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

By
R5 Old-Growth Definition Team 2
Jo Ann Fites, Zone 4 Ecologist & Team 2 Leader-Eldorado N.F.
Mike Chappel, Wildlife Biologist-Tahoe N.F.
Beth Corbin, Botanist-Lassen N.F.
Mike Newman, Silviculturist-Foresthill R.D., Tahoe N.F.
Tom Ratcliff, East-zone Wildlife Biologist-Plumas N.F.
Dave Thomas, Silviculturist-Eldorado N.F.
Pacific Southwest Region
US Forest Service

January 29, 1991

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.

LITERATURE CITED

Ashton-Tate Corp. 1988. dBase IV.

Bernsten, C.M. 1960. Productivity of a mature Douglas-fir stand. Res. Note 188. Portland, Oregon: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 4p.

Brown, E.R., tech. ed. 1985. Management of wildlife and fish habitats in forests of western Oregon and Washington. Part 1-Chapter narratives, 332 p. Publ. R6-F&WL-192-1985. Portland, Oregon: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region.

Bull, E.L.; Holthausen, R.; Marx, D.B. 1990. How to determine snag density. West. J. Applied Forestry 5(2):56-58.

Carlson, A.; Chapel, M.; Colborn, A.; Craig, D.; Flaherty, T.; Marshall, C.; Pratt, D.; Reynolds, M.; Tanguay S.; Thompson W.; and S. Underwood. 1991. Old Forest and Riparian Habitat Planning Project: Review of literature addressing wildlife and fish habitat relationships in riparian and stream habitats. Unpublished document on file at Tahoe National Forest. Nevada City, California: U.S. Department of Agriculture, Forest Service, Pacific Southwest Region.

DeBell D.S. and J.F. Franklin. 1987. Old-growth Douglas-fir and western hemlock: a 36-year record of growth and mortality. W. J. Applied Forestry. 2:111-114.

Dunning, D. 1942. A site classification for the mixed-conifer selection forests of the Sierra Nevada. Res. Note 28. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station.

Eyre, F. H., ed, 1980. Forest cover types of the United States and Canada. Soc. Amer. Foresters, Washington D.C.

FSH 2409.21B Timber Management Plan Inventory Handbook. Pacific Southwest Region, Forest Service, U.S. Department of Agriculture.

FSM 2090.22 Region 5 Ecosystem Classification and Inventory Handbook. Pacific Southwest Region, Forest Service, U.S. Department of Agriculture.

Franklin, J.; Spies, T. 1989. Generic definition of old-growth forests. In house document. U.S. Department of Agriculture, Forest Service. Washington D.C.

Franklin, J. F.; Spies,T. 1991a. Ecological definitions of old-growth Douglas-fir Forests. p. 61-69 In: Wildlife and Vegetation of Unmanaged Douglas-fir Forests. PNW-GTR-285-1991. Portland, Oregon: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station.

Franklin, J. F.; Spies,T. 1991b. Composition, function, and structure of old-growth Douglas-fir forests. p. 71-80 In: Wildlife and Vegetation of Unmanaged Douglas-fir Forests. PNW-GTR-285-1991. Portland, Oregon: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station.

Franklin J.F.; Waring, R.H. 1980. Distinctive features of the northwestern coniferous forest: development, structure and function. In: Waring, R.H. ed. Forests: fresh perspectives from ecosystem analysis. Proc. of the 40th Annual Biological Colloquium; 1979 April 27-28; Corvallis, OR. Corvallis, OR: Oregon State University Press:59-86.

Gordon 1980. White fir (SAF 211). In: Eyre F.H. ed, Forest cover types of the United States and Canada. Soc. of Amer. Foresters, Washington, D.C.

Harr, R.D. 1986. Effects of clearcutting on rain-on-snow runoff in western Oregon: a new look at old studies. Water Resources Research. 22:1095-1100.

Hopkins, W. E. in draft. White/grand fir old-growth definition on National Forest lands in eastern Oregon and Washington. U.S. Department of Agriculture, Forest Service, Pacific Northwest Region, Silviculture Laboratory, Bend, Oregon.

