutes 64% of the stand. Western juniper constitutes 15% of the stand. Red fir constitutes 9%, and lodgepole pine averages 7%. Other conifer species constitute 5%.

2.Age: Stands on these sites assume old growth characteristics at approximately 80 years.

3.Tree height: Dominant trees on the site will have attained 40 feet.

4.Stand Structure: An irregular structure is most common on these sites, but they commonly appear as 2 storied stands. The Aspen component exhibits an even-aged structure with most stems centered approximately around a 16 inch diameter tree. Aspen regeneration tends to be high due to the sprouting characteristics of this species. Trees larger than 25" are generally conifers that have invaded these sites in the past. They impart a bimodal structure to the stand. Different size classes are distributed randomly throughout the stand. At least 3 size classes are present as indicated below.

5.Canopy Layering: canopy layers coincide with diameter distributions. In those stands which approach an even age structure, a single canopy layer predominates. In stands with several diameter classes, several canopy layers are present.

6.Live Trees:

Aspen trees >18-25"<

Number of trees - The average number of trees per acre in these size classes is 7.6. The standard deviation is 7.3. Values range from 0 to 21.8. At the 90% probability level more than 1.5 trees per acre between 18 and 25 inches DBH will be present.

Basal Area - The average basal area per acre in these size classes is 18.7. The standard deviation is 17.8. Values range from 0 to 53.3. At the 90% probability level more than 7.2 square feet per acre will be present.

Conifer trees ≥30"DBH

Number of trees - The average number of trees per acre in these size classes is 5.9. The standard deviation is 7.0. Values range from 0 to 18.9. At the 75% probability level more than 1.2 trees per acre ≥30"DBH will be present.

Basal Area - The average basal area per acre in these size classes is 56.7. The standard deviation is 72.5. Values range from 0 to 200.0. At the 75% probability level more than 48.6 square feet per acre will be present in trees ≥30" DBH.

7.Snags:

Aspen snags >18-25"DBH

Number of snags The average number of snags per acre in these size classes is 0.4. The standard deviation is 1.0. Values range from 0 to 2.7.

Basal Area The average basal area per acre in these size classes is 1.0. The standard deviation is 2.5. Values range from 0 to 6.7.

Conifer snags ≥30"DBH

Number of snags - The average number of snags per acre in these size classes is 0.4. The standard deviation is 0.8. Values range from 0 to 2.0.

Basal Area - The average basal area per acre in these size classes is 3.0. The standard deviation is 5.4. Values range from 0 to 13.3.

8. Logs:

Logs all species >18" large end	
Number of logs	The average number of logs per acre in these size classes is 2.0. The standard deviation is 3.5. Values range from 0 to 6.0.

TABLE 1

CHARACTERISTICS OF OLD GROWTH
CALIFORNIA MIXED SUBALPINE FORESTS

WESTERN WHITE PINE ASSOCIATION

	R5 SITE CLASS 0-3	R5 SITE CLASS 4-5
1. SPECIES COMPOSITION	PERCENT COVER IN WESTERN WHITE PINE IS 30% ± 17%	PERCENT COVER IN WESTERN WHITE PINE IS 35% ± 18%
2. AGE	≥150 YEARS	≥200 YEARS
3. HEIGHT OF DOMINANTS	WESTERN WHITE PINE DOMINANTS ≥75 FEET	WESTERN WHITE PINE DOMINANTS ≥65 FEET
4. STAND STRUCTURE	IRREGULAR. AT LEAST 3 DIAMETER CLASSES PRESENT	IRREGULAR. AT LEAST 3 DIAMETER CLASSES PRESENT
5. CANOPY LAYERING	MULTILAYERED. LAYERS CORRESPOND TO DIAMETER DISTRIBUTION	MULTILAYERED. LAYERS CORRESPOND TO DIAMETER DISTRIBUTION
6. LIVE TREES ≥30" DBH		
NUMBER	20.8 ± 11.9 90% OF STANDS: ≥5	16.5 ± 7.0 90% OF STANDS: ≥7
BASAL AREA (SQ FT)	177.5 ± 98.1 90% OF STANDS: ≥52	132.2 ± 59.8 90% OF STANDS: ≥55
7. SNAGS ≥30" DBH		
NUMBER	1.2 ± 1.6	1.8 ± 1.8
BASAL AREA (SQ FT)	14.8 ± 21.4	14.9 ± 16.1
8. LOGS ≥30" LARGE END		
NUMBER	2.0 ± 2.0	1.7 ± 2.3

TABLE 2

CHARACTERISTICS OF OLD GROWTH
CALIFORNIA MIXED SUBALPINE FORESTS

MOUNTAIN HEMLOCK ASSOCIATION

	R5 SITE CLASS 0-3	R5 SITE CLASS 4-5
1.SPECIES COMPOSITION	PERCENT COVER IN MOUNTAIN HEMLOCK IS 44% ± 26%	PERCENT COVER IN MOUNTAIN HEMLOCK IS 41% ± 28%
2.AGE	≥150 YEARS	≥200 YEARS
3.HEIGHT OF DOMINANTS	MOUNTAIN HEMOLCK DOMINANTS ≥85 FEET	MOUNTAIN HEMLOCK DOMINANTS ≥65 FEET
4.STAND STRUCTURE	IRREGULAR. AT LEAST 3 DIAMETER CLASSES PRESENT	IRREGULAR. AT LEAST 3 DIAMETER CLASSES PRESENT
5.CANOPY LAYERING	MULTILAYERED. LAYERS CORRESPOND TO DIAMETER DISTRIBUTION	MULTILAYERED. LAYERS CORRESPOND TO DIAMETER DISTRIBUTION
6.LIVE TREES ≥30" DBH		
NUMBER	22.3 ± 10.6 90% OF STANDS:≥8	13.3 ± 7.3 90% OF STANDS: ≥7
BASAL AREA (SQ FT)	191.6 ± 86.5 90% OF STANDS: ≥80	112.3 ± 65.8 90% OF STANDS: ≥55
7.SNAGS ≥30" DBH		
NUMBER	1.7 ± 2.0	1.4 ± 1.3
BASAL AREA (SQ FT)	17.2 ± 21.5	12.7 ± 13.2
8.LOGS ≥25" LARGE END		
NUMBER	3.6 ± 5.0	2.0 ± 2.5

TABLE 3

CHARACTERISTICS OF OLD GROWTH
CALIFORNIA MIXED SUBALPINE FORESTS

WHITE FIR-JEFFREY PINE ASSOCIATION

	R5 SITE CLASS 0-3	R5 SITE CLASS 4-5
1. SPECIES COMPOSITION	PERCENT COVER IN WHITE FIR 44% ± 24% JEFFREY PINE 22% ± 17%	PERCENT COVER IN WHITE FIR 33% ± 27% JEFFREY PINE 21% ± 14%
2. AGE	≥150 YEARS	≥200 YEARS
3. HEIGHT OF DOMINANTS	WHITE FIR OR JEFFREY PINE DOMINANTS ≥95 FEET	WHITE FIR OR JEFFREY PINE DOMINANTS ≥75 FEET
4. STAND STRUCTURE	IRREGULAR. AT LEAST 3 DIAMETER CLASSES PRESENT	IRREGULAR. AT LEAST 3 DIAMETER CLASSES PRESENT
5. CANOPY LAYERING	MULTILAYERED. LAYERS CORRESPOND TO DIAMETER DISTRIBUTION	MULTILAYERED. LAYERS CORRESPOND TO DIAMETER DISTRIBUTION
6. LIVE TREES ≥30" DBH		
NUMBER	20.6 ± 10.6 90% OF STANDS: ≥7	12.8 ± 7.8 90% OF STANDS: ≥3
BASAL AREA (SQ FT)	187.8 ± 101.0 90% OF STANDS: ≥58	97.6 ± 60.8 90% OF STANDS: ≥20
7. SNAGS ≥30" DBH		
NUMBER	2.8 ± 2.7	2.4 ± 2.1
BASAL AREA (SQ FT)	24.5 ± 24.4	19.2 ± 15.0
8. LOGS ≥30" LARGE END		
NUMBER	4.0 ± 4.8	NOT OBSERVED

TABLE 4

CHARACTERISTICS OF OLD GROWTH
CALIFORNIA MIXED SUBALPINE FORESTS

WESTERN JUNIPER ASSOCIATION

	ALL SITE CLASSES
1. SPECIES COMPOSITION	PERCENT COVER IN: WESTERN JUNIPER 58% ± 28% JEFFREY PINE 14% ± 17%
2. AGE	≥200 YEARS
3. HEIGHT OF DOMINANTS	WESTERN JUNIPER DOMINANTS ≥30 FEET
4. STAND STRUCTURE	IRREGULAR. AT LEAST 3 DIAMETER CLASSES PRESENT
5. CANOPY LAYERING	MULTILAYERED. LAYERS CORRESPOND TO DIAMETER DISTRIBUTION
6. LIVE TREES ≥30" DBH	
NUMBER	11.0 ± 5.6 90% OF STANDS: ≥4
BASAL AREA (SQ FT)	102.5 ± 49.9 90% OF STANDS: ≥39
7. SNAGS ≥30" DBH	
NUMBER	1.2 ± 1.1
BASAL AREA (SQ FT)	13.3 ± 11.3
8. LOGS ALL SIZES	
NUMBER	2.0 ± 1.9

TABLE 5

CHARACTERISTICS OF OLD GROWTH
CALIFORNIA MIXED SUBALPINE FORESTS

QUAKING ASPEN ASSOCIATION

	R5 SITE CLASS 0-3	R5 SITE CLASS 4-5
1.SPECIES COMPOSITION	PERCENT COVER IN QUAKING ASPEN 62% ± 25%	PERCENT COVER IN QUAKING ASPEN 64% ± 21% WESTERN JUNIPER 15% ± 20%
2.AGE	≥100 YEARS	≥100 YEARS
3.HEIGHT OF DOMINANTS	QUAKING ASPEN DOMINANTS ≥65 FEET	QUAKING ASPEN DOMINANTS ≥40 FEET
4.STAND STRUCTURE	IRREGULAR. AT LEAST 2 DIAMETER CLASSES PRESENT	IRREGULAR. AT LEAST 2 DIAMETER CLASSES PRESENT
5.CANOPY LAYERING	MULTILAYERED. COMMONLY 2 STORIED. LAYERS CORR-ESPOND TO DIAMETER DISTRIBUTION	MULTILAYERED. COMMONLY 2 STORIED. LAYERS CORR-ESPOND TO DIAMETER DISTRIBUTION
6.ASPEN TREES 18-25" DBH		
NUMBER	17.7 ± 12.1 90% OF STANDS: ≥2	7.6 ± 7.3 90% OF STANDS: ≥1
BASAL AREA (SQ FT)	47.0 ± 32.3 90% OF STANDS: ≥19	18.7 ± 17.8 90% OF STANDS: ≥7
7.ASPEN SNAGS 18-25" DBH		
NUMBER	2.5 ± 4.4	0.4 ± 1.0
BASAL AREA (SQ FT)	6.2 ± 10.7	1.0 ± 2.5
8.LOGS ≥18" LARGE END		
NUMBER	10.0 ± 8.5	2.0 ± 3.5

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Ecological Characteristics of Old Growth Lodgepole Pine in California

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INTRODUCTION

The Chief, Forest Service has directed all Regions to prepare quidelines which define old growth for major forest types. These guidelines have been prepared in response to that direction. In Region 5 of the Forest Service an effort is also underway to classify these forests into Ecological Types for purposes of management and research. Since many of the samples taken for classification were in late seral stands of lodgepole pine (Pinus contorta var. murrayana), they were examined to determine which characteristics could also be used to describe older lodgepole pine forests. This paper describes the features of these forests useful in such a characterization, and it provides guidelines that can be used to define old growth stands that lie in the lodgepole pine cover type (218) recognized by the Society of American Foresters (1980). Results are summarized in Table 1 on page 14.

DISTRIBUTION

Lodgepole pine covers a wide range in the west. It extends from the Yukon to Baja California and east to South Dakota (Griffin and Critchfield 1972). In California the Sierra Nevada-Cascade form is known as Pinus contorta var. murrayana, and it extends from the eastern Siskyou mountains in the north to the Modoc Plateau and south through the Sierra Nevada to the penninsular ranges of southern california. Elevations range from near sea level to almost 12,000 feet. Throughout most of the range in California it occupies middle to upper elevations. It commonly occurs in pure stands, but just as often it is mixed with other species.

METHODS

Samples came from data collected as part of the Ecological Type Classification being conducted by Region 5 of the Forest Service (Allen, 1987). They were intended to be used for classification purposes. The basic unit of sample was a stand, and no limits were placed on size of stand for sampling purposes. Stands were selected based on their appearance as relatively undisturbed habitats with homogeneous species composition in late seral condition. The concept used to select stands was to sample from a range of aspects, elevations, species composition, soil types, community structure, and site index. No attempt was made to include or exclude stands because of features suspected of describing old growth characteristics. For this reason, the stands selected are felt to represent conditions on the majority of lodgepole pine stands in these forests. Variation in species composition, cover values, structural diversity, and habitat was sought rather than indications of the aging process.

Data collection followed the procedures described in the Region 5 Ecosystem Classification Handbook and the Region 5 Timber Management Plan Inventory Handbook. At each sample site a 1/10 acre circular plot was used to gather information on species composition, cover values, abundance and environmental setting. One tenth acre and 1/2 acre circular plots were used to obtain information on snags and logs. A 3 point "cluster" was used to establish variable radius plot centers as the basis for determining tree species composition, stand structure, basal area, and volume. Determination of site index came from a sample of height and age of dominant and codominant trees on each point in the cluster. Diameters were recorded at breast height in classes for purposes of data analysis. The diameter classes used were: 1-5.9", 6-10.9", 11-17.9", 18-24.9", 25-29.9", 30-39.9", and 40"+.

To meet the criteria for the lodgepole pine cover type, stands must contain a plurality of the basal area stocking in lodgepole pine. That is, lodgepole pine must comprise the largest proportion in stands of mixed composition. In California, lodgepole pine is commonly associated with red fir (Abies magnifica and Abies magnifica var. shastensis), Jeffrey pine (Pinus Jeffreyii), white fir (Abies concolor), western white pine (Pinus monticola), mountain hemlock (Tsuga mertensiana), western juniper (Juniperus occidentalis), and quaking aspen (Populus tremuloides). These species are often in intimate mixtures. This is partucularly true in the Sierra Nevada Range where many stands in which lodgepole pine is a significant component actually contain more basal area in red fir. And yet, it is known from classification work in these forests (Potter, unpublished) that the presence of lodgeple pine above a threshold level often indicates different environmental conditions. Therefore, the rule used to select lodgepole pine samples from the larger data set was that lodgepole pine must represent more than 25% of the total basal area stocking, and it must represent a plurality of the basal area stocking of species other than red fir.

To date, 740 stands have been sampled for classification purposes in the region from Lake Tahoe south to the Sequoia National Forest. Among them a subset of 91 stands met the criteria for lodgepole pine and were selected as the data set to be used in the analysis. Approximately 30% of the stands contained 100% of the basal area stocking in lodgepole pine. In 52% of the stands lodgepole pine comprised more than 50% of the basal area stocking, and in 18% of the stands lodgepole comprised a plurality of the stocking in species other than red fir. The following National Forests and National Parks were represented in the sample: the Eldorado, Stanislaus, Sierra, Sequoia, Inyo, Lake Tahoe Basin Management Unit, and Toiyabe National Forests and Yosemite and Sequoia-Kings Canyon National Parks. As noted, these samples were taken on undisturbed sites.

Stand ages were based on the age of the oldest tree measured on each site. Samples used for classification purposes usually had three dominant or codominant trees measured per site. In many cases, because of species or size differences, additional trees were measured. No attempt was made; however, to fully age each stand through a complete sample of all size classes. To attempt to report on stand age from stands with skewed and irregular structures, as many of these are, could also be misleading. Therefore it was decided to use the age of the oldest tree as the measure of stand age. This is in agreement with investigators doing work in associated red fir (Schumacher 1928) as well as other types.

Forty nine variables were examined. They emphasized 5 areas of concern: the effects of species composition, changes in cover values, stand structure, and biomass accumulation over time, and stand size. The analysis proceeded in two parts. First, information on stand structure, trees and snags per acre by diameter group, species composition and site index were determined for each sample using R5*FS.FIA-SUMMARY and R5*FS.FIA-MATRIX part of a series of Region 5 timber inventory and data expansion programs known as Forest Inventory and Analysis (FIA). Each plot was also processed through PROGNOSIS, a stand growth and yield simulation model developed by Stage and others (Stage 1973) to determine values for quadratic mean diameter, stand density index, mean annual increment, and total cubic foot volume. Values from these programs were combined into a single data set for further analysis. Cover values for shrubs, forbs, and grasses were obtained from data sets developed for the classification project. A separate data set for logs had been developed for the classification effort, and it was used to derive values reported for logs. Samples were then aggregated into two site index groups: Region 5 site index 0 to 3 representing high sites, and Region 5 site index 4 and 5 representing low sites. To examine stand size, existing data bases on each of the National Forests in the study area were queried for number of stands that existed in certain size classes. The size classes examined were 0-10 acres, 10-20 acres, 20-30 acres, 30-50 acres, 50-100 acres, and those exceeding 100 acres.

Variables were tested for normality and transformed as necessary for statistical analysis. The analysis then proceeded using regression techniques to explore diameter, height, and age relationships of individual trees by species and site group. This was followed by examining survivorship curves for individual species and stands. Scatter plots and linear regression were used to explore relationships among variables over time, and time series was also used to look in detail at the data through time. The results of this analysis became the framework for which an Analysis of Variance to isolate variables correlated with broad differences in age was performed. The ability of those variables to differentiate between age groupings were tested using Discriminant Analysis techniques. Finally, Chi square was used to evaluate differences in stand size.

RESULTS

The data set for lodgepole pine is not large for younger stands. Consequently, clear patterns of stand development over long time periods could not be fully determined. However, based on work in red fir, which is a common associate in these forests, it would appear that similar patterns of stand development through time are present. Red fir develops features characteristic of older stands in approximately 150 years on sites 0 to 3 and 200 years on sites 4 to 5. The analysis performed for this type indicates similar patterns.

Height-diameter relationships indicate that lodgepole pine is smaller in diameter and shorter in height than red fir at comparable ages. While stands may appear younger due to smaller diameters, they are not necessarily different from associated red fir or white fir in age. The oldest lodgepole pine measured on sites 0 to 3 was 364 years while on sites 4 to 5 the oldest tree was 443 years. Survivorship curves shows steady but substantial mortality over a relatively long period in both site groups. Substantial losses commence around 80 years and continue at high rates until nearly 300 to 350 years. This would appear to indicate that losses later in the life of a stand are due to more than inter-tree competition. While early losses in stands are due to natural thinning, environmental factors such as fire, drought, insects, disease, or wind eventually become major contributors to mortality.

Time series analysis showed consistent variation in biomass accumulation by site class in older stands. This was correlated with changes in the distribution of trees by size class, and reflected steady mortality in large trees with concurrent recruitment of small trees through time. Examination of stand structures over time illustrated these patterns well. They showed that at some point in time stands assume an irregular structure and several size classes are occupying sites simultaneously. Young stands are characterized by little regeneration, a high number of small trees, and few large trees. Older stands are characterized by moderate regeneration, substantially fewer small trees, trees in several size classes, and a significant component of large trees.

On high sites the picture that emerges from the data is one of high numbers of trees occupying stands at some point after a major stand replacing event. This is followed by significant losses due to thinning early in the life of the stand, and it is followed still later by a stabilized condition characterized by a constantly changing structure in which many classes are present on a site simultaneously. This last condition results as small gaps and openings are created in a mature overstory in response to environmental conditions such as fire, wind, or drought. Regeneration then becomes established in these openings, grows, self thins, and matures. In time, several size classes, including a substantial portion of larger trees, are represented,and the stand exhibits an irregular structure. On sites 0 to 3 this seems to occur around 150 years. It also occurs on many, but not all, low sites around 200 years. This corresponds well with ages found to be representative of old growth conditions in red fir, a commonly associated species. It supports the hypothesis that as stands occupy sites for longer and longer periods environmental factors become more important in developing stand structures that characterize old growth conditions. These same factors continue to be important in maintaining old growth conditions until the site suffers a stand replacing event, and the cycle renews.

On many low sites the patterns are different. First, many of these stands are very open with low tree densities. Except for sites with a high shrub component, it is difficult to imagine enough fuel to carry a stand replacing fire. Nor is it reasonable to expect that other events such as insects or disease would replace entire stands. Avalanche would appear to be the one environmental factor capable of such an event, and while common in certain areas, they are not widespread. Second, in the Lodgepole Pine Type few stands on low sites were found that were less than 200 years old. This confirms what has been found in red fir and mixed subalpine stands associated with lodgepole pine. Few stands less than 200 years old are present on low sites. This implies that these stands do not cycle through a stand initiation phase in which high numbers of trees originate more or less simultaneously and progress through time as cohorts. Rather, stand development appears to be sporadic as opportunities arise in response to disturbance levels. Small patches or stands may react similar to better sites with simultaneous stand origin, followed by crown closure, self thinning, and stand opening as gaps are created. However, in most cases, it appears stand initiation is a prolonged process with many aborted attempts. Stand development occupies considerable periods of time, and during these long periods the probability is high that an environmental event will impact the stand and recycle portions back to an earlier period. Inevitably, some individuals escape environmental damage and mature into larger members of the stand. In time, the stand takes on a very open appearance with an irregular stand structure dominated by large trees which are the survivors of several stand altering events. Thus, these stands arrive at a structure similar to better sites but with lower densities and through a different process of development. Other than in early stages of stand initiation, mortality appears to be responding to environmental circumstance more than competition.

Variables that could be used to distinguish between age groups in each of the associations were examined by One-way Analysis of Variance and Discriminant Analysis techniques. Several variables were identified, and those that would be useful in field applications were incorporated into the descriptions. In most cases snag and log numbers were highly variable with skewed distributions. Reliable comparisons with Analysis of Variance techniques could not be developed except for snags larger than 40 inches and logs less than 18 inches on sites 0-3.

When comparing stands less than 150 years with those over 150 years on sites 0 to 3 and those less than 200 with those over 200 on sites 4 to 5 several variables were found to be significantly different at the 95% probability level. These results are summarized as follows:

Variables significantly higher by age group

Sites 0-3

<150 Years	>150 Years
Trees per acre 11-18"	Quadratic Mean Diameter Height of dominant trees Trees per acre >30" DBH Snags per acre >40" DBH Logs per acre <18"

Sites 4-5

<200 Years	>200 Years
Total trees per acre Trees per acre <11" DBH	None

These variables were then examined by Stepwise Discriminant Anlaysis. On sites 0 to 3, a 78.6% correct classification function was attained using number of trees in size classes between 11 and 18 inches, and height of dominant trees. In essence, this means the presence of higher numbers of trees between

12 and 18 inches can be used to discriminate younger stands, while the attainment of most of the height growth potential of the site by dominant trees can be used to discriminate older stands on sites 0 to 3.

On sites 4 to 5 a 77.1% correct classification function was attained using the number of trees <11 inches. It appears then, that higher number of trees per acre smaller than 11 inches can be used to differentiate stands less than 200 years old.

In actual practice, the use of several variables is preferred to a paired down list. The variability of many features of these stands is often wide, and if more variables can be used in concert to distinguish between older and younger stands a better solution on the ground is likely. On the other hand some of the variables identified in the analysis are impractical for field use. Quadratic Mean Diameter and total trees per acre are examples. For this reason, variables which were felt to be readily observed on the ground are included.

Chi Square analysis of the distribution by size class confirms what had been observed in the field: the lodgepole pine forest is a mosiac of different size stands intertwined with non-forested areas. Distributions toward smaller size stands were significant. Thus, the number of stands smaller than 20 acres is higher than might be expected, and the number of stands greater than 100 acres is smaller than might be expected. This would probably also be true in smaller sizes except that most forest data bases do not track stands smaller than 10 acres. Comparisons were made with roaded and unroaded areas and between forested and non-forested areas (shrub stands) with similar results. Thus, the lodgepole pine forest appears as a spatially complex ecosystem with a general pattern of relatively small to middle size stands.

DISCUSSION

Often lodgepole pine forests are viewed as being relatively even aged as a result of fire. They are perceived to exhibit a normal distribution of size classes or a two storied or bimodal distribution. Interior stands of lodgepole pine in the Rocky Mountains and Pacific Northwest, for example, do exhibit an even sized structure, apparently from fire, but this does not seem to be the case in many areas of California. Fire frequency and intensity appear to be low in these forests (Parsons,1980; J. van Wagtendonk personal communication; Potter unpublished), and thus the patterns of development are different. Individual stands may exhibit even aged characteristics, but often they do not. Even age or bimodal structures do appear commonly at the edge of meadows, and in moist areas. The most common distribution,however, is one approaching the reversed J-shape of an uneven aged stand.

Models of stand dynamics in old growth forests are not abundant. Foresters commonly use the culmination of mean annual increment to define the point at which stands are considered mature. In California yield tables have not been developed for lodgepole pine. The only associated species for which such work has been done is red fir. In red fir forests, available yield tables

(Schumacher, 1928) indicates the culmination of mean annual increment to be around 140 years. The age at which stands assume old growth characteristics is unclear using this guide.

The Society of American Foresters cover types provide a description of vegetation existing on sites at the moment. They convey little insight into the change of vegetation over time. Conceptual models such as successional change, climax conditions, or potential natural vegetation that may be useful in gaining insights into old growth conditions are not a part of these descriptions. They do not, for example, explore the variation in species composition, stand structure, or ecosystem functioning that links particular plant communities to specific habitats over time. They do, however, provide a practical tool that can be used in large scale inventory and cross regional comparisons.

Vegetation in the forests occupied by lodgepole pine has been stabilizing over long periods of time. In the Sierras, for example, the last major glacial advance appears to have ended around 10,000 years ago, and the vegetaion on vacated sites has been sorting itself out ever since. In other areas, volcanism or climatic shifts have been creating similar conditions. Time in these forests is a continum of which human perception catches only a glimpse. Relatively few stands of lodgepole pine originate within a specific period, develop as cohorts, and die simultaneously. Stand replacing fires do occur in lodgepole pine, but this does not appear to be a widespread or large scale phemomenon. Neither are blowdown, insects, disease, lightning, or avalanche. It appears that all of these factors are operating continuously, but on a small scale. This results in a constantly changing species composition and structure within a stand as individuals and small groups of trees and other vegetation are cycled into and out of the stand in different amounts at different times. This makes it difficult to define the age of a stand other than in a general sense, but it does focus attention on characteristics other than age which are suggestive of the passing of time within a particular stand.

