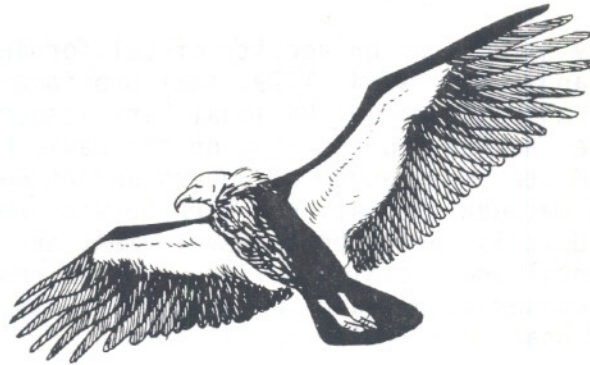
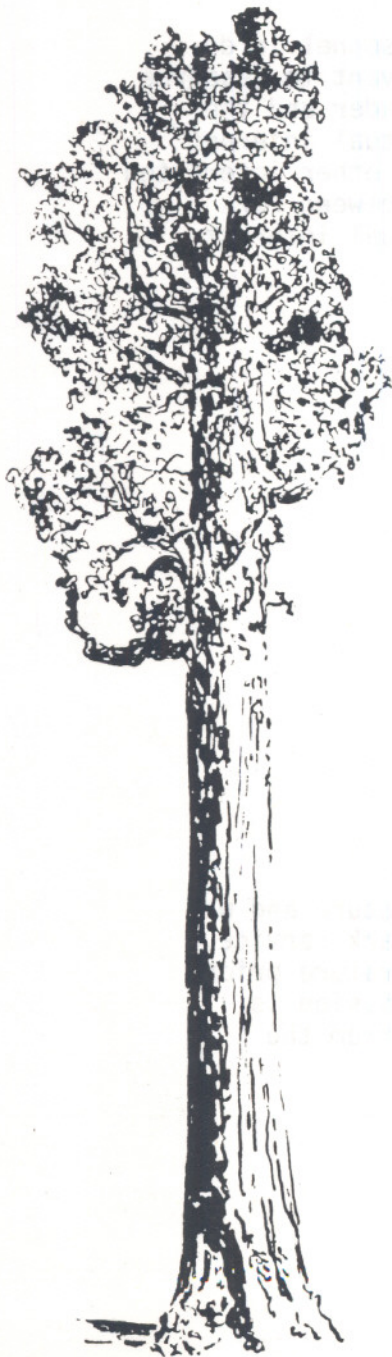
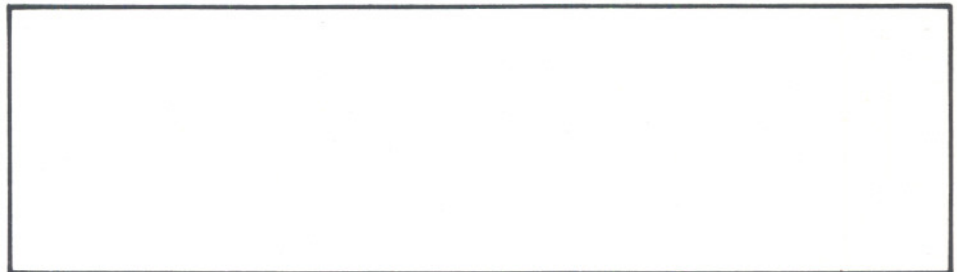


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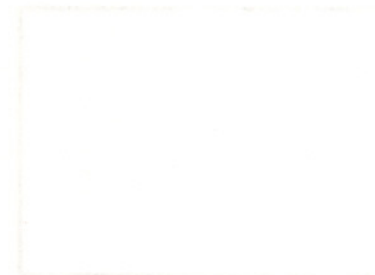
COOPERATIVE NATIONAL PARK RESOURCES STUDIES UNIT

University of California - National Park Service

The National Park Service and the University of California signed a Master Memorandum of Understanding on May 4, 1979, that provided for the establishment and operation of the Cooperative National Park Resources Studies Unit as an affiliate of the Institute of Ecology on the Davis Campus. Effective October 1, 1981, the Master Memorandum of Understanding was superceded by a Cooperative Agreement between the National Park Service and the University of California. This Unit is dedicated to development and facilitation of ecological, environmental and sociological programs of research and study in the interest of use, conservation, and management of natural areas and other components of the National Park system in California.

The Unit Leader conducts research and assists Park Service personnel in developing and coordinating research to provide information relevant to resource management decision in park areas. Cooperatively, the Unit Leader and the Unit Coordinator consider programs of research and study of mutual interest to the National Park Service and researchers in California and other interested parties, and promote and facilitate cooperative interactions between Park Service and research personnel on problems and programs of mutual interest.

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Technical Report No. 32

Characteristics of Mixed Conifer Forest Reference  
Stands at Sequoia National Park, California

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August 1988

Final Report to National Park Service

Characteristics of Mixed Conifer Forest Reference Stands  
at Sequoia National Park, California

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## ABSTRACT

Six forest stands were selected for the purpose of establishing permanent sample plots for quantitative description of Sierran mixed conifer forests at Sequoia and Kings Canyon National Parks. Forest types represented are mixed conifer (1.1 ha), riparian mixed conifer (1.4 ha), white fir (0.9 ha), Jeffrey pine (1.0 ha), riparian giant sequoia (2.0 ha), and giant sequoia (2.5 ha). Trees  $\geq$  breast height (1.37 m) were tagged and diameters measured; trees were stem mapped and tree characteristics were evaluated. Tree reproduction and standing and down dead wood were measured. Tree composition, frequency, density, volume, and basal area are presented for each reference stand. These reference stands provide scientists interested in the Sierran mixed conifer forests with pre-described permanent sample plots.



## INTRODUCTION

Sequoia National Park was selected as the site for a major interdisciplinary team effort in 1982 and 1983 to better understand forest and stream ecosystems and their interactions in the mixed conifer zone of the Sierra Nevada (Franklin and Riegel 1984; Matthews 1983). Referred to here as the Sierran Pulse, a major activity of this effort was establishment of a series of permanent plots to facilitate the collection of basic descriptive data on the stream, riparian and forest systems. A pulse is a short intensive period of interdisciplinary research activity aimed at generating and integrating new knowledge about a subject ecosystem. Three other pulses have been conducted in the Pacific Northwest: Waldo Lake in the Cascade Range of Central Oregon in 1976, Olympic National Park's Hoh River Valley in 1978 (Matthews 1980), and Mt. St. Helens in 1980 and 1981. Objectives for establishing permanent plots were to: (1) describe forest stand structure and composition within the Sierran mixed conifer forest type, and (2) acquire a data base for monitoring long-term change in these forest ecosystems.

Permanent plots, defined here as reference stands, have been established in a variety of forest ecosystems throughout the Pacific Northwest for the purpose of gathering baseline vegetation data to assess change through time. Presently there are 63 reference stands established in numerous vegetation types, from subalpine forests in the Cascades of Washington to ponderosa pine forests in central Oregon. Reference stands exist in Olympic and Mt. Rainier National Parks, Cascade Head and H.J. Andrews Experimental Forests, and Pacific Northwest Research Natural Areas. This reference system is the responsibility of Research Work Unit 4151, U.S. Forest Service, Pacific Northwest Research Station, Corvallis, Oregon.

Results to date of interdisciplinary research that has been conducted within the reference stands at Sequoia National Park include: decay rates and classification for white fir logs (Harmon, Cromack, and Smith 1987); riparian vegetation composition, structure and biomass along the forested stream reaches (McKee et al. 1984); physical and retentive characteristics and effect of annual inputs of large organic debris in the streams within the riparian reference stands (Luchessa and Speaker 1988); litterfall and

decomposition rates (Stohlgren and Riegel 1984); classification, chemical, and mechanical composition of soils (Ohsumi 1983); age and stand structure and reproductive spatial patterns of a mixed conifer forest (Riegel et al. 1988); and classification of subalpine meadow communities (Halpern 1985, 1986).

### Study Site

Sequoia National Park is located in the southern Sierra Nevada of California. Climate is mediterranean, with cool, moist winters and hot dry summers. The majority of precipitation occurs from November through April. Fifty year (1932-1983) mean annual precipitation at Giant Forest/Lodgepole (Figure 1) is 1172 mm/year, falling mostly as snow (Sequoia and Kings Canyon National Parks, unpublished data). Elevation, aspect, average slope, topographic position, and soil depth are listed in Table 1.

## METHODS

Three reference stands were established between 2012 and 2109 m in elevation along Suwanee Creek in the upper drainage of the Marble Fork of the Kaweah River. In the upper drainages of the Middle Fork of the Kaweah River two reference stands were established at 2219 and 2440 m in elevation. A final reference stand was established near Lodgepole on a south slope (Figure 1).

The reference stands represent examples of Sierran mixed conifer, giant sequoia [Sequoiadendron giganteum (Lindl.) Buchh.] -mixed conifer (with and without riparian zones), and Jeffrey pine (Grev. & Balf.) forest types (Rundel et al. 1977). Stand locations were based on ease of accessibility, and vegetation and physical site homogeneity, and proximity to streams for the mixed conifer and giant sequoia reference stands. Stand size ranges from 0.9 to 2.5 hectares (Table 1).

Reference stands are rectangular in shape, surveyed with a staff compass and slope corrected every 25 m. Rebar was installed at 25 m intervals to permanently locate corners within each 25 m<sup>2</sup> plot (Appendix 1).

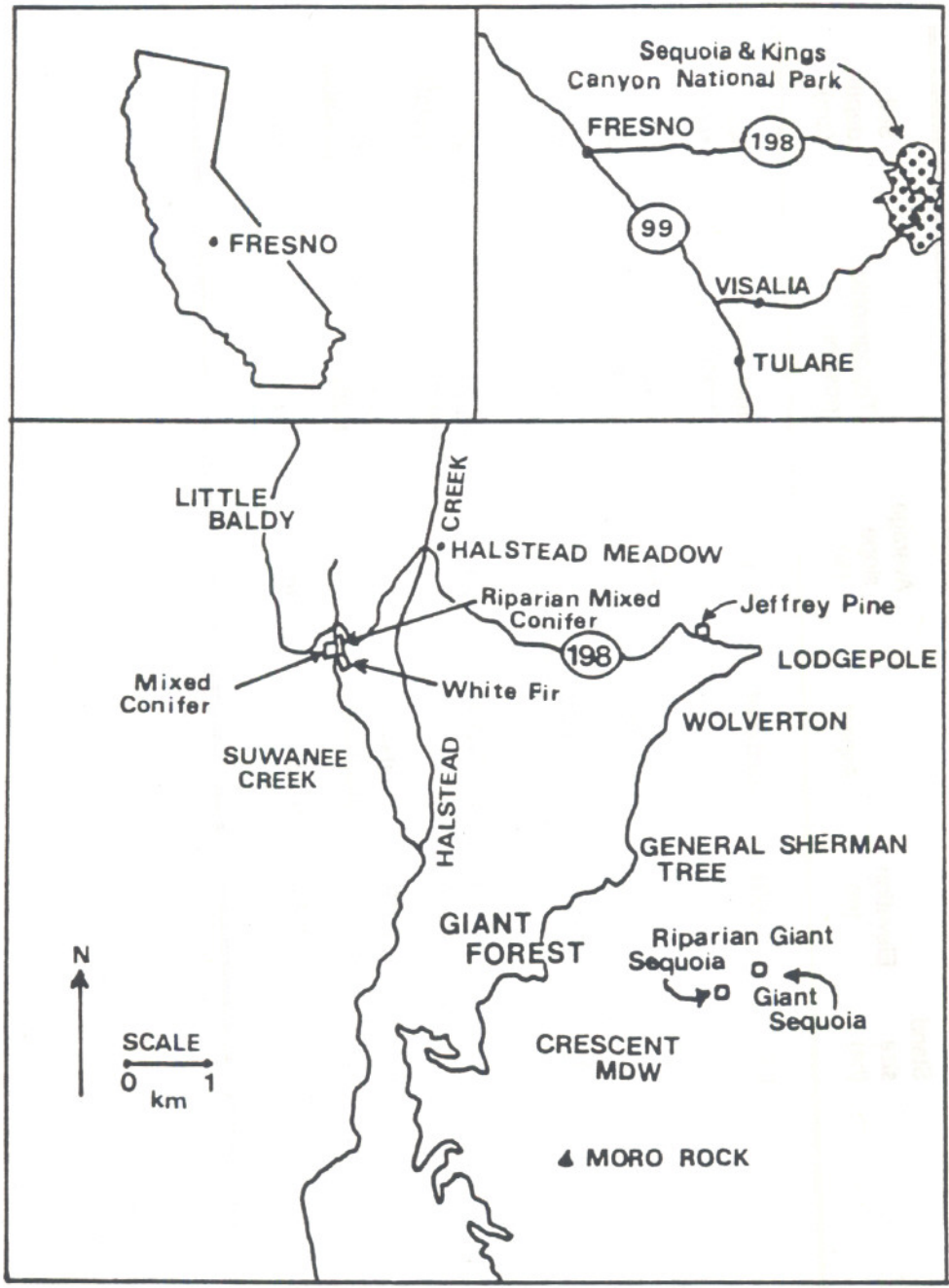


Figure 1. Location of Sequoia National Park and reference stands.

Table 1. Site characteristics of the Sequoia National Park Reference Stands.

Reference Stand	Stand size (ha)	Elevation (m)	Aspect	Average slope (%)	Topographic position	Soil depth (cm)
Mixed Conifer	1.1	2091	southeast	11	mid slope-bench	80-100
Riparian Mixed Conifer	1.4	2048	southwest/southeast	45	lower slope	48-85
White Fir	0.9	2012	southwest	20	bench	75-100
Jeffrey Pine	1.0	2109	southeast	23	upper slope	not available
Riparian Giant Sequoia	2.0	2219	southwest/southeast	10	lower slope	not available
Giant Sequoia	2.5	2440	west	40	upper slope	130

Each stand was divided into 5 x 5 m grids to facilitate tree tagging and stem mapping. All trees greater than or equal to breast height (1.37 m) were tagged with numbered aluminum tags.

Data recorded for each tree include sequential tree tag number, species alpha code (Garrison et al. 1976), and diameter at breast height (dbh) in cm. Canopy class, overall tree vigor, crown condition, bole condition, rooting condition and disturbance condition were also recorded for each tree. These codes are explained in Appendix 2 and actual data are in Appendix 3.

Tree reproduction, as seedlings (0 to 2.0 dm in height) and saplings (2.0 dm to 1.37 m in height), was tallied by species in a 5 m radius subplot located in the center of each 25 m<sup>2</sup> section.

A stem map was prepared for each reference stand (Appendix 1). Snags, stumps and downed logs (> 15 cm in diameter) were mapped as well as all living tagged trees.

Tree volumes and heights in the reference stands were measured with an optical dendrometer. All giant sequoia were measured. Sugar pine [*Pinus lambertiana* (Dougl.)], incense-cedar [*Calocedrus decurrens* (Torr.) Florin], white fir [*Abies concolor* (Gord. & Glend.) Lindl. ex Hildebr.], Jeffrey pine, and California red fir [*Abies magnifica* (A. Murr.)] were sampled in proportion to their abundance in 10 cm diameter classes between 20-180 cm dbh. California red fir were measured at two sites (Little Baldy and Wolverton Mountains) not within reference stands. A visual approach to tree selection within diameter classes was used, with the exception of giant sequoia, to avoid trees with dead tops. The dendrometer data is used to set up a regression between diameter and volume. Stand volumes are generated and, along with individual species densities, estimates of biomass are attainable.

## RESULTS

Both quantitative and qualitative data collected within the reference stands were analyzed and are presented in summary form (Stafford et al. 1984).<sup>1</sup>

Frequency, density, volume, and basal area for each reference stand are provided in Tables 2 and 3 (volume equations used are in Appendix 5). Calculated size class distributions, inclusive of reproduction, are presented in Figures 2-7 and actual data are in Appendix 4. Canopy class breakdowns by species and by reference stand are provided in Table 4.

### I. Suwanee Creek Reference Stands

There are three reference stands located contiguously along a 425 m stretch of Suwanee Creek (Figure 1, Appendix 1). The Riparian Mixed Conifer Reference Stand straddles Suwanee Creek with the Mixed Conifer Reference Stand bordering the west side and the White Fir Reference Stand abutting the southeastern side.

Topographic variation within the short distance of the reference stands produced variable soil conditions reflected in vegetation structure and productivity (Ohsumi, 1983).

#### 1. Suwanee Creek Mixed Conifer Reference Stand

The Mixed Conifer Reference Stand is a mosaic of large old trees forming a relatively open canopy with aggregates or clumps of suppressed reproduction interspersed throughout the stand (Appendix 1). Tree

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<sup>1</sup>This information along with all other reference stand data is available from the Data Bank, Department of Forest Science, Oregon State University, Corvallis, Oregon 97331.

Table 2. Frequency (percent) and density (trees/hectare) for all species for all reference stands.

Species	Mixed Conifer Reference Stand		Riparian Reference Stand		White Fir Reference Stand		Jeffrey Pine Reference Stand		Riparian Giant Sequoia Reference Stand		Giant Sequoia Reference Stand	
	Frequency	Density	Frequency	Density	Frequency	Density	Frequency	Density	Frequency	Density	Frequency	Density
White fir	68	477	55	403	60	456	8	14	71	237	77	326
California red fir	0.001	1	4	31	4	27			20	67	14	61
Incense-cedar	9	65	19	143	28	213	2	3				
Jeffrey pine			1	1			79	141	1	2		
Sugar pine	21	149	20	145	8	64	2	4	2	7	5	22
Ponderosa pine	0.003	2										
California black oak	1	5	1	11			9		16			
Giant Sequoia									7	24	3	13
Total		699		734		700		178		337		422

distribution may be correlated to varying macrotopography. The reference stand is comprised of a series of staircase benches with varying soil depths.

White fir, sugar pine, and incense-cedar dominate the stand in density, volume and basal area, respectively (Tables 2 and 3). The dominance of white fir in the smaller size classes is attributed to lack of recent fire and shade tolerance. It is likely that in the future white fir will dominate the stand in all size classes if no disturbances are allowed to occur.

The overall canopy class structure correlates well with the size classes (Table 4, Appendix 4). There are appreciably more suppressed individuals than the intermediate codominant and dominant canopy classes combined. White fir is the most abundant species in all canopy classes except in the dominant class where sugar pine and white fir are found in nearly equal numbers.

The minor species within this stand include California red fir, ponderosa pine [*Pinus ponderosa* (Dougl. ex Loud.)], and California black oak [*Quercus kelloggii* (Newb.)]. The stand is representative of the Sierran mixed conifer type (Rundel et al. 1977). Species composition by size class is presented in Figure 2 and Appendix 4.

## 2. Suwanee Creek Riparian Mixed Conifer Reference Stand

The Riparian Mixed Conifer Reference Stand is typified by a lush herbaceous riparian community growing along Suwanee Creek, with an overstory of mixed conifers (Appendix 1). The vegetation structure and species composition on the west and east banks varies due to differences in aspect, slope and soil development (Ohsumi 1983). The west bank is more mesic with dense clumps of suppressed white fir and some scattered large trees. There is little understory vegetation once one moves away from the riparian zone, 20 to 30 m from the stream. On the east side of the stream the slope is open, with large expanses of exposed glaciated granite. Toward the lower end of the reference stand California red fir becomes



Figure 2.

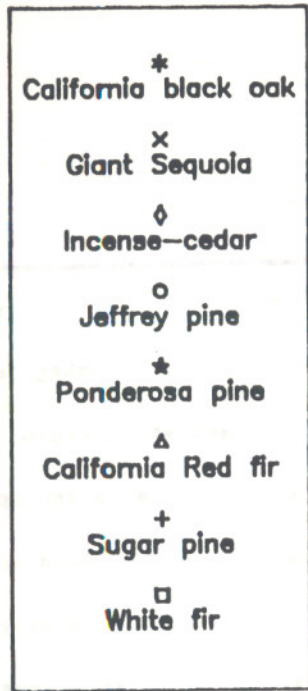


Figure 2-7. Provide numeric and graphic representations of tree species ( $\geq$ DBH in height) by size class per hectare for each reference stand.

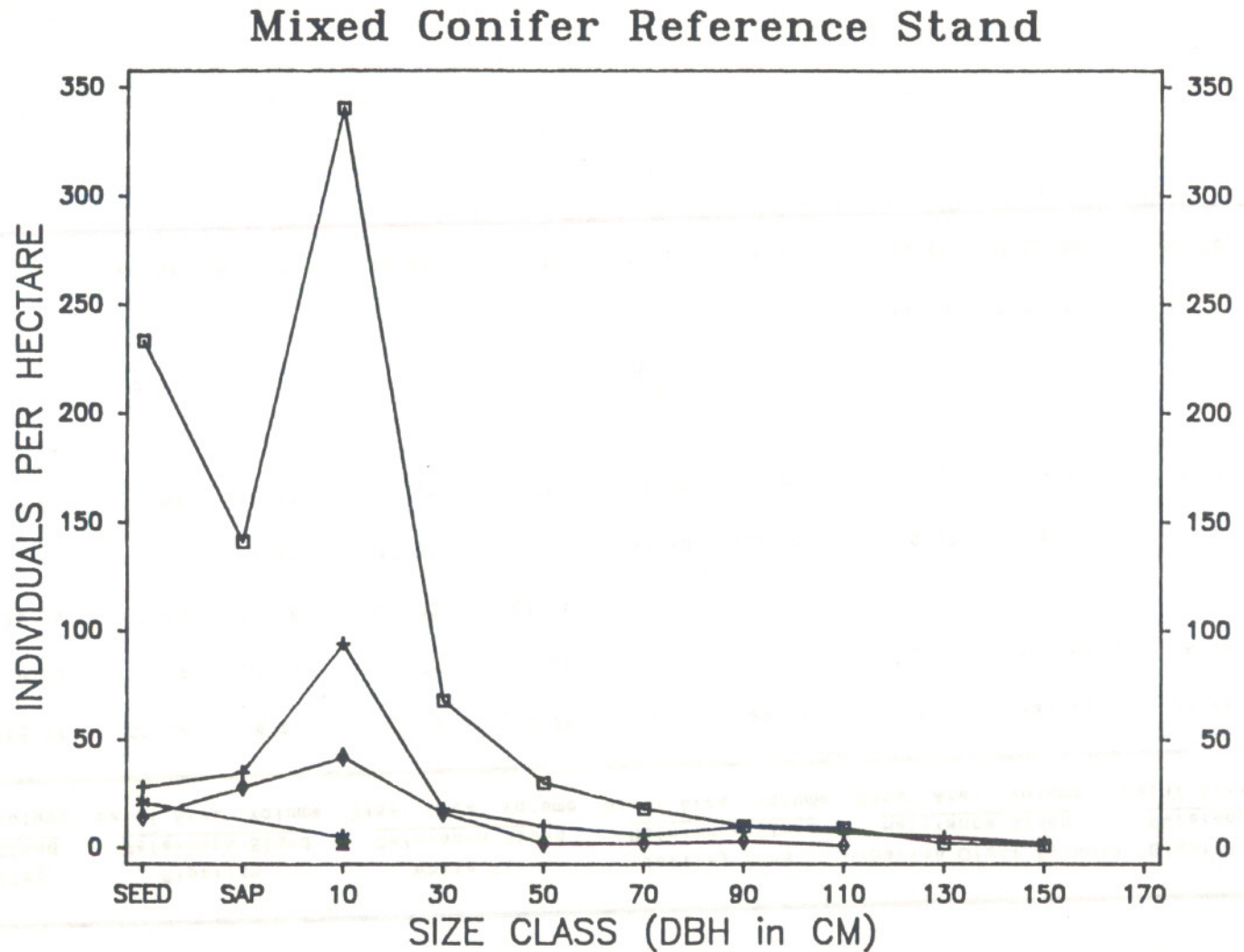


Table 3. Basal area (m<sup>2</sup>/ha) and volume (m<sup>3</sup>/ha) for species in all reference stands.

Species	Mixed Conifer		Riparian		White Fir		Jeffrey Pine		Riparian Giant Sequoia		Giant Sequoia	
	Basal Area	Volume	Basal Area	Volume	Basal Area	Volume	Basal Area	Volume	Basal Area	Volume	Basal Area	Volume
White fir	36.21	465.64	32.34	418.91	42.09	534.75	2.10	22.11	37.22	547.49	41.45	595.98
California red fir	0.02	0.06	5.94	88.10	5.75	83.31			6.79	139.62	5.34	71.34
Incense-cedar	4.85	30.78	7.43	50.28	11.73	84.81						
Jeffrey pine				1.07	17.51		15.78	132.46	0.10	0.44		
Sugar pine	26.30	379.06	17.52	241.52	11.88	159.90	1.26	19.84	0.79	8.03	2.88	40.12
Ponderosa pine	0.02	0.03										
California black oak	0.04		0.01				0.18					
Giant Sequoia									114.73	2193.80	95.07	1846.16
Total	67.44	875.57	64.31	814.32	71.45	862.77	19.32	174.41	159.63	2889.38	144.74	2553.58

Table 4. Frequency and density of tree species by canopy class within each reference stand.