Jimerson, T.M. 1991. Ecological Definition for Old-growth Douglas-fir/Tanoak/Madrone (Society of American Forester's type 234). U.S. Department of Agriculture, Forest Service, Pacific Southwest Region, Six Rivers National Forest.

Jimerson, T.M. 1989. Snag densities in old-growth stands on the Gasquet Ranger District, Six Rivers National Forest, California. U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Research Station, Res. Pap. PSW-196. 12p.

Jimerson, T.M. in draft. Ecological definitions for old-growth white fir (Society of American Forester's type 211) for northwestern California. U.S. Department of Agriculture, Forest Service, Pacific Southwest Region, Six Rivers National Forest.

Jimerson, T.M.; Fites, J. 1989. Preliminary old growth definitions for Northwest California. In review. 118 p.

Kaufman, B. 1986. The ecological response of the shrub component to prescribed burning in Mixed Conifer Ecosystems. PhD Dissertation, University of California, Berkeley.

Laudenslayer W. 1991. Personnel communication.

Lundquist R.W.; Mariani, J.M. 1991. Nesting habitat and abundance of snag-dependent birds in the Southern Washington Cascade Range. p. 221-243 In: Wildlife and Vegetation of Unmanaged Douglas-fir Forests. PNW-GTR-285-1991. Portland, Oregon: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station.

Maser, C; Maser, Z. 1988. Interactions among squirrels, mycorrhizal fungi, and coniferous forests in Oregon. Great Basin Naturalist. 48:358-368.

Maser, C.; Tarrant, R.F.; Trappe, J.M.; Franklin, J.F., tech eds. 1988. From the forest to the sea: a story of fallen trees. Gen. Tech.Rep. PNW-229. Portland, Oregon: U.S. Department of Agriculture, Pacific Northwest Forest and Range Experiment Station.

Norusis, M.J. 1988. SPSS/PC+ V2.0 for the IBM PC/XT/AT and PS/2. Chicago, IL: SPSS Inc. 606 p.

Potter D. 1991. Preliminary guidelines defining old growth forests in the red fir type of California. U.S. Department of Agriculture, Forest Service, Pacific Southwest Region, Stanislaus National Forest.

Romme, W.H. 1982. Fire and landscape diversity in subalpine forests of Yellowstone National Park. Ecological Monographs 52(2):199-221.

Romme, W.H.; Knight, D.H. 1981. Fire frequency and subalpine forest succession along a topographic gradient in Wyoming. Ecology 62(2):319-326.

Schumaker F. 1928. Yield, stand and volume tables for red fir in California. University of California Bull. 456. Berkeley, California.

Smith, S. 1991. Interim guidlines defining old-growth stands: Pacific Ponderosa Pine (SAF 245). U.S. Department of Agriculture, Forest Service, Modoc National Forest,Alturas, California.

Software Publishing Corporation. 1987. Harvard Graphics. Mountain View, CA. 487 p.

Spies, T.A.; Franklin J.F. 1991. The structure of natural young, mature, and old-growth Douglas-fir forests in Oregon and Washington. p. 91-108 In: Wildlife and Vegetation of Unmanaged Douglas-fir Forests. PNW-GTR-285-1991. Portland, Oregon: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station.

U.S. Department of Agriculture, Forest Service. 1987. R-5 FSH 2060, Ecosystem classification handbook. U.S. Department of Agriculture, Forest Service, Region 5, San Francisco, CA p.

U.S. Department of Agriculture, Forest Service. 1988. R-5 FSH 2409.21b, Timber management plan inventory handbook. U.S. Department of Agriculture, Forest Service, Region 5, San Francisco, CA 525 p.

Veblen 1985. Stand dynamics of Chilean Nothophaus forests. In: The Ecology of Natural Disturbance and Patch Dynamics. Academic Press, New York, NY.

Williamson, R.L.; Price, F.E. 1971. Initial thinning effects in 70- to 150-year-old Douglas-fir - Western Oregon and Washington. Res. Paper PNW-117. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 15 p.

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 stócking 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)