A model felt to be applicable to better sites and some low sites, and one which seems to fit observations in the field, is that outlined by Peet and Christiansen (1987) and developed initially by Oliver (1981). Under this model four phases of stand development are recognized: establishment, thinning, transition, and the steady state. Competition-induced mortality is a key feature of stands in the thinning phase, which can last for relatively long time periods; however, the transition and steady state phases are of most interest here. During the transition phase mortality becomes independent of stand density, gaps in the canopy occur, and these are filled with young age classes. This phase may last for several decades. The steady state forest is then typified by an uneven age or irregular structure composed of relatively small even age patches. This pattern cycles over time as younger patches become established, thin themselves, and form gaps. All three of the earlier phases are present simultaneously. This stage is most likely terminated by a stand replacing disturbance such as fire. As noted earlier, this model does not fit all cases on lower sites. The model described in the Results section seems to provide better agreement with field observations in many cases;

nevertheless, the steady state forest does seem to develop essentially the same general structure over time. It appears this form can be used to define old growth forests of lodgepole pine, and that is the approach used here.

The distinction between transition and steady state is not sharp. It may cover several decades. Therefore, attention was focused on identifying variables that could be used to approximate the age at which stands developed characteristics typical of a transition phase. Once this age was identified it was assumed that older stands would be in the transition or steady state condition if they continued to exhibit characteristics such as an irregular or uneven age structure, presence of larger trees, and relatively high stand density for the site. No attempt was made to differentiate between the transition and steady state phases since forests in both phases have similar characteristics.

The point at which a period of increasing Quadratic Mean Diameter in younger developing stands is followed by a significant decrease was one feature that might suggest the beginning of the transition phase. A decrease in Quadratic Mean Diameter at that point would imply the stand was breaking up. It would be expected to coincide with an increase in regeneration and smaller size classes (saplings and poles). This would indicate the formation of gaps in the canopy that could not be filled by crown closure and became available for regeneration. The presence of large numbers of these smaller trees reduces the quadratic mean diameter. Stand density index usually increases at this time as well. As noted earlier, the data set for lodgepole pine forests contains few samples in early seral condition, and the point at which Quadratic Mean Diameter increases substantially and is followed by a sharp decline was not obvious. What is clear from the data is that these stands have apparently already arrived at a condition that can be described as old growth. Considerable variation in productivity, Quadratic Mean Diameter, and density is occuring, and this variation is reflected in the structure of the stands. Many size classes are present including regeneration and small trees. This indicates the opening of the stand and establishment of younger age classes has occurred.

Development of larger size trees is a trait that develops over time, and this can often be used to indicate advancing stand age. Generally, at the point of transition the number of larger trees increases to levels that are typical from that point on. This is usually further substantiated when the number of trees in the smaller size class decreases significantly at the same time. This decrease results from both growth of smaller size classes into larger classes as well as a response to competition-induced mortality which thins suppressed individuals of this size class. As noted above, the data set for lodgepole pine does not provide a clear picture of early stand development, and most of the stands in the sample are felt to already be in an old growth condition. What can be observed is that trees larger than 25 inches are present in somewhat stable numbers. They vary over time in response to environmental conditions, but they have essentially become permanent features of the stand.

Generally, mortality becomes independent of density as stands age. This does seem to be the case for these forests. The time series for snags illustrates a correlation between the number of smaller snags and the number of small trees up to 150 years on sites 0 to 3 and 200 years on sites 4 and 5. Logs smaller than 18 inches are also significantly more abundant in stands less than 150 years on sites 0 to 3. This is to be expected as the result of heavy thinnings during this period. Time series for most of the stands in the data set show mortality of larger size classes to be somewhat uncorrelated with density. Survivorship curves on both high and low sites show a steady decline in individuals over time. This would also indicate that at least some mortality is occuring which is independent of density.

Under the model presumed to describe these forests, an irregular or uneven age structure would be present in stands past the transition phase. This structural pattern has been noted elsewhere as characteristic of older stands (Assman,1970; Baker,1962; Veblen,1985; Parker,1985; Taylor,1991). Profiles of diameter distributions indicate structures skewed to the right with high numbers of trees less than 11 inches during the thinning phase. Regeneration at this time is low, and large size classes are missing. Past the thinning phase, few of the samples fit an ideal "reverse J" pattern of an optimally distributed uneven age stand, but an irregular structure in which large size classes are overrepresented and regeneration is generally underrepresented is common. In most stands at least 3 size classes appeared to be present. While there are many patches that exhibit the "normal" distribution of even age stands, they generally do not cover large, continuous areas. Trees from different size classes tend to be distributed randomly or in small patches within a stand. If the general structure was irregular or uneven age in appearance with dominants in at least 3 size classes then it was presumed this condition had been satisfied and the stands were in the transition or steady state phase. The stands in this data set do reflect such a structure.

Decadence as reflected in broken and missing tops, scars, the presence of bole, root, and foliage disease, group kills, and lack of crown vigor is an important, but not widespread, component of these forests. Equally important is the presence of decay fungi, and other organisms involved in the decomposition of woody material. The occurance of broken and multiple tops or the frequency and severity of disease related mortality as stands age may have important ramifications in seed production and dissemination and eventual species compostion and site occupancy. These characteristics were not sampled in the initial phases of the classification project, however, and they must remain as general observations at this time.

The lodgepole pine forest cannot be viewed apart from its general setting. The characteristics used to describe these forests are representative of only a portion of the forest. Specifically, only stands with greater than 10% crown cover are described. The lodgepole pine forest is an ecosystem, however, wherein non-forested areas are equally a part of the landscape and fulfill important roles in the overall functioning of that ecosystem. To describe only older stands of trees neglects the "totality" of the lodgepole pine forest. Thus, when using these guides it must be realized that only forested areas are described. The old growth lodgepole pine forest, however, is larger than a simple summary of individual old growth stands.

Linked to the general view of the lodgepole pine forest outlined above is the consideration of size. Size of stands that function as ecological units is important in understanding lodgepole pine ecosystems. Whatever our preconceptions are as to the "optimal" size they must fit with the patterns these forests have evolved over long periods of time. Obviously, these forests are spatially complex, with a range of stand sizes. It is not uncommon to observe undisturbed stands smaller than 5 acres in the field, and stands smaller than 1 acre are not uncommon in these forests. Such stands appear to be complete components of the surrounding ecosystem with full complements of flora and fauna. The guides presented here are intended to be used in stands of all sizes.

An important consideration in old growth lodgepole pine forests is the amount of disturbance these stands have undergone. The stands sampled for this analysis were in late seral condition with as little disturbance as possible. However, as noted earlier, timber harvest has been increasing for the past 40 years, and several stands sampled had logging adjacent to them. Grazing also has been a factor of these forests since the middle to late 1800's. This activity peaked in the latter 1800's and early part of the 1900's, but most stands continue to be grazed. Fire suppression activities started to become effective in the 1930's, and mining activity was important in localized situations. More recently, air quality is being reduced over many areas by the current activities of man. Of course wind, fires, insects and disease, cutting by indigeneous pre-European populations, and browsing by herbivores has been present over long periods. The point is made that old growth lodgepole pine forests are not in an undisturbed condition, nor have they been particularly free of broad ranging effects of man for many decades. For practical purposes, however, the stands described have been undisturbed except for natural phenomenon, fire suppression, and grazing. Timber harvest has not been a part of the stand history.

These guides were developed from and intended for use in stands that became established and developed for long periods under naturally occuring processes (except for grazing). These processes include: natural fires, insect and disease activity, browsing by indigeneous herbivores, wind, avalanches, climatic cycles, lightning, competition, and species selection processes. Establishment has been the result of natural distribution of seed from parents generally in close proximity to a stand. Stand density, diameter distribution, spacing, growth patterns, and vertical arrangement are generally the result of these naturally occuring processes.

CONCLUSION

From the analysis it appears lodgepole pine stands begin to assume old growth characteristics around 150 to 200 years. Since old growth forests are too complex for simple descriptions to be useful, multiple characteristics are used in the descriptions. Variables which were felt to be readily observed on the ground but could not be statistically compared are also included. Numbers of snags, number of logs, and stand structure are examples. Most have been used by others in describing old growth forests. Judgement will be necessary when using the guides since overlaps occur, and not all characteristics will be present in any one stand or area at any one time. The general setting and characteristics of surrounding stands must be considered as well as the stand under examination. The variables that are used to describe old growth characteristics in this type are: species composition, age, height of dominant trees in the stand, stand structure, canopy layering, stems and basal area per acre of live trees in larger size classes, stems and basal area per acre of dead trees in larger size classes, and number of logs in larger size classes.

DESCRIPTIONS

The following outlines the characteristics and significant observations of old growth forests in the lodgepole pine cover type. They are arranged by site and summarized in Table 1 (page 14). To many, the variation in some of the basic attributes may seem unsettling. They would prefer simpler, more concrete definition. Such definition, however, often raises more questions than it answers. Variation is a fundamental feature of nature, and it must be recognized. Consequently, the mean, standard deviation, and range are shown where appropriate. In addition, where possible, probability statements are included which define minimums expected at a specified level of probability. It was felt this would be more useful to a variety of users in different settings and give a clearer picture of the characteristic over a range of samples. The mean ± one standard deviation will capture the expected values in most situations, and the range will alert one to extreme values that may be outliers. Interpretations can then legitimately be made by users. Regeneration layers are not used in stand structure descriptions. All values are given on a per acre basis.

Lodgepole Pine - SAF Cover Type (218)

Sites 0 to 3

1.Species composition: Conifer tree cover is moderate on these sites. The mean tree cover is 65%. The standard deviation is 16%. Values range from 25 to 95%. Lodgepole pine constitutes 67% of the stand. Red fir constitutes 26%. Other conifer species constitute 7%.

2.Age: Stands on these sites assume old growth characteristics at approximately 150 years.

3.Tree height: Dominant lodgepole pine on the site will have attained 85 feet.

4.Stand Structure: An irregular structure is most common on these sites. Different size classes are distributed in patches throughout the stand. At least 3 size classes must be present. Trees ≥25"DBH or ≥150 years old are present as indicated below.

5.Canopy Layering: canopy layers coincide with diameter distributions. In those stands which approach an even age structure, a single canopy layer predominates. In stands with several diameter classes, several canopy layers are present.

6.Live Trees:

Conifer trees ≥25"DBH

Number of trees -	The average number of trees per acre in these size classes is 21.8. The standard deviation is 8.9. Values range from 8.0 to 41.8. At the 90% probability level more than 10.4 trees per acre ≥25" DBH will be present.
Basal Area -	The average basal area per acre in these size classes is 143.2. The standard deviation is 65.3. Values range from 40.0 to 346.6. At the 90% probability level more than 59.6 square feet per acre will be present in trees ≥25" DBH.

7.Snags:

Conifer snags ≥25"DBH

Number of snags	The average number of snags per acre in these size classes is 3.6. The standard deviation is 6.7. Values range from 0 to 36.0
Basal Area	The average basal area per acre in these size classes is 24.9. The standard deviation is 44.4. Values range from 0 to 240.0

8.Logs:

Conifer logs ≥25" large end

Number of logs	The average number of logs in these size classes is 2.8. The standard deviation is 3.4. Values range from 0 to 8.

Sites 4 to 5

1.Species composition: Conifer tree cover is moderate on these sites. The mean tree cover is 50%. The standard deviation is 18%. Values range from 15 to 80%. Lodgepole pine constitutes 73% of the stand. Other conifer species constitute 23%.

2.Age: Stands on these sites assume old growth characteristics at approximately 200 years.

3.Tree height: Dominant trees on the site will have attained 70 feet.

4.Stand Structure: An irregular structure is most common on these sites. Different size classes are distributed in patches or singly throughout the stand. At least 3 size classes must be present. Trees ≥25"DBH or ≥200 years old are present as indicated below.

5.Canopy Layering: canopy layers coincide with diameter distributions. In those stands which approach an even age structure, a single canopy layer predominates. In stands with several diameter classes, several canopy layers are present.

6.Live Trees:

Conifer trees ≥25"DBH

Number of trees -	The average number of trees per acre in these size classes is 17.3. The standard deviation is 21.4. Values range from 3.3 to 133.3. At the 75% probability level more than 2.9 trees per acre ≥25" DBH will be present.
Basal Area -	The average basal area per acre in these size classes is 83.9. The standard deviation is 47.4. Values range from 16.0 to 239.9. At the 80% probability level more than 42.7 square feet per acre will be present in trees ≥25" DBH.

7.Snags:

Conifer snags ≥25"DBH

Number of snags	The average number of snags per acre in these size classes is 1.8. The standard deviation is 2.7. Values range from 0 to 10.0.
Basal Area	The average basal area per acre in these size classes is 11.9. The standard deviation is 16.8. Values range from 0 to 66.6.

8.Logs:

Conifer logs ≥25"

Number of logs	The average number of logs in these size classes is 1.4. The standard deviation is 1.5. Values range from 0 to 6.

TABLE 1

CHARACTERISTICS OF OLD GROWTH LODGEPOLE PINE FORESTS

	R5 SITE CLASS 0-3	R5 SITE CLASS 4-5
1.SPECIES COMPOSITION	PERCENT COVER IN LODGEPOLE PINE 68% ± 26%	PERCENT COVER IN LODGEPOLE PINE 73% ± 27%
2.AGE	≥150 YEARS	≥200 YEARS
3.HEIGHT OF DOMINANTS	LODGEPOLE PINE DOMINANTS ≥85 FEET	LODGEPOLE PINE DOMINANTS ≥70 FEET
4.STAND STRUCTURE	IRREGULAR. AT LEAST 3 DIAMETER CLASSES PRESENT	IRREGULAR. AT LEAST 3 DIAMETER CLASSES PRESENT
5.CANOPY LAYERING	MULTILAYERED. LAYERS CORRESPOND TO DIAMETER DISTRIBUTION	MULTILAYERED. LAYERS CORRESPOND TO DIAMETER DISTRIBUTION
6.LIVE TREES >25" DBH		
NUMBER	21.8 ± 8.9 90% OF STANDS: ≥10	17.3 ± 21.4 75% OF STANDS: ≥3
BASAL AREA (SQ FT)	143.2 ± 65.3 90% OF STANDS: ≥60	83.9 ± 47.4 90% OF STANDS: ≥23
7.SNAGS ≥25" DBH		
NUMBER	3.6 ± 6.7	1.8 ± 2.7
BASAL AREA (SQ FT)	24.9 ± 44.4	11.9 ± 16.8
8.LOGS >25" LARGE END		
NUMBER	2.8 ± 3.4	1.4 ± 1.5

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INTERIM GUIDELINES DEFINING OLD GROWTH STANDS:
COAST REDWOOD (SAF 232) OF
SOUTHERN MONTEREY COUNTY
CALIFORNIA

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1. INTRODUCTION

Ecosystem Classification plot data were used to formulate an old growth stand descriptor for the coast redwood (Sequoia sempervirens) cover type in central coastal California. This is an Interim Definition.

In southern Monterey County coast redwood forests occur along the coastal drainages usually within 150 feet of perennial or emphemeral streams. Redwood forest acreage between Big Sur and Salmon Creek is less than 15,000 acres. Holland (1986) terms this type Upland Redwood Forest and distinguishes it from the Alluvial Redwood Forest (82310) of northern California by it lower overall stature and tendency to mix with other tree species, particularly hardwoods (Lithocarpus densiflorus and Umbellularia californica).

2. METHODS

Data were derived entirely from Ecosystem Classification plots. A limited number of Forest Inventory plots were available for this type but they were not used in the analysis.

A. ECOSYSTEM CLASSIFICATION PLOTS

Data collection is detailed in Borchert et al. 1988. Minimally disturbed sample stands were selected in a variety of environments in order to sample the variation in the target type. Homogeneous, late seral stage stands were well represented in the data set. A total of 108 Ecology Program plots were used in the analysis.

Each ecosystem classification plot included three variable radius points within the plot using a 80 area factor prism. One point was placed at the center and the other and two at the periphery of the plot. Attributes collected at each point included basal area, diameter at breast height, and height of the average tree in the tallest layer.

Data were collected entirely on Los Padres National Forest. The interim definition should not be used outside this geographic area.

3. LIMITATIONS OF THE ANALYSIS

The Coast Redwood/Common Manroot-Common Vetch//Gamboa-Sur (Borchert et al. 1988) ecological type was not included in the analysis because of the low occurrence of trees $\geq$ 40 inches diameter at breast height. Trees in this ecological type occur on steep slopes near the ocean and are heavily pruned by aerisol salt spray. As a result of their low stature (average height 62 feet) and high density they periodically crown fire and regenerate primarily as resprouts. Thus, trees in this ET rarely reach 35 inches dbh and are likely not nearly the age of the large ($\geq$ 40 inches dbh) that occur fairly regularly in other coast redwood ETs.

Old growth definition in this forest type is based entirely on the basal area and abundance of trees larger than 40 inches dbh which are also the oldest trees in the forest. A final definition must include the quantification of other attributes such as tree layering, downed woody material, snag density, crown condition etc.

4. DATA ANALYSIS PROCEDURES

Counts of tree $\geq$ 40" dbh were averaged for each stand in the other 5 ETs. Basal area was calculated for these trees and density/acre calcualted from basal area using a conversion factor of 9.17. Typical ranges are the mean $\pm$ 2 standard errors.

5. LIMITATIONS

These data are designed to be used to identify and evaluate old growth stands in coast redwood in the southern part of its range. This is an interim definition. When field testing the interim definition, common sense should be applied. Field testing may result in changes in the minimums.

6. OLD GROWTH ATTRIBUTES

The following attributes comprise a standard summary required by the National Old Growth Task Group (2410 letter, 11/21/90, Enclosure 2):

I. Live Trees in Main Canopy; Trees per Acre:
Stand Basal Area: Mean = 560; standard dev. = 192; typical range= 450-650.
Average total tree canopy cover = 100. Typical range= 85-105%.

a. >40"dbh: minimum= 15 trees per acre

Typical range: 25-45 trees per acre >=40" dbh

Basal area of >40" trees: mean= 300; sd= 180; typical range= 260-340

II. Variation in Tree Diameters

Some variation in tree diameters is acceptable. About 50% of the basal area stocking in the stand should be represented by large trees (>40" dbh).

III. Dead Trees

A. Standing snags per acre: No data.

B. Down pieces per acre: No data.

IV. Tree Decadence (Flattening tops, spike tops, bole or root decay, large fire scars)

No data.

V. Number of Tree Canopies

Greater than or equal to 1.

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INTERIM GUIDELINES DEFINING OLD GROWTH STANDS:
PACIFIC PONDEROSA PINE (SAF 245)
PACIFIC SOUTHWEST REGION

Old Growth Definition Team #4:
Sydney Smith, Team Leader; Zone 2 Ecologist
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Pacific Southwest Region
USDA Forest Service
May, 1991

1. INTRODUCTION

Ecology and Forest Inventory data were examined and analyzed to formulate a set of old growth stand descriptors for the Pacific Ponderosa Pine existing vegetation cover type in California. **This is an Interim Definition**.

Pacific Ponderosa Pine, SAF cover type 245 is represented by ponderosa pine in pure (greater than 80% basal area stocking), or nearly pure stands, although other conifer and hardwood species may be present in small amounts. The Pacific ponderosa pine type is most extensive and best developed in the Pacific Southwest Region in the Sierra Nevada from Shasta southward through El Dorado County. It lies in a narrow elevational band that varies from 1000 to 2000 ft. in the northern part of the state to about 3500 ft. in the central Sierra Nevada mountains. The type has been subject to heavy disturbance from fire, cutting, recreation, grazing, road construction, and other activities for many years (Eyre, 1980).

Synonyms for Pacific Ponderosa Pine in the Pacific Southwest Region are: Ponderosa Pine (Mayer et al 1988); Westside Ponderosa Pine Forest (CNDDB, 1986); Sierran Yellow Pine Forest; (Kuchler, 1977); Yellow Pine Forest (Munz and Keck, 1973); Ponderosa Pine; Mixed Conifer-Pine (Parker and Matyas, 1981); Ponderosa/Jeffrey Pine (Payson et al, 1980); and Yellow Pine Forest (Thorne, 1976).

2. METHODS

Data were derived from two sources: Ecosystem Classification plots and Forest Inventory plots. A total of 53 plots were used in the analysis.

A. ECOSYSTEM CLASSIFICATION PLOTS

Data collection followed the procedures outlined in the Region 5 Ecosystem Classification Handbook (USDA Forest Service 1987). Procedures included a modified Region 5 Forest Inventory Analysis (FIA) (USDA Forest Service 1988) sample at each plot. Minimally disturbed sample stands were selected in a variety of environments in order to sample the variation in the target type. The data were collected as part of the Zone 4 Mixed Conifer Classification (Benson, Fites, in draft). Homogeneous, older stands were best represented in the data set. A total of 14 Ecology Program plots were used in the analysis.

Each ecosystem classification plot included a cluster of three variable radius points using a 20 or 40 basal area factor prism. The points were placed at: cluster plot center, and one chain north, and one chain east of cluster plot center, respectively. Attributes collected at each point included basal area, diameter at breast height, age, height, crown class, and 10 and 20 year radial growth increment of a dominant or codominant site tree.

A complete species list and percent cover of vegetative layers were recorded on a 1/10 acre circular plot placed at cluster plot center

Data were collected on the Plumas, Eldorado, Lassen, Shasta-Trinity, and Tahoe National Forests.

B. FOREST INVENTORY ANALYSIS (FIA) PLOTS

Thirty-nine plots from the Region 5 Forest Inventory were used in the analysis. Inventory data bases from the Angeles, Mendocino, Lassen, Plumas, Sierra, Eldorado, Stanislaus, Tahoe National Forests and the Lake Tahoe Basin Management Unit were examined for suitable plots. Plots were deemed to be suitable if basal area stocking was at least 80% ponderosa pine. These data were collected using the procedures in the R-5 Timber management plan inventory handbook (USDA Forest Service 1988). These plots were located in various seral stages, and disturbance history of the plots could not be determined from the raw data.

Age of the oldest measure tree was used in the combined data set as the measure of stand age. This resulted in more consistency between the two somewhat different data sets:

The Ecosystem plots were sited for purposes of classification. Sample stands were selected subjectively, without preconcieved bias (Mueller-Dombois and Ellenberg, 1974). The cluster points in these stands tended to represent homogeneous forest stand conditions, with uniform aggregations of tree sizes. The FIA plots were stratified and located randomly, and these plots tend to show more variation with respect to stocking, tree size, and age. Average measure tree age is a suitable estimate of stand age in the more homogeneous Ecosystem plots, but not in the FIA plots. Age of the oldest tree is therefore a "common denominator" measure of stand age in the two different data sets.

Raw data from both data sets were reduced and compiled by means of the Region 5 Forest Inventory data analysis programs. These programs were used to derive information on stand structure, growth, and species composition for each plot. These data were then examined using statistics and graphics programs. Analysis methods are described in : 5. Data Analysis Procedures.

3. OLD GROWTH ATTRIBUTES

The National Old Growth Task Group (2410 letter, 11/21/90, Enclosure 2) requires the following attriburtes:

I. Live Trees in Main Canopy; Trees per Acre:

A. R-5 Site Classes 1a, 1 (High)

n = 18
Beginning of Old Growth stage: 125 years.
Stand Basal Area: Mean = 248; standard dev. =119; typical range= 113-327.

Conifers >=30" + Hardwoods >=15":

Mean=19.6 sd=11.1 minimum (hypothesis) =11
Typical range=11-28

Large pine trees have yellow platy bark.

B. R-5 Site Classes 2,3,4,5 (Moderate-Low)

n = 20
Beginning of Old Growth stage: 145 years
Stand Basal Area: Mean =101 ; standard dev. =50; typical range= 54-149.

Conifers >=30" + Hardwoods >=15":

Median=2.7 minimum (hypothesis) = 2 Typical range= 2 - 11

Large trees have yellow platy bark.

II. Variation in Tree Diameters

Some variation in tree diameters is acceptable.

III. Dead Trees

A. Standing snags per acre: Greater than or equal to 2/acre.

B. Down pieces per acre: Greater than or equal to 1/acre.

Numbers of snags and down logs vary widely in Pacific Ponderosa Pine depending on stand history. Stands with a history of frequent low-intensity fires and low mortality from insect and disease pathogens may have few or no snags or logs.

IV. Tree Decadence (Flattening tops, spike tops, bole or root decay, large fire scars)

Greater than or equal to 1/acre

V. Number of Tree Canopies

Greater than or equal to 2.

4. LIMITATIONS

The data set used for this definition is small and variable. The type has been subjected to heavy disturbance and different kinds of type conversion in the last 100 years, and there is no way to determine the level of disturbance in the measured plots. **These definitions are Interim, and documented field testing is required**.

5. DATA ANALYSIS PROCEDURES

Data were expanded and summarized using the Region 5 Forest Inventory and Analysis computer programs FIA*SUMMARY and FIA*MATRIX. Attributes extracted from these programs included total basal area/acre, basal area by tree diameter groups, quadratic mean diameter, trees per acre by stand and by diameter groups; R-5 Site Class; and growth estimates.

The data were analyzed with the SYSTAT and SYGRAPH statistical software (Wilkinson, 1990). Some 40 attributes and attribute combinations were examined. Scatterplots of different stand attributes vs age of the oldest tree were constructed and smoothed via a robust locally weighted regression algorithm (Cleveland, 1979, Chambers et al 1983). These plots were examined visually and inflection points hypothesized that are typical of the onset and cycling of old growth characteristics in the stands. A comparison of different groupings of attributes by site classes with one-way analysis of variance and Tukey box plots resulted in the combining of site classes into two categories: High (R-5 Site Classes 0,1) and Moderate-low (R-5 Site Classes 2,3,4,5). Cutoff points in the data set were determined for "old growth" and "non-old growth" plots by site class grouping, and summary statistics generated for each group.

Distributions were examined, and, where appropriate, parametric descriptors were used to describe the data. When distributions were non-normal, rank order statistics were used to describe the data (Chatfield, 1990).

The hypothesized minimum is the lower interquartile.

The "typical range" reported is the interquartile range in both normal and non-normal data.

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PROCEDURE FOR TESTING STANDS

1. The stand to be sampled should be at least five acres in area.

2. Lay out a standard R-5 FIA cluster with the center point near the middle of the stand. If the stand is linear, sample along a transect where the tree points are at least two chains (one chain = 66') apart.

3. Measure basal area with variable radius plot techniques at each point. Record tree and snag tallies by diameter on the Stand Structure Worksheet (Appendix B). Use this information to determine if you are in the correct SAF type. If in Interior Ponderosa Pine, you should be within the geographic area of the type, and 80% of the stand basal area should be ponderosa or Jeffrey pine. Ponderosa pine should comprise the majority (>50%) of the pine stocking.

4. Measure the height and age of at least two dominant or codominant trees and use the table in Appendix A to determine R-5 Site Class.

5. Fill out the Stand Evaluation Standard Error Calculation Sheet (Appendix C) to determine if the stand has been adequately sampled.

6. Compare the numbers on the completed Stand Structure Worksheet to the tabular numbers in this report to determine if the stand meets the old growth criteria.

7. A fixed area belt or circular plot may be installed to estimate snag and log numbers.

8. Note other important features in the stand, such as number of canopy layers; stand stability; regeneration; disturbance.

9. Use the (Draft!!) Old Growth Rating Spreadsheet (Appendix D) to rate the relative value of the stand on a 1-100 scale.

Comments are welcome. Please return them to:

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APPENDIX A

TIMBER MANAGEMENT PLAN INVENTORY HANDBOOK

TABLE 1. REGION FIVE SITE CLASSES
(HEIGHT BY AGE AND SITE CLASS CODE)

	Site Class (Field 9)					
Age	0	1	2	3	4	5
40	95	81	66	49	43	35
50	106	90	75	56	49	39
60	115	98	82	63	53	43
70	122	105	88	68	58	45
80	129	111	93	73	61	48
90	135	116	98	77	64	50
100	140	121	102	81	67	54
110	145	125	106	84	70	54
120	149	129	109	87	72	55
130	153	133	112	90	74	57
140	157	136	115	93	76	58
150	160	139	118	95	78	60
160	163	142	120	98	80	61
170	166	144	123	100	81	62
180	169	147	125	102	83	63
190	172	149	127	104	84	64
200	175	152	129	106	86	65
220	179	156	133	109	88	67
240	184	160	136	112	90	68
260	188	163	139	115	93	70
280	191	166	142	117	95	71
300	195	169	145	120	96	73
320	198	172	147	122	98	74
340	201	175	150	124	100	75
360	204	177	152	126	101	76
380	206	180	154	128	103	77
400	209	182	156	130	104	78

Note: Based on ponderosa pine, Jeffrey pine, sugar pine, Douglas-fir, red fir, and white fir. Age is in years. Total height is in feet of average dominant and predominant trees with tree age of at least 50 years. Adapted from Dunning's site index curves for height at 300 years. Bulletin #28 Forest Research Notes 12/1/42, rerun 11/58. (Predominant and dominant are defined in Field 21, Crown Position.)

STAND STRUCTURE WORKSHEET

SAF Type: | Location:

Examiner:

Diam	Tally*	x BAF	= Total BA	÷ BA/Tree	÷ #PTS	= TPA	% Stand BA	Diam	Tally*	x BAF	= Total BA	÷ BA/Tree	÷ #PTS	= TPA	% Stand BA
8				.3491				27				3.9767			
9				.4418				28				4.2761			
10				.5454				29				4.5869			
11				.6600				30				4.9087			
12				.7854				31				5.2414			
13				.9218				32				5.5851			
14				1.0690				33				5.9396			
15				1.2272				34				6.3050			
16				1.3963				35				6.6813			
17				1.5763				36				7.0686			
18				1.7671				37				7.4667			
19				1.9689				38				7.8758			
20				2.1817				39				8.2958			
21				2.4053				40				8.7266			
22				2.6398				41				9.1684			
23				2.8852				42				9.6211			
24				3.1416				43				10.0847			
25				3.4080				44				10.5592			
26				3.6870				45				11.0447			
								TOTAL							

*For live trees, use Dot Tally : 10 = 

For snags 15' DBH, 20' high, use Line Tally: 5 = 

Number of Points =

Total TPA =

Total Snags per Acre =

Stand BA $= \dfrac{\left\{\sum LiveTreeTally\right\} \times BAF}{No.\ of\ Points} =$ ________

Y.Studinski 5/91

Comments:

Stand Evaluation Standard Error Calculation Sheet

Location:

Examiner: | Date:

Cluster Point (n)	BA/Point (x)	x^2
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
	$\sum x =$	$\sum x^2 =$

$\bar{x} = \frac{\sum x}{n} =$ [ ]

Standard Deviation (Sd) = $\sqrt{\dfrac{\sum x^2 - \frac{(\sum x)^2}{n}}{n-1}} = \sqrt{\dfrac{\quad - \dfrac{\quad}{\quad}}{\quad}}$

$= \sqrt{\dfrac{\quad - \quad}{\quad}} = \sqrt{\quad} =$ [ ]

Standard Error (SE) = $\frac{Sd}{\sqrt{n}} = \frac{\quad}{\sqrt{\quad}} =$ [ ]

% Standard Error (% SE) = $\frac{SE}{\bar{x}}$ x 100 = ______ x 100 = [%SE*]

Coefficient of Variation (%) = $\frac{Sd}{\bar{x}}$ x 100 = —— x 100 = [ ]

Y. Stodinski 5/91

*If %SE is > 20%, then take more points and recalculate %SE.

APPENDIX D
OLD GROWTH IMPORTANCE RATING SPREADSHEET
DRAFT DRAFT DRAFT
6/1/91

UNIT- TOTAL VALUE - 0 RATING IS:

USE THE FOLLOWING CHART TO DETERMINE THE RELATIVE OLD GROWTH IMPORTANCE LEVEL:

TOTAL VALUE	CLASS
<30	VERY LOW
31-40	LOW
41-50	MODERATE
51-75	HIGH
75+	VERY HIGH

INSTRUCTIONS

ENTER A "1" IN COLUMN ONE FOR EACH FACTOR WHICH IS PRESENT ON THE SITE BEING RATED AND A "0" FOR EACH FACTOR WHICH IS ABSENT. PICK ONLY ONE FROM EACH GROUP OF FACTORS BETWEEN THE SINGLE DASHED LINES. IF NONE OF THE FACTORS ARE TRUE THAN ENTER ALL ZEROS.

RATING TABLE

PRESENT - 1 ABSENT - 0	RATING FACTOR	WEIGHT	VALUE
	1. STAND SIZE		
0	100 ACRES PLUS	25	0
0	50-99 ACRES	15	0
0	25-49 ACRES	10	0
0	10-24 ACRES	7	0
0	<10 ACRES	5	0
	2. LARGE TREES		
0	MEETS OG REQ FOR LARGE TREES, WITHIN 1 SD OF THE MEAN	15	0
0	MEETS MINIMUM OG REQ FOR LARGE TREES, FROM 1.28 TO 1 SD FROM MEAN	12	0
0	POTENTIAL TO MEET LARGE TREE NUMBERS WITHIN 50 YEARS	10	0
0	POTENTIAL IN 50-100 YEARS	3	0
	3. SITE INTEGRITY		
0	UNDISTURBED; SHR, HERBS INTACT	15	0
0	LIGHT DISTURBANCE, >10 YRS OLD	12	0
0	RECENT, HEAVY DISTURBANCE	5	0
	4. SNAGS		
0	>=3/ACRE >20"DBH; 20 FT HIGH	15	0
0	2-3/ACRE >20"DBH; 20 FT HIGH	12	0
0	0.5-2/ACRE >15"DBH; 20 FT HIGH	10	0
0	0-0.5/ACRE >15"DBH; 20 FT HIGH	5	0
	5. LOGS		
0	>=1.5/ACRE, 20in x 10in x 10ft	15	0
0	0.5-1.5/ACRE, 20in x 10in x 10	10	0
0	0-0.5/ACRE, 20in x10in x 10ft	5	0
	6. STAND CONTINUITY		
0	GAPS/OPENINGS <= 10% OF AREA	5	0
0	GAPS/OPENINGS >=11% OF AREA	3	0

7. STAND STABILITY

0..........	STABLE:STOCKING;FUELS PRECLUDE STAND REPLACING EVENTS INCLUDING HIGH INTENSITY FIRE; PANDEMIC INSECT; PATHOGEN OUTBREAKS. STAND APPEARS STABLE FOR AT LEAST 50 YEARS	10	0
0..........	MODERATELY UNSTABLE: PRESENCE OF FUEL OR STAND STRUCTURE CONDITIONS AS ABOVE ON >35% OF THE AREA. STAND APP STABLE FOR 25-50 YRS.	8	0
0..........	MANAGEMENT ACTIVITIES IN PLACE TO SPECIFICALLY MAINTAIN AND PROMOTE OLD GROWTH INTEGRITY AND STABILITY. INCLUDES THINNING, UNDERBURNING, ETC.	7	0
0..........	UNSTABLE CONDITIONS THROUGHOUT THE AREA. STAND AT HIGH RISK FOR STAND REPLACING FIRES, HEAVY INSECT;PATHOGEN OUTBREAKS.	3	0

TOTAL OLD GROWTH IMPORTANCE VALUE= 0

//

REVISED INTERIM OLD GROWTH DEFINITIONS
FOR
INTERIOR PONDEROSA PINE (SAF 237) IN
NORTHEAST CALIFORNIA

By
Sydney Smith, Zone 2 Ecologist
USDA Forest Service
December, 1991

1. INTRODUCTION

Ecology classification and Forest Inventory data were examined and analyzed to formulate a set of descriptors for old growth stands in the Interior Ponderosa Pine existing vegetation cover type in northeastern California. This is an ecological definition, based on field observations of vegetational structure and composition, rather than on economic value, timber age, or stocking-classes (Marcot et al 1991).

Interim guidelines were distributed, tested, and reviewed during the summer of 1991. Appropriate changes suggested by the testing and review process are incorporated in this paper.

The development of the descriptors responds to direction from the Chief of the Forest Service (2410 letter, 1/17/90), and by the Regional Forester, Pacific Southwest Region (2410 letter, 2/27/90).

Interior Ponderosa Pine, SAF cover type 237, labels forest stands characterized by ponderosa pine in pure stands (greater than 80% basal area stocking), or mixed species stands where ponderosa pine is a plurality species (largest proportion basal area stocking). Distribution of the type in the Pacific Southwest Region is east of a line connecting Lake Tahoe to central Siskiyou County, generally east of the Sierra Nevada crest (Barrett et al 1980). The descriptors in this paper apply to the same area.

Synonyms for Interior Ponderosa Pine in the Pacific Southwest Region are: Eastside Pine (Mayer et al 1988); Eastside Ponderosa Pine Forest (CNDDB, 1986); Yellow Pine-Shrub Forest (Kuchler, 1977); Yellow Pine Forest (Munz and Keck, 1973); Ponderosa Pine (Parker and Matyas, 1981); Ponderosa/Jeffrey Pine (Payson et al, 1980); Yellow Pine Forest (Thorne, 1976).

2. METHODS

Data were derived from two sources: Ecosystem Classification plots and Forest Inventory plots.

A. ECOSYSTEM CLASSIFICATION PLOTS

The data were collected as part of a classification project of Eastside Pine (ponderosa pine and Jeffrey Pine potential vegetation series) stands in northeastern California National Forests. Data collection followed the procedures outlined in the Region 5 Ecosystem Classification Handbook (USDA Forest Service 1987). Minimally disturbed sample stands were selected in a variety of environments in order to sample the diversity of vegetation and habitats in the target type. Sample stands were selected subjectively, without preconcieved bias (Mueller-Dombois and Ellenberg, 1974). Homogeneous, older stands are well represented in the data set. A total of 283 Ecology Program plots that met the basal area requirements for SAF 237 were used in the analysis.

Data collection at each plot included a sampling of timber attributes according to modified Forest Inventory Analysis protocols developed in Region 5 (USDA Forest Service 1988). Trees were sampled at three variable radius points per plot. Attributes collected for prism trees included basal area, diameter at breast height, and crown class. One dominant or codominant site tree was measured for age, height, and 10 and 20 year radial growth increment at each of the three points.

Snag and log data were collected on a smaller subset of the ecosystem classification plots.

A complete species list and percent cover of vegetative layers were recorded on a 1/10 acre circular plot placed at cluster plot center

Data were collected on the Klamath, Shasta-Trinity, Modoc, Lassen, Plumas, and Tahoe National Forests in 1985, 1986, 1987, and 1990.

B. FOREST INVENTORY ANALYSIS (FIA) PLOTS

Forty-six plots from the Region 5 Forest Inventory were used in the analysis. Inventory data bases from the Klamath, Modoc, Lassen, Plumas, and Tahoe National Forests were examined for suitable plots. Most of this data was collected in the late 1970's and early 1980's. Inventory plots were included in the old growth definition data set if basal area stocking was at least 80% ponderosa and/or Jeffrey Pine, and if ponderosa pine was the majority species in the pine stocking. These data were collected using the procedures in the R-5 Timber Management Plan Inventory Handbook (USDA Forest Service 1988). The plots were located in different aged stands. Environmental setting and disturbance history of these plots could not be determined from the raw data. Plots that displayed structures suggesting unusual heterogeneity or recent logging disturbance were removed from the data set.

Age of the oldest measure tree (rather than average of the 3-5 measure tree ages) was used in the combined data set as the measure of stand age. This allowed for more consistent comparisons between the two somewhat different source data sets. Age of the oldest tree and average measure tree age are, however, highly correlated (r =.93) in the data set.

C. DATA ANALYSIS PROCEDURES

The raw data were expanded and summarized using the Region 5 Forest Inventory and Analysis computer programs FIA*SUMMARY and FIA*MATRIX (USDA Forest Service 1988). Attributes extracted from these programs included total basal area/acre (BA/ACRE), basal area by tree diameter groups, quadratic mean diameter (QMD), trees per acre (TPA) by stand and by diameter groups, R-5 Site Class; and growth estimates.

The data were analyzed with the SYSTAT and SYGRAPH statistical software (Wilkinson, 1990a,b). Some 40 attributes and attribute combinations were examined. Robust locally weighted regression (Cleveland 1979, Chambers et al 1983) was used to smooth scatterplots of BA/ACRE, TPA, QMD, numbers of small, medium, and large trees, measures of diameter diversity, and a snag and log subset vs. age of the oldest measure tree.

The smoothed scatterplot curves were examined visually to determine the average age where stand structure changes from growth stage to a maintenance or plateau stage. This point was interpreted as the beginning of the old growth stage, and occurred at a point on the curves where QMD, BA/acre, and numbers of large trees culminated, accompanied by a decrease in total trees per acre. Preliminary curves for numbers of large snags and logs suggested that these variables culminate thirty to fifty years later than the live tree variables.

Statistics were developed by using the stand age breakpoints suggested by the smoothed scatterplot curves to partition the data set into old growth and non-old growth classes, and describing the old growth stands in terms of averages of stands attributes.

Comparing different groupings of attributes by site classes with analysis of variance and Tukey box plots (McGill et al 1978; Wilkinson 1990b) resulted in the combining of site classes into two categories: high-medium (R-5 Site Classes 1,2,3) and low (R-5 Site Classes 4,5).

Minimums were hypothesized in two ways:

1. Normally distributed variables

   The point in the distribution at the 90% probability level. This point is about 1.28 standard units below the mean. The probability cutoff of 90% was chosen subjectively.

2. Non-normal variables

   The lower interquartile was reported as the minimum. This minimum level was also selected subjectively.

Distributions were examined, and, where appropriate, averages and standard deviations were used to describe the data. When distributions were non-normal, medians and interquartiles were used to describe the data (Chatfield, 1990).

The "typical range" reported is the interquartile range in both normal and non-normal data.

D. TESTING

a. Data set testing

   The descriptors were tested in the data set by graphical and numerical exploratory data techniques (notched box plots, stem-and-leaf plots, analysis of variance) and by discriminant analysis of transformed, standardized variables.

The graphical exploration techniques and discriminant analysis indicated that applying the minimum large tree numbers to the data set was an effective means of partitioning the data set into old growth and non-old growth components.

b. Field testing

The old growth descriptors presented in this paper were field tested in 1991. Twenty-six stands on the Modoc, Deschutes, Plumas, Lassen, and Klamath National Forests were used to evaluate the descriptors. Some refinements to clarify the descriptors resulted.

3. OLD GROWTH ATTRIBUTES (see Table I)

The National Old Growth Task Group (2410 letter, 11/21/90, Enclosure 2) requires reporting of the following standard attributes:

I. Live Trees in Main Canopy; Trees per Acre:

A. R-5 Site Classes 1,2,3 (High-moderate):

Number of plots: n = 144
Beginning of Old Growth stage: 150 - 180 years.
Stable Old Growth reached at: 230 years.
Stand Basal Area: Mean = 159; standard dev. = 47; typical range = 120-187.
Average total tree canopy cover = 60%. Typical range = 50-70%.

a. Trees ≥ 21"dbh:

mean = 31.9 sd = 12.9 90% of stands = 15 trees per acre including 3 trees per acre ≥ 30" dbh (see b. below)

Typical range: 22-40 trees per acre ≥ 21" dbh
Basal area of ≥ 21" trees: mean = 131; sd = 46; min = 74; typical range = 100-160

b. ≥ 30"dbh:

median = 7.3 lower interquartile = 3.0

Typical range: 3-11 trees per acre ≥ 30" dbh
Basal area of ≥ 30" trees: median = 47; min = 20; typical range = 20-80

Largest trees are Dunning's Ponderosa Pine Tree Classes 3,4,5,7. (USDA Forest Service 1957)

B. R-5 Site Classes 4,5 (Low)

Number of plots: n = 81
Beginning of Old Growth stage: 200 years.
Stable Old Growth reached at: 330 years.
Stand Basal Area: mean = 128; standard dev. = 49; typical range = 93-153
Average total tree canopy cover = 50%. Typical range = 35-65%

a. ≥ 21"dbh:

mean = 26.4   sd = 10.5   90% of stands = 13 trees per acre

Typical range: 18-34 trees per acre ≥ 21" dbh
Basal area of ≥ 21" trees: mean = 100; sd = 42; min = 46; typical range = 67-127

b. >30"dbh:

median = 4   lower interquartile = 1

Typical range: 1-7 trees per acre ≥ 30" dbh
Basal area of ≥30" trees: median = 27; minimum = 7; typical range = 7-54

Note: 30"+ trees may be absent in old growth stands in the lowest site classes. In these cases use the definition for 21"+ trees.

II. Variation in Tree Diameters

One output of the FIA-MATRIX program is number of trees in each of seven DBH classes (1-4", 5-10", 11-14", 15-20", 21-28", 29-38", 39+"). Variation in tree diameters was evaluated in two ways: a. by calculating a diversity measure, Hill's N2 number, using the diameter classes as "species", and (b) by calculating the variance of tree diameters in the seven diameter classes.

a. Hill's N2

Hill's N2 diversity number is considered to be a reasonably robust measure of species diversity, and is more interpretable than other diversity indices (Magurran, 1988; Ludwig & Reynolds 1988). Hill's N2 is expressed in units of species (diameter class) numbers. The number measures the "effective number" of species (diameter classes) present in a sample. When the data are partitioned into old growth and non-old growth classes using the minimum large tree number descriptors, the N2 number is significantly different (P = .01) between the two groups. Stands classified as old growth in the data have significantly higher numbers of "effective species" (tree diameter classes represented) than younger stands.

Hill's N2 is calculated for each plot by taking the reciprocal of Simpson's Lambda:

Lambda = Eni(ni-1)/N(N-1), where ni = frequency of trees in each of seven diameter classes, and N = the total number of individual trees in each plot.

Hill's N2 in old growth stands: (n = 252)

mean = 2.4 sd = 0.6

Hill's N2 in non-old growth stands (n=61)

mean = 2.0 sd = 0.6

b. Variance of diameters

The calculated variance of tree diameters was a more robust indicator of variation in tree diameter than Hill's N2 in discriminant analysis. The variance of diameters was calculated as:

$$\text{variance of diameters} = \frac{Efi*xi^2 - (Efi*xi)^2/Efi}{Efi - 1}$$

where fi = frequency of trees in each diameter class, xi = median diameter for each diameter class (Old Growth Definition Team 2, 1991).

Variance of diameters of old growth stands was significantly higher (P = .01) than the variance of non-old growth stands.

Average variance of old growth stands: 64.3
Average variance of non old-growth stands: 29.6

Smoothed scatterplots suggested a direct relationship between increased numbers of large trees (≥ 21" and ≥ 30") and increased Hill's N2 and diameter variance. Numbers of small trees and the variance measures are inversely related, that is, as numbers of small trees (1"-11") in stands increase, Hill's N2 and diameter variance both decrease.

Higher levels of variance in older stands compared to younger stands has been observed in other studies (Spies and Franklin, 1991).

III. Dead Trees

A subset of ecosystem classification plots was examined for snag and log characteristics. A large snag is 20" dbh and 20' high. A large log is 20" at the large end and at least 20' long.

Results are as follows:

A. Standing snags per acre:

High-Medium sites: n = 36

range = 0-6   median = 0   Typical range = 0-2.

Low sites: n = 19

range = 0-6 median = 0 Typical range = 0-2.

B. Down pieces per acre:

High-Medium sites: n = 36

range = 0-4 median = 2 Typical range = 0-4.

Low sites: n = 19

range = 0-14 median = 2 Typical range = 0-4

Numbers of snags and down logs vary widely in Interior Ponderosa Pine depending on stand history. Stands with a history of frequent low-intensity fires and low mortality from insect and disease pathogens may have few or no snags or logs. Stands that have been excluded from fire and have a history of insect and disease mortality may have high numbers of snags and logs, usually clumped in distribution. The presence of snags and logs affects the relative old-growth value of a stand, but is not absolutely required for old growth designation.

IV. Tree Decadence (Flattening or rounding tops, shortening crowns, large horizontal or drooping branches, large gnarled or twisted branches, forked tops, spike tops, bole or root decay, large fire scars)

Use Dunning's Ponderosa Pine Classes 3,4,5,7.

Greater than or equal to 2 trees/acre, Dunning's Classes 3,4,5,7.

V. Number of Tree Canopies

Greater than or equal to 1.

4. LIMITATIONS

This definition is intended to describe the old growth seral stage. No attempt is made to describe optimum conditions for other resources, such as wildlife or recreation. Determining the relative value of an old growth stand for a particular resource is a separate process from determining if the stand displays the ecological old growth characteristics described in this paper.

The minimums are suited for old growth inventory of existing stands only. The means ± one standard deviation (or medians & interquartiles) represent more optimum conditions for old growth than the minimums, and these should be used for "Desired Future Condition" in stand management, particularly where the old growth component is deficient and younger stands are targeted for long-term old-growth recruitment.

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TABLE 1

CHARACTERISTICS OF OLD GROWTH
INTERIOR PONDEROSA PINE FORESTS, SAF 237
NORTHEASTERN CALIFORNIA

(Numbers are means ± standard deviations unless otherwise indicated)

	R-5 SITE CLASS 1-3	R-5 SITE CLASS 4,5
1. LIVE TREES IN MAIN CANOPY		
TREES PER ACRE ≥21" DBH	31.9 ± 12.9 90% OF STANDS:>15	26.4 ± 10.5 90% OF STANDS:>13
inc TPA ≥30" DBH	≥ 3	≥ 0
STAND BASAL AREA	159 ± 47 INTQ.RNGE:120-187	128 ± 49 INTQ.RNGE: 93-153
2. VARIATION IN TREE DIAMETERS		
HILL'S N2 (see text)	2.4 ± 0.6	
MEAN VARIANCE IN DBH:	64.3	
At least two of the following diameter classes are present: DBH: 1-4"; 5-10"; 11-14"; 15-20"; 21-28"; 29-38"; 39"+.		
3. DEAD TREES		
SNAGS ≥20"DBH, ≥ 20' high	≥ 0 INTQ.RNGE:0-2	≥ 0 INTQ.RNGE:0-2
LOGS ≥20" LARGE END ≥ 20' long	≥ 0 INTQ.RNGE:0-4	≥ 0 INTQ.RNGE:0-4
4. TREE DECADENCE		
DUNNING'S TREE CLASSES 3,4,5,7	≥ 2 PER ACRE	≥ 2 PER ACRE
5. NUMBER OF TREE CANOPIES	≥ 1	≥ 1
6. TOTAL TREE CANOPY COVER:	60% ± 10	50% ± 15

Preliminary Ecological Old-Growth Definitions for Mixed Conifer (SAFTYPE 243) in California

By

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Executive Summary

Introduction

Old-growth is an important and controversial issue in resource management. A National Task Force, formed in 1989, directed the development of ecological definitions of old-growth for use in inventory and management. From an ecological perspective, old-growth is a late successional stage of forest development (Franklin and Spies 1991). Late successional forests are distinguished from younger forests by both their structure and ecological functioning, but structure is the most easily described. Structurally, late successional forests contain trees that are large for their species and site, often a variety of tree sizes, large snags and logs, and a developed and often patchy understory (Franklin and Spies 1989). The National Task Force identified a set of minimum structural attributes to be included in the definitions: age, size, and density of large trees; variation in canopy layers and diameters; decadence; and size and density of large logs and snags.

Region 5 was given the task of defining old-growth for 13 forest types (Society of American Foresters' Forest Types). This document includes a description of ecological characteristics of old-growth mixed conifer (SAF forest type 243). The dominant species in the mixed conifer old-growth forests described here are white fir, ponderosa pine, sugar pine, incense-cedar, Jeffrey pine, Douglas-fir, and California black oak. Red fir is present in small amounts at higher elevations. Stands with three conifer tree species, each with at least 10% of the total basal area of the stand and that did not meet criteria for other SAF types were included in the analysis. The geographic extent includes the Sierra Nevada, southern Cascade, and central Klamath mountains; the interior coast ranges in Mendocino and Lake Counties; and small pockets south of the Tehachapi Mountains.

Data Sources and Analysis

The definitions were developed using Ecoystem Classification, Forest Inventory Analysis, and Stand Exam plots. Three hundred and eighty plots were in the data set, including mature and old-growth stands. The data was stratified by site class (Dunning 1942) into three groups: 1A-1, 2-3, and 4-5. Trend analysis was completed to determine where structural attributes visibly changed between mature and older stands. The ages where the changes in structural attributes for stands were evident were used as cut-offs to separate mature stands and late successional stands. Statistics for the structural attributes were then calculated by site class group for the stands below and above the cut-off age.

Results and Discussion

There was much variability in the structural attributes. This is typical for late successional stands and is probably due to several factors: (1) effect of varied stand history, such as fire, insect, or other natural disturbance; (2) the variable tree composition in mixed conifer; and (3) variation of plant community types. The variability in snag data may also be due to the prism sampling technique used for some of the plots, where under-estimation is prevalent. The definitions were field-tested and overall worked well and were readily applied on the ground. Some of the attributes, diameter and canopy diversity, were more indicative of plant community type than successional stage. Large snags and logs are naturally highly variable, but are good indicators of old-growth if large areas in the landscape are evaluated. Stand age is difficult to determine and generally is not a necessary structural attribute of late successional forests, but it may be indicative of the level of ecological functioning. A score-card or indexing system needs to be devised to rate the ecological significance of individual old-growth forests, including factors such as proximity to riparian or wetland areas, size and shape of stand, structure of adjacent vegetation, and level and type of disturbance.