Reference Stand	Canopy Classes											
	Dominant			Codominant			Intermediate			Suppressed		
<b>Mixed Conifer</b>												
White fir	4 <sup>1</sup>	3 <sup>2</sup>	19 <sup>3</sup>	9 <sup>1</sup>	6 <sup>2</sup>	42 <sup>3</sup>	22 <sup>1</sup>	15 <sup>2</sup>	101 <sup>3</sup>	65 <sup>1</sup>	45 <sup>2</sup>	305 <sup>3</sup>
California red fir									100	.001	1	
Incense-cedar				6	1	4	26	2	17	68	6	44
Sugar pine	14	3	20	7	2	11	23	5	34	56	12	81
Ponderosa pine									100	.003	2	
California black oak							40	.003	2	60	.004	3
Total by Canopy Class	--	6	39	--	8	57	--	22	154	--	64	436
<b>Riparian Mixed Conifer</b>												
White fir	4	2	18	10	5	39	30	17	124	56	31	229
California red fir	16	1	5	16	1	5	37	2	12	30	1	9
Incense-cedar	2	.003	2	4	1	6	41	8	60	53	10	77
Jeffrey pine	50	.001	1			50	.001	1				
Sugar pine	8	2	12	7	1	10	42	8	62	43	8	63
California black oak						40	1	4	60	1	7	
Total by Canopy Class	--	5	38	--	8	60	--	35	263	--	52	385
<b>White Fir</b>												
White fir	5	3	24	11	7	54	32	19	149	51	31	239
California red fir	7	.003	2	19	1	5	37	1	10	37	1	10
Incense-cedar	2	.004	5	1	1	3	45	13	98	52	14	113
Sugar pine	10	1	7	16	1	10	53	5	35	21	2	14
Total by Canopy Class	--	5	38	--	9	72	--	38	292	--	48	376
<b>Jeffrey Pine</b>												
White fir	50	4	7				50	4	7			
Incense-cedar							33	1	1	67	1	2
Jeffrey pine	20	16	28	10	8	14	57	45	80	13	11	19
Sugar pine	25	1	1	25	1	1	25	1	1	25	1	1
California black oak							100	9	18			
Total by Canopy Class	--	20	38	--	8	15	--	59	105	--	12	22

Table 4. (cont.)

Reference Stand	Canopy Classes											
	Dominant			Codominant			Intermediate			Suppressed		
<b>Riparian Giant Sequoia</b>												
White fir	3	2	7	13	10	32	23	16	55	6	43	144
California red fir	3	.004	2	7	1	5	9	2	6	81	16	54
Jeffrey pine						50	.003	1	50	.001	1	
Sugar pine	13	.001	1	13	.003	1	25	1	2	50	1	4
Giant Sequoia	46	3	11	25	2	6	13	1	3	17	1	4
Total by Canopy Class	--	6	21	--	13	44	--	20	67	--	61	207
<b>Giant Sequoia</b>												
White fir	1	1	2	14	10	43	40	31	126	46	36	147
California red fir	1	.001	.40	10	2	6	44	6	26	45	6	27
Sugar pine	2	.001	.40	10	.005	2	49	3	10	39	2	8
Giant Sequoia	60	2	8	30	1	4	3	.001	.40	7	.002	1
Total by Canopy Class	--	3	10.8	--	13	55	--	39	162.4	--	45	183

<sup>1</sup> Percent of that particular species.

<sup>2</sup> Percent of total number of trees in reference stand.

<sup>3</sup> Number per hectare.

increasingly more abundant as the topography flattens. A few trees -- sugar pine, incense-cedar, California black oak and Jeffrey pine -- and shrubs, buckbrush [*Ceanothus cuneatus* (Hook.) Nutt. ex T. & G.], dominate the site (Tables 2 and 3).

The stand is very similar to the Mixed Conifer Reference Stand in size class and canopy structure, though the riparian stand contains more incense-cedar and California red fir (Figure 3, Table 4, Appendix 4).

### 3. Suwanee Creek White Fir Reference Stand

The White Fir Reference Stand is located directly below the Riparian Mixed Conifer Reference Stand on the east side of Suwanee Creek (Appendix 1). The vegetation structure and species composition change from a dense canopy of white fir and California red fir near the stream to a mixed conifer forest with scattered sugar pine and incense-cedar along a bench on the east side of the reference stand. There are scattered outcrops of bedrock; soil depth appears shallower near the eastern edge as the bench is replaced by a moderately steep west facing slope (Ohsumi 1983).

Like the two previous reference stands, volume, density, and basal area are dominated by white fir; though sugar pine volume and basal area are next highest, they are less than the mixed conifer and riparian stands (Tables 2 and 3). Incense-cedar is more numerous in the White Fir Reference Stand than in the previous two. Incense-cedar is particularly important in the smaller diameter classes (Figure 4, Appendix 4). The seedling sapling/ratio for white fir in the Riparian and White Fir Stands are notable: there are many more sapling to 10 cm dbh white fir than seedlings (Figures 3 and 4, Appendix 4). The opposite is true for the Mixed Conifer Reference Stand (Figure 2, Appendix 4).

Figure 3.

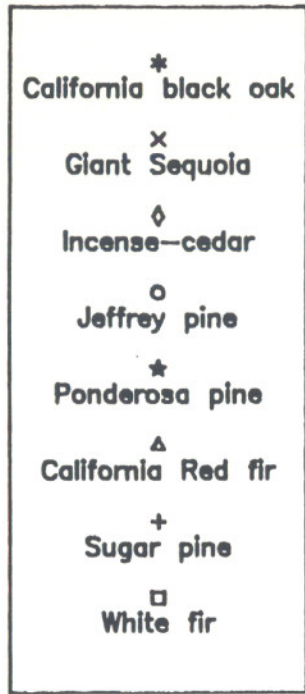


Figure 2-7. Provide numeric and graphic representations of tree species (>DBH in height) by size class per hectare for each reference stand.

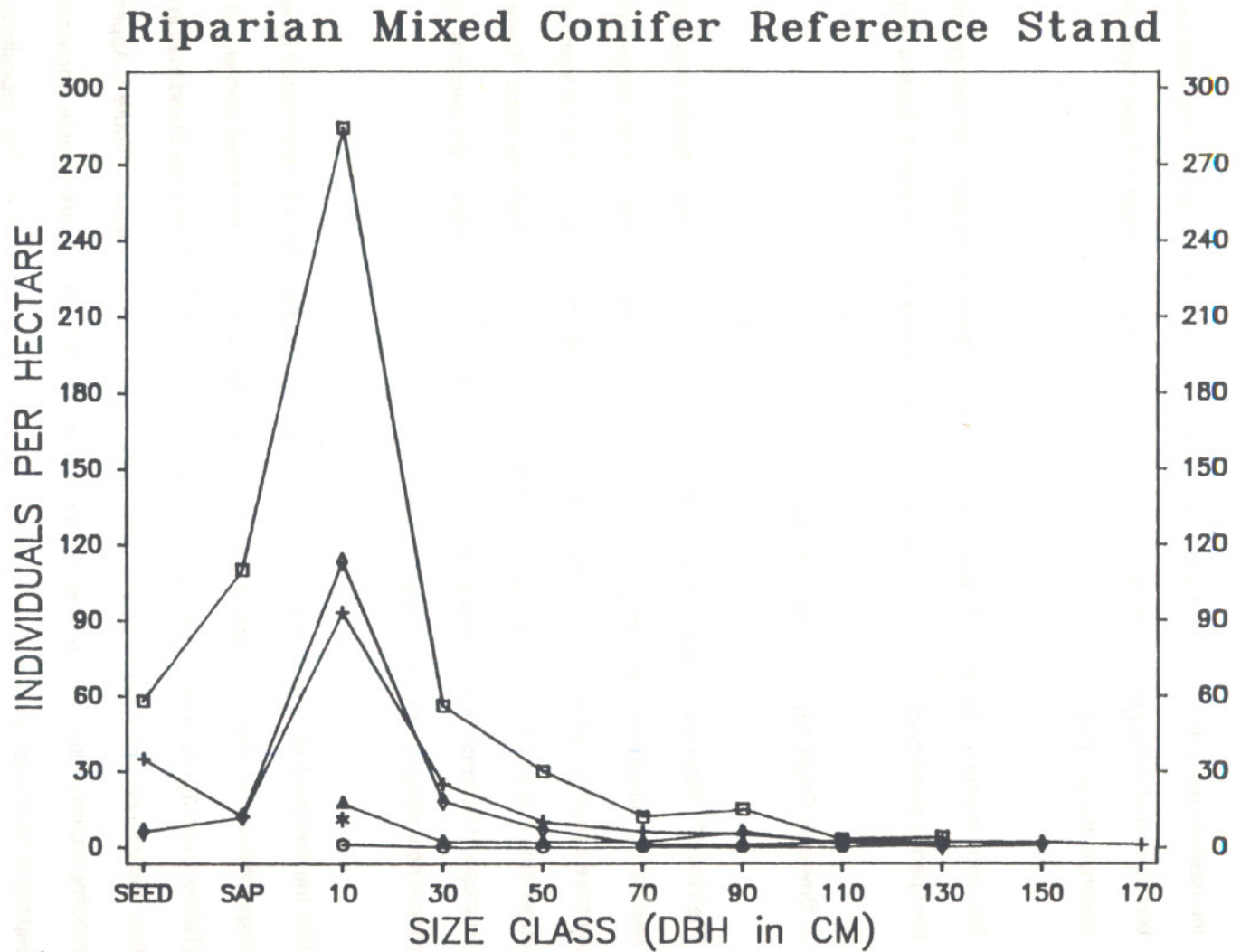


Figure 4.

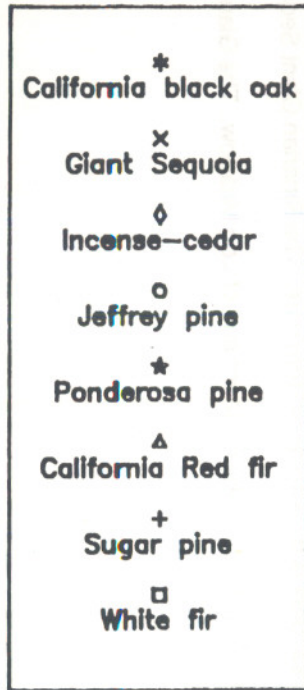
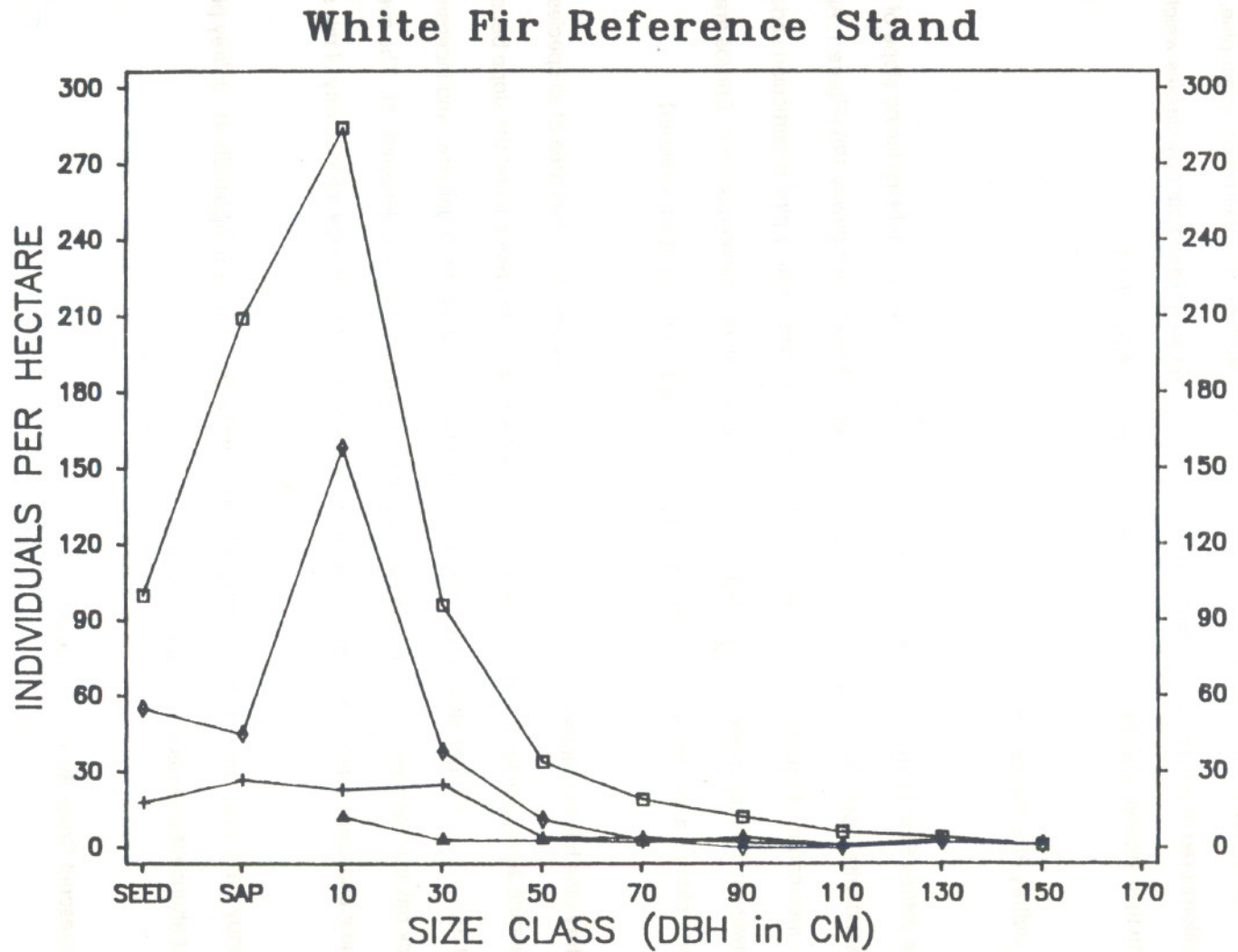


Figure 2-7. Provide numeric and graphic representations of tree species (>DBH in height) by size class per hectare for each reference stand.



Within all canopy classes white fir is the most abundant (Table 4). Incense-cedar, sugar pine, and California red fir are more abundant in the intermediate and suppressed canopy classes which correlates with their smaller size class distribution (Table 4, Figure 4, Appendix 4).

## II. Jeffrey Pine Reference Stand

The Jeffrey Pine Reference Stand is situated on a moderately steep, southeast facing slope of glaciated granodiorite, approximately 3.2 km west of Lodgepole, 200 m above highway 198 (Figure 1, Appendix 1). An open canopy forest of Jeffrey pine dominates this rocky site. Jeffrey pine is particularly adapted to growing in the coarse textured soil that is found in fissures of the glaciated granite. Shrubs are scattered in dense clumps and dominantly greenleaf manzanita [*Arctostaphylos patula* (Greene)].

Jeffrey pine has the highest frequency (in all size classes), volume and basal area of all species within this reference stand (Tables 2 and 3). Towards the lower end of the reference stand the slope becomes flatter and the aspect changes slightly, providing suitable habitat for white fir, sugar pine, and incense-cedar. Black oak is most common in size classes less than 10 cm dbh (Figure 5, Appendix 4). The overall low volume and basal area of the Jeffrey Pine Reference Stand attest to the low productivity of this site.

Canopy class structure reflects size class distribution (Table 4, Figure 5, Appendix 4). Jeffrey pine is the most abundant species in all canopy classes.

## III. Crescent Creek Reference Stands

Two reference stands were established along portions of Crescent Creek (Figure 1, Appendix 1). Both are mixed conifer forests where giant sequoia is the structural dominant. The Riparian Giant Sequoia Reference Stand is located above Tharp's Log at the northern end of Log Meadow. The Giant Sequoia



Figure 5.

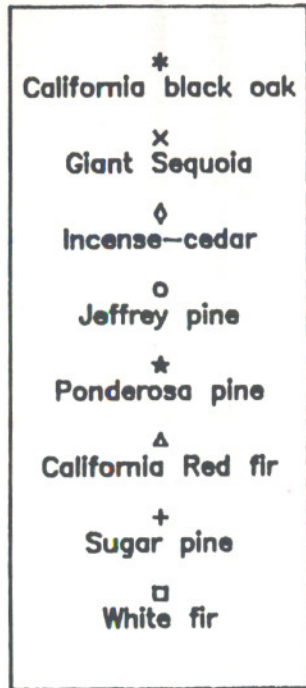
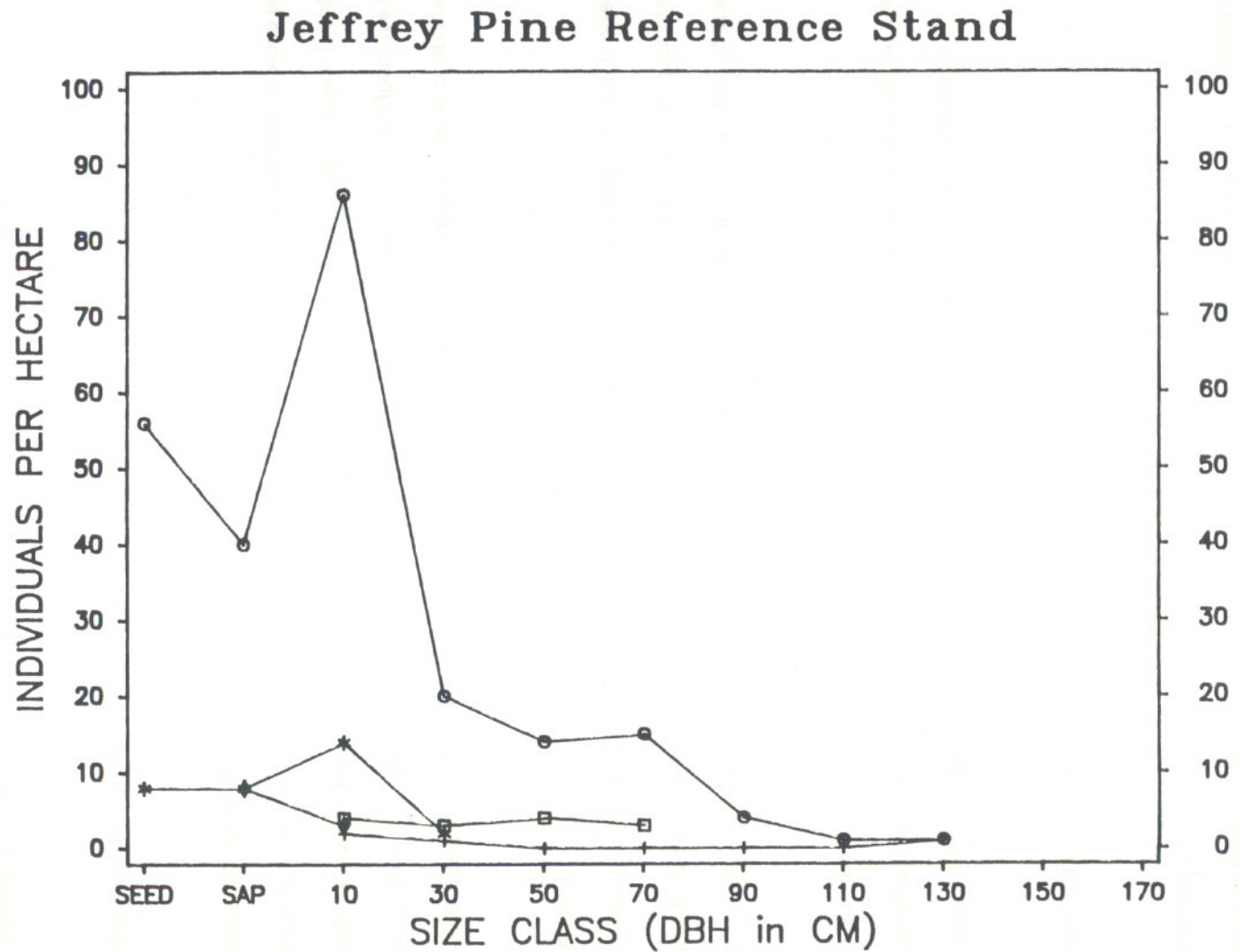


Figure 2-7. Provide numeric and graphic representations of tree species (>DBH in height) by size class per hectare for each reference stand.



Reference Stand, located approximately 0.5 km northeast of the Riparian Giant Sequoia Stand, is on a fork of Crescent Creek.

#### 1. Crescent Creek Riparian Giant Sequoia Reference Stand

This reference stand straddles both sides of the lower section of Crescent Creek (Appendix 1). There is a narrow corridor of herbaceous riparian vegetation. Composition of the overstory is a typical mixed conifer stand dominated by giant sequoia (Rundel et al. 1977).

Giant sequoia comprises three times the volume and over twice the basal area of all other species combined, even though it makes up only six percent of the individuals (Tables 2 and 3). Heights up to 90.7 m and diameters up to 640 cm account for the incredible volume and basal area of this species (Appendix 4).

Size class distribution of all species except giant sequoia follows the typical distribution of an reverse-J shaped (Figure 6). Giant sequoia is the only species having an even distribution throughout the range of size classes. White fir density, frequency, basal area, and volume is greatest of all species, except second in volume and basal area to giant sequoia (Tables 2 and 3). The size class distribution of white fir is nearly identical to the Riparian and White Fir Stands.

#### 2. Upper Crescent Creek Giant Sequoia Reference Stand

Giant sequoia is most abundant in the dominant canopy classes, while white fir is most abundant in the codominant, intermediate, and suppressed canopy classes.

This reference stand is bisected by a stream with moderately steep slopes on either side (Appendix 1). Vegetation structure is similar to the Riparian Giant Sequoia Reference Stand, however overstory

Figure 6.

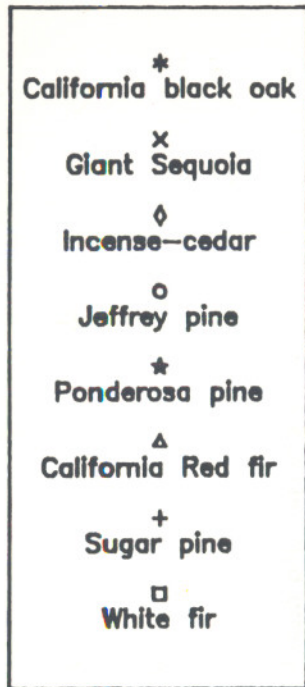
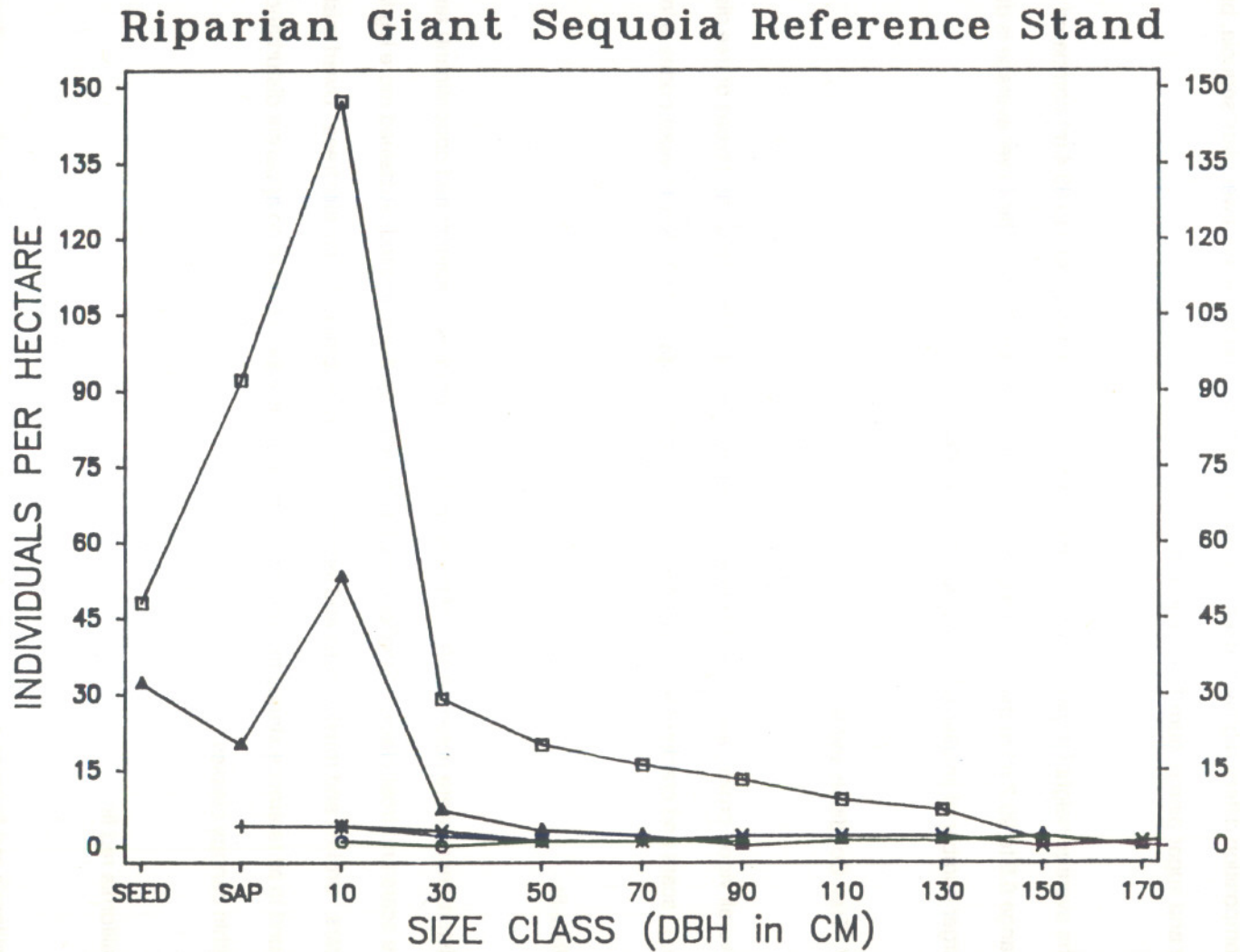


Figure 2-7. Provide numeric and graphic representations of tree species (>DBH in height) by size class per hectare for each reference stand.



composition differs slightly (Tables 2, 3, and 4). In this stand there are fewer giant sequoia, but more white fir and sugar pine (Figure 7, Appendix 4).

The average height for giant sequoia in this stand is 65.1 m (range 38.9 to 83.4 m) compared with 49.6 m (range 6.5 to 90.7 m) in the Riparian Giant Sequoia Reference Stand. This lower average is due to the larger number of smaller sequoia in the Riparian Stand.

#### IV. Tree Condition and Vigor

Overall vigor, crown, and bole condition, rooting medium, and frequency and types of tree disturbances (e.g., scars and cracks) are provided for each species in Appendix 3. Key to vigor codes is in Appendix 2.

##### White fir

Disturbances were noted on 50% of the white fir. Larger trees (dominant and codominant) tended to have fire scars and frost cracks. Smaller trees (intermediate and suppressed) sustained more log fall and animal scars. Broken and multiple tops and leaders were more common in smaller trees. Dwarf mistletoe was found in all reference stands throughout the canopy classes. There is no apparent disturbance pattern within canopy classes.

##### California red fir

California red fir boles and crowns in the codominant canopy classes were usually in excellent condition. Very few disturbances were noted on these larger, more vigorous trees. Smaller, suppressed trees showed more signs of mistletoe and had more pistol butt and crooks.

Figure 7.

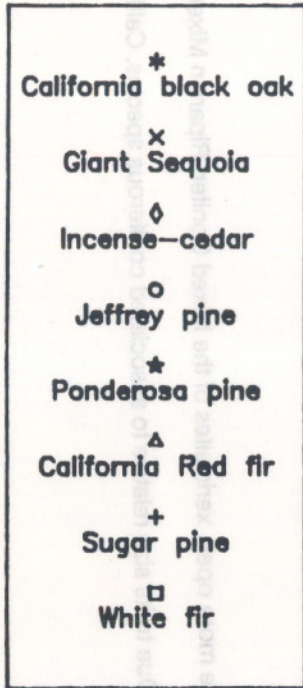
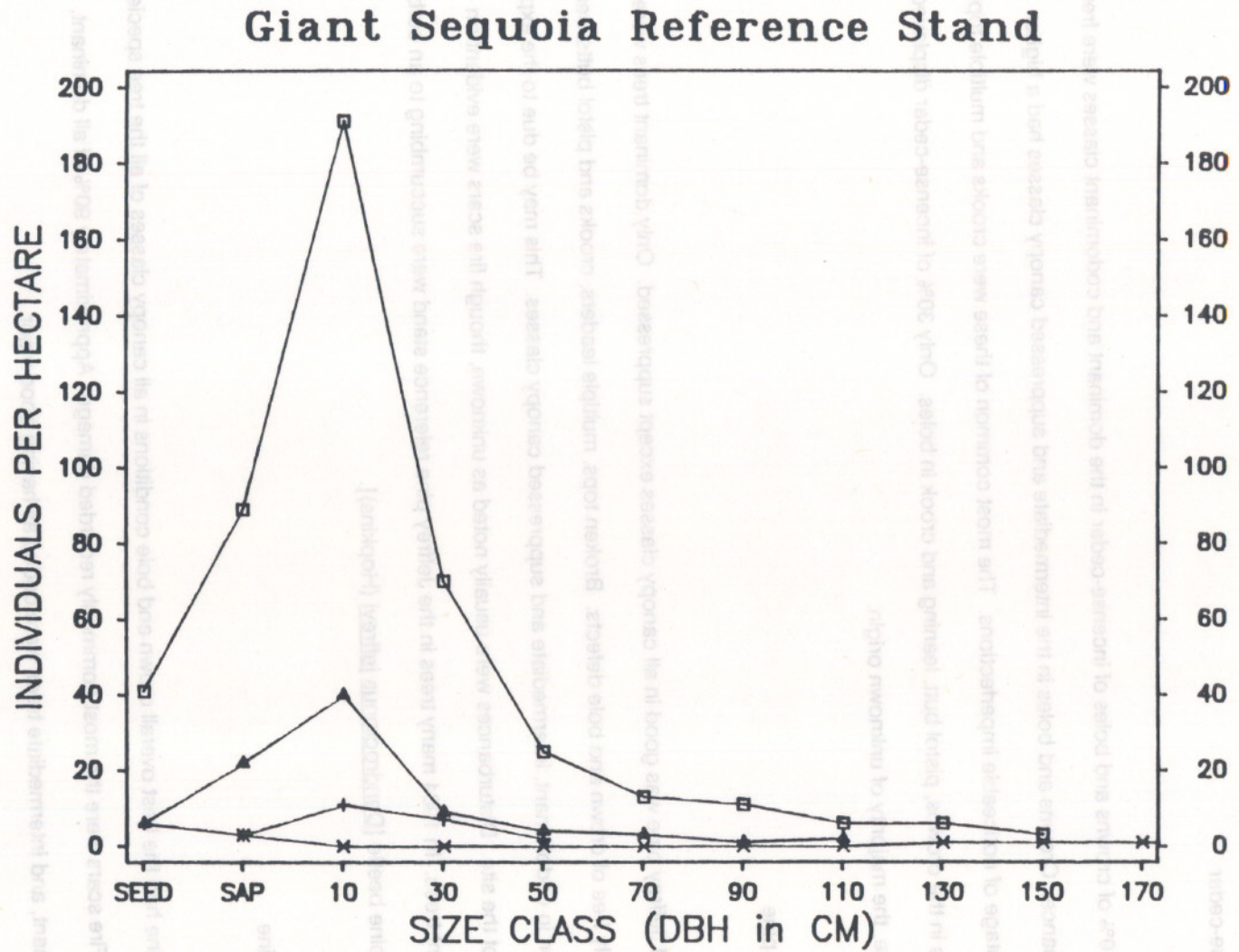


Figure 2-7. Provide numeric and graphic representations of tree species (>DBH in height) by size class per hectare for each reference stand.



Incense-cedar

Over 70% of crowns and boles of incense-cedar in the dominant and codominant classes were free of disturbance. Crowns and boles in the intermediate and suppressed canopy classes had a higher percentage of noticeable imperfections. The most common of these were crooks and multiple tops or leaders in the crowns, pistol butt, leaning and crook in boles. Only 30% of incense-cedar displayed damage, the majority of unknown origin.

Jeffrey pine

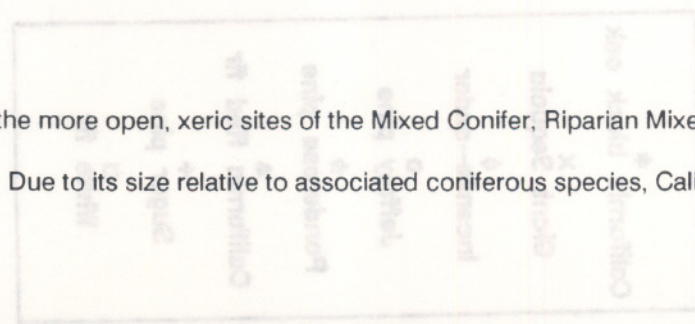
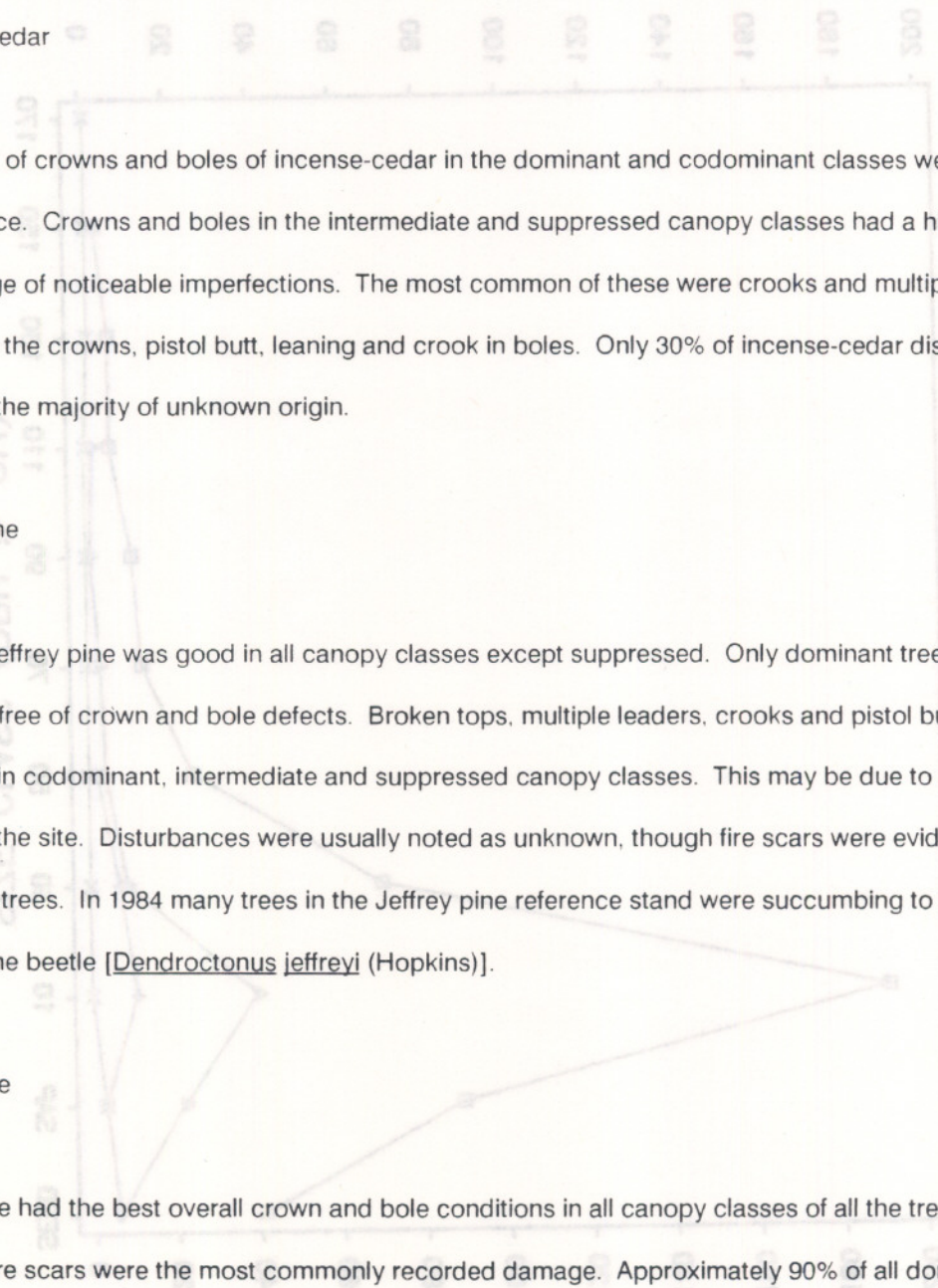
Vigor of Jeffrey pine was good in all canopy classes except suppressed. Only dominant trees were generally free of crown and bole defects. Broken tops, multiple leaders, crooks and pistol butts were common in codominant, intermediate and suppressed canopy classes. This may be due to the exposed nature of the site. Disturbances were usually noted as unknown, though fire scars were evident on dominant trees. In 1984 many trees in the Jeffrey pine reference stand were succumbing to an outbreak of Jeffrey pine beetle [*Dendroctonus jeffreyi* (Hopkins)].

Sugar pine

Sugar pine had the best overall crown and bole conditions in all canopy classes of all the tree species noted. Fire scars were the most commonly recorded damage. Approximately 90% of all dominant, codominant, and intermediate trees were coded as having good vigor.

California black oak.

California black oak is restricted to the more open, xeric sites of the Mixed Conifer, Riparian Mixed Conifer, and Jeffrey Pine Reference Stands. Due to its size relative to associated coniferous species, California



black oak was never rated as a dominant or codominant. Since the growth form of this species cannot be compared with conifers, crown and bole assessments are of little value. Disturbance of some kind, typically unknown, was noted on approximately half of the intermediate trees. Half of the suppressed individuals had log fall scars. Nearly all oaks were rated as having good vigor (see Appendix 2).

#### Giant sequoia

Giant sequoia's typically had broken tops with straight, butt-swollen boles in the dominant and codominant canopy classes. In the intermediate and suppressed canopy classes many trees had leaning or sweeping boles with few crown anomalies. Fire and lightning scars were common on taller trees. Animal scars and frost cracks were associated with smaller trees. Vigor of giant sequoia dominants and codominants was rated good; intermediate and suppressed trees were rated only fair.

### CONCLUSION

These reference stands provide scientists interested in the Sierran mixed conifer forests with pre-described permanent sample plots. They are already being used for a variety of investigations of nutrient cycling in ecosystems, as exemplified by; litter decomposition studies of Stohlgren (NPS), nitrogen dynamics by Matson (NASA, Ames), throughfall and soil solution chemistry of Vitousek (Stanford), and the effects of acid rain by Rundel (UCLA).

These plots also provide baselines for long-term study of tree population and tree decay processes in Sierran mixed conifer forests. All trees have been assessed for mortality (including probable causes) annually since the establishment of the plots. Trees will be remeasured for growth in 1988 and ingrowth (trees reaching 1.37 m dbh) trees recorded and tagged. This is expected to be only the first of many 5-year

remeasurements which will provide a long-term demographic record, perhaps the first, for Sierran mixed conifer forests and species.

The remeasurement program will also provide data on the creation, decomposition, and disappearance of coarse woody debris (snags and logs).

In summary, the reference stands will provide a significant scientific resource for Sequoia and Kings

Canyon National Parks and a basis for measuring natural and man-induced changes in forest condition and composition.

CONCLUSION

These reference stands provide scientists interested in the Sierran mixed conifer forests with pre-described permanent sample plots. They are already being used for a variety of investigations of nutrient cycling in ecosystems, as exemplified by litter decomposition studies of Sequoia (PipS), nitrogen dynamics by Madison (NASA, Aves), throughfall and soil solution chemistry of Visozer (Sirovick), and the effects of and can be found (LCA).

These plots also provide baselines for long-term study of tree population and tree decay processes in Sierran mixed conifer forests. All trees have been assessed for mortality (including probable causes) annually since the establishment of the plots. Trees will be remeasured for growth in 1985 and 1986 (trees reaching 1.37 m dbh) trees recorded and tagged. This is expected to be only the first of many 5-year



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Stem maps of each reference stand  
(see envelope inside back cover)

APPENDIX 1.

## APPENDIX 2.

## Key to Vigor Codes

## CC = Canopy Class

- D Dominant: crown completely above canopy layer, open on top and all sides
- C Co-dominant: composes the canopy layer, not open on all sides
- I Intermediate: mostly beneath canopy, at least 1 side or top exposed to sun
- S Suppressed: completely beneath canopy layer

## OV = Overall Vigor

- 1 OK, good
- 2 Fair
- 3 Poor, dying

(based on comparative foliage color, density of crown & visible signs of suppression)

Crown = Crown Condition (crown is defined as that part above the 1st foliated branch)

- 1 OK
- 2 Broken top
- 3 Multiple tops or leaders
- 4 Dead top
- 5 Unknown top (cannot see to determine condition)
- 6 Half-crowned: crown developed on one side only
- 7 Crook in crown: severe bend in crown
- 8 Mistletoe: visible witches broom or swelling in branches
- 9 Flat top (added in 1984)

Bole = Bole Condition (bole is defined as that part below the 1st foliated branch)

- 1 Good, straight
- 2 Pistol butt
- 3 Butt swell
- 4 Forked or multiple butt
- 5 Leaning
- 6 Grouse or wolf ladder: open grown tree with branches developed to ground
- 7 Sweeping: subtle curve(s) in bole
- 8 Crook: severe bend in bole
- 9 Conks (added in 1983)

## Rooting = Rooting Condition

- 1 Mineral
- 2 Organic (rotting wood)
- 3 Unknown

## Disturbance = Disturbance Condition

- 1 OK, none
- 2 Fire scar
- 3 Log fall scar
- 4 Unknown
- 5 Animal scar
- 6 Frost crack
- 7 Lightning
- 8 Rock fall scar

## APPENDIX 3.

Vigor code values represented by the total number of trees combined (percent/trees per hectare) occurring within the Sequoia National Park reference stands, California.

## White fir

	DOMINANT		CODOMINANT		INTERMEDIATE		SUPPRESSED	
	%	#/ha	%	#/ha	%	#/ha	%	#/ha
OVERALL VIGOR								
GOOD	3.2131	72.8054	10.0321	182.8378	26.3477	482.2064	33.4880	666.4023
FAIR	.1071	2.4842	1.1782	20.3932	3.2488	59.6684	15.4945	297.5479
POOR	.0357	.8850	.2856	5.1549	1.0353	18.2932	5.5337	90.9404
CROWN CONDITION								
GOOD CONDITION	2.1778	52.3347	6.8190	128.9335	17.5295	333.1108	21.5637	445.3465
BROKEN TOP	.2142	4.4128	.8568	15.4453	2.8561	42.6956	3.3559	53.3438
MULTIPLE TOPS	.2856	7.0318	1.1067	17.5795	2.7847	49.3355	5.8551	110.1839
DEAD TOP	.0714	1.5992	.5355	8.4246	.7140	13.4160	2.1064	37.8447
UNKNOWN TOP	.0714	.8000	1.1067	12.5000	.7854	8.9000	.1071	1.3000
HALF-CROWNED	.1428	2.4992	.8568	12.3476	2.8918	42.0351	8.0328	126.5257
CROOK IN CROWN	.0714	1.0000	1.0353	15.8398	5.9622	108.6348	19.6001	
MISTLE TOE	1.1067	24.9723	1.7137	42.0681	2.1064	49.4014	1.9636	44.7981
FLAT TOP	.0357	.5000	.0357	.5000	.0000	.0000	.0000	.0000
BOLE CONDITION								
GOOD	1.7137	40.7908	5.9622	114.7531	10.8890	208.9023	10.7819	244.0643
PISTOL BUTT	.2499	4.4286	1.0710	16.9271	9.7108	172.1839	21.5637	392.5181
BUTT SWELL	.2499	7.4405	.1785	4.7183	.2142	5.1183	.4641	12.1588
FORKED	.0357	1.0000	.1071	1.9111	.2499	5.2476	.5712	8.2246
LEANING	.5355	11.3485	1.9636	31.9511	3.8915	66.5178	10.4963	195.5520
GROUSE LADDER	.0000	.0000	.6426	7.5143	.6783	7.8000	.5355	6.0000
SWEEPING	.4641	9.5669	2.0707	33.6901	6.3192	107.1694	13.2453	225.3900
CROOKS	.2499	4.6985	.6069	11.6787	4.3913	83.9699	17.9222	333.7424
CONKS	.2499	5.1271	.7140	14.0947	.8568	16.3962	1.3567	25.2977

ROOTING CONDITION								
MINERAL	3.2845	74.1746	11.1032	200.5285	30.2749	552.0003	52.9097	1026.3940
ORGANIC	.0000	.0000	.0000	.0000	.0000	.0000	.6426	9.2143
UNKNOWN	.0714	2.0000	.3927	7.8571	.3213	7.2857	.9639	19.2857

DISTURBANCE CONDITION								
NO DISTURBANCE	1.8922	46.0750	6.2121	118.3552	20.9568	396.6031	33.4880	670.7416
FIRE SCAR	.5712	11.0049	1.0353	16.7692	.7140	12.1104	.5355	8.6857
LOGGING SCAR	.3213	5.9564	.5712	10.1699	1.7494	30.2762	3.5345	61.2088
UNKNOWN SCAR	.3213	8.6104	2.9632	53.1632	5.4980	92.4315	14.0307	258.0989
ANIMAL SCAR	.0357	.5000	.0357	.5000	.17853	.8810	1.7137	36.5168
FROST CRACK	.3927	7.1707	1.0353	16.0000	1.7137	28.8874	1.6066	25.7812
LIGHTNING	.0000	.0000	.0714	1.0000	.0000	.0000	.0000	.0000
	.0000	.0000	.0000	.0000	.0714	1.1143	.1071	2.1429

Vigor code values represented by the total number of trees combined (percent/trees per hectare) occurring within the Sequoia National Park reference stands, California.

VIGOR CONDITION								
GOOD CONDITION	3.3663	9.7833	4.8128	8.8878	12.0145	30.8803	13.2011	58.1483
MODERATE CONDITION								
POOR CONDITION								

California red fir

	DOMINANT		CODOMINANT		INTERMEDIATE		SUPPRESSED	
	%	#/ha	%	#/ha	%	#/ha	%	#/ha
OVERALL VIGOR								
GOOD	3.9660	9.5222	8.4986	17.6444	25.4958	47.5143	28.0453	52.1311
FAIR	.0000	.0000	1.4164	2.3000	3.3994	5.7143	18.1303	31.5397
POOR	.0000	.0000	.5666	.9000	.56669	1.0000	.9150	17.3000

CROWN CONDITION								
GOOD CONDITION	2.2663	6.1937	4.8159	9.8619	15.0142	30.9603	13.5977	26.7492
BROKEN TOP	.0000	.0000	.8499	1.7143	3.9660	6.5286	3.1161	5.9111
MULTIPLE TOPS	.0000	.0000	1.9830	4.0429	4.8159	7.9254	7.6487	12.8000
DEAD TOP	.0000	.0000	.0000	.0000	.56662	.8000	.8329	4.3000
UNKNOWN TOP	.5666	.8000	1.6997	2.4000	.0000	.0000	.0000	.0000
HALF-CROWNED	.5666	1.2143	1.6997	2.7143	2.8329	4.1000	6.7989	9.9000
CROOK IN CROWN	.8499	1.7143	1.9830	4.7540	5.6657	8.7143	32.2946	57.1818
MISTLE TOE	.0000	.0000	1.6997	3.2143	1.9830	3.3000	8.4986	15.1143
FLAT TOP	.0000	.0000	.0000	.0000	.5666	1.0000	.2833	.7143

BOLE CONDITION								
GOOD	2.8329	7.0937	6.7989	14.3016	9.3484	18.9238	4.5326	10.5698
PISTOL BUTT	.2833	.7143	1.1331	1.8000	10.4816	19.0048	27.1955	50.3183
BUTT SWELL	.2833	.5000	.0000	.0000	.2833	.4000	.0000	.0000
FORKED	.0000	.0000	.0000	.0000	1.1331	1.6000	.8499	1.2000
LEANING	.0000	.0000	.5666	1.1143	3.1161	5.5254	9.9150	15.3286
GROUSE LADDER	.0000	.0000	.8499	1.2000	.2833	.4000	.0000	.0000
SWEETING	.5666	1.2143	1.4164	2.5143	3.6827	5.7143	15.0142	24.1428
CROOKS	.2833	.5000	.0000	.0000	5.0992	9.6000	29.4618	53.8508
CONKS	.0000	.0000	.5666	1.2143	.2833	.5000	1.9830	3.9286



	ROOTING CONDITION							
MINERAL	3.6827	8.8079	10.4816	20.8444	29.4618	54.2286	56.0907	100.9708
ORGANIC	.2833	.8850	.0000	.0000	.0000	.0000	.0000	.0000
UNKNOWN	.2833	.7143	.0000	.0000	.0000	.0000	.0000	.0000
	DISTURBANCE CONDITION							
NO DISTURBANCE	3.1161	7.5937	6.7989	13.2587	19.2635	35.6238	22.9462	43.3024
FIRE SCAR	.8499	1.9286	1.1331	2.6429	1.9830	5.2476	.5666	1.6111
LOGGING SCAR	.0000	.0000	.0000	.0000	2.2663	3.5143	4.8159	8.8429
UNKNOWN SCAR	.0000	.0000	1.9830	3.5143	5.3824	8.7429	19.2635	32.2143
ANIMAL SCAR	.0000	.0000	.0000	.0000	.2833	.5000	1.9830	3.5000
FROST CRACK	.0000	.0000	1.1331	2.6429	.5666	1.0000	7.3654	13.0000
LIGHTNING	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

Vigor code values represented by the total number of trees combined (percent/trees per hectare) occurring within the Sequoia National Park reference stands, California.

	ROOTING CONDITION							
GOOD	.0000	.0000	.5747	.3143	.0000	.0000	.5183	15.4803
BVIB	.4593	7.4588	.3747	.8820	5.1473	10.0273	16.2192	33.0237
GOOD	.0292	4.0438	3.3750	15.9138	38.1728	187.8438	32.3138	142.2898

CONTINUAL

CONDONIAL

INTERMEDIATE

DETERIORATED

INCURSED-DEPT

Incense-cedar

	DOMINANT		CODOMINANT		INTERMEDIATE		SUPPRESSED	
	%	#/ha	%	#/ha	%	#/ha	%	#/ha
OVERALL VIGOR								
GOOD	.8565	4.0476	3.2120	12.8136	38.1156	161.8496	35.1178	145.5646
FAIR	.4283	1.4286	.2141	.8850	2.1413	10.0913	16.9165	73.0521
POOR	.0000	.0000	.2141	.7143	.0000	.0000	2.7837	12.4603

CROWN CONDITION								
GOOD CONDITION	.8565	4.0476	2.7837	11.2144	28.6938	122.9371	26.5525	115.2866
BROKEN TOP	.2141	.7143	.0000	.0000	2.1413	9.0715	2.3555	8.4246
MULTIPLE TOPS	.2141	.7143	.4283	1.7699	3.4261	16.1350	7.4946	30.6195
DEAD TOP	.0000	.0000	.0000	.0000	.0000	.0000	3.2120	14.2302
UNKNOWN TOP	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
HALF-CROWNED	.2141	.7143	.0000	.0000	1.9272	7.2222	5.9957	23.8571
CROOK IN CROWN	.0000	.0000	.4283	1.5992	6.2098	25.2500	14.5610	58.6753
MISTLE TOE	.0000	.0000	.0000	.0000	.2141	.7143	.2141	1.1111
FLAT TOP	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

BOLE CONDITION								
GOOD	.8565	4.0476	2.1413	9.2422	11.7773	53.2940	7.0664	31.3457
PISTOL BUTT	.0000	.0000	1.0707	3.5714	18.6296	77.6788	19.0578	78.0361
BUTT SWELL	.0000	.0000	.0000	.0000	.6424	2.8810	.2141	.8850
FORKED	.0000	.0000	.0000	.0000	.0000	.0000	.6424	2.9365
LEANING	.0000	.0000	.2141	.7143	5.7816	23.8215	12.8480	54.2582
GROUSE LADDER	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
SWEEPING	.4283	1.4286	.2141	.8850	6.2098	23.6627	13.0621	51.9645
CROOKS	.0000	.0000	.0000	.0000	7.2805	29.2778	20.5567	86.0999
CONKS	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

	ROOTING CONDITION							
MINERAL	1.2848	5.4762	3.2120	12.9843	40.2570	171.9409	53.1049	225.3621
ORGANIC	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
UNKNOWN	.0000	.0000	.2141	.7143	.2141	.7143	1.7131	5.7143

	DISTURBANCE CONDITION							
NO DISTURBANCE	.0000	.0000	2.1413	8.9008	30.1927	135.2506	41.7559	180.8065
FIRE SCAR	.8565	4.0476	.6424	2.4842	1.2848	4.6825	.4283	1.4286
LOGGING SCAR	.2141	.7143	.4283	1.4286	5.1392	19.5238	5.7816	20.8730
UNKNOWN SCAR	.0000	.0000	.2141	.8850	2.9979	10.7382	5.9957	24.9409
ANIMAL SCAR	.2141	.7143	.0000	.0000	.6424	2.1429	.8565	3.0278
FROST CRACK	.0000	.0000	.0000	.0000	.4283	1.4286	.2141	.7143
LIGHTNING	.2141	.7143	.0000	.0000	.0000	.0000	.0000	.0000
	.0000	.0000	.0000	.0000	.4283	1.4286	.0000	.0000

Vigor code values represented by the total number of trees combined (percent/trees per hectare) occurring within the Sequoia National Park reference stands, California.

Jeffrey pine

	DOMINANT		CODOMINANT		INTERMEDIATE		SUPPRESSED	
	%	#/ha	%	#/ha	%	#/ha	%	#/ha
OVERALL VIGOR								
GOOD	19.1781	27.7143	9.5890	14.0000	51.3699	75.0000	10.2740	15.0000
FAIR	.6849	1.0000	.0000	.0000	4.7945	5.71432	.7397	4.0000
POOR	.0000	.0000	.0000	.0000	.6849	1.0000	.6849	.5000

CROWN CONDITION								
GOOD CONDITION	11.6438	16.7143	2.7397	4.0000	26.7123	39.0000	2.7397	4.0000
BROKEN TOP	2.7397	4.0000	2.0548	3.0000	5.4795	7.2143	1.3699	2.0000
MULTIPLE TOPS	4.7945	7.0000	4.1096	6.0000	6.8493	9.5000	3.4247	5.0000
DEAD TOP	.6849	1.0000	.0000	.0000	2.0548	3.0000	1.3699	2.0000
UNKNOWN TOP	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
HALF-CROWNED	.0000	.0000	.6849	1.0000	13.6986	20.0000	5.4795	8.0000
CROOK IN CROWN	2.7397	4.0000	.6849	1.0000	10.2740	14.0000	2.0548	2.5000
MISTLE TOE	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
FLAT TOP	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

BOLE CONDITION								
GOOD	12.3288	18.0000	6.1644	9.0000	18.4932	27.0000	1.3699	2.0000
PISTOL BUTT	4.7945	6.7143	1.3699	2.0000	22.6027	32.2143	4.1096	6.0000
BUTT SWELL	.6849	1.0000	.6849	1.0000	.0000	.0000	.0000	.0000
FORKED	.0000	.0000	.6849	1.0000	2.7397	4.0000	1.3699	2.0000
LEANING	.6849	1.0000	.6849	1.0000	8.2192	11.0000	4.7945	7.0000
GROUSE LADDER	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
SWEEPING	2.0548	3.0000	.0000	.0000	2.7397	3.5000	2.0548	2.5000
CROOKS	2.0548	2.7143	.6849	1.0000	6.8493	10.0000	4.7945	7.0000
CONKS	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

	ROOTING CONDITION							
MINERAL	14.3836	21.0000	8.9041	13.0000	54.7945	78.7143	11.6438	16.5000
ORGANIC	.0000	.0000	.0000	.0000	.6849	1.0000	.0000	.0000
UNKNOWN	5.4795	7.7143	.6849	1.0000	1.3699	2.0000	2.0548	3.0000
	DISTURBANCE CONDITION							
NO DISTURBANCE	12.3288	18.0000	8.2192	12.0000	48.6301	70.2143	8.9041	12.5000
FIRE SCAR	2.7397	3.7143	.6849	1.0000	.0000	.0000	.0000	.0000
LOGGING SCAR	1.3699	2.0000	.0000	.0000	.6849	1.0000	.0000	.0000
UNKNOWN SCAR	3.4247	5.0000	.6849	1.0000	7.5342	10.5000	4.1096	6.0000
ANIMAL SCAR	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
FROST CRACK	.0000	.0000	.0000	.0000	.0000	.0000	.6849	1.0000
LIGHTNING	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

Vigor code values represented by the total number of trees combined (percent/trees per hectare) occurring within the Sequoia National Park reference stands, California.

	VIGOR CONDITION							
GOOD	14.3836	21.0000	8.9041	13.0000	54.7945	78.7143	11.6438	16.5000
FAIR	.0000	.0000	.0000	.0000	.6849	1.0000	.0000	.0000
POOR	5.4795	7.7143	.6849	1.0000	1.3699	2.0000	2.0548	3.0000
	VIGOR CONDITION							
GOOD	12.3288	18.0000	8.2192	12.0000	48.6301	70.2143	8.9041	12.5000
FAIR	2.7397	3.7143	.6849	1.0000	.0000	.0000	.0000	.0000
POOR	1.3699	2.0000	.0000	.0000	.6849	1.0000	.0000	.0000
UNKNOWN	3.4247	5.0000	.6849	1.0000	7.5342	10.5000	4.1096	6.0000
ANIMAL	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
FROST	.0000	.0000	.0000	.0000	.0000	.0000	.6849	1.0000
LIGHTNING	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

Sugar pine

	DOMINANT		CODOMINANT		INTERMEDIATE		SUPPRESSED	
	%	#/ha	%	#/ha	%	#/ha	%	#/ha
OVERALL VIGOR								
GOOD	9.6192	40.5635	7.8156	31.4646	33.6673	128.1584	23.2465	86.5972
FAIR	.0000	.0000	.8016	3.1549	3.6072	14.4288	16.8337	66.3962
POOR	.2004	.5000	.0000	.0000	.2004	.4000	4.0080	16.3139

CROWN CONDITION								
GOOD CONDITION	7.4148	31.3966	7.0140	27.4288	22.8457	89.8875	9.6192	38.0604
BROKEN TOP	1.0020	4.1985	.4008	1.5992	1.4028	5.7215	3.0060	11.3041
MULTIPLE TOPS	.4008	1.5992	.4008	1.7699	3.4068	13.7732	6.2124	24.6101
DEAD TOP	.2004	.7143	.0000	.0000	1.0020	3.8246	6.0120	19.7075
UNKNOWN TOP	.4008	.9000	.0000	.0000	.6012	1.5143	.0000	.0000
HALF-CROWNED	.0000	.0000	.6012	3.1072	3.4068	11.1333	8.2164	27.2778
CROOK IN CROWN	1.0020	4.1985	.2004	.7143	7.0140	25.3415	22.0441	87.9249
MISTLE TOE	.2004	.8850	.4008	1.8254	.4008	1.4286	.2004	.7143
FLAT TOP	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

BOLE CONDITION								
GOOD	7.4148	32.3380	6.2124	26.4496	11.2224	48.3682	4.2084	17.3838
PISTOL BUTT	.4008	1.2850	.6012	2.1429	16.4329	57.8360	15.6313	57.6389
BUTT SWELL	.2004	1.0000	.0000	.0000	.0000	.0000	.2004	.8850
FORKED	.0000	.0000	.0000	.0000	.0000	.0000	1.0020	3.3397
LEANING	1.4028	5.1271	1.0020	3.6985	3.6072	13.8429	12.2244	47.3103
GROUSE LADDER	.0000	.0000	.0000	.0000	.4008	1.5111	.2004	.4000
SWEEPING	.2004	.7143	.0000	.0000	6.0120	20.6398	11.8236	42.9832
CROOKS	.4008	1.3850	1.0020	2.8286	7.8156	28.6376	15.2305	58.4830
CONKS	.2004	.7143	.0000	.0000	.2004	.7143	.4008	1.7699

ROOTING CONDITION								
MINERAL	9.2184	38.9207	8.2164	33.1909	36.6733	139.8441	44.0882	169.3068
ORGANIC	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
UNKNOWN	.6012	2.1429	.4008	1.4286	.8016	3.1429	.0000	.0000
DISTURBANCE CONDITION								
NO DISTURBANCE	6.2124	26.3291	6.0120	25.7353	27.0541	104.4789	25.8517	98.7330
FIRE SCAR	1.8036	7.1113	.2004	.7143	1.2024	4.6825	.8016	2.8571
LOGGING SCAR	.2004	.7143	1.0020	3.2571	3.0060	11.1111	4.8096	18.1072
UNKNOWN SCAR	1.0020	4.7660	.6012	2.2699	5.0100	18.4019	9.4188	35.8356
ANIMAL SCAR	.2004	.7143	.2004	.7143	.8016	3.1985	2.8056	12.2187
FROST CRACK	.6012	2.1429	.4008	1.2143	.8016	2.5429	.4008	1.5992
LIGHTNING	.0000	.0000	.0000	.0000	.0000	.0000	.4008	1.3850
	.0000	.0000	.2004	.7143	.2004	.7143	.0000	.0000

Vigor code values represented by the total number of trees combined (percent/trees per hectare) occurring within the Sequoia National Park reference stands, California.

Ponderosa pine

DOMINANT % #/ha CODOMINANT % #/ha INTERMEDIATE % #/ha SUPPRESSED % #/ha

OVERALL VIGOR

GOOD	.0000	.0000	.0000	.0000	.0000	.0000	.0000
FAIR	.0000	.0000	.0000	.0000	.0000	.0000	.0000
POOR	.0000	.0000	.0000	.0000	.0000	100.0000	1.7699

CROWN CONDITION

GOOD CONDITION	.0000	.0000	.0000	.0000	.0000	.0000	.0000
BROKEN TOP	.0000	.0000	.0000	.0000	.0000	.0000	.0000
MULTIPLE TOPS	.0000	.0000	.0000	.0000	.0000	50.0000	.8850
DEAD TOP	.0000	.0000	.0000	.0000	.0000	50.0000	.8850
UNKNOWN TOP	.0000	.0000	.0000	.0000	.0000	.0000	.0000
HALF-CROWNED	.0000	.0000	.0000	.0000	.0000	.0000	.0000
CROOK IN CROWN	.0000	.0000	.0000	.0000	.0000	100.0000	1.7699
MISTLE TOE	.0000	.0000	.0000	.0000	.0000	.0000	.0000
FLAT TOP	.0000	.0000	.0000	.0000	.0000	.0000	.0000

BOLE CONDITION

GOOD	.0000	.0000	.0000	.0000	.0000	.0000	.0000
PISTOL BUTT	.0000	.0000	.0000	.0000	.0000	50.0000	.8850
BUTT SWELL	.0000	.0000	.0000	.0000	.0000	.0000	.0000
FORKED	.0000	.0000	.0000	.0000	.0000	.0000	.0000
LEANING	.0000	.0000	.0000	.0000	.0000	50.0000	.8850
GROUSE LADDER	.0000	.0000	.0000	.0000	.0000	.0000	.0000
SWEEPING	.0000	.0000	.0000	.0000	.0000	.0000	.0000
CROOKS	.0000	.0000	.0000	.0000	.0000	50.0000	.8850
CONKS	.0000	.0000	.0000	.0000	.0000	.0000	.0000



	ROOTING CONDITION							
MINERAL	.0000	.0000	.0000	.0000	.0000	.0000	100.0000	1.7699
ORGANIC	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
UNKNOWN	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

	DISTURBANCE CONDITION							
NO DISTURBANCE	.0000	.0000	.0000	.0000	.0000	.0000	50.0000	.8850
FIRE SCAR	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
LOGGING SCAR	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
UNKNOWN SCAR	.0000	.0000	.0000	.0000	.0000	.0000	50.0000	.8850
ANIMAL SCAR	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
FROST CRACK	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
LIGHTNING	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

Vigor code values represented by the total number of trees combined (percent/trees per hectare) occurring within the Sequoia National Park reference stands, California.

California black oak

	DOMINANT		CODOMINANT		INTERMEDIATE		SUPPRESSED	
	%	#/ha	%	#/ha	%	#/ha	%	#/ha
OVERALL VIGOR								
GOOD	.0000	.0000	.0000	.0000	63.8889	21.1707	33.3333	9.0834
FAIR	.0000	.0000	.0000	.0000	2.7778	.8850	.0000	.0000
POOR	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
CROWN CONDITION								
GOOD CONDITION	.0000	.0000	.0000	.0000	27.7778	8.4564	5.5556	1.7699
BROKEN TOP	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
MULTIPLE TOPS	.0000	.0000	.0000	.0000	36.1111	12.8850	5.5556	1.5992
DEAD TOP	.0000	.0000	.0000	.0000	5.5556	1.7143	2.7778	.7143
UNKNOWN TOP	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
HALF-CROWNED	.0000	.0000	.0000	.0000	2.7778	1.0000	.0000	.0000
CROOK IN CROWN	.0000	.0000	.0000	.0000	19.4444	5.4564	27.7778	7.3135
MISTLE TOE	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
FLAT TOP	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
BOLE CONDITION								
GOOD	.0000	.0000	.0000	.0000	8.3333	2.8850	5.5556	1.7699
PISTOL BUTT	.0000	.0000	.0000	.0000	2.7778	1.0000	19.4444	5.0000
BUTT SWELL	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
FORKED	.0000	.0000	.0000	.0000	25.0000	9.0000	.0000	.0000
LEANING	.0000	.0000	.0000	.0000	22.2222	7.8850	22.2222	5.8850
GROUSE LADDER	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
SWEEPING	.0000	.0000	.0000	.0000	2.7778	.8850	.0000	.0000
CROOKS	.0000	.0000	.0000	.0000	19.4444	5.1707	27.7778	7.3135
CONKS	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

ROOTING CONDITION								
MINERAL	.0000	.0000	.0000	.0000	38.8889	12.0556	33.3333	9.0834
ORGANIC	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
UNKNOWN	.0000	.0000	.0000	.0000	27.7778	10.0000	.0000	.0000
DISTURBANCE CONDITION								
NO DISTURBANCE	.0000	.0000	.0000	.0000	30.5556	10.7699	11.1111	3.3692
FIRE SCAR	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
LOGGING SCAR	.0000	.0000	.0000	.0000	5.5556	2.0000	19.4444	5.0000
UNKNOWN SCAR	.0000	.0000	.0000	.0000	30.5556	9.2857	2.7778	.7143
ANIMAL SCAR	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
FROST CRACK	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
LIGHTNING	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

Vigor code values represented by the total number of trees combined (percent/trees per hectare) occurring within the Sequoia National Park reference stands, California.

CROWN CONDITION								
GOOD	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
FAIR	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
POOR	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

ROOTING CONDITION								
GOOD	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
FAIR	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
POOR	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

Giant Sequoia

	DOMINANT		CODOMINANT		INTERMEDIATE		SUPPRESSED	
	%	#/ha	%	#/ha	%	#/ha	%	#/ha
OVERALL VIGOR								
GOOD	50.6173	18.4000	23.4568	8.7000	1.2346	.4000	3.7037	1.4000
FAIR	2.4691	1.0000	1.2346	.4000	7.4074	3.0000	4.9383	1.9000
POOR	.0000	.0000	1.2346	.5000	.0000	.0000	3.7037	1.5000

CROWN CONDITION								
GOOD CONDITION	29.6296	10.5000	13.5802	4.9000	1.2346	.5000	2.4691	1.0000
BROKEN TOP	3.7037	1.5000	2.4691	1.0000	1.2346	.5000	1.2346	.4000
MULTIPLE TOPS	7.4074	3.0000	4.9383	2.0000	.0000	.0000	1.2346	.5000
DEAD TOP	2.4691	1.0000	2.4691	1.0000	.0000	.0000	3.7037	1.5000
UNKNOWN TOP	9.8765	3.3000	2.4691	.8000	.0000	.0000	.0000	.0000
HALF-CROWNED	.0000	.0000	2.4691	.9000	1.2346	.5000	2.4691	.8000
CROOK IN CROWN	6.1728	2.5000	3.7037	1.3000	7.4074	2.9000	7.4074	3.0000
MISTLE TOE	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
FLAT TOP	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

BOLE CONDITION								
GOOD	28.3951	9.5000	8.6420	2.9000	1.2346	.5000	1.2346	.5000
PISTOL BUTT	1.2346	.5000	1.2346	.5000	1.2346	.5000	4.9383	1.9000
BUTT SWELL	18.5185	7.5000	9.8765	3.9000	1.2346	.5000	1.2346	.4000
FORKED	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
LEANING	4.9383	2.0000	9.8765	3.9000	2.4691	1.0000	4.9383	2.0000
GROUSE LADDER	.0000	.0000	1.2346	.4000	.0000	.0000	.0000	.0000
SWEEPING	8.6420	3.4000	2.4691	1.0000	3.7037	1.4000	1.2346	.4000
CROOKS	2.4691	1.0000	.0000	.0000	1.2346	.5000	3.7037	1.5000
CONKS	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

ROOTING CONDITION

MINERAL	53.0864	19.4000	25.9259	9.6000	8.6420	3.4000	11.1111	4.3000
ORGANIC	.0000	.0000	.0000	.0000	.0000	.0000	1.2346	.5000
UNKNOWN	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

DISTURBANCE CONDITION

NO DISTURBANCE	8.6420	2.8000	12.3457	4.4000	2.4691	.9000	4.9383	1.9000
FIRE SCAR	34.5679	12.6000	7.4074	2.7000	.0000	.0000	2.4691	.9000
LOGGING SCAR	.0000	.0000	1.2346	.5000	.0000	.0000	.0000	.0000
UNKNOWN SCAR	7.4074	2.9000	2.4691	1.0000	2.4691	1.0000	1.2346	.5000
ANIMAL SCAR	.0000	.0000	.0000	.0000	1.2346	.5000	1.2346	.5000
FROST CRACK	4.9383	2.0000	2.4691	1.0000	2.4691	1.0000	3.7037	1.5000
LIGHTNING	.0000	.0000	1.2346	.5000	.0000	.0000	.0000	.0000
	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

APPENDIX 4.

Size class distribution (10 cm intervals) of trees occurring within Sequoia National Park reference stands, California (trees per hectare).

Reference Stand	Seedling	Sapling	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100-110	110-120	120-130	130-140	140-150
<b>Mixed Conifer</b>																	
White fir	233	141	274	66	36	32	19	11	11	7	6	4	5	4	2	--	--
California red fir	---	---	---	1	--	--	--	--	--	--	--	--	--	--	--	--	--
Incense-cedar	14	28	27	15	11	5	2	--	2	--	1	2	1	--	--	--	--
Sugar pine	28	35	73	21	9	9	5	5	4	2	5	5	2	5	2	3	2
Ponderosa pine	---	---	1	1	--	--	--	--	--	--	--	--	--	--	--	--	--
California black oak	21	---	3	2	--	--	--	--	--	--	--	--	--	--	--	--	--
<b>Riparian Mixed Conifer</b>																	
White fir	58	110	228	56	34	22	21	9	7	5	9	6	2	1	1	3	--
California red fir	---	---	10	7	1	1	2	--	1	1	2	4	1	--	--	--	--
Incense-cedar	6	12	81	32	10	8	3	4	--	1	1	--	1	1	--	--	1
Jeffrey pine	---	---	---	1	--	--	--	--	--	--	--	--	--	--	--	1	--
Sugar pine	35	12	62	31	16	9	6	4	4	2	4	1	1	1	2	---	1
California black oak	---	---	11	--	--	--	--	--	--	--	--	--	--	--	--	--	--
<b>White Fir</b>																	
White fir	100	209	188	96	60	36	20	14	13	6	6	6	4	2	3	1	1
California red fir	---	---	8	4	1	2	1	2	1	1	3	1	--	1	--	--	--
Incense-cedar	55	45	111	47	30	8	3	8	1	2	--	--	--	--	--	2	1
Sugar pine	18	27	13	10	14	11	2	2	1	3	2	--	1	--	1	2	--
<b>Jeffrey Pine</b>																	
White fir	---	---	3	1	3	--	1	3	3	--	--	--	--	--	--	--	--
Incense-cedar	---	8	3	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Jeffrey pine	56	40	53	33	12	8	8	6	8	7	1	3	--	1	--	1	--
Sugar pine	---	---	1	1	--	1	--	--	--	--	--	--	--	--	1	--	--
California black oak	8	8	7	7	2	--	--	--	--	--	--	--	--	--	--	--	--

HOLTING CONDITION

Reference Stand	Seedling	Sapling	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
			0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100-110	110-120	120-130	130-140	140-150
<b>Riparian Giant Sequoia</b>																	
White fir	48	92	118	29	18	11	12	8	7	9	7	6	4	5	4	3	--
California red fir	32	20	41	12	5	2	1	2	2	--	--	--	--	1	--	1	1
Jeffrey pine	---	---	---	1	--	--	1	--	--	--	--	--	--	--	--	--	--
Sugar pine	---	4	2	2	1	1	1	--	1	--	1	--	--	--	--	--	--
Giant Sequoia	---	---	3	1	2	1	--	1	1	--	1	1	2	--	1	1	--
<b>Giant Sequoia</b>																	
White fir	41	89	123	68	42	28	14	11	8	5	6	5	3	3	4	2	2
California red fir	6	22	28	12	5	4	4	--	2	1	--	1	1	1	--	--	--
Sugar pine	6	3	6	5	4	3	1	1	--	--	--	--	--	--	--	--	--
Giant Sequoia	---	3	---	--	--	--	--	--	--	--	--	--	--	--	--	1	--

APPENDIX 4. (continued)

Reference Stand	15	16	17	18	19	20	21	22	23	24	25	26	27	28
	150-160	160-170	170-180	180-190	190-200	200-250	250-300	300-350	350-400	400-450	450-500	500-550	550-600	600-650
<b>Mixed Conifer</b>														
White fir	1	--												
California red fir	--	--												
Incense-cedar	--	--												
Sugar pine	--	--												
Ponderosa pine	--	--												
California black oak	--	--												
<b>Riparian Mixed Conifer</b>														
White fir	--	--												
California red fir	--	--												
Incense-cedar	--	--												
Jeffrey pine	--	--												
Sugar pine	1	1												
California black oak	--	--												
<b>White Fir</b>														
White fir	--	--												
California red fir	--	--												
Incense-cedar	--	--												
Sugar pine	--	--												
<b>Jeffrey Pine</b>														
White fir	--	--	50	15	2	5	1	5	1	1	1	1	1	1
Incense-cedar	--	--	100	60	15	30	15	11	9	2	2	2	2	2
Jeffrey pine	--	--												
Sugar pine	--	--												
California black oak	--	--	2	1	3	1	--	1	1	--	1	3	--	1
<b>Riparian Giant Sequoia</b>														
White fir	1	--	1	1	--	1	1	1	1	1	1	1	1	1
California red fir	1	--	1	1	1	1	1	1	1	1	1	1	1	1
Jeffrey pine	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Sugar pine	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Giant Sequoia	--	1	--	1	1	6	2	1	1	1	1	1	1	1



APPENDIX 4. (continued)

Reference Stand	15	16	17	18	19	20	21	22	23	24	25	26	27	28
	150-160	160-170	170-180	180-190	190-200	200-250	250-300	300-350	350-400	400-450	450-500	500-550	550-600	600-650
Giant Sequoia														
White fir	1	--	--	--	--									
California red fir	--	--	--	--	--									
Sugar pine	--	--	--	--	--									
Giant Sequoia	1	--	1	--	--	3	1	--	1	1	1	1	--	1

Giant sequoia  
 ponderosa pine  
 sugar pine  
 Jeffrey pine  
 incense cedar  
 California red fir  
 white fir  
 sequoia

$V_{0.1} = (e_g)(DBH_{0.1})^2$   
 Equations for stem volume in reference stands  
 APPENDIX 4

APPENDIX 5.

Equations for stem volumes in reference stands.

$$\text{Volume} = (e^a)(\text{DBH}^b)$$

Species	a	b
White fir	-10.0668	2.73151
California red fir	-10.7233	2.89392
Incense cedar	-11.4183	2.89458
Jeffrey pine	-12.0955	3.10825
Sugar pine	-9.91941	2.68219
Ponderosa pine	-12.0955	3.10825
Giant sequoia	-9.90024	2.56974

Great sequoia  
 white fir  
 California red fir  
 white fir  
 Great sequoia

Reference stand

APPENDIX 5 (cont.)

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