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Forest Growth and Stand Structure at Blodgett Forest Research Station 1933-95

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A. INTRODUCTION

This report summarizes results of analyses of data collected at Blodgett Forest Research Station (hereafter referred to as the Forest) from 1933 to 1995. This data set represents the longest existing set of time-series information on the effects of alternative silvicultural treatments on stand growth and development of mixed conifer forests. As such, it can be used as a benchmark in evaluating the likely consequences of alternative scenarios for the management of Sierran Forests on forest sites of similar productivity. The first part of this report describes the nature of the Forest and its management since its inception in 1933, and the second compares the effects of alternative silvicultural treatments on growth, yield, and stand structure, regeneration, and fuel accumulation.

B. Blodgett Forest and its Compartment Structure

The University of California at Berkeley's 3,000 ac Blodgett Forest Research Station is managed by the Department of Environmental Science, Policy, and Management, College of Natural Resources. It is located in the Sierran mixed conifer type (Guide to Wildlife Habitat in California, Mayer and Laudenslayer 1988) on the west side of the Sierra Nevada between 3900 and 4800 feet, near Georgetown, California, along the Georgetown Divide. Most of the Forest was acquired as a gift in 1933 from the Michigan-California Lumber Company. In 1963, an inholding of 160 ac was purchased from the Bacchi family.

Prior to the turn of the century some trees were probably taken from the Forest during the gold rush and to construct the Georgetown Ditch which was built to transport water from Loon Lake and Pilot Creek to Georgetown. Just at or after the turn of the century, logging began in earnest using narrow gauge railroad with access and ground skidding by cable steam engines. Nearly the entire area was harvested. In approximately three different entries, 1900, 1908, and 1913, probably the majority of timber volume was removed from the Forest and much of the forest was burned to reduce logging slash.

The Forest is managed to provide opportunities for research, teaching and demonstration. As the Forest developed from primarily brushfields to vigorous young-growth stands, the research program broadened from studies on regeneration to all aspects of forest ecology and management. Since the late 1950s, literally hundreds of research projects have been conducted and reported (See Bibliography of Publications Based on Blodgett Forest Research, Nov. 1993, 49 p.). Since 1957, an annual timber harvest has been tailored to develop a continuing series of age classes and diverse stand structures for research. The timber sales are conducted in a manner equivalent to that used by a private forest landowner. Currently, timber harvest plans are submitted to and approved by the California Department of Forestry and Fire Protection. Timber sales are advertized regionally and logs are offered and sold to the highest bidder. The actual logging is :ontracted separately to a licensed timber operator.

The Forest has 109 compartments dedicated to various management schemes designed to provide a diversity of stand structures (Figures 1a and 1b). In general there are five broad

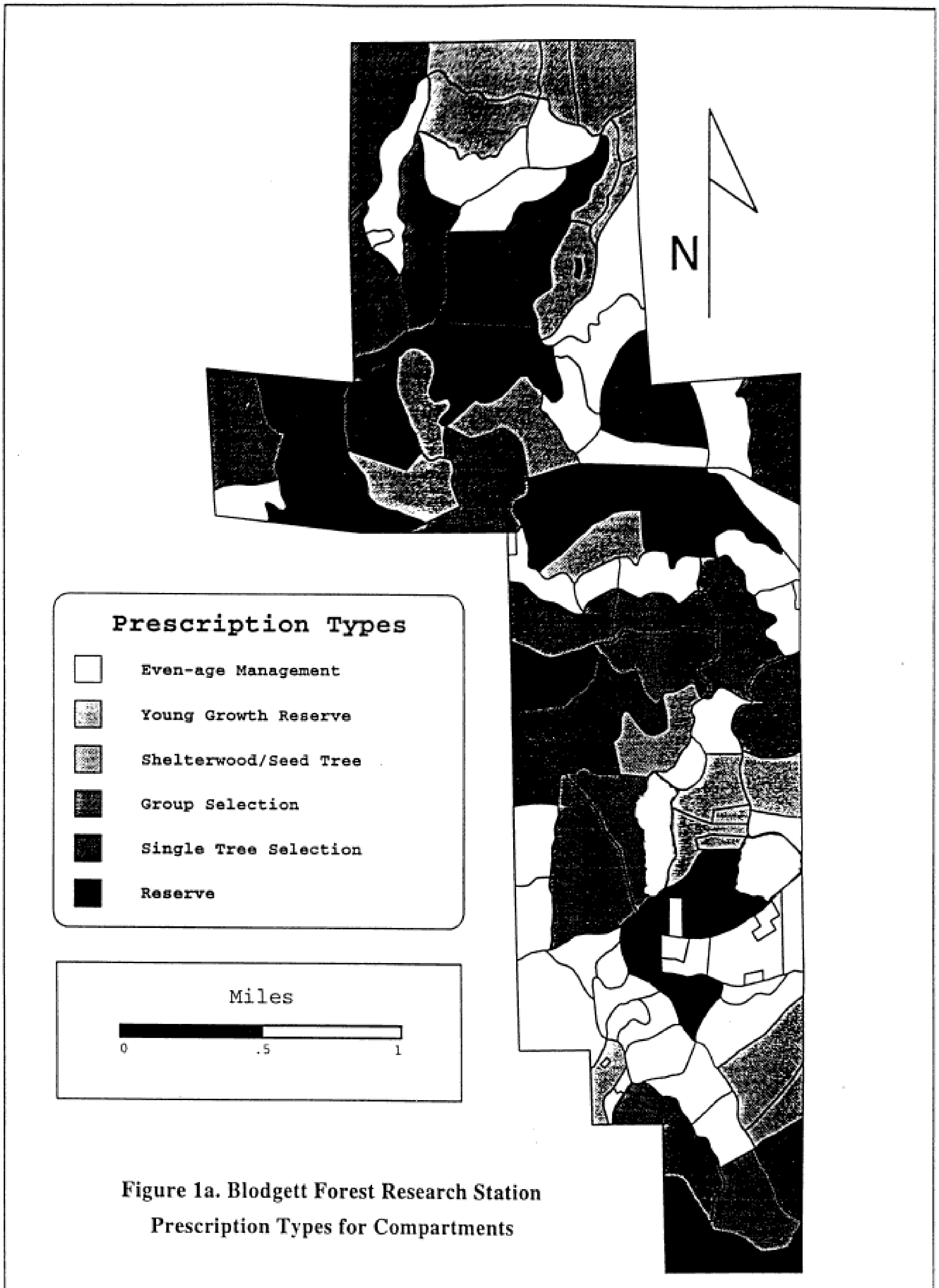

Figure 1a. Blodgett Forest Research Station Prescription Types for Compartments