Introduction

Old-growth forests are currently under much scrutiny and controversy by the public and land managers. Much of the controversy about old-growth forests concerns what it is and how much of it remains. The U.S. Forest Service formed a National Old-Growth Task Group to guide the development of old-growth forest definitions that would help answer these two questions. Before an assessment can be made of how much old-growth forest remains, a common, acceptable definition of old-growth must exist. The National Task Group and the Region 5 old-growth definition team leaders have determined that an ecological definition of old-growth is the most appropriate. Refinements of the ecological definitions can be made later, based upon individual management needs, public concerns, wildlife habitat needs or for aesthetic or social values. The objective for the old-growth defintion team was to develop an ecological defintion of old-growth mixed conifer, based upon the best available information. This document includes a description of the ecological characteristics of old-growth mixed conifer (SAF forest type 243) for Region 5 and the methods used to develop and analyze the characteristics. Later revisions of the definition may be made as further data is available.

Ecological Definition of Old-Growth Forests

From an ecological perspective, old-growth is a late successional stage of forest development (Franklin and Spies 1991a). As forests increase in age and develop, their structure changes. Successional stages are most often recognized by structural characteristics, such as size of trees, distribution of tree sizes, presence and size of snags and logs, understory composition and heterogeneity, and horizontal diversity in structure. Late successional forests in general contain trees that are large for their species and the site, often a variety of tree sizes, large snags and logs, and a developed and often patchy understory (Franklin and Spies 1989). While the structural features of late successional forests, or old-growth, are generally recognizeable, a myriad of community and ecosystem interactions (or functions) may also be diagnostic (Franklin and Spies 1991b) but are more difficult to measure and describe. It is assumed for the description of old-growth presented here, that the structural attributes reflect the presence of the community and ecosystem interactions (Franklin and Spies 1991b). Stand age is often considered less important than structure in describing late successional forests because the rate of stand development depends more on environment and stand history rather than age alone. However, forest age may be an indicator of the level of development of community and ecoystem interactions, and therefor the level of ecological functioning.

Variability of Old-Growth Forests and Definition Limitations

The late successional stage of stands, old-growth intergrades with mature and sometimes earlier successional stages. It is difficult to precisely define where old-growth begins and where it ends. However, there is a critical need to quantitatively describe the characteristics of old-growth to enable consistent and repeatable inventory and management.

Fire and other types of disturbance caused by weather or insects are considered natural, and an integral part of stand structural development or community succession. Stands that had natural disturbance were included if the disturbance did not alter the structure enough to result in one that more closely resembled mature or early successional stage structures. The degree of the effect of natural disturbance on stand structure of old-growth varies across the landscape and with time, due to the varying periodicity and intensities of these natural disturbance events. Due to the great variability in degree of effects of natural disturbance on stand structure of old-growth, it is likely that some naturally disturbed stands that have characteristics that intergrade between old-growth and younger successional stages, were excluded from this analysis. Stands that had a predominance of regeneration over older trees, due to fire or other stand history, were excluded from the definition because of their structural similarity to mature or early successional forests. These stands were excluded due to the apparent lack of distinguishing attributes between mature and old-growth and lack of data on these types of stands. However, these stands may be functioning as old-growth and should be considered on a site specific basis when using the definitions for inventory or managment.

Across much of the range of the Sierra Nevada Mixed Conifer Type, fire is a common natural disturbance factor (Kaufman 1986). Even with recent fire suppression efforts, many of the late mature stands sampled for the Region 5 Ecology Program have shown evidence of fire (unpublished data on file, Eldorado National Forest). It is possible that the structure and even species composition of the mixed conifer type may have been different prior to extensive fire suppression. Due to the complex patterns of fires across the landscape (Romme and Knight 1981, Romme 1982), often with a mosaic of intensity and consumption, it is possible that there was still much variety in the composition of old-growth mixed conifer stands prior to fire suppression. Numerous historical accounts include descriptions of stands in the mixed conifer zone with widely spaced large trees and little midstory or understory. In areas in the landscape with high natural fire frequencies -ridge tops, south-facing slopes and upper slopes- this widely spaced stand structure was probably more common. Fire-intolerant species, such as white fir, were probably less prevalent. The large numbers of white fir in the present midstory of many mixed conifer stands are evidence of their recent prevalence in the stands. In other more mesic areas, such as drainages or north-facing slopes, natural fire frequency is lower and more sporadic, and the old-growth structure found in these locations in the present is probably very similar to that prior to fire suppression.

The past fire history and recent fire suppression effects are acknowledged but the definitions presented here are based upon data collected within the last ten years. Information is not available at this time to stratify the data based upon different fire histories, which might result in different old-growth structures.

Application of Definitions

The definition is applicable in stands that meet the species composition criteria for Sierra Nevada Mixed Conifer specified below. The stands should be measured for site class, and the appropriate characteristics applied for that site class group. The definitions were developed from stands without apparent human-caused disturbance or drastic natural disturbance. A few stands with one or two trees removed for sanitation or railroad logging more than fifty or so year ago, were included if the stand structure did not appear affected. Therefore, the definition here, applies to essentially undisturbed (especially human-caused) stands and in applying the definitions to disturbed stands, disturbance should be noted in detail and evaluated for effects on the ecological function or significance. Ecological significance is referred to here as ecological function and would include such ecosystem and community processes and interactions as nutrient cycling, hydrological regulation, productivity, and wildlife and plant habitat (Franklin and Spies 1991b). Some stands with very minor disturbance was included because of the prevalence of human influence in montane forests in the past and were included only if there was evidence that the stands had recovered from the disturbance.

Composition of Mixed Conifer and Geographic Extent

The Society of American Foresters has defined mixed conifer forests for the South Pacific as the "Sierra Nevada Mixed Conifer" type, #243 (Tappeiner 1980). The dominant species include California white fir, ponderosa pine, sugar pine, incense-cedar, California black oak and Douglas-fir. The Sierra Nevada Mixed Conifer type is variable in species composition and dominance. White fir or Douglas-fir are generally more predominate on northerly slopes or higher elevations, while ponderosa pine is more dominant on southerly slopes or lower elevations. Some mixed conifer with Jeffrey pine occur on serpentine substrates.

This broad definition is not adequate for detailed analysis. The Region 5 team leaders developed some specific composition requirements for all of the SAF types being defined in this Region, to ensure that the data available could be stratified with no overlap between the similar types. Mixed conifer intergrades into several different SAF types including Pacific ponderosa pine - Douglas-fir, Pacific Douglas-fir, Pacific ponderosa pine, Jeffrey pine, white fir and red fir. To distinguish mixed conifer from these other types, the following guidelines were used. Mixed conifer was defined as having at least three species present, with each species having a basal area equal to or greater than 10% of the total basal area of the stand (relative basal area). Mixed conifer with less than 50% red fir was also included. The definitions for the other SAF types are included in Appendix A.

The geographic extent of SAF type 243 encompasses the west side of the Sierra Nevada, generally between 3,000 and 6,000 feet in elevation, locally on the west side-east side transition in the northern Sierras, the interior coast ranges in Mendocino and Lake counties, the Klamath Mountains, and the southern Cascades. Small pockets may also be found south of the Tehachapi Mountains.

Methods

Data

The data set used to develop the old-growth definitions included Ecosystem Classification (EC) Plots (FSM 2090.22), Forest Inventory Analysis (FIA) Plots (FSH2409.21B), and Stand Exam Plots. Three-hundred and eighty plots were included in this data set, of which 269 were Ecosystem Classification Plots. Eighty FIA plots and twenty-eight Stand Exam plots were also included. The Ecosystem Classification Plots were placed in undisturbed late seral stands. No predetermination of whether the stands were old-growth or not were made, only an assessment of the stage of stand development. The plots include mature, late mature and old-growth stands. Past disturbance such as fire, disease, small slumps or windstorm were considered to be a natural component of the stands and plots were placed in stands where these disturbances have occurred, unless the disturbance had affected the seral stage of the stand. The Ecosystem Classification Plots were primarily located on the following National Forests: Eldorado, Tahoe, Plumas, Lassen, Shasta-Trinity and Mendocino. The Sierra Nevada Mixed Conifer type occurs on other areas in the Region, therefore FIA data was also used. FIA plots from the following National Forests were used: Angeles, Eldorado, Klamath, Los Padres, Lassen, Lake Tahoe Basin, Mendocino, Modoc, Plumas, Stanislaus, San Bernedino, Sequoia, Shasta-Trinity and Tahoe. There is no written description of the disturbance history of the FIA plots and therfore the data was closely examined and compared with undisturbed EC data were used to eliminate stands that appeared to have been disturbed sufficiently to change the seral stage (i.e. low volumes with small numbers of large trees and an old-aged tree). There was no snag or defect data available for most of the EC plots; therefore, the FIA data was also included to provide data on these attributes that are part of the national old-growth defintion minimum standards. The Stand Exam data included plots where there was knowledge that there had been little or no disturbance.

Analysis

Forty-three variables were examined in the analysis for old-growth characteristics (Table 1.). For this draft definition, emphasis was placed on analyzing the characteristics that are part of the national old-growth definition minimum standards (table 2). Structural features such as the trees/acre by diameter groupings, standing cubic volume, quadratic mean diameter and frequency of snags were the primary characteristics analyzed. The diameter classes used were those that are available in the R5 Forest Inventory Analysis (FIA) analysis programs: 1-5, 6-10, 11-14, 15-20, 21-28, 29-38 and 39+ inches. The variance of tree diameters was calculated using the following forumula:

Variance of Diameters =

$$\frac{\sum f_i \cdot x_i^2 - \sum (f_i \cdot x_i)^2 / \sum f_i}{\sum f_i - 1}$$

where fi is the frequency of trees in each diameter class and xi is the median diameter for each diameter class.

The Region 5 Forest Inventory Analysis programs, FIA MATRIX, FIA CONVERT and FIA SUMMARY, were used to calculate the above characteristics and Dunning's

Table 1– Variables used in data analysis of structural characteristics of old-growth.

Variable	*Classes*
Conifer Trees/Acre	1-4",5-10",11-14",15-20" 21-28",29-38",39"+ d.b.h.
Hardwood Trees/Acre	" "
Decadent Trees/Acre	" "
Snags/Acre	" "
Logs/Acre	3-9",10-19",20-29",30-39" 40"+ bottom diameter
% Basal Area by Species	
Dunning's Site Class	1A,1,2,3,4,5
Conifer Basal Area	
Hardwood Basal Area	
Conifer Cubic Volume	
Hardwood Cubic Volume	
Conifer Quadratic Mean Diameter	
Hardwood Quadratic Mean Diameter	
Quadratic Mean Diameter	
Variance of Diameters	
Stand Age	

Table 2– National minimum standards for variables to be used in developing old-growth definitions, established by the National Old-Growth Task Group.

1. Live trees in main canopy"
   - d.b.h.
   - trees per acre
   - age

2. Variation in tree diameters

3. Dead trees:
   - standing trees per acre
   - down pieces per acre

4. Tree decadence (spike or deformed tops, bole or root root decay):
   - trees per acre

5. Number of tree canopies

site class (Dunning 1942). Statistical analyses were performed with SPSS (Norusis 1988) and trend analyses with Harvard Graphics (Software Publ. Corp. 1987). The data was stored and managed in DBASE IV (Ashton-Tate Corp. 1988).

The relative % basal area for each plot was used to determine whether it met the criteria for the SAF type 243, using the definitions described in the Introduction. The data was further stratified by site class (Dunning 1942) into three groups: site class 1A to 1, 2 to 3, and 4 to 5. It has been found previously that stand structure and old-growth characteristics vary significantly between different site class groups (Jimerson and Fites 1989). The number of plots included in the site class groups were: (1) site class 1A-1 -183 plots, with 150 from EC data; (2) site class 2-3 group - 133 plots, with 78 from EC data; and (3) 64 plots, with 41 from EC data.

Once the stands were stratified by SAF type and site class, trend analysis was conducted to determine which data should be analyzed for old-growth defintions and which data included stands from earlier seral stages. The trends examined for this purpose included the change in standing cubic volume, quadratic mean diameter and the trees/acre by diameter classes with estimates of stand age. Trends of snags, logs and decadence were not evaluated due to low numbers of samples for these attributes or lack of associated age data.

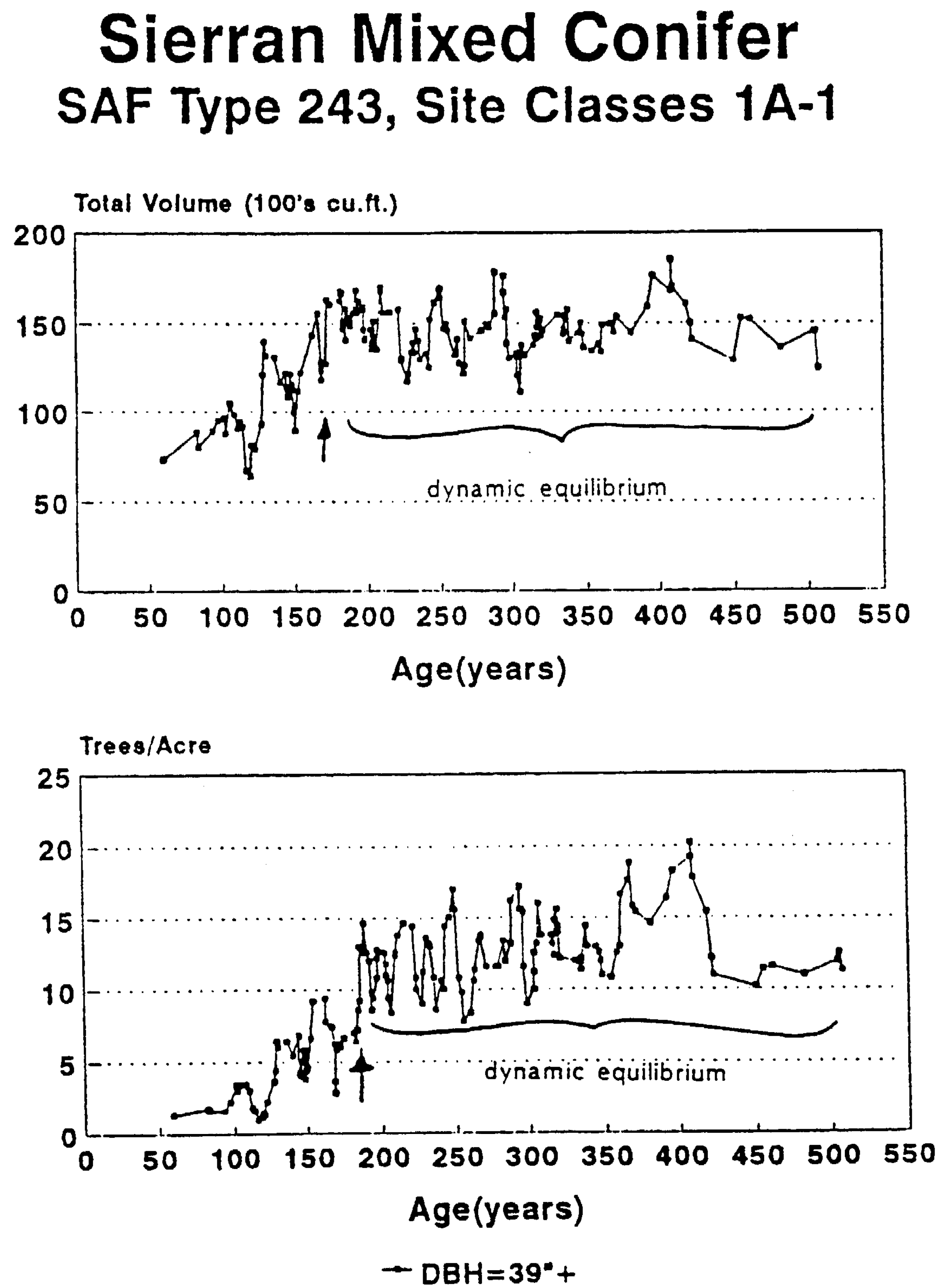
The oldest age of the co-dominant or dominant large diameter trees in the stand was used as an approximation of stand age. Three co-dominant or dominant trees were measured for each EC plot and generally five co-dominant or dominant trees were measured for each FIA plot. Due to the variability in the composition of late seral stands and often skewed age or diameter distributions (Potter draft, Schumacher 1928, Veblen 1985), it was decided that an average of the three or five ages would not be as meaningful as the age of the oldest measured tree. Some of the FIA plots were eliminated at this stage if large diameter trees were present in the stand but were not measured for age. Because of the limited sampling for stand age, it is considered only as a broad estimate and is only useful for general trend analyses.

An ecological interpretation of a late seral stage is that the stand has developed to a self-perpetuating state (Spies and Franklin 1991a). However, forest structure is rarely static, even in late seral stages, due to natural stand processes (i.e. mortality) and minor natural disturbances. Therefore, any trend analysis must be interpreted with this dynamic nature in mind.

The trends were examined for the attainment of a maximum, dynamic equilibrium of standing cubic volume, quadratic mean diameter and number of large trees per acre. The ages at which these maximums occurred were used as cut-offs for further analysis of old-growth characteristics. This cut-off age is an arbitrary age determined by the trend analysis, below which stands were considered not old-growth. An example is shown in figure 1. Because of the limited sampling for the ages, they are useful only for a data stratification tool and not for determining the minimum age at which old-growth occurs. The cut-offs, based upon the trend analysis that were used to stratify the data for further analysis were 185 years for site class group 1A-1, 210 years for site class group 2-3, 270 years for site class group 4-5.

Once the cut-offs were determined, statistics were calculated for the characteristics of the minimum national old-growth definition standards. The mean, standard deviation, and range were calculated. Frequency distributions of the attributes were plotted and compared with normal distributions. Some of the attributes showed normal distributions for old-growth, but not for the mature data, and therefore, percentiles were used to calculate the low and high ranges. The 10%, 15%, 85% and 90% percentiles were calculated. The percentile levels that showed clear differences between the mature and old-growth data were used. .Following the determination of the statistics for each attribute, the data set and trend analysis graphs were examined for obvious outliers.

Figure 1– Trends in total live tree volume (100's cubic ft.) and number of large (d.b.h. >39 inches) trees per acre with increasing stand age, for mixed conifer (SAF type 243), high site (Dunning's 1A and 1) stands.



Stands younger than the cut-off ages that had attained the structural attributes of old-growth as described here were added. Recalculation of statistics followed.

Snag data from 1991 Ecology Plots, recent Stand Exams and FIA plots were used. Much of the data came from FIA plots, since snags were not being measured at the time that most of the Ecology plot data was collected. The snags were sampled with the same procedures and basal area factor used to measure the live trees. It has been well demonstrated in the literature (Bull et. al 1990), that a more intensive, fixed area sampling procedure is more appropriate for snag inventories. It is likely that the snag densities presented here are an underestimate due to the sampling method for FIA plots and relatively small number of samples and should be considered a first approximation. As additional data is collected on snags, it will be added.

Most of the plots for the decadence analysis were also from the FIA data set. Recent Ecology Plots and Stand Exams were also used. Decadence recorded for the FIA plots included: presence of fungi conks, fire or other basal trunk scars, dead or broken tree tops, forked tree tops, and trees that are apparently afflicted with heart-rott and are not merchantable.

Little log data was available. The data sources included recent Ecology Plots, some Stand Exams Plots and Wildlife Inventories. Inconsistency in size classes used in data collection resulted in some of this data being excluded.

Snag, log and live tree decadence data from the different site class groups were pooled for final analysis, due to the small number of samples available and absence of apparent differences between the site class groups.

Field Testing

The definitions were examined in the field to evaluate their consistency with actual old-growth stand structures and ease of applicablity on the ground. For most of the field-testing, structural data was collected and compared with attribute statistics in the definition. Several of the field-exams included an ocular evaluation of the structural characteristics.

RESULTS

Table 3–Structural characteristics of old-growth mixed conifer forests (SAF type 243) by Dunning's site classes.

	MIXED CONIFER		
	Site 1A-1	Site 2-3	Site 4-5
NUMBER OF SAMPLES	122	58	23
DBH OF LARGE TREES (inches)	39+	39+	29+
NO. LARGE TREES (trees/acre)			
Mean	13	10	11
S.D.	5.6	4.4	5.9
Range, low	8*	6*	5*
Range, high	18*	17*	17*
VARIANCE OF TREE DIAMETERS			
Median	100	90	67
CANOPY VARIATION[1]			
No. of Layers	2-4[2]	2-3[2]	2-3[2]
AGE (years)			
Mean	285	351	323
S.D.	84	109	69
Range, low	188*	253*	256*
Range, high	408*	483*	450*

1. The four canopy layers are: 70-100% of the dominant canopy layer height, 40-69% of the dominant canopy layer height, <39% of the canopy layer height (excluding the regeneration layer), and the regeneration layer (trees < 4.9" d.b.h.).

2. Best professional judgment used to estimate the canopy variation, using ecology plot data and field observations.

* Calculated from the 15 and 85 percentiles.

** Calculated from the 10 and 90 percentiles.

Table 4–Structural characteristics of old-growth mixed conifer forests (SAF type 243) by Dunning's site classes.

	MIXED CONIFER Site 1A-5	
	SNAG DENSITY[3] (>29" dbh & > 10')	LIVE TREE DECADENCE[4] (>29" dbh)
Mean	1.3	3.0
S.D.	1.6	2.2
Range	0-2.7*	1.2-4.8*
Number of Samples	45	47
	(>39" dbh & > 10')	(>39" dbh)
Mean	0.6	1.6
S.D.	0.9	1.7
Range	0-1.3*	0.7-3.1*
Number of Samples	45	47
	LOG DENSITY (10-20" diam. & >10')	
Mean	18.4	
S.D.	32.2	
Range	0-39.0*	
Number of Samples	20	
	(>20" diam. & >10')	
Mean	13.5	
S.D.	7.0	
Range	0-20.2*	
Number of Samples	20	
	(>40" diam. & >10')	
Mean	0.9	
S.D.	1.5	
Range	0-2.2*	
Number of Samples	20	

* Calculated from the 85 percentile, except for 0 values.

3. Note: snag densities may be understimated due to the use of prism sampling technique for many of the plots; a technique known to understimate snag levels.

4. Decadence includes characteristics of live trees including: broken tops, spike tops, multiple leaders, conks, fire or other bole scars.

Discussion

Variablility in Structure

The results were similar to those reported in other old-growth definitions in Region 5, with much variation observed for the old-growth characteristics (Potter in 1991, Smith 1991, Jimerson 1991). This is partly due to the inherently variable nature of old-growth stands, which may be attributed to their relatively older age and the wide variety of stand history events that may affect their structure. Variation due to fire, environmental factors, plant community composition and data limitations of some attributes is possible.

Past fire disturbance, including a myriad of intensities and durations, may have greatly increased the structural diversity of old-growth stands included in this analysis. Stands in areas of higher fire frequencies, such as ridge tops, upper slopes and south-facing slopes would have had different disturbance regimes than those with lower fire frequencies, such as lower slopes, drainages and north-facing slopes. Insect and disease disturbance have also likely resulted in structural variation in old growth. As mentioned in the Introduction, old-growth stands that have had natural disturbance that changed the structure such that the characteristics intergrade between old-growth and mature successional stages were not sampled extensively or included in this analysis. Addition of these types of stands would likely result in further variability in the old-growth characteristics.

Another likely cause of the high variation found in the old-growth characteristics, even within a site class group, is the variety of environments where old-growth stands occur. Stands occuring on ridgetops or on the upper one-third of slopes are drier and hotter, and often have less canopy layer diversity than stands occuring in ravines or on lower slopes. Another source of indirect variation related to the environment is the plant community composition. Mixed conifer with a dense layer of bear-clover in the understory generally has low canopy layer and diameter diversity, and sometimes fewer large trees per acre. In contrast, mixed conifer with a mid-story of dogwood generally has a very high canopy layer and diameter diversity. Further refinements of the old-growth definitions based upon the plant communities will be examined in the future as the Region 5 Ecosystem Classification Program progresses. These differences may result in different ecological significance for the varied structures and topographically different stands. For example, high structural diversity in mixed conifer with dogwood, leads to high biodiversity due to the increase in wildlife species and use in structurally diverse forests. In addition, mixed conifer with dogwood is often found adjacent to riparian or wet areas, increasing it's hydrologic as well as biodiversity functions.

In addition, some of the high variation in some of the old-growth characteristics described here, may be due to the small data set for some of the characteristics, snags and decadence, or the low number of samples for the low site group. The snag data may also be highly variable because the sampling technique used for snags in the FIA plots is known to result in an underestimation of snag density (Bull et. al 1990). Because of the low number of samples in the low site group, the statistics for the low site old-growth characteristics should be considered very preliminary and may change with additional data.

Field Testing- Diagnostic Characteristics

The definitions were generally easily applied in the field. Attributes that were difficult to assess in the field, were variation in diameters and canopy layers. However, it seems that the number of canopy layers is more dependent upon environment and plant community than seral stage. For example, mixed conifer with dogwood stands typically have four layers in both mature and old-growth forests, while mixed conifer with bear-clover stands typically have 2 layers in both mature and old-growth forests. Diameter variance is highly variable in old-growth stands, depending greatly on disturbance history and plant community. Higher diameter variation was observed in both mature and old-growth stands on high sites, or plant communities such as mixed conifer dogwood. Lower diameter variation was observed on drier, lower sites, or in plant communities such as mixed conifer bear-clover. Mature and old-growth mixed conifer stands often have a high variation in diameters due to the diversity of tree species.

The attributes that were the most useful in distinguishing mature and old-growth stands were the number of large trees per acre, presence of decadence in live trees and often presence of snags and logs. Snags and logs are naturally highly variable in space and time, lessening their diagnositic utility (Laudenslayer pers. comm.). However, in most of the stands tested in the field, snags and logs were evident, but were often very patchy in distribution and widely spaced. Where snags and logs were not present, or were few in number, there was often evidence of past disturbance, such as salvage, sanitation or fire hazard tree removal, that would have resulted in snag removal or potential snag or log removal. Natural disturbances, such as weather events and fire, can also result in a lack or high numbers of snags and logs. Since the presence of large snags and logs is common in old-growth stands, when large areas are examined, but sometimes absent due to natural conditions, their presence can help confirm that old-growth conditions occur but stands should not be eliminated from consideration as old-growth if they are absent.

Ecologically Significant Old-Growth

Ecological significance, as referred to here, relates to the ecological functioning of an old-growth stand. Franklin and Spies (1991b) give the following examples of old-growth ecosystem functions: "production, the capture of the sun's energy through photosynthesis and its conversion to organic substances; regulation of nutrient cycling, including accumulation and conservation of nutrients; regulation of hydrologic cycles; and provision of habitat for organisms". Some research has been completed on ecological functioning of old-growth in the Pacific Northwest (Franklin and Spies 1991b) but little has been completed in California, especially in Sierran Mixed Conifer. The ecological functions that have been characterized in the Pacific Northwest likely apply to California in general, although some differences in the specific characteristics probably vary due to the different climate and fire ecology. However, it is important to consider ecological significance when applying the old-growth definitions to managing old-growth, so a discussion of the characteristics of old-growth ecoystem functions found in the Pacific Northwest is pertinent.

Large logs play an important role in nutrient cycling, providing retention and slow release of nutrients, sites for nitrogen fixation (Franklin and Spies 1991b), and habitat for microorganisms and invertebrates that are integral in nutrient cycling (Maser et. al. 1988). Snags function as foraging and breeding habitat for vertebrates (Brown 1985, Lundquist and Mariani 1991, Maser et. al 1988), and as recruitment for logs.

Mixed conifer old-growth is likely one of the most structurally and compositionally diverse old-growth forest types, due to the wide variety of tree species present. In addition to the importance of structural diversity in determining the biodiversity of wildlife in old-growth stands the presence of riparian areas, wetlands or water sources in or near the old-growth stands is also key. The presence of these areas, greatly increases the biodiversity of wildlife. Further analysis on the minimum stand size, or perimeter to interior ratios need to be completed to assess what size stands are necessary to ensure the community biodiversity of the old-growth stand through providing the necessary habitat for plant and animal species that are present in such environments.

The effect of old-growth structure on hydrologic function is related to the large tree canopies and canopy diversity, as well as the presence of logs (Franklin and Spies 1991b, Harr 1986). The potential for rain-on-snow flood events is reduced, due to greater canopy interception and protection of accumulated snow. Logs reduce soil erosion and play an important role in aquatic ecosystems. Ann Carlson and others (1991) attributed the following functions to large woody debree in aquatic ecosystems: dissipate hydraulic energy; reduce potential erosion of the channel bed and stream banks; serves as a filtering device, retaining sediment, detritus and nutrients; provides rich habitat for fish and invertebrate organisms.

Large leaf areas found in the large and layered canopies of old-growth forests (Franklin and Waring 1980), provide the capacity for much photosynthetic production (Franklin and Spies 1991b). Franklin and Spies (1991b) concluded that biomass accumulations are generally stable in old-growth (Bernsten 1960, DeBell and Franklin 1987, Williamson and Price 1971).

Application of Definitions

Based upon the results of the field-testing, it seems that not all of the characteristics defined are necessary for applying the definitions for inventory. Canopy layer diversity is not diagnostic of old-growth mixed conifer but is important for ecological significance and should be included in old-growth inventories. The old-growth characteristics that are diagnostic and should be included are densities of large trees, decadence of large live trees, large snags and large logs. While these attributes are diagnostic, some stands may not have all of the old-growth attributes, but rather a subset. To determine if stands that only have some of the attributes present fit the definition, it is recommended that an index or rating system be used for assessing how well the stand meets the definition. The preferrable method for developing such an index would be quantitative and objective, such as Discriminate Analysis (Spies and Franklin 1991). However, to apply disciminant analysis and derive dependable results, all of the variables should have the same degree of reliability. The data set used here includes fewer snag and log data than for the live tree attributes, resulting in different degrees of reliability for the variables. Collection of additional snag and log data to fill in this data gap is planned. Despite these limitations, the development of an index for assessing how well the definitions fit using Discriminant Analysis is being explored. Alternatively, an interdisciplinary team could develop an index for assessing how well the stands meet the definition, would be to have an interdisciplinary team develop one.

For inventory of old-growth, the range values for the attributes should be applied, in order to accurrately identify the variability of old-growth that is naturally present. For management of old-growth, it is recommended that the means and high ranges be applied for determining desired future condition. This would ensure that high quality old-growth is attained and maintained. Maintenance of old-growth would be assured by allowing a buffer for the effects of minor natural disturbance. Site specific evaluation of areas that meet the low range levels of the attributes rather than the means should be made to assess whether the low range would be the more appropriate desired future condition, due to environment limitations or plant community characteristics that would prevent the forest from ever attaining mean levels.

Application of the definitions for determination of old-growth management areas, should take features of ecological significance into account. Another index or rating system, to assess the level of ecological significance would be useful for this application as well. The characteristics or features that should be included in rating ecological significance are: density of large trees; size, density and decay classes of logs and snags; size of the stand and structure of surrounding vegetation; level and nature of disturbance; presence of rare wildlife; presence or adjacency of wet or riparian areas; and abundance and location of nearby old-growth forests.

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APPENDIX A

KEY TO SAF FOREST TYPES

1a. Redwood or Port-Orford cedar present and comprising >33% of stocking (2)
1b. Redwood or Port-Orford cedar absent or comprising <33% of stocking (3)

2a. Redwood comprising >33% of stocking...Redwood (SAF 232)
2b. Port-Orford cedar comprising >33% of stocking...Port-Orford cedar (SAF 231)

3a. Three or more species comprising the majority of the stocking (9)
3b. One or two species comprising the majority of the stocking (4)
(Dominants are white fir, red fir, Douglas-fir, ponderosa pine, jeffrey pine, lodgepole pine, western white pine, whitebark pine, or mountain hemlock)

4a. True fir comprising >50% of stocking (5)
4b. True fir < 50% of the stocking (6)

5a. Red fir >50% of stocking...Red Fir (SAF 207)
5b. White fir >60% of stocking...White Fir (SAF 211)

6a. Douglas-fir >50% of the stocking...(7)
6b. Douglas-fir <50% of the stocking (8)

7a. White fir present and/or hardwoods (tree form) absent or < 10% cover ....Pacific Douglas-fir (SAF 229)
7b. White fir absent and evergreen hardwoods present and >10% cover ....Douglas-fir/Tanoak/Madrone (SAF 234)
7c. Ponderosa pine present and >20% stocking...Pacific Ponderosa Pine - Douglas-fir (SAF 244)

8a. Ponderosa or Jeffrey pine comprise >50% of the stocking (9)
8b. Ponderosa or Jeffrey pine comprise <50% of the stocking (10)

9a. Ponderosa pine comprises >80% of conifer stocking, west of Sierran-Cascade crest ....Pacific Ponderosa Pine (SAF 245)
9b. Ponderosa pine or Jeffrey pine comprise >80% of stocking...Eastside Pine (SAF)
9c. Douglas-fir comprising >20% of stocking, Ponderosa pine comprising >20% of stocking, both species together comprising >75% of stocking...........Pacific Ponderosa Pine - Douglas-fir (SAF 244)

10a. Mixture of montane species (white fir, ponderosa pine, sugar pine, Douglas-fir, incense cedar, black oak and red fir) comprise majority of stocking. At least three conifer species present, with at least 10% of stocking each......................Sierra Nevada Mixed Conifer (SAF 243)
10b. Subalpine species (mountain hemlock, lodgepole pine, western white pine, whitebark pine or aspen) comprise a majority of stocking (11)

PRELIMINARY ECOLOGICAL OLD-GROWTH DEFINITIONS FOR WHITE FIR (SAFTYPE 211) CALIFORNIA

By

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Pacific Southwest Region

US Forest Service

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Executive Summary

Introduction

Old-growth is an important and controversial issue in resource management. A National Task Group, formed in 1989, directed the development of ecological definitions of old-growth for use in inventory and management. From an ecological perspective, old-growth is a late successional stage of forest development (Franklin and Spies 1991). Late successional forests are distinguished from younger forests by both their structure and ecological functioning, but structure is the most easily described. Structurally, late successional forests contain trees that are large for their species and site, often a variety of tree sizes, large snags and logs, and a developed and often patchy understory (Franklin and Spies 1989). The National Task Group identified a set of minimum structural attributes to be included in the definitions: age, size, and density of large trees; variation in canopy layers and diameters; decadence; and size and density of large logs and snags.

Region 5 was given the task of defining old-growth for 13 forest types (Society of American Foresters' Forest Types). This document includes a description of ecological characteristics of white fir (SAF forest type 211). White fir dominates the overstory and regeneration of white fir forests, comprising greater than 50% of the total basal area in the north Coastal Range and the western Klamath Mountains, and greater than 60% of the total basal area in the rest of the Region. The geographic extent of white fir forests includes the north Coast Range, Klamath Mountains, southern Cascade Range, the Sierra Nevada Range, the Warner Mountains and scattered locations in southern California.

Data Sources and Analysis

The definitions were developed using Ecoystem Classification, Forest Inventory Analysis, and Stand Exam plots. Two data sets were used. One, from the Six Rivers and western Klamath National Forests, included 442 plots. The second data set, from all of the other forests in the Region included 137 plots. Both data sets included samples from mature and old-growth forests. The data was stratified by site class (Dunning 1942) into three groups: 1A-1, 2-3, and 4-5. Trend analysis was completed to determine where structural attributes visibly changed between mature and older stands. The ages where the changes in structural attributes for stands were evident were used as cut-offs to separate mature stands and late successional stands. Statistics for the structural attributes were then calculated by site class group for the stands below and above the cut-off age.

Results and Discussion

There was much variability in the structural attributes. This is typical for late successional stands and is probably due to several factors: (1) effect of varied stand history, such as fire, insect, or other natural disturbance; and (2) variation of plant community types or site environment. The variability in snag data may also be due to the prism sampling technique used for some of the plots, where under-estimation is prevalent. The definitions were field-tested and overall worked well and were readily applied on the ground. Some of the attributes, diameter and canopy diversity, were more indicative of plant community type or site environment than successional stage. Large snags and logs are naturally highly variable, but are good indicators of old-growth if large areas in the landscape are evaluated. Stand age is difficult to determine and generally is not a necessary structural attribute of late successional forests, but it may be indicative of the level of ecological functioning. A score-card or indexing system needs to be devised to rate the ecological significance of individual old-growth forests, including factors such as proximity to riparian or wetland areas, size and shape of stand, structure of adjacent vegetation, and level and type of disturbance. Data from the Warner Mountains was more similar to Region 6 data than Region 5.

Introduction

Old-growth forests are currently under much scrutiny and controversy by the public and land managers. Much of the controversy about old-growth forests concerns what it is and how much of it remains. The U.S. Forest Service formed a National Old-Growth Task Group to guide the development of old-growth forest definitions that would help answer these two questions. Before an assessment can be made of how much old-growth forest remains, a common, acceptable definition of old-growth must exist. The National Task Group determined that an ecological definition of old-growth is the most appropriate. Refinements of the ecological definitions can be made later, based upon individual management needs, public concerns, wildlife habitat needs or for aesthetic or social values. The objective for the old-growth defintion team was to develop an ecological defintion of old-growth white fir, based upon the best available information. This document includes a description of the ecological characteristics of old-growth white fir (SAF forest type 211) for Region 5 and the methods used to develop and analyze the characteristics. Later revisions of the definition may be made as further data is available.

Ecological Definition of Old-Growth Forests

From an ecological perspective, old-growth is a late successional stage of forest development (Franklin and Spies 1991a). As forests increase in age and develop, their structure changes. Successional stages are most often recognized by structural characteristics, such as size of trees, distribution of tree sizes, presence and size of snags and logs, understory composition and heterogeneity, and horizontal diversity in structure. Late successional forests in general contain trees that are large for their species and the site, often a variety of tree sizes, large snags and logs, and a developed and often patchy understory (Franklin and Spies 1989). While the structural features of late successional forests, or old-growth, are generally recognizeable, a myriad of community and ecosystem interactions (or functions) may also be diagnostic (Franklin and Spies 1991b) but are more difficult to measure and describe. It is assumed for the description of old-growth presented here, that the structural attributes reflect the presence of the community and ecosystem interactions (Franklin and Spies 1991b). Stand age is often considered less important than structure in describing late successional forests because the rate of stand development depends more on environment and stand history rather than age alone. However, forest age may be an indicator of the level of development of community and ecoystem interactions, and therefor the level of ecological functioning.

Variability of Old-Growth Forests and Definition Limitations

The late successional stage of forests, old-growth, intergrades with mature and sometimes earlier successional stages. It is difficult to precisely define where old-growth begins and where it ends. However, there is a critical need to quantitatively describe the characteristics of old-growth to enable consistent and repeatable inventory and management.

Fire and other types of disturbance caused by weather or insects are considered natural, and an integral part of stand structural development or community succession. Stands that had natural disturbance were included if the disturbance did not alter the structure enough to result in one that more closely resembled mature or early successional stage structures. The degree of the effect of natural disturbance on stand structure of old-growth varies across the landscape and with time, due to the varying periodicity and intensities of these natural disturbance events. Due to the great variability in degree of effects of natural disturbance on stand structure of old-growth, it is likely that some naturally disturbed stands that have characteristics that intergrade between old-growth and younger successional stages, were excluded from this analysis. Stands that had a predominance of regeneration over older trees, due to fire or other stand history, were excluded from the definition because of their structural similarity to mature or early successional forests. These stands were excluded due to the apparent lack of distinguishing attributes between mature and old-growth and lack of data on these types of stands. However, these stands may be functioning as old-growth and should be considered on a site specific basis when using the definitions for inventory or managment.

Across much of the range of the white fir type in California, fire is a common natural disturbance factor, although the fire frequency is probably variable in the different environments within the range of white fir. Since white fir is not fire resistant, the role of white fir in forests is greatly influenced by fire. At higher elevations, and on cooler sites (north-facing slopes, ravines), white fir forests probably have a lower fire frequency than white fir forests that occur within the mixed conifer zone. In these latter stands, where the natural fire frequency is known to be high (Kaufman 1986), white fir can become dominant with a lack of fire, especially on moderate or cool sites. The fire supression efforts this century and natural variation in fire locations have resulted in regeneration and dominance of white fir in some areas in the mixed conifer zone. This same pattern is also apparent in the transitional area between the westside and eastside climatic zones of the Sierras and southern Cascades, where previously eastside pine or mixed stands of white fir and pine were likely more prevalent prior to fire suppression. White fir has become more dominant in these environments since the advent of fire suppression. The structure of forests in the areas where white fir has become dominant due to a lack of fire, may be different than if there had been fire disturbance. With frequent, natural fire disturbance, some of the white fir stands currently present in these areas would not be present at all, instead replaced with mixed conifer or eastside pine. On cooler, moister sites, such as north-facing slopes and ravines, with lower natural fire frequencies and intensities, white fir forests have likely been less impacted by fire suppression. Given the natural variation in fire sizes, frequencies and intensities, some areas within the mixed conifer or east-side zones would have remained unaffected by fire.

The past fire history and recent fire suppression effects are acknowledged but the definitions presented here are based upon data collected within the last ten years. Information is not available at this time to stratify the data based upon different fire histories, which might result in different old-growth structures.

Application of Definitions

The definition is applicable in stands that meet the species composition criteria for white fir specified below. The stands should be measured for site class, and the appropriate characteristics applied for that site class group. The definitions were developed from stands without apparent human-caused disturbance or drastic natural disturbance. A few stands with one or two trees removed for sanitation or railroad logging more than fifty or so year ago, were included if the stand structure did not appear affected. Therefore, the definition here, applies to essentially undisturbed (especially human-caused) stands and in applying the definitions to disturbed stands, disturbance should be noted in detail and evaluated for effects on the ecological function or significance. Ecological significance is referred to here as ecological function and would include such ecosystem and community processes and interactions as nutrient cycling, hydrological regulation, productivity, and wildlife and plant habitat (Franklin and Spies 1991b). Some stands with very minor disturbance was included because of the prevalence of human influence in montane forests in the past and were included only if there was evidence that the stands had recovered from the disturbance.

Composition of White Fir and Geographic Extent

The Society of American Foresters has defined white fir forests for the south pacific as the "White Fir" type, #211 (Gordon 1980). The dominate species is white fir. It often occurs in pure stands or sometimes with low amounts of red fir, ponderosa pine, Jeffrey pine, sugar pine, Douglas-fir and occasionally Port-Orford-cedar.

This broad definition is not adequate for detailed analysis. The Region 5 team leaders developed some specific composition requirements for all of the SAF types being defined in this Region, to ensure that the data available could be stratified with no overlap between the similar types. White fir inter-grades into several different SAF types including: red fir, Sierra Nevada mixed conifer, Pacific ponderosa pine, Pacific Douglas-fir, Jeffrey pine and interior ponderosa pine. To distinguish white fir from these other types, the following guidelines were used. White fir was defined as having a basal area equal to or greater than 60% of the total basal area of the stand (relative basal area), except for the north Coast Ranges and western Klamath mountains, where a cut-off basal area of 50% was used (Jimerson in draft). In the second area, white fir tends to occur more as a dominant component of mixed stands, whereas in the remainder of its distribution, white fir occurs often in more pure stands. The definitions for the other SAF types are included in Appendix A.

The Society of American Foresters (1980) described the geographic extent of SAF type 211 as occurring throughout the range of the species on the West Coast. It occurs at mid-elevations in the Cascades and Siskyou Mountains of Oregon. In the southwestern portion of the Cascades in southern Oregon and northern California, white fir stands are extensive. It also is found in the Warner Mountains. In the Sierra Nevada, white fir stands occur in a band below the red fir zone and on northern slopes or cooler sites.

Methods

Data

The data set used to develop the old-growth definitions included Ecosystem Classification (EC) Plots (FSM 2090.22), Forest Inventory Analysis (FIA) Plots (FSH2409.21B), and Stand Exam Plots. Six hundred and nineteen plots were included in this data set, of which 516 were Ecosystem Classification Plots. Sixty-eight FIA plots and thirty-five Stand Exam plots were also included. The Ecosystem Classification Plots were placed in undisturbed late seral stands. No predetermination of whether the stands were old-growth or not were made, only an assessment of the stage of stand development. The plots include mature, late mature and old-growth stands. Past disturbance such as fire, disease, small slumps or windstorm were considered to be a natural component of the stands and plots were placed in stands where these disturbances have occurred, unless the disturbance had affected the seral stage of the stand.

Two data sets were used to define the characteristics for old-growth white fir stands in California. One data set includes EC plots (442) only and covers the north Coast Ranges and western portion of the Klamath Mountains (Jimerson draft). The second data set includes 74 EC plots located on the following forests: Eldorado, Tahoe, Plumas, Lassen, Shasta-Trinity, Mendocino, Lake Tahoe Basin, Stanislaus, Sierra and Sequoia and Toiyabe National Forests. The second data set was small and the white fir type occurs on other areas in the Region, therefore the FIA data was also used. FIA data from the following forests were used: Angeles, Eldorado, Klamath, Los Padres, Lassen, Lake Tahoe Basin, Mendocino, Modoc, Plumas, Stanislaus, San Bernedino, Sequoia, Shasta-Trinity and Tahoe National Forests. There is no written description of the disturbance history of the FIA plots and close examination of the data and comparison with undisturbed EC data were used to eliminate stands that appeared to have been disturbed (i.e. low volumes with small numbers of large trees). There was no snag or defect data available for most of the EC plots; therefore, the FIA data was also included to provide data on these attributes that are part of the national old-growth defintion minimum standards. Stand exam data from known undisturbed stands was included from the Tahoe, Modoc, Lassen and Eldorado National Forests.

Analysis

Forty-three variables were examined in the analysis for old-growth characteristics (Table 1.). For this draft definition, emphasis was placed on analyzing the characteristics that are part of the national old-growth definition minimum standards (table 2). Structural features such as the trees/acre by diameter groupings, standing cubic volume, quadratic mean diameter and frequency of snags were the primary characteristics analyzed. The diameter classes used were those that are available in the R5 Forest Inventory Analysis (FIA) analysis programs: 1-5, 6-10, 11-14, 15-20, 21-28, 29-38 and 39+ inches. The variance of tree diameters was calculated using the following forumula:

Variance of Diameters =

$$\frac{\sum f_i \cdot x_i^2 - \sum (f_i \cdot x_i)^2 / \sum f_i}{\sum f_i - 1}$$

where fi is the frequency of trees in each diameter class and xi is the median diameter for each diameter class.

Table 1– Variables used in data analysis of structural characteristics of old-growth.

Variable	*Classes*
Conifer Trees/Acre	1-4",5-10",11-14",15-20" 21-28",29-38",39"+ d.b.h.
Hardwood Trees/Acre	" "
Decadent Trees/Acre	" "
Snags/Acre	" "
Logs/Acre	3-9",10-19",20-29",30-39" 40"+ bottom diameter
% Basal Area by Species	
Dunning's Site Class	1A,1,2,3,4,5
Conifer Basal Area	
Hardwood Basal Area	
Conifer Cubic Volume	
Hardwood Cubic Volume	
Conifer Quadratic Mean Diameter	
Hardwood Quadratic Mean Diameter	
Quadratic Mean Diameter	
Variance of Diameters	
Stand Age	

Table 2– National minimum standards for variables to be used in developing old-growth definitions, established by the National Old-Growth Task Force.

1. Live trees in main canopy
   - d.b.h.
   - trees per acre
   - age

2. Variation in tree diameters

3. Dead trees:
   - standing trees per acre
   - down pieces per acre

4. Tree decadence (spike or deformed tops, bole or root root decay):
   - trees per acre

5. Number of tree canopies

The Region 5 Forest Inventory Analysis programs, FIA MATRIX, FIA CONVERT and FIA SUMMARY, were used to calculate the above characteristics and Dunning's site class (Dunning 1942).. Statistical analyses were performed with SPSS (Norusis 1988) and trend analyses with Harvard Graphics (Software Publ. Corp. 1987). The data was stored and managed in DBASE IV (Ashton-Tate Corp. 1988).

The relative % basal area for each plot was used to determine whether it met the criteria for the SAF type 211, using the definitions described in the Introduction. The data was further stratified by site class (Dunning 1942) into three groups: site class 1A to 1, 2 to 3, and 4 to 5. It has been found previously that stand structure and old-growth characteristics vary significantly between different site class groups (Jimerson and Fites 1989). The number of plots included in the site class groups for the north Coast data set were: (1) site class 1A-1 -188 plots; (2) site class 2-3 group - 223 plots; and (3) 31 plots. The number of plots included in the site class groups for data set from the rest of the Region were: (1) site class 1A-1 -53 plots, with 42 from EC data, 9 from FIA data, 2 from SE data; (2) site class 2-3 group - 79 plots, with 24 from EC data, 31 from FIA data, 24 from SE data; and (3) 45 plots, with 8 from EC data, 28 from FIA data, 9 from SE data.

Once the stands were stratified by SAF type and site class, trend analysis was conducted to determine which data should be analyzed for old-growth defintions and which data included stands from earlier seral stages. The trends examined for this purpose included the change in standing cubic volume, quadratic mean diameter and the trees/acre by diameter classes with estimates of stand age. Trends of snags, logs and decadence were not evaluated due to low numbers of samples for these attributes or lack of associated age data.

The oldest age of the co-dominant or dominant large diameter trees in the stand was used as an approximation of stand age. Three co-dominant or dominant trees were measured for each EC plot and generally five co-dominant or dominant trees were measured for each FIA plot. Due to the variability in the composition of late seral stands and often skewed age or diameter distributions (Potter draft, Schumacher 1928, Veblen 1985), it was decided that an average of the three or five ages would not be as meaningful as the age of the oldest measured tree. Some of the FIA plots were eliminated at this stage if large diameter trees were present in the stand but were not measured for age. Because of the limited sampling for stand age, it is considered only as a broad estimate and is only useful for general trend analyses.

An ecological interpretation of a late seral stage is that the stand has developed to a self-perpetuating state (Spies and Franklin 1991a). However, forest structure is rarely static, even in late seral stages, due to natural stand processes (i.e. mortality) and minor natural disturbances. Therefore, any trend analysis must be interpreted with this dynamic nature in mind.

The trends were examined for the attainment of a maximum, dynamic equilibrium of standing cubic volume, quadratic mean diameter and number of large trees per acre. The ages at which these maximums occurred were used as cut-offs for further analysis of old-growth characteristics. Because of the limited sampling for the ages, they are useful only for a data stratification tool and not as the minimum age at which old-growth occurs. For the second data set (including the Sierras, Cascades, southern California, the Klamath Mountains and the Mendecino Coast Range), based upon the trend analysis the cut-offs used were: 145 years for the site class 1A-1 group, 185 years for the site class 2-3 group and 255 years for the site class 4-5 years. For the data set from the North Coast Range and the western Klamath Mountains, based upon the trend analysis, the cut-offs used were: 160 years for site class group 1A-1, 200 for site class group 2-3, and 300 years for site class group 4-5 (Jimerson unpublished data). Because the trend analysis for the two different data sets yielded different cut-off ages and the number of snags/acre were much higher in the north Coast Range data set, the data sets were kept separate.

Once the cut-offs were determined, statistics were calculated for the characteristics of the minimum national old-growth definition standards. The mean, standard deviation, and range were calculated. Frequency distributions of the attributes were plotted and compared with normal distributions. Although some of the attributes showed approximately normal distributions, others did not, and therefore percentiles were used to calculate the low and high ranges. The 10%, 15%, 85% and 90% percentiles were calculated. The percentiles that showed clear differences between the mature forest data were used. Following the determination of the statistics for each attribute, the data set and trend analysis graphs were examined for obvious outliers. Stands younger than the cut-off ages that had attained the structural attributes of old-growth as described here were added. Recalculation of statistics followed.

Snag and log data from the north Coast Range data set were collected on large, nested, fixed-area plots (Jimerson 1989). The other data set included snag data from 1991 Ecology Plots, recent Stand Exams and FIA plots. Much of the data came from FIA plots, since snags were not being measured at the time that most of the Ecology plot data was collected. The snags were sampled with the same procedures and basal area factor used to measure the live trees. It has been well demonstrated in the literature (Bull et. al 1990), that a more intensive, fixed area sampling procedure is more appropriate for snag inventories. It is likely that the snag densities presented here are an underestimate due to the sampling method for FIA plots and relatively small number of samples and should be considered a first approximation. As additional data is collected on snags, it will be added.

Most of the plots for the decadence analysis were also from the FIA data set. Recent Ecology Plots and Stand Exams were also used. Decadence recorded for the FIA plots included: presence of fungi conks, fire or other basal trunk scars, dead or broken tree tops, forked tree tops, and trees that are apparently afflicted with heart-rott and are not merchantable.

Little log data for the second data set was available. The data sources included recent Ecology Plots, some Stand Exams Plots and Wildlife Inventories. Inconsistency in size classes used in data collection resulted in some of this data being excluded.

Snag, log and live tree decadence data from the different site class groups were pooled for final analysis, due to the small number of samples available and absence of apparent differences between the site class groups.

Field Testing

The definitions were examined in the field to evaluate their consistency with actual old-growth stand structures and ease of applicablity on the ground. For most of the field-testing, structural data was collected and compared with attribute statistics in the definition. Several of the field-exams included an ocular evaluation of the structural characteristics.

Results

Table 3–Structural characteristics of old-growth white fir forests (SAF type 211) by Dunning's site classes for the Sierra Nevada, Cascades, E. Klamath Mountains, central Coast Range and southern California.

	WHITE FIR *Sierra Nevada, Cascades, E. Klamath Mts, So. Cal.*		
	Site 1A-1	Site 2-3	Site 4-5
NUMBER OF SAMPLES	33	28	12
DBH OF LARGE TREES (inches)	39+	39+	29+
NO. LARGE TREES (trees/acre)			
Mean	12	10	14
S.D.	5.9	4.2	5.7
Range,low	7*	6*	6**
Range,high	19*	16*	19**
VARIANCE OF TREE DIAMETERS			
Median	Not Applicable		
CANOPY VARIATION[1]			
No. of Layers	1-2[2]	1-2[2]	1-2[2]
AGE (years)			
Mean	260	274	301
S.D.	111	77	74
Range,low	143**	188*	239**
Range,high	413**	376*	359**

1. The four canopy layers are: 70-100% of the dominant canopy layer height, 40-69% of the dominant canopy layer height, <39% of the canopy layer height (excluding the regeneration layer), and the regeneration layer (trees < 4.9" d.b.h.).
2. Best professional judgment used to estimate the canopy variation, using ecology plot data and field observations.
* Calculated from the 15 and 85 percentiles.
** Calculated from the 10 and 90 percentiles.

Table 4–Structural characteristics of white fir old-growth forests (SAF type 211) by Dunning's site classes for the Sierra Nevada, Cascades, E. Klamath, central Coast Range, and southern California.

	WHITE FIR Site 1A-5 *Sierra Nevada, Cascades, E. Klamath Mts, So. Cal.*	
	SNAG DENSITY[3] (>29" dbh & > 10')	LIVE TREE DECADENCE[4] (>29" dbh)
Mean	3.5	3.9
S.D.	2.7	3.0
Range	0-5.8*	2.0-5.8*
Number of Samples	46	34
	(>39" dbh & > 10')	(>39" dbh)
Mean	1.8	2.0
S.D.	2.2	1.7
Range	0-3.6*	0.9-3.0*
Number of Samples	46	34
	LOG DENSITY (10-20" diam. & >10')	
Mean	17.1	
S.D.	13.0	
Range	6.1-28*	
Number of Samples	11	
	(>20" diam. & >10')	
Mean	10.2	
S.D.	5.9	
Range	5.2-15.2*	
Number of Samples	11	
	(>40" diam. & >10')	
Mean	2.4	
S.D.	3.1	
Range	0-5*	
Number of Samples	11	

* Calculated with the 15 and 85 percentiles.

** Calculated with the 10 and 90 percentiles.

3. Note: snag densities may be understimated due to the use of prism sampling technique for many of the plots; a technique known to understimate snag levels.

4. Decadence includes characteristics of live trees including: broken tops, spike tops, multiple leaders, conks, fire or other bole scars.

Table 5–Structural characteristics of old-growth white fir forests (SAF type 211) by Dunning's site classes for the north Coast Range and western Klamath Mountains. (Data from: Jimerson, in draft).

	WHITE FIR *North Coast Range, W. Klamath Mts.*		
	Site 1A-1	Site 2-3	Site 4-5
NUMBER OF SAMPLES	188	223	31
DBH OF LARGE TREES			
(inches)	30+	30+	25+
NO. LARGE TREES			
(trees/acre)			
Mean	23	21	38
S.D.	14	16	15
Range,low	20.9ˆ	18.4ˆ	28.0ˆ
Range,high	25.9ˆ	24.4ˆ	48.0ˆ
VARIANCE OF TREE DIAMETERS			
Median	not determined		
CANOPY VARIATION[1]			
No. of Layers	2	2	2
AGE (years)			
Mean	262	310	425
S.D.	88	90	109
Range,low	160	200	303
Range,high	540	633	575

1. The four canopy layers are: 70-100% of the dominant canopy layer height, 40-69% of the dominant canopy layer height, <39% of the canopy layer height (excluding the regeneration layer), and the regeneration layer (trees < 4.9" d.b.h.).

ˆ Values calculated from 1/- 2 standard errors.

Table 6–Structural characteristics of white fir old-growth forests (SAF type 211) by Dunning's site classes for the north Coast Range and western Klamath mountains. (Data from: Jimerson, in draft).

	WHITE FIR Site 1A-5 *North Coast Range, W. Klamath Mts.*	
	SNAG DENSITY (>20" dbh & > 15')	LIVE TREE DECADENCE (>29" dbh)
Mean	7.4	Not available
S.D.	5.8	
Range	6-8.8^	
Number of Samples	250	
	LOG DENSITY (>20" diam. & >10')	
Mean	20.9	
S.D.		
Range	17.5-24.3^	
Number of Samples	250	

^ Values calculated from +/- 2 standard errors.

Discussion

Variablility in Structure

The results were similar to those reported in other old-growth definitions in Region 5, with much variation observed for the old-growth characteristics (Potter 1991, Smith 1991, Jimerson 1991). This is partly due to the inherently variable nature of old-growth stands, which may be attributed to their relatively older age and the wide variety of stand history events that may affect their structure. Variation due to fire, environmental factors, plant community composition and data limitations of some attributes is possible.

Past fire disturbance, including a myriad of intensities and durations, may have greatly increased the structural diversity of old-growth white fir forests included in this analysis. Stands in areas of higher fire frequencies, such as ridge tops, upper slopes and south-facing slopes would have had different disturbance regimes than those with lower fire frequencies, such as lower slopes, drainages and north-facing slopes. White fir forests on south-facing slopes may have had a co-dominant or dominant component of pine or a mixed conifer composition. Although, some white fir stands have originated in fire generated shrubfields, where white fir regeneration is favored due to its shade tolerance. Insect and disease disturbance have also likely resulted in structural variation in old growth. As mentioned in the Introduction, old-growth stands that have had natural disturbance that changed the structure such that the characteristics intergrade between old-growth and mature successional stages were not sampled extensively or included in this analysis. Addition of these types of stands would likely result in further variability in the old-growth characteristics.

Another likely cause of the high variation found in the old-growth characteristics, even within a site class group, is the variety of environments where old-growth stands occur. Stands occuring on ridgetops or on the upper one-third of slopes are drier and hotter, and often have less canopy layer diversity than stands occuring in ravines or on lower slopes. Another source of indirect variation related to the environment is the plant community composition, although white fir forests tend to have more uniform structure across community types than other forest types. Most white fir stands have few canopy layers. This may be due to the tendency of white fir to develop as even-aged stands. An exception is on moist or wet sites, where white fir stands are often more layered. Further refinements of the old-growth definitions based upon the plant communities will be examined in the future as the Region 5 Ecosystem Classification Program progresses. These differences may result in different ecological significance for the varied structures and topographically different stands.

In addition, some of the high variation in some of the old-growth characteristics described here for the forests other than in the north Coast , may be due to the small data set for some of the characteristics, snags and decadence, or the low number of samples for the low site group. The snag data may also be highly variable because the sampling technique used for snags in the FIA plots is known to result in an underestimation of snag density (Bull et. al 1990). This may explain in part why the estimates for snag density were twice as great in the north Coast data set. There may also be higher natural snag levels in the north Coast. Because of the low number of samples in the low site group, the statistics for the low site old-growth characteristics should be considered very preliminary and may change with additional data.

Data from the Warner Mountains on the Modoc National Forest differed visibly from the rest of the data set. The cut-off ages seemed greater than for comparable sites in other areas, the large diameters were smaller, and the density of trees higher for comparable sites. The white fir forests in the Warner Mountains appears more similar to those described by Hopkins (in draft) for the eastern Oregon. There is insufficient data at this time to develop separate definitions for the Warner Mountains. Until further data is collected and analyzed, the definitions for Region 6 (Hopkins in draft) should be applied in the interim.

Field Testing- Diagnostic Characteristics

The definitions were generally easily applied in the field. Attributes that were difficult to assess in the field, were variation in diameters and canopy layers. However, it seems that the number of canopy layers is more dependent upon environment, plant community and initial stocking than seral stage. Canopy layer and diameter diversity were generally low in the white fir stands tested in the field. High variability in these attributes were observed in two situations: 1) moist sites, and 2) densely stocked stands. Structural diversity observed in white fir forests became more apparent when large areas were examined, and patches with a variety of size classes were seen. In densly stocked stands, diameter variation can be prevalent in mature stands, due to the effects of competition and resulting growth differences between suppressed and dominant trees. This stocking induced diameter variation may or may not persist into the old-growth seral stage.

The attributes that were the most useful in distinguishing mature and old-growth stands were the number of large trees per acre, presence of decadence in live trees and often presence of snags and logs. Snags and logs are naturally highly variable in space and time, lessening their diagnositic utility (Laudenslayer pers. comm.). However, in most of the stands tested in the field, snags and logs were evident, but were often very patchy in distribution and widely spaced. Where snags and logs were not present, or were few in number, there was often evidence of past disturbance, such as salvage, sanitation or fire hazard tree removal, that would have resulted in snag removal or potential snag or log removal. Natural disturbances, such as weather events and fire, can also result in a lack or high numbers of snags and logs. Since the presence of large snags and logs is common in old-growth stands, when large areas are examined, but sometimes absent due to natural conditions, their presence can help confirm that old-growth conditions occur but stands should not be eliminated from consideration as old-growth if they are absent.

Ecologically Significant Old-Growth

Ecological significance, as referred to here, relates to the ecological functioning of an old-growth stand. Franklin and Spies (1991b) give the following examples of old-growth ecosystem functions: "production, the capture of the sun's energy through photosynthesis and its conversion to organic substances; regulation of nutrient cycling, including accumulation and conservation of nutrients; regulation of hydrologic cycles; and provision of habitat for organisms". Some research has been completed on ecological functioning of old-growth in the Pacific Northwest (Franklin and Spies 1991b) but little has been completed in California, especially in Sierran Mixed Conifer. The ecological functions that have been characterized in the Pacific Northwest likely apply to California in general, although some differences in the specific characteristics probably vary due to the different climate and fire ecology. However, it is important to consider ecological significance when applying the old-growth definitions to managing old-growth, so a discussion of the characteristics of old-growth ecoystem functions found in the Pacific Northwest is pertinent.

Large logs play an important role in nutrient cycling, providing retention and slow release of nutrients, sites for nitrogen fixation (Franklin and Spies 1991b), and habitat for microorganisms and invertebrates that are integral in nutrient cycling (Maser et. al. 1988). Snags function as foraging and breeding habitat for vertebrates (Brown 1985, Lundquist and Mariani 1991, Maser et. al 1988), and as recruitment for logs.

In addition to the importance of structural diversity in determining the biodiversity of wildlife in old-growth stands the presence of riparian areas, wetlands or water sources in or near the old-growth stands is also key. The presence of these areas, greatly increases the biodiversity of wildlife. Further analysis on the minimum stand size, or perimeter to interior ratios need to be completed to assess what size stands are necessary to ensure the community biodiversity of the old-growth stand through providing the necessary habitat for plant and animal species that are present in such environments.

The effect of old-growth structure on hydrologic function is related to the large tree canopies and canopy diversity, as well as the presence of logs (Franklin and Spies 1991b, Harr 1986). The potential for rain-on-snow flood events is reduced, due to greater canopy interception and protection of accumulated snow. Logs reduce soil erosion and play an important role in aquatic ecosystems. Ann Carlson and others (1991) attributed the following functions to large woody debree in aquatic ecosystems: dissipate hydraulic energy; reduce potential erosion of the channel bed and stream banks; serves as a filtering device, retaining sediment, detritus and nutrients; provides rich habitat for fish and invertebrate organisms.

Large leaf areas found in the large and layered canopies of old-growth forests (Franklin and Waring 1980), provide the capacity for much photosynthetic production (Franklin and Spies 1991b). Franklin and Spies (1991b) concluded that biomass accumulations are generally stable in old-growth (Bernsten 1960, DeBell and Franklin 1987, Williamson and Price 1971).

Application of Definitions

Based upon the results of the field-testing, it seems that not all of the characteristics defined are necessary for applying the definitions for inventory. Canopy layer diversity is not diagnostic of old-growth white fir but is important for ecological significance and should be included in old-growth inventories. The old-growth characteristics that are diagnostic and should be included are densities of large trees, decadence of large live trees, large snags and large logs. While these attributes are diagnostic, some stands may not have all of the old-growth attributes, but rather a subset. To determine if stands that only have some of the attributes present fit the definition, it is recommended that an index or rating system be used for assessing how well the stand meets the definition. The preferrable method for developing such an index would be quantitative and objective, such as Discriminate Analysis (Spies and Franklin 1991). However, to apply disciminant analysis and derive dependable results, all of the variables should have the same degree of reliability. The data set used here includes fewer snag and log data than for the live tree attributes, resulting in different degrees of reliability for the variables. Despite these limitations, the development of an index for assessing how well the definitions fit using Discriminant Analysis is being explored. Alternatively, an interdisciplinary team could develop an index for assessing how well the stands meet the definition, would be to have an interdisciplinary team develop one.

For inventory of old-growth, the range values for the attributes should be applied, in order to accurrately identify the variability of old-growth that is naturally present. For management of old-growth, it is recommended that the means and high ranges be applied for determining desired future condition. This would ensure that high quality old-growth is attained and maintained. Maintenance of old-growth would be assured by allowing a buffer for the effects of minor natural disturbance. Site specific evaluation of areas that meet the low range levels of the attributes rather than the means should be made to assess whether the low range would be the more appropriate desired future condition, due to environment limitations or plant community characteristics that would prevent the forest from ever attaining mean levels.

Application of the definitions for determination of old-growth management areas, should take features of ecological significance into account. Another index or rating system, to assess the level of ecological significance would be useful for this application as well. The characteristics or features that should be included in rating ecological significance are: density of large trees; size, density and decay classes of logs and snags; size of the stand and structure of surrounding vegetation; level and nature of disturbance; presence of rare wildlife; presence or adjacency of wet or riparian areas; and abundance and location of nearby old-growth forests.

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APPENDIX A

KEY TO SAF FOREST TYPES

1a. Redwood or Port-Orford cedar present and comprising >33% of stocking (2)
1b. Redwood or Port-Orford cedar absent or comprising <33% of stocking (3)

2a. Redwood comprising >33% of stocking...Redwood (SAF 232)
2b. Port-Orford cedar comprising >33% of stocking...Port-Orford cedar (SAF 231)

3a. Three or more species comprising the majority of the stocking (9)
3b. One or two species comprising the majority of the stocking (4) (Dominants are white fir, red fir, Douglas-fir, ponderosa pine, jeffrey pine, lodgepole pine, western white pine, whitebark pine, or mountain hemlock)

4a. True fir comprising >50% of stocking (5)
4b. True fir < 50% of the stocking (6)

5a. Red fir >50% of stocking...Red Fir (SAF 207)
5b. White fir >60% of stocking...White Fir (SAF 211)

6a. Douglas-fir >50% of the stocking...(7)
6b. Douglas-fir <50% of the stocking (8)

7a. White fir present and/or hardwoods (tree form) absent or < 10% cover ....Pacific Douglas-fir (SAF 229)
7b. White fir absent and evergreen hardwoods present and >10% cover ....Douglas-fir/Tanoak/Madrone (SAF 234)
7c. Ponderosa pine present and >20% stocking...Pacific Ponderosa Pine - Douglas-fir (SAF 244)

8a. Ponderosa or Jeffrey pine comprise >50% of the stocking (9)
8b. Ponderosa or Jeffrey pine comprise <50% of the stocking (10)

9a. Ponderosa pine comprises >80% of conifer stocking, west of Sierran-Cascade crest ....Pacific Ponderosa Pine (SAF 245)
9b. Ponderosa pine or Jeffrey pine comprise >80% of stocking...Eastside Pine (SAF)
9c. Douglas-fir comprising >20% of stocking, Ponderosa pine comprising >20% of stocking, both species together comprising >75% of stocking............Pacific Ponderosa Pine - Douglas-fir (SAF 244)

10a. Mixture of montane species (white fir, ponderosa pine, sugar pine, Douglas-fir, incense cedar, black oak and red fir) comprise majority of stocking. At least three conifer species present, with at least 10% of stocking each.......................Sierra Nevada Mixed Conifer (SAF 243)
10b. Subalpine species (mountain hemlock, lodgepole pine, western white pine, whitebark pine or aspen) comprise a majority of stocking (11)

Ecological Definition for
Old-growth Pacific Douglas-fir
(Society of American Forester's type 229)

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INTRODUCTION

Old-growth forests represent a unique plant community of significant biological and social value. The once plentiful forests of old-growth in the United States have greatly diminished through past logging practices and wildfire. The management of the remaining old-growth stands, which are now primarily found on public lands (Spies & Franklin 1988), has become a critical and controversial resource issue. The distinctive structural and biological attributes of old-growth forests serve as sites of high biological and genetic diversity, as needed habitat for many wildlife species, and provide a unique recreational value. These same forests are also the source of raw material needed to produce high value lumber products. The Forest Service recognizes the values of these forests and is providing direction for the maintenance and management of old-growth habitat on National Forest lands (Robertson 1989).

Old-growth forests are fairly complex and often cannot be distinguished from other stands by one or two stand structure attributes. Several key attributes together distinguish these stands from other seral stages (Franklin & Spies 1989). Biologically, mature forest stands become old-growth when the standing cubic volume culminates (the stand reaches maximum site carrying capacity). The numbers of trees in the larger diameter classes increase significantly and the stand quadratic mean diameter culminates. Old-growth forests are characterized by large conifers in stands with multiple canopy layers and on higher quality sites have relatively dense canopy cover. Decadence is significant in the latter part of the old-growth seral stage and is evident in the accumulation of large standing snags, downed logs and malformed live trees.

Direction for resource management cannot be resolved without first defining the biological and structural features which distinguish old-growth stands from other seral stages. The Old-Growth Definition Task Group (1986) developed interim definitions for old-growth Douglas-fir and mixed-conifer forests in western Washington, Oregon and California. National direction to develop specific old-growth definitions for each forest type was established in 1989 (Robertson 1989).

The objective of this paper is to define the characteristics of old-growth stands in Society of American Foresters (1964) (SAF) type 229: Pacific Douglas-fir. The definition included herein is an assimilation of data collected in Northwest California and provides quantitative, measurable criteria to identify key features which distinguish old-growth stands from mature forest stands. Minimum values are not provided here, as we view the mean values and 95% confidence limits as being more appropriate for identifying optimal old-growth conditions. The old-growth definition goes beyond the standards for large trees, snags, and logs by providing criteria for additional understory features. The definition will also assist the resource manager in establishing standards for maintaining certain old-growth characteristics.

This old-growth definition is intended only as descriptions of the old-growth seral stage. The stated characteristic values may or may not meet all of the requirements needed to provide for other resource values, especially wildlife. A stand of timber with old-growth features may or may not equally provide for all wildlife species.

STUDY AREA

In California, the Pacific Douglas-fir type is found primarily in the northwestern portion of the state in the northern and central Coast Ranges and western Klamath Mountains.

It occurs in the same general area as the Douglas-fir/Tanoak/Madrone type but on higher elevation drier sites. The primary difference between these two closely related types is the reduction in the hardwood component, primarily tanoak. The elevational range of the The Pacific Douglas-fir SAF type extends from 2400 to 5300 feet. It is comprised of the conifer species Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco), white fir (*Abies concolor* Gord. & Glend.), and sugar pine (*Pinus lambertiana* Dougl.) along with the hardwood species canyon live oak (*Quercus chrysolepis* Liebm.), madrone (*Arbutus menziesii* Pursh.), giant chinquapin (*Castanopsis chrysophylla* Dougl.), and black oak (*Quercus kelloggii* Newb.). Other plant species occurring in the Pacific Douglas-fir SAF type are listed in Table 1. We have included a species list here to allow the reader to compare the Pacific Douglas-fir SAF type with the closely related Douglas-fir/Tanoak/Madrone SAF type 234 and to provide the site specific vegetation information from which these definitions were developed.

The Pacific Douglas-fir SAF type is referred to by different names by different authors. For instance, the Regional Ecology Group (1981) refers to this forest type as the Mixed Conifer-Fir Series. Holland (1986) describes this type as Upland Douglas-fir Forests, while Franklin and Dyrness (1973) refer to these forests as Douglas-fir on mixed conifer sites.

Climate in the study area is characterized by warm, dry summers and cool wet winters. Temperatures range from 10 F to 25 F (12 C to 4 C) in the winter and up to 90 F (32 C) in the summer (Parsons and Knox 1984). Precipitation ranges from 60 to 120 inches per year (203-305 mm) (Albert 1979).

Geographically, the northern Coast Range is comprised of a series of small independent ranges orientated north north-westerly along the california coast from the Oregon border to San Francisco. The Coast Range mountains are generally lower and more rounded than the Klamath Mountains with smaller drainages. The Klamath Mountains are positioned inland from the coastal range, orientated from north to south and include South Fork mountain, the Trinity Alps, Salmon Mountains and Siskiyou Mountains. Terrain in the Klamath Mountains is generally more rugged than in the Coast Range with slopes ranging from 30 to 80 percent. Abrupt changes in slope, aspect and soils are typical of these two mountain ranges and have contributed to the mosaic of vegetation types which are characteristic of this area.

The relatively recent geological origin of these mountains is evident in the varied and diverse rock types included in the Coast and Klamath Mountains. Bedrock types include Mesozoic ultrabasic intrusive, Jurassic-Triassic meta-volcanic, pre-Cretaceous meta-sedimenary, upper Jurassic marine sedimentary formations and Mesozoic (Irwin 1966). The soils derived from these rock types are as varied as the parent bedrock type from which they came. The Douglas-fir forest types are found primarily on soils derived from meta-sedimentary and meta-igneous rock formations.

In addition to the varied geological and topographical features of these mountains, the introduction of fire has played a key role in the origin and development of Douglas-fir forests throughout the area. The repeated introduction of natural and human-caused fire altered stand structure, seral stage distribution and development within these forests. After fire control measures were adapted in the early 1900's, the role of fire became increasingly less significant. However, in more recent times, the affects of human disturbance, and in particular, logging activities, has shifted the overall forest landscape to include a higher porportion of younger seral stages and less old-growth.

METHODS

Data for these old growth definitions was collected on the Six Rivers National Forest, the Western half of the Klamath National Forest (Ukonom, Happy Camp, and the western half of Salmon River Districts).

The methods described below were previously described in Jimerson & Fites (1989). They are restated here for the benefit of the reader.

Data Collection

Data collection followed the Region 5 Ecosystems Sampling Procedures (Allen 1987). This included a modified Region 5 Compartment Inventory Analysis (CIA) (USDA 1986) sample at each plot. Sample sites were selected after a thorough review of the information on vegetation, soils, geology, landform, and an extensive aerial photo and ground reconnaissance of the study area. Sample sites were systematically selected to ensure:

a. complete coverage of the area;
b. inclusion of all forested plant associations;
c. diversity in aspect and slope;
d. sampling of all mapped parent materials,
e. and, coverage of all mapped soil units.

Sample plot locations were restricted to homogeneous forested stands (Pfister and Arno 1980). The SAF vegetation type was identified using the SAF type key contained in Appendix A.

Plots were included in all seral stages, although primarily in late seral stage stands. Early seral stage stands sampled were subjected to intensive forest management. They originated primarily from clearcut and broadcast burn treatments. Mature and late seral stands were unmanaged, originating primarily after stand replacing fires. Sampling of all seral stages was completed in order to examine the changes in stand structure over time. The principle emphasis of this paper was to identify structural characteristics that identify the end of the mature seral stage and the beginning of the old-growth seral stage.

Each plot included three variable radius sub-plots to measure tree basal area using a 20 or 40 basal area factor (BAF) prism (Bitterlich 1948). The three variable radius sub-plots were placed at 1.) plot center, and 2.) two chains north (azimuth 360), and 3.) two chains east (azimuth 90), from plot center (USDA 1986). Basal area, diameter at breast height, age, height, and 10 and 20 year radial growth data of a dominant or codominant site tree were measured at each of the three sub-plots. Structural features such as number of layers and spatial arrangement were noted for each plot on the vegetation type/seral stage characteristic card found in Appendix B. Canopy layering was completed indirectly by examining the diameter classes present. Densities of snags and logs and percent cover of logs were also measured using the methods described in Jimerson (1989) for 317 plots in the Gasquet Ranger District of the Six Rivers National Forest. Plant species and percent cover were recorded for the tree, shrub, herb, and grass layers.

Stand age was determined from the age of the oldest dominant or codominant tree measured for site index information. Pre-dominant trees, those that had their origin in a previous stand, were not used to determine stand age. The standard method of aging trees, using increment borers to bore the tree at breast height (4.5 ft.), was used to determine the stand age (Bonham 1988). Trees with rotten cores were excluded from stand age measurements. For trees with large diameters, age was estimated using the number of rings in the last inch of the core and extrapolating for the missing section. This may introduce an error in estimation of age due to the extrapolation of ring width and number in the unsampled center of the tree. However, since our primary objectives were to determine the age of transition from mature to old growth stands, and < 5% of the trees required extrapolation, this extrapolation error is thought to have little influence on the definition. Further research on the viability of old growth stands is needed. Looking at the older stands to examine viability would require other aging methods to decrease the age estimation error.

Data Analysis

The data were first stratified by major forest type to examine structural differences in old-growth due to major differences in overstory species composition. Society of American Foresters' Forest Cover Type definitions (1964) were used to identify the major forest types. Stands were classified as Pacific Douglas-fir (SAF type 229) if white fir was present and/or the hardwood canopy cover (understory and/or overstory) was less than ten percent using the SAF type key in Appendix A.

The data were stratified secondarily, within each major forest type, by site classes using Dunning site curves at base age 300 years (Dunning 1942) (Table 3). This was done to examine structural differences due to site class observed in the field.

Four hundred and fifteen plots were used to analyze the characteristics of old-growth Pacific Douglas-fir stands. The site class distribution of stands included 235 plots in site classes 1A-1, 144 plots in site classes 2-3 and 36 plots in site classes 4-5.

Compartment Inventory Analysis or Forest Inventory Analysis, R5*Convert and R5*Summary (USDA 1986) were used to calculate stand characteristics including: softwood and hardwood basal area (ft^2/acre), number of softwood and hardwood trees per acre (trees/acre), softwood bag-10 (10 year growth/acre in ft^2), softwood and hardwood cubic volume (100's ft^3/ac to utilized top), site class, and trees per acre by dbh class and species. The quadratic mean diameter (QMD) was used to describe average tree size for conifers and to determine stand density index (SDI) (Weatherhead et. al 1985). They were calculated using the respective formulas (Reineke 1933)

Quadratic Mean Diameter (QMD) = $\sqrt{\frac{\sum d^2}{n}}$, n = number of trees,
d = diameter of each tree,

Stand Density Index (SDI) = $N(dq/10)^{1.605}$, N = number of trees/acre
dq = quadratic mean diameter.

Snag and log densities were calculated by multiplying the number of snags and logs per plot by the area correction factor. Log volumes were calculated using Smalian's cubic volume of logs formula (Wenger 1984):

$V \text{ (Smalian's)}=0.002727(D^2 + D^2)L,$

V = volume in cubic feet,
D_0 = diameter inches large end,
D_1 = diameter inches small end,
L = length in feet.

The stratified data were sorted by age and then examined graphically as an ecological series (Legendre and Legendre 1983) substituting space for time (Strayer et. al 1986). Stands of different ages, geographically spaced throughout the study area, were examined in order to identify trends in stand development. All of the stand characteristic variables recorded and other variables, such as herb cover, grass cover, shrub cover and tree cover, were plotted against the estimated age of the stand.

Scatter plots of variables with stand age were generated using Harvard Graphics (Software Publishing Corporation 1987). All variables were plotted and the graphs examined by three site class groups as follows: 1A-1 high site, 2-3 moderate site, and 4-5 low site. Categories of stand development (young, mature, and old-growth) were identified and used as grouping variables. These groups were analyzed using Stepwise Discriminant Analysis (Jennrich and Sampson 1985) to identify a set of discriminating variables. The variables that showed interpretable trends, consistent with previous information on stand development and climax structure (Franklin et. al 1981), were selected as core variables. Preference was also given to variables that could be easily measured in the field and provide a working definition.

Robust locally weighted regression (Cleveland 1979), was used to examine the relationship between stand structural features (cubic volume, basal area, quadratic mean diameter, trees/acre) and stand age. The program generates a set of points that form a nonparametric regression of y on x. Robust refers to an adaptation of iterated weighted least squares that prevents highly variable points (outliers) from distorting smoothed points. The data were graphed using Harvard Graphics.

Visual examination of the smoothed graphs was used to determine the stand age at which stand structure changed from an increasing mode to a maintenance mode or plateau. The ages at which stand structure maintained consistent features was interpreted as old-growth. Means, standard deviations, standard errors, snag density, and coarse woody debris volume were determined through SPSSPC+ (Norusis 1988).

The age at which stand structure was determined to be old-growth was used to develop a set of average characteristics for old-growth.

RESULTS AND DISCUSSION

The variables found to be acceptable and consistent identifiers of the age at which stand structure shifts from a increasing mode (mature seral stage) to a maintenance or plateau mode (old-growth seral stage), are listed below.

1. Culmination of standing cubic volume.
2. Culmination of quadratic mean diameter.
3. Changes in the density (trees/acre) of large diameter trees.
4. Changes in vegetative cover by stratum.
5. Significant increases in density, diameter, and height of large snags.
6. A significant increase in the number of large logs.

The numbers of diameter classes and stand density index were found to maximize during the mature seral stage. This makes it a characteristic of old-growth but not an identifier of the onset of the old-growth seral stage.

Tree species and size

Two variables, constancy and characteristic cover, are used to describe the relative association and cover of plant species. Constancy measures the frequency of occurrence within vegetation plots, while average cover for each species in plots is described by characteristic cover. Constancy varies by species along environmental gradients.

Old-growth stands in SAF forest type 229 are dominated in the overstory by the conifers Douglas-fir (100% constancy), white fir (66% constancy), and sugar pine (36% constancy) in association with a mixture of hardwood tree species. canyon live oak (28% constancy), Pacific madrone (25% constancy), giant chinquapin (21% constancy) and black oak (15% constancy) are the dominant hardwoods (Table 1). Overstory conifers attain heights which often exceed 175 feet tall and 50 inches DBH (diameter at breast height). Understory conifers attain heights of over 120 feet and 25 inches DBH.

Structure/stories

Old-growth stands in the Pacific Douglas-fir SAF type were characterized by at least two stories (Table 2). Douglas-fir dominates the overstory which is subtended by a mixture of conifers including white fir and sugar pine. Hardwoods were occasionally the dominant feature of the understory and include canyon live oak, Pacific madrone, giant chinquapin and black oak. The Pacific Douglas-fir SAF type differs from the Douglas-fir/Tanoak/Madrone SAF type in that tanoak is absent or < 10 % cover in the Pacific Douglas-fir SAF type.

The structure of old-growth stands within SAF type 229 varies by age and site class. High sites (site classes 1a and 1) enter the old-growth seral stage at 180 years. This age is accompanied by a shift in the number of trees/acre by diameter class. The dominant diameter class shifts from dominance by smaller size classes (6-11, 11-18, 18-25, 25-30 in.) to dominance by trees ≥ 40 inches dbh. The mean number of trees/acre for the ≥ 40 inch dbh class was found to be 13.5 (Table 2). Large (greater than 30 inches DBH) Douglas-fir trees predominate old-growth stands on high and moderate sites. On high sites the majority (68%) of basal area (mean total basal area = 317 sq. ft. per acre) occurs in the larger (≥ 30 in. DBH) size classes of conifers, while the highest density of trees occurs in smaller (≤ 30 in. DBH) size classes of conifers. Approximately 14% of the conifer trees (mean total conifer density = 171 trees per acre) were ≥ 30 inches DBH.

Moderate sites (site classes 2 and 3) reach the old-growth seral stage at 260 years. The number of trees/acre ≥ 30 inches was the dominant feature of this group. The mean number of trees/acre ≥ 30 in. for stands ≥ 260 years was 19.2 (Table 2). On moderate sites, the majority (63%) of basal area (mean total basal area = 271 sq. ft. per acre) occurs in the larger (≥ 30 in. DBH) size classes of conifers, while the highest density of trees occurs in smaller (≤ 30 in. DBH) size classes of conifers. Approximately 11% of the conifer trees (mean total conifer density = 177 trees per acre) were ≥ 30 inches DBH.

Low sites (site classes 4 and 5) enter the old-growth seral stage at 295 years (Table 2). As with the higher site index groups, there was a shift in dominance of the number of trees/acre by diameter class with increasing age, but on these low sites it is the trees ≥ 25 in. The mean number of trees ≥ 25 in. was 26.3 trees/acre. On low sites, trees ≥ 25 in. DBH dominate the stands. The majority (64%) of basal area (mean total basal area = 239 sq. ft. per acre) occurs in the larger (≥ 25 in. DBH) size classes of conifers, while the highest density of trees occurs in smaller (≤ 25 in. DBH) size classes of conifers. Approximately 13% of the conifer trees (mean total conifer density = 192 trees per acre) were ≥ 25 inches DBH.

Snags

Snag densities change over a time as a function of pulses associated with stand development and competition induced mortality. The first significant pulse of large snags (snags ≥ 20 inches DBH and ≥ 15 feet tall) occured at culmination of mean annual increment. Here competition between trees for light, moisture, and nutrients produced a significant pulse of mortality. This pulse is followed by a series of pulses regularly spaced in time beginning at the advent of the old-growth seral stage.

Snag density (all species combined) appeared constant between site classes. Total density of snags greater than 20 inches DBH and ≥ 15 feet tall averaged 4.4 snags per acre on all sites. Hardwoods contributed 20% of the total density of snags.

Snag densities are not uniform throughout a stand. In examining the point samples used to construct these definitions it was determined that 20% of the stands fail to meet the standard of 2.4 ± 0.4 snags/acre. This does not mean that these stands should not be considered old-growth, it points to snag densities as a feature of old-growth but not a determining variable.

Down logs

Density, volume, and weight of logs appeared constant between site classes. Log densities showed a decrease with stand age from 1 to 100 years. In general, log density showed a lag behind snag density. There was a significant increase in the mean log density of logs ≥ 20 in. diameter and ≥ 10 ft. long between stands 100 to 170 years and stands greater than 180 years old, with the mean density increasing from 10 to 23.2 logs/acre (table 2).

As explained above for snags, log densities are also variable within a stand, as many as 30% of the stands considered old-growth do not meet the log density standard. This can be explained partly by the use of point counts and partly by the steepness of the terrain. Gravity plays a roll in determining which positions in the landscape have high log densities as well as periodic disturbance. Logs are a characteristic of old-growth, but should not be used as the sole determinant of whether or not a stand is considered old-growth.

The log volume showed a similar pattern to that of log density, with an initial decrease until 100 years, followed by a series of small peaks. Thereafter, there was a significant increase in the mean log volumes with stand age. The mean log volume increased from 1500 $ft.^3$ in stands between 100 to 170 years to 4250 $ft.^3$ for stands greater than 180 years and a weight of 60 tons per acre (Table 2). Hardwoods contributed 4% of the total density of logs.

Understory characteristics

Vegetation cover by layer changed over time in relation to site class. On high and moderate sites conifer cover was the dominant feature throughout the sere (the stand development sequence), averaging 71% in the old-growth seral stage. Conifers dominated the site by the beginning of the pole seral stage. On low sites conifers shared dominance with shrubs.

Hardwood cover in the Pacific Douglas-fir SAF type was much lower than the Douglas-fir/Tanoak/Madrone SAF type, averaging 10%. It increased with age, reaching a stable maximum at approximately 100 years stand age.

Shrub cover increased with age, reaching a stable cover in the old-growth seral stage. It also increased with a decrease in site quality. On high sites shrub cover averaged 27%, while moderate sites averaged 41%, and low sites averaged 53%.

High forb cover was a characteristic of the Pacific Douglas-fir SAF type. Forb cover also increased with stand age, reaching its highest level during the old-growth seral stage. Unlike shrub cover, forb cover increased with site quality. High sites averaged 25% forb cover, moderate sites averaged 15% cover, and low sites averaged 11% cover.

Grass cover was low in the Pacific Douglas-fir SAF type and does not appear to be related to site quality.

Decadence

The presence of logs and snags was a primary indicator of the decadence of old-growth stands. A full range of size and decay classes of logs and snags, which contribute to ecosystem functioning, occured in Pacific Douglas-fir old-growth stands. Most (68%) logs occured in a high state of decay (decay classes 3,4,5). While most (58%) snags were found in a low state of decay (decay classes 1 and 2).

Decadence of old-growth stands was also characterized by the presence of diseased, broken-topped,or malformed live trees. Live conifer trees possessed conks and swollen knots or were resinous. This was particulary evident in the true fir component of the Pacific Douglas-fir SAF type. While hardwoods were a minor component of this type, many live hardwood trees exhibited broken or dead tops. Both hardwoods and conifers exhibited natural and excavated cavities.

As with snag and log density, decadence should not be used as a determinant of old-growth. When stands enter the old-growth seral stage, particularly on high sites decadence is not evident. During the early phase of old-growth, overstory trees may show rounding of their crowns as their only sign of decadence.

Table 1--List of species identified in the Pacific Douglas-fir vegetation type, with summary statistics for species with constancy ≥ 10 percent.

	CONSTANCY	FREQ	MIN	MAX	RANGE	MEAN	S.D.	S.E.	CI- 5%
					(CHARACTERISTIC COVER)				
ELEVATION	100%	227	610	5600	4990	3879.6	826.5	54.9	107.5
SLOPE	100%	227	0	95	95	44.4	19.9	1.3	2.6
TOTAL VEGETATION COVER	100%	227	60	100	40	92.8	7.4	.5	1.0
STAND AGE	100%	227	13	570	557	235.3	120.0	8.0	15.7
TOTAL BASAL AREA	95%	216	13	747	734	300.0	106.5	7.2	14.2
TOTAL FORB COVER	100%	227	1	97	96	19.0	23.2	1.5	3.0
TOTAL GRASS COVER	100%	227	0	80	80	4.3	11.3	.8	1.5
TOTAL SHRUB COVER	100%	227	0	99	99	23.0	28.7	1.9	3.7
TOTAL TREE COVER	99%	226	0	99	99	77.3	17.8	1.2	2.3
OVERSTORY TREES									
Pseudotsuga menziesii	99%	225	1	99	98	49.4	21.5	1.4	2.8
Abies concolor	66%	151	1	75	74	20.4	12.1	1.0	1.9
Pinus lambertiana	36%	83	1	30	29	7.4	6.7	.7	1.5
Quercus chrysolepis	28%	64	1	75	74	21.2	21.5	2.7	5.4
Arbutus menziesii	25%	59	1	45	44	7.2	6.9	.9	1.8
Castanopsis chrysophlla	21%	49	1	50	49	8.8	9.4	1.3	2.7
Quercus kelloggii	15%	35	1	20	19	6.6	6.1	1.0	2.1
Lithocarpus densiflora	12%	29	1	45	44	5.5	8.2	1.5	3.1
Acer macrophyllum	12%	28	1	25	24	7.1	6.5	1.2	2.5
UNDERSTORY TREES									
Abies concolor	65%	149	1	25	24	2.6	3.6	.3	.6
Pseudotsuga menziesii	64%	147	1	15	14	1.8	2.0	.2	.3
Quercus chrysolepis	44%	101	1	25	24	3.5	4.1	.4	.8
Lithocarpus densiflorus	28%	64	1	60	59	7.6	12.4	1.6	3.1
Pinus lambertiana	23%	53	1	8	7	1.2	1.0	.1	.3
Castanopsis chrysophylla	22%	52	1	20	19	3.3	4.5	.6	1.2
Libocedrus decurrens	17%	39	1	2	1	1.1	.3	.0	.1
Arbutus menziesii	14%	33	1	2	1	1.1	.3	.1	.1
SHRUBS									
Rosa gymnocarpa	59%	136	1	8	7	1.4	1.0	.1	.2
Berberis nervosa	46%	105	1	60	59	5.1	8.0	.8	1.5
Symphoricarpos mollis	38%	87	1	10	9	1.4	1.3	.1	.3
Corylus cornuta californica	34%	79	1	20	19	3.2	3.9	.4	.8
Rubus ursinus	28%	64	1	35	34	1.7	4.3	.5	1.1
Quercus sadleriana	22%	50	1	70	69	18.1	22.0	3.1	6.3
Paxistima myrsinites	18%	42	1	40	39	3.0	6.5	1.0	2.0
Quercus vaccinifolia	18%	42	1	85	84	24.6	24.1	3.7	7.5
Holodiscus discolor	16%	37	1	7	6	2.0	1.6	.3	.5
Vaccinium parvifolium	15%	35	1	35	34	7.4	10.2	1.7	3.5
Amelanchier florida	14%	33	1	20	19	2.3	3.4	.6	1.2
Rhus diversiloba	14%	32	1	20	19	4.7	5.1	.9	1.9
Arctostaphylos nevadensis	11%	26	1	25	24	5.6	5.6	1.1	2.3
HERBS									
Chimaphila umbellata occidentale	50%	115	1	30	29	4.3	5.5	.5	1.0
Pyrola picta	46%	106	1	1	0	1.0	.0	.0	.0
Hieracium albiflorum	44%	102	1	7	6	1.2	.7	.1	.1

	CONSTANCY	FREQ	MIN	MAX	RANGE	MEAN	S.D.	S.E.	CI- 5%
Goodyera oblongifolia	40%	93	1	3	2	1.0	.2	.0	.0
Iris sp.	37%	86	1	3	2	1.1	.4	.0	.1
Whipplea modesta	36%	82	1	50	49	8.5	11.3	1.3	2.5
Polystichum munitum	34%	79	1	7	6	1.5	1.1	.1	.2
Disporum hookeri	33%	77	1	5	4	1.3	.7	.1	.2
Adenocaulon bicolor	29%	67	1	10	9	1.6	1.7	.2	.4
Chimaphila menziesii	25%	57	1	2	1	1.0	.1	.0	.0
Trientalis latifolia	25%	57	1	10	9	1.6	1.5	.2	.4
Achlys triphylla	24%	56	1	50	49	9.2	12.8	1.7	3.4
Pteridium aquilinum lanuginosa	21%	49	1	75	74	3.1	10.5	1.5	3.0
Linnaea borealis longiflora	20%	46	1	50	49	14.9	14.9	2.2	4.4
Galium triflorum	18%	43	1	10	9	1.5	1.6	.2	.5
Smilacina racemosa amplexicaulis	18%	42	1	2	1	1.0	.2	.0	.1
Campanula prenanthoides	17%	39	1	5	4	1.4	.9	.1	.3
Arnica discoidea	16%	38	1	3	2	1.3	.6	.1	.2
Xerophyllum tenax	16%	37	1	95	94	7.9	16.7	2.7	5.5
Osmorhiza chilensis	14%	33	1	10	9	2.0	2.1	.4	.8
Apocynum pumilum	14%	32	1	2	1	1.1	.3	.1	.1
Viola sempervirens	14%	32	1	15	14	2.3	3.4	.6	1.2
Pyrola secunda	13%	31	1	2	1	1.1	.2	.0	.1
Fragaria californica	12%	29	1	8	7	1.4	1.4	.3	.5
Stellaria jamesiana	12%	28	1	1	0	1.0	.0	.0	.0
Eburophyton austinae	12%	28	1	1	0	1.0	.0	.0	.0
Clintonia uniflora	11%	27	1	12	11	3.2	3.1	.6	1.2
Viola glabella	11%	27	1	2	1	1.2	.4	.1	.2
Corallorhiza sp.	11%	26	1	1	0	1.0	.0	.0	.0
Corallorhiza striata	11%	25	1	1	0	1.0	.0	.0	.0
Viola sheltonii	11%	25	1	2	1	1.2	.4	.1	.2
Cynoglossum grande	10%	24	1	5	4	1.6	1.2	.3	.5
Vancouveria planipetala	10%	24	1	25	24	3.9	5.4	1.1	2.3
Corallorhiza maculata	10%	23	1	1	0	1.0	.0	.0	.0
Trillium ovatum	10%	23	1	2	1	1.0	.2	.0	.1
GRASS									
Festuca occidentalis	20%	47	1	20	19	2.1	3.4	.5	1.0
Bromus marginatus	15%	36	1	10	9	1.4	1.5	.3	.5
Festuca subulata	15%	35	1	25	24	4.0	4.9	.8	1.7
Festuca californica	11%	26	1	80	79	15.2	24.5	4.8	9.9

Table 2. Standards for Pacific Douglas-fir old-growth stands by Dunning's site classes, base age 300 years.

Variables	Dunning site class groups 1a-1	2-3	4-5
Age (years) 1/	180	260	295
Conifer live trees (trees/acre) 2/			
≥ 40" dbh	13.5 ± 1.4	NA	NA
≥ 30" dbh	NA	19.2 ± 1.9	NA
≥ 25" dbh	NA	NA	26.3 ± 5.1
Snags (all species) 2/ Density 3/ (≥ 20" dbh & ≥ 15' tall)	4.4 ± 0.8 for all site classes		
Logs (all species) 2/ Density (logs/acre) 3/ (≥ 20" large dia. & ≥ 10' long)	23.2 ± 4.4 for all site classes		
Layers	Conifer overstory over a conifer mid-layer. Forb layer achieves prominance in ground cover during the old-growth seral stage.		

1/ Derived from robust locally weighted regression.

2/ Average values with 95% confidence interval.

3/ Snag and log densities are variable and should not be used as the sole determinant of old-growth.

Table 3. Region 5 site classes (height by age) from Dunning base age 300 years.

	Site Class					
Age	0	1	2	3	4	5
40	95	81	66	49	43	35
50	106	90	75	56	49	39
60	115	98	82	63	53	43
70	122	105	88	68	58	45
80	129	111	93	73	61	48
90	135	116	98	77	64	50
100	140	121	102	81	67	54
110	145	125	106	84	70	54
120	149	129	109	87	72	55
130	153	133	112	90	74	57
140	157	136	115	93	76	58
150	160	139	118	95	78	60
160	163	142	120	98	80	61
170	166	144	123	100	81	62
180	169	147	125	102	83	63
190	172	149	127	104	84	64
200	175	152	129	106	86	65
220	179	156	133	109	88	67
240	184	160	136	112	90	68
260	188	163	139	115	93	70
280	191	166	142	117	95	71
300	195	169	145	120	96	73
320	198	172	147	122	98	74
340	201	175	150	124	100	75
360	204	177	152	126	101	76
380	206	180	154	128	103	77
400	209	182	156	130	104	78

Note: Based on ponderosa pine, Jeffrey pine, sugar pine, Douglas-fir, red fir, and white fir. Age is in years. Total height is in feet of average dominant and predominant trees with tree age of at least 50 years. Adapted fron Dunning's site index curves for height at 300 years.

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Appendix A. Key to the Society of American Foresters SAF vegetation types.

1a. Douglas-fir dominant in the overstory or cover > 50% of the canopy cover.. 2

- 2a. White fir present and/or hardwoods (tree form) absent (tanoak, madrone, canyon live oak) or less than 10% cover........................... Pacific Douglas-fir

- 2b. White fir absent and evergreen hardwoods (tanoak, madrone, canyon live oak) present and greater than 10% cover................. Douglas-fir/Tanoak/Madrone

1b. Douglas-fir absent in overstory or < 50% cover............ 3

- 3a. Jeffrey pine dominant in overstory.............. Jeffrey Pine

- 3b. True fir (white or red fir) dominant in overstory 4

  - 4a. Red fir canopy cover > 50% or red fir basal area > 50%................... Red fir

  - 4b. White fir canopy cover > 50% or white fir basal area > 50%................. White fir

Appendix B. Vegetation type/seral stage attribute data card.

PLOT ______________ DATE ______________ NAME ______________________________

MAJOR VEGETATION TYPE (CIRCLE ONE)

Douglas-Fir/Tanoak/Madrone   Pacific Douglas-fir   White Fir   Red Fir
Jeffrey Pine   Port-Orford cedar   Lodgepole Pine   Ponderosa Pine
Douglas-fir/Pine   Other_______________

LAYERS (CIRCLE ALL PRESENT) ______ CIRCLE IF PRESENT

L1   L2   L3   L4   L5   SUPPRESSED   REGENERATION

AGE (BY LAYER)

L1____ L2____ L3____ L4____ L5____ SUPPRESSED____ REGENERATION____

DBH CLASSES (CIRCLE ALL PRESENT)

2   8   14   21   27   35   40+

SHRUB LAYER (CIRCLE ONE)

NONE	DEPAUPERATE	MODERATE	WELL DEVELOPED	DENSE
(1% <)	(2-10%)	(10-35%)	(35-60%)	(60% >)

SNAGS (CIRCLE ALL PRESENT)

SMALL (< 20" DBH AND OR < 20' TALL)   MEDIUM (> 20" DBH AND 20-50' TALL)

LARGE (> 20" DBH AND > 50' TALL)   NONE

DECAY CLASSES (CIRCLE ALL PRESENT)

1   2   3   4   5

LOGS (CIRCLE ALL PRESENT)

SMALL (< 20" DIA LARGE END AND OR < 20' LONG)

MEDIUM (> 20" DIA LARGE END AND 20-50' LONG)

LARGE (> 20" DIA LARGE END AND > 50' LONG)   NONE

DECAY CLASSES (CIRCLE ALL PRESENT)

1   2   3   4   5

PROJECTED SERAL STAGE (IF BETWEEN STAGES CIRCLE CLOSEST ONE AND PUT A LINE AT APPROXIMATE STAGE OF DEVELOPMENT)

SHRUB/FORB POLE MATURE OLD-GROWTH

COMMENTS:

Ecological Definition for Old-growth Douglas-fir/Tanoak/Madrone (Society of American Forester's type 234)

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INTRODUCTION

Old-growth forests represent a unique plant community of significant biological and social value. The once plentiful forests of old-growth in the United States have greatly diminished through past logging practices and wildfire. The management of the remaining old-growth stands, which are now primarily found on public lands (Spies & Franklin 1988), has become a critical and controversial resource issue. Because of the distinctive structural and biological attributes of old-growth, old-growth forests serve as sites of high biological and genetic diversity, as needed habitat for many wildlife species, and provide a unique recreational value. These same forests are also the source of raw material needed to produce high value lumber products. The Forest Service recognizes the values of these forests and is providing direction for the maintenance and management of old-growth habitat on National Forest lands (Robertson, 1989).

Old-growth forests are fairly complex and often cannot be distinguished from other stands by one or two stand structure attributes. Several key attributes together distinguish these stands from other seral stages (Franklin et al. 1981, Jimerson and Fites in review, Bingham and Sawyer 1991, Spies and Franklin 1991). A mature forest stand can be considered old-growth when the standing cubic volume culminates (the stand reaches maximum site carrying capacity). This is a gradual process that is affected by a number of biological and physical factors such as forest type, site quality and disturbance. With the culmination of standing cubic volume there are several other attributes indicative of old-growth structure. The numbers of trees in the larger diameter classes increase significantly and the stand quadratic mean diameter culminates. These large conifers in combination with smaller trees and shrubs form multiple canopy layers. Decadence is significant in the latter part of the old-growth seral stage and is evident in the accumulation of large standing snags, downed logs and malformed live trees. These are some of the attributes key to an ecological definition of old-growth (Franklin and Spies 1989).

Direction for resource management cannot be resolved without first defining the biological and structural features which distinguish old-growth stands from other seral stages. National direction to develop specific old-growth definitions for each forest type described by the Society of American Foresters (SAF 1964) was established in 1989 (Robertson 1989).

The objective of this paper is to define the characteristics of old-growth stands in Society of American Foresters (SAF) type 234: Douglas-fir/tanoak/madrone. The definition included herein is an assimilation of data collected in Northwest California and provides quantitative, measurable criteria to identify key features which distinguish old-growth stands from mature forest stands. Minimum values are not provided here, as we view the mean values and 95% confidence limits as being more appropriate for identifying optimal old-growth conditions. The old-growth definition goes beyond the standards for large trees, snags, and logs by providing criteria for additional understory features. The definition will also assist the resource manager in establishing standards for maintaining certain old-growth characteristics.

The old-growth definition is intended only as descriptions of the old-growth seral stage. The stated characteristic values may or may not meet all of the requirements needed to provide for other resource values, especially wildlife.

A stand of timber with old-growth features may or may not equally provide for all wildlife species.

STUDY AREA

In California, the Douglas-fir/Tanoak/Madrone SAF type is found primarily in the northwestern portion of the state in the northern and central Coast Ranges and western Klamath Mountains. It occurs primarily inland from the coastal Redwood forests occupying the upland more xeric sites (Stuart 1987). This forest type extends up into Oregon and south into Monterey County where sites become drier and Douglas-fir is replaced by evergreen oaks, tanoak and madrone (Sawyer et al. 1977, Wainright and Barbour 1984). The elevational range of the The Douglas-fir/Tanoak/Madrone type extends from 500 to 3400 feet. It is comprised of conifer species Douglas-fir (Pseudotsuga menziesii [Mirb.] Franco) and sugar pine (Pinus lambertiana Dougl.) along with the hardwood species tanoak (Lithocarpus densiflora [H. & A.] Rehd.), madrone (Arbutus menziesii Pursh.), giant chinquapin (Castanopsis chrysophylla Dougl.), canyon live oak (Quercus chrysolepis Liebm.) and California bay (Umbellularia californica (H. & A.) Nutt.). Other plant species occurring in the Douglas-fir/Tanoak/Madrone SAF type are listed in Table 1. We have included a species list here to allow the reader to compare the Douglas-fir/Tanoak/Madrone SAF type with the closely related Pacific Douglas-fir SAF type 229 and to provide the site specific vegetation information from which these definitions were developed.

The Douglas-fir/Tanoak/Madrone SAF type is referred to by different names by different authors. For instance, Sawyer et al. (1977) refers to this forest type as Douglas-fir/hardwood to distinguish these forests from those in Oregon and Washington where Douglas-fir occurs in combination with other conifer associates instead of hardwoods. Franklin and Dyrness (1973) refer to these forests as Douglas-fir on mixed evergreen sites.

Climate in the study area is characterized by warm, dry summers and cool wet winters. Temperatures range from 10 F to 25 F (12 C to 4 C) in the winter and up to 90 F (32 C) in the summer (Parsons and Knox 1984). Precipitation ranges from 60 to 120 inches per year (203-305 mm) (Albert 1979).

Geographically, the northern Coast Range is comprised of a series of small independent ranges orientated north north-westerly along the California coast from the Oregon border to San Francisco. The Coast Range mountains are generally lower and more rounded than the Klamath Mountains with smaller drainages. The Klamath Mountains are positioned inland from the coastal range, orientated from north to south and include South Fork Mountain, the Trinity Alps, Salmon Mountains and Siskiyou Mountains. Terrain in the Klamath mountains is generally more rugged than in the Coast Range with slopes ranging from 30 to 80 percent. Abrupt changes in slope, aspect and soils are typical of these two mountain ranges and have contributed to the mosaic of vegetation types which are characteristic of this area.

The relatively recent geological origin of these mountains is evident in the varied and diverse rock types included in the Coast and Klamath Mountains. Bedrock types include Mesozoic ultrabasic intrusive, Jurassic-Triassic meta-volcanic, pre-Cretaceous meta-sedimenary, upper Jurassic marine sedimentary formations and Mesozoic (Irwin 1966). The soils derived from these rock types are as varied as the parent bedrock type from which they came. The Douglas-fir forest types are found primarily on soils derived from meta-sedimentary and meta-igneous rock formations.

In addition to the varied geological and topographical features of these mountains, the introduction of fire has played a key role in the origin and development of Douglas-fir forests throughout the area. The repeated introduction of natural and human-caused fire altered stand structure, seral stage distribution and development within these forests. After fire control measures were adapted in the early 1900's, the role of fire became increasingly less significant. However, in more recent times, the affects of human disturbance, and in particular, logging activities, have shifted the overall forest landscape to include a higher porportion of younger seral stages and less old-growth.

METHODS

SOURCE OF DATA

Data for this definition came from the Region 5 Ecology Program (732 plots from a range of seral stages) and the Old-growth Douglas-fir Research Program conducted by the Pacific Southwest Forest and Range Experiment Station (149 plots from late seral stages >200 years). Data were collected on the Six Rivers National Forest, the western half of the Klamath National Forest (Ukonom, Happy Camp, and the western half of Salmon River Districts), Siskiyou National Forest (Illinois Valley District), and the Northern California Coast Range Preserve, owned by the Nature Conservancy and the Bureau of Land Management (BLM). A small number of study stands were located on privately owned lands.

The methods described below apply to the data collected through the Region 5 Ecology Program and were described previously by Jimerson & Fites (1989). Data collection and analysis methods used in the Old-growth Douglas-fir Research Program conducted by the Pacific Southwest Forest and Range Experiment Station are described in Bingham & Sawyer (1991).

Data Collection

Data collection followed the Region 5 Ecosystems Sampling Procedures (Allen 1987). This included a modified Region 5 Compartment Inventory Analysis (CIA) (USDA 1986) sample at each plot. Sample sites were selected after a thorough review of the information on vegetation, soils, geology, landform, and an extensive aerial photo and ground reconnaissance of the study area. Sample sites were systematically selected to ensure:

a. complete coverage of the area;
b. inclusion of all forested plant associations;
c. diversity in aspect and slope;
d. sampling of all mapped parent materials,
e. and, coverage of all mapped soil units.

Sample plot locations were restricted to homogeneous forested stands (Pfister and Arno 1980). The SAF vegetation type was identified using the SAF type key contained in Appendix A.

Plots were included in all seral stages, although primarily in late seral stage stands. Early seral stage stands sampled were subjected to intensive forest management. They originated primarily from clearcut and broadcast burn treatments. Mature and late seral stands were unmanaged, originating primarily after stand replacing fires. Sampling of all seral stages was completed in order to examine the changes in stand structure over time. The principle emphasis of this paper was to identify structural characteristics that identify the end of the mature seral stage and the beginning of the old-growth seral stage.

Each plot included three variable radius sub-plots to measure tree basal area using a 20 or 40 basal area factor (BAF) prism (Bitterlich 1948). The three variable radius sub-plots were placed at 1.) plot center, and 2.) two chains north (azimuth 360), and 3.) two chains east (azimuth 90), from plot center (USDA 1986). Basal area, diameter at breast height, age, height, and 10 and 20 year radial growth data of a dominant or codominant site tree were measured at each of the three sub-plots. Structural features such as number of layers and spatial arrangement were noted for each plot. Canopy layering was assessed indirectly by examining the diameter classes present. Densities of snags and logs and percent cover of logs were also measured using the methods described in Jimerson (1989) for 317 plots in the Gasquet Ranger District of the Six Rivers National Forest. Plant species and percent cover were recordedfor the tree, shrub, herb, and grass layers.

Stand age was determined from the age of the oldest dominant or codominant tree measured for site index information. Pre-dominant trees, those that had their origin in a previous stand, were not used to determine stand age. The standard method of aging trees, using increment borers to bore the tree at breast height (4.5 ft.), was used to determine the stand age (Bonham 1988). Trees with rotten cores were excluded from stand age measurements. For trees with large diameters, age was estimated using the number of rings in the last inch of the core and extrapolating for the missing section. This may introduce an error in estimation of age due to the extrapolation of ring width and number in the unsampled center of the tree. However, since our primary objectives were to determine the age of transition from mature to old growth stands, and $< 5\%$ of the trees required extrapolation, this extrapolation error is thought to have little influence on the definition. Further research on the viability of old growth stands is needed. Looking at the older stands to examine viability would require other aging methods to decrease the age estimation error.

Data Analysis

The data were first stratified by major forest type to examine structural differences in old-growth due to major differences in overstory species composition. Society of American Foresters' Forest Cover Type definitions (1964) were used to identify the major forest types. Stands were classified as Douglas-fir/Tanoak/Madrone (SAF type 234) if the hardwood canopy cover (understory and/or overstory) of Tanoak equalled or exceeded ten percent.

The data were stratified secondarily, within each major forest type, by site classes using Dunning site curves at base age 300 years (Dunning 1942) (Table 4). This was done to examine structural differences due to site class observed in the field.

Seven hundred and thirty-two plots were used to analyze the characteristics of old-growth Douglas-fir/Tanoak/Madrone stands. The site class distribution of stands included 509 plots in site classes 1A-1, 168 plots in site classes 2-3 and 55 plots in site classes 4-5.

Compartment Inventory Analysis or Forest Inventory Analysis, R5*Convert and R5*Summary (USDA 1986) were used to calculate stand characteristics including: softwood and hardwood basal area (ft^2/acre), number of softwood and hardwood trees per acre (trees/acre), softwood bag-10 (10 year growth/acre in ft^2), softwood and hardwood cubic volume (100's ft^3/ac to utilized top), site class, and trees per acre by dbh class and species. The quadratic mean diameter (QMD) was used to describe average tree size for conifers and to determine stand density index (SDI) (Weatherhead et. al 1985). They were calculated using the respective formulas (Reineke 1933)

Quadratic Mean Diameter (QMD) $= \sqrt{\frac{\sum d^2}{n}}$, n = number of trees, d = diameter of each tree,

Stand Density Index (SDI) $= N(dq/10)^{1.605}$, N = number of trees/acre, dq = quadratic mean diameter.

Snag and log densities were calculated by multiplying the number of snags and logs per plot by the area correction factor. Log volumes were calculated using Smalian's cubic volume of logs formula (Wenger 1984):

V (Smalian's) $=0.002727(D^2 + D^2)L$, V = volume in cubic feet, D_0 = diameter inches large end, D_1 = diameter inches small end, L = length in feet.

The stratified data were sorted by age and then examined graphically as an ecological series (Legendre and Legendre 1983) substituting space for time (Strayer et. al 1986). Stands of different ages, geographically spaced throughout the study area, were examined in order to identify trends in stand development. All of the stand characteristic variables recorded and other variables, such as herb cover, grass cover, shrub cover and tree cover, were plotted against the estimated age of the stand.

Scatter plots of variables with stand age were generated using Harvard Graphics (Software Publishing Cororation 1987). All variables were plotted and the graphs examined for site classes 1A-5, groups. Categories of stand development (young, mature, and old-growth) were identified and used as grouping variables. These groups were analyzed using Stepwise Discriminant Analysis (Jennrich and Sampson 1985) to identify a set of discriminating variables. The variables that showed interpretable trends, consistent with previous information on stand development and climax structure (Franklin et. al 1981), were selected as core variables. Preference was also given to variables that could be easily measured in the field and provide a working definition.

Robust locally weighted regression (Cleveland 1979), was used to examine the relationship between stand structural features (cubic volume, basal area, quadratic mean diameter) and stand age. The program generates a set of points that form a nonparametric regression of y on x. Robust refers to an adaptation of iterated weighted least squares that prevents highly variable points (outliers) from distorting smoothed points. The data were graphed using Harvard Graphics (Software Publishing Corporation 1987).

Visual examination of the smoothed graphs was used to determine the stand age at which stand structure changed from an increasing mode to a maintenance mode or plateau. The ages at which stand structure maintained consistent features was interpreted as old-growth. Means, standard deviations, standard errors, snag density, and coarse woody debris volume were determined through SPSSPC+ (Norusis 1988).

The age at which stand structure was determined to be old-growth was used to develop a set of average characteristics for old-growth.

RESULTS AND DISCUSSION

The variables found to be acceptable and consistent identifiers of the age at which stand structure shifts from a increasing mode (mature seral stage) to a maintenance or plateau mode (old-growth seral stage), are listed below.

1. Culmination of standing cubic volume.
2. Culmination of quadratic mean diameter.
3. Changes in the density (trees/acre) of large diameter trees.
4. Changes in vegetative cover by stratum.
5. Significant increases in density, diameter, and height of large snags.
6. A significant increase in the number of large logs.

The numbers of diameter classes and stand density index were found to maximize during the mature seral stage. This makes it a characteristic of old-growth but not an identifier of the onset of the old-growth seral stage.

Tree species and size

The relative association of a species within the Douglas-fir/Tanoak/Madrone SAF type is described using constancy. Constancy measures the frequency of occurrence of a species within the vegetation plots (Table 1). Constancy varies by species along environmental gradients.

Old-growth stands in SAF forest type 234 are dominated in the overstory by Douglas-fir (100% constancy) most frequenly in association with Tanoak (90% constancy) (Table 1). Several other species can be present in the overstory and understory. Overstory conifers can attain average heights of >130 feet and average diameters (DBH) of >30 inches. Understory hardwoods can attain average heights of >75 feet average diameters of >20 inches DBH. Individual conifers and hardwoods can have diameters >75 inches and >30 inches respectively.

Structure/stories

Old-growth stands in the Douglas-fir/Tanoak/Madrone SAF type are characterized by at least two stories (Table 2). Conifers dominate the overstory which is subtended by a mixture of conifers and hardwoods. Hardwoods are the dominant feature of the understory.

The structure of old-growth stands within SAF type 234 varies by age and site class. High sites (site classes la and 1) enter the old-growth seral stage at 180 years. This age is accompanied by a shift in the number of trees/acre by diameter class. The dominant diameter class shifts from dominance by smaller size classes (6-11, 11-18, 18-25, 25-30 in.) to dominance by trees ≥ 40 inches dbh. The number of trees ≥ 40 inches continues to increase and reaches the greatest numbers at 360 years. The mean number of trees/acre for the ≥ 40 inch dbh class was found to be 11 (Table 2).

Moderate sites (site classes 2 and 3) reach the old-growth seral stage at 240 years. The number of trees/acre ≥ 30 inches is the dominant feature of this group. The mean number of trees/acre ≥ 30 in. for stands ≥ 240 years was 16.3 (Table 2).

Low sites (site classes 4 and 5) enter the old-growth seral stage at 300 years (Table 2). As with the higher site index groups, there is a shift in dominance of the number of trees/acre by diameter class with increasing age. At 300 years, the number of trees in the 27 in. dbh class sharply decreases and reaches a similar level to the number of trees ≥ 30 in. and trees in the 21 in. diameter class. The mean number of trees ≥ 30 in. is 11 trees/acre.

Large (greater than 30 inches DBH) Douglas-fir trees predominate old-growth stands. Generally, for all sites the majority (151.5 sq ft/acre; >50 %) of basal area (mean total stand basal area = 282 sq. ft. per acre) occurs in the larger (≥ 35 inches DBH) size classes of conifers (Table 2). In terms of density, approximately 25% of the conifer trees >2 inches DBH (mean total conifer density = 51 trees per acre) are ≥30 inches DBH, while the highest density of trees occurs in smaller (≤ 18 inches DBH) size classes of hardwoods.

<u>Snags</u>

Snag densities change over a time as a function of pulses associated with stand development and competition induced mortality. The first significant pulse of large snags (snags ≥ 20 inches DBH and ≥ 15 feet tall) occurs at culmination of mean annual increment. Here competition between trees for light, moisture, and nutrients produces a significant pulse of mortality. This pulse is followed by a series of pulses regularly spaced in time beginning at the advent of the old-growth seral stage.

Snag density (all species combined) appears constant between site classes. Total density of snags greater than 20 inches DBH averages 2.4 snags per acre on all sites. Hardwoods typically contribute >15 % of the total density of snags.

Snag densities are not uniform throughout a stand. In examining the point samples used to construct these definitions it was found that 20% of the stands fail to meet the standard of 2.4 ± 0.4 snags/acre. This does not mean that these stands should not be considered old-growth, it points to snag densitites as a feature of old-growth but not a determining variable.

<u>Down logs</u>

Density, volume, and weight of logs appears constant between site classes. Log densities show a decrease with stand age from 1 to 100 years. In general, log density shows a lag behind snag density. There is a significant increase in the mean log density of logs ≥ 20 in. diameter and ≥ 10 ft. long between stands 180 to 250 years and stands greater than 250 years old, with the mean density increasing from 4.05 to 11.5 logs/acre (table 2).

As explained above for snags, log densities are also variable with as many as 30% of the stands considered old-growth not meeting the log density standard. This can be explained partly by the use of point counts and partly by the steepness of the terrain. Gravity plays a roll in determining which positions in the landscape have high log densities as well as periodic disturbance. Logs are a characteristic of old-growth, but should not be used as the sole determinant of whether or not a stand is considered old-growth.

The log volume shows a similar pattern to that of log density, with an initial decrease until 100 years, followed by a series of small peaks. Thereafter there is a significant increase in the mean log volumes with stand age. The mean log volume increases from 889 $ft.^3$ in stands between 180 to 250 years to 1902 $ft.^3$ for stands greater than 250 years and a weight of 11.6 tons per acre (Table 2). Hardwoods contribute >20% of the total density of logs.

Understory characteristics

Vegetation cover by layer changes over time in relation to site class. On high and moderate sites hardwood cover is the dominant feature in young stands. Conifers dominate the site by the beginning of the mature seral stage. Hardwood cover increases with age, reaching a stable maximum at approximately 200 years stand age. The conifer cover decreases in the transition from mature to old growth stands, stabilizing at equal values to hardwood cover at 200 years. Shrub cover also dominates during the early stages of stand development. It however, loses dominance as both conifers and hardwoods close canopy above it. As the overstory canopy begins to open in the later part of the mature seral stage shrub cover increases.

On low sites shrub cover dominates the sites. Conifer cover peaks early with hardwood cover as a limited component.

Decadence

The presence of large logs and snags is a primary indicator of the decadence of old-growth stands, although a full range of sizes and decay classes of logs and snags, which contribute to ecosystem functioning, is characteristic. The distribution of dead wood along a gradient of decay from sound to rotten is typically normal (Harmon et al 1986). High accumulations in any particular stages of decay are often a result of input pulses related to past disturbances or events such as fire or insect infestations.

Decadence of old-growth stands is also characterized by the presence of diseased, broken-topped, or malformed live trees. Moderate to high percentages of live conifer canopy trees possess conks and swollen knots or are resinous, damaged crowns, cavities and scars related to fire (Table 3).

As with snag and log density, decadence should not be used alone as a determinant of old-growth. When stands enter the old-growth seral stage, particularly on high sites decadence is not evident. During the early phase of old-growth, overstory trees may show rounding of their crowns as their only sign of decadence.

Table 1--List of species identified in the Douglas-fir-Tanoak-Madrone SAF type, with constancies of ≥ 10 percent.

	CONSTANCY
OVERSTORY TREES	
Psuedotsuga menziesii	100%
Lithocarpus densiflora	90%
Arbutus menziesii	51%
Castanopsis chrysophlla	31%
Quercus chrysolepis	28%
Pinus lambertiana	24%
Acer macrophyllum	14%
Chamaecyparis lawsoniana	13%
Cornus nuttallii	13%
UNDERSTORY TREES	
Lithocarpus densiflorus	95%
Pseudotsuga menziesii	70%
Quercus chrysolepis	39%
Castanopsis chrysophylla	22%
Pinus lambertiana	21%
Arbutus menziesii	18%
Umbellularia californica	17%
Chamaecyparis lawsoniana	12%
SHRUBS	
Gaultheria shallon	45%
Vaccinium ovatum	44%
Berberis nervosa	58%
Rubus ursinus	39%
Rhododendron macrophyllum	21%
Rosa gymnocarpa	54%
Rhus diversiloba	53%
Lonicera hispidula vacillan	43%
Ceanothus velutinus	18%
Vaccinium parvifolium	13%
Corylus cornuta californica	25%
Symphoricarpos mollis	13%
FORBS	
Polystichum munitum	67%
Pteridium aquilinum lanuginosa	51%
Goodyera oblongifolia	45%
Whipplea modesta	51%
Chimaphila umbellata occidentale	33%
Xerophyllum tenax	20%
Chimaphila menziesii	49%
Trientalis latifolia	38%
Achlys triphylla	31%
Viola sempervirens	20%
Disporum hookeri	37%
Iris sp.	18%
Pyrola picta	37%

Vancouveria planipetala	40%
Linnaea borealis longiflora	11%
Hieracium albiflorum	18%
Oxalis oregana	13%
Smilacina racemosa amplexic	18%
Trillium ovatum	13%
Adenocaulon bicolor	18%
Pyrola picta aphylla	11%
Corallorhiza maculata	13%
Whipplea modesta	28%
Madia madioides	11%
Polygala californica	18%
GRASS	
Festuca occidentalis	26%
	CONSTANCY

Table 2. Standards for Douglas-fir/tanoak/madrone old-growth stands by Dunning's site classes, base age 300 years.

Variables	Dunning site class groups 1a-1	2-3	4-5
Age (years) 1/	180	240	300
Conifer live trees (trees/acre) 2/ ≥ 40" dbh	11 ± 1	–	NA
≥ 30" dbh	–	16.3 ± 1.9	11 ± 2.7
Snags (all species) 2/ Density (snags/acre)/3 (≥ 20" dbh & ≥ 15' tall)	2.4 ± 0.4 for all site classes		
Logs (all species) 2/ Density (logs/acre)/3 (≥ 20" large dia. & ≥ 10' long)	11.5 ± 2.2 for all site classes		
Layers	Conifer layer with lower tier of hardwoods < 130 ft. tall. Conifers and hardwoods present in understory.		
Tree Cover	Dense cover exceeding 60% overstory and understory combined		Moderate cover exceeding 40% overstory and understory combined

1/ Derived from robust locally weighted regression.

2/ Average values with 95% confidence interval.

3/ Snag and log densities are variable and should not be used as the sole determinant of old-growth.

Table 3. Stand conditions and live-tree decadence in Douglas-fir/tanoak/madrone forests >200 years old. Mean values and 95% confidence limits are for canopy trees only. Trees present in the understory as canopy intermendiates or suppressed trees are not represented. Only characteristics that had their highest values in old-growth are reported. Characteristics that showed only minor differences between stands >200 years old and younger stands are indicated by "NA". Characteristics are not exclusive in that one tree may exhibit several conditions. For example, a single tree may contribute to the percentages for more than one disease and more than one type of cavity characteristic. Data are for all Dunning site classes (n=40).

	Conifers
Disease	
Conks on lower bole	17.6 ± 4.5 percent
Conks on mid and upper bole	7.8 ± 2.6 percent
Resinosous	9.7 ± 2.6 percent
Swollen knots	6.0 ± 1.9 percent
Crown Condition 3/	
Broken tops	5.0 ± 1.5 percent
Dead tops	4.2 ± 2.1 percent
Bole condition	
Leaning boles	30.8 ± 4.6 percent
Forked or multiple bole below breast height	7.3 ± 2.3 percent
Cavities 1/	
Root collar cavities	11.4 ± 3.2 percent
Lower bole cavities	11.4 ± 4.2 percent
Mid bole cavities	1.4 ± 0.9 percent
Excavated cavities in mid or or lower bole	5.2 ± 3.0 percent
Disturbance 2/	
Fire blackened bark	65.1 ± 7.5 percent
Fire scars	9.6 ± 3.4 percent
Fall scars	4.7 ± 2.2 percent

1/Root collar, lower bole, and mid bole cavities are natural openings that afford protection for wildlife from precipitation. Natural cavities can be caused by fire, tree fall or fragmentation, rot, or other natural phenomena and exhibit a wide range of sizes. Excavated cavities are often well formed and may be less than one inch in diameter.
2/Tree damage resulting from disturbances such as fire and tree fall include cavities and other deep scars. Fire blackened bark does not include damage below the bark surface.
3/The crown decadence features described in this table may not occur on high sites in the early phase of the old-growth seral stage.

Table 4. Region 5 site classes (height by age) from Dunning base age 300 years.

Age	Site Class 0	1	2	3	4	5
40	95	81	66	49	43	35
50	106	90	75	56	49	39
60	115	98	82	63	53	43
70	122	105	88	68	58	45
80	129	111	93	73	61	48
90	135	116	98	77	64	50
100	140	121	102	81	67	54
110	145	125	106	84	70	54
120	149	129	109	87	72	55
130	153	133	112	90	74	57
140	157	136	115	93	76	58
150	160	139	118	95	78	60
160	163	142	120	98	80	61
170	166	144	123	100	81	62
180	169	147	125	102	83	63
190	172	149	127	104	84	64
200	175	152	129	106	86	65
220	179	156	133	109	88	67
240	184	160	136	112	90	68
260	188	163	139	115	93	70
280	191	166	142	117	95	71
300	195	169	145	120	96	73
320	198	172	147	122	98	74
340	201	175	150	124	100	75
360	204	177	152	126	101	76
380	206	180	154	128	103	77
400	209	182	156	130	104	78

Note: Based on ponderosa pine, Jeffrey pine, sugar pine, Douglas-fir, red fir, and white fir. Age is in years. Total height is in feet of average dominant and predominant trees with tree age of at least 50 years. Adapted fron Dunning's site index curves for height at 300 years.

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Appendix A. Key to the Society of American Foresters SAF vegetation types.

1a. Douglas-fir dominant in the overstory or cover > 50% of the canopy cover.. 2

2a. White fir present and/or hardwoods (tree form) absent (tanoak, madrone, canyon live oak) or less than 10% cover........................... Pacific Douglas-fir

2b. White fir absent and evergreen hardwoods (tanoak, madrone, canyon live oak) present and greater than 10% cover................. Douglas-fir/Tanoak/Madrone

1b. Douglas-fir absent in overstory or < 50% cover............ 3

3a. Jeffrey pine dominant in overstory.............. Jeffrey Pine

3b. True fir (white or red fir) dominant in overstory 4

4a. Red fir canopy cover > 50% or red fir basal area > 50%................... Red fir

4b. White fir canopy cover > 50% or white fir basal area > 50%................. White fir

Appendix B. Vegetation type/seral stage attribute data card.

PLOT ____________ DATE ____________ NAME ______________________

MAJOR VEGETATION TYPE (CIRCLE ONE)

Douglas-Fir/Tanoak/Madrone Pacific Douglas-fir White Fir Red Fir
Jeffrey Pine Port-Orford cedar Lodgepole Pine Ponderosa Pine
Douglas-fir/Pine Other______________

LAYERS (CIRCLE ALL PRESENT) CIRCLE IF PRESENT

L1 L2 L3 L4 L5 SUPPRESSED REGENERATION

AGE (BY LAYER)

L1_____ L2_____ L3_____ L4_____ L5_____ SUPPRESSED_____ REGENERATION_____

DBH CLASSES (CIRCLE ALL PRESENT)

2 8 14 21 27 35 40+

SHRUB LAYER (CIRCLE ONE)

NONE	DEPAUPERATE	MODERATE	WELL DEVELOPED	DENSE
(1% <)	(2-10%)	(10-35%)	(35-60%)	(60% >)

SNAGS (CIRCLE ALL PRESENT)

SMALL (< 20" DBH AND OR < 20' TALL) MEDIUM (> 20" DBH AND 20-50' TALL)

LARGE (> 20" DBH AND > 50' TALL) NONE

DECAY CLASSES (CIRCLE ALL PRESENT)

1 2 3 4 5

LOGS (CIRCLE ALL PRESENT)

SMALL (< 20" DIA LARGE END AND OR < 20' LONG)

MEDIUM (> 20" DIA LARGE END AND 20-50' LONG)

LARGE (> 20" DIA LARGE END AND > 50' LONG) NONE

DECAY CLASSES (CIRCLE ALL PRESENT)

1 2 3 4 5

PROJECTED SERAL STAGE (IF BETWEEN STAGES CIRCLE CLOSEST ONE AND PUT A LINE AT APPROXIMATE STAGE OF DEVELOPMENT)

SHRUB/FORB POLE MATURE OLD-GROWTH

COMMENTS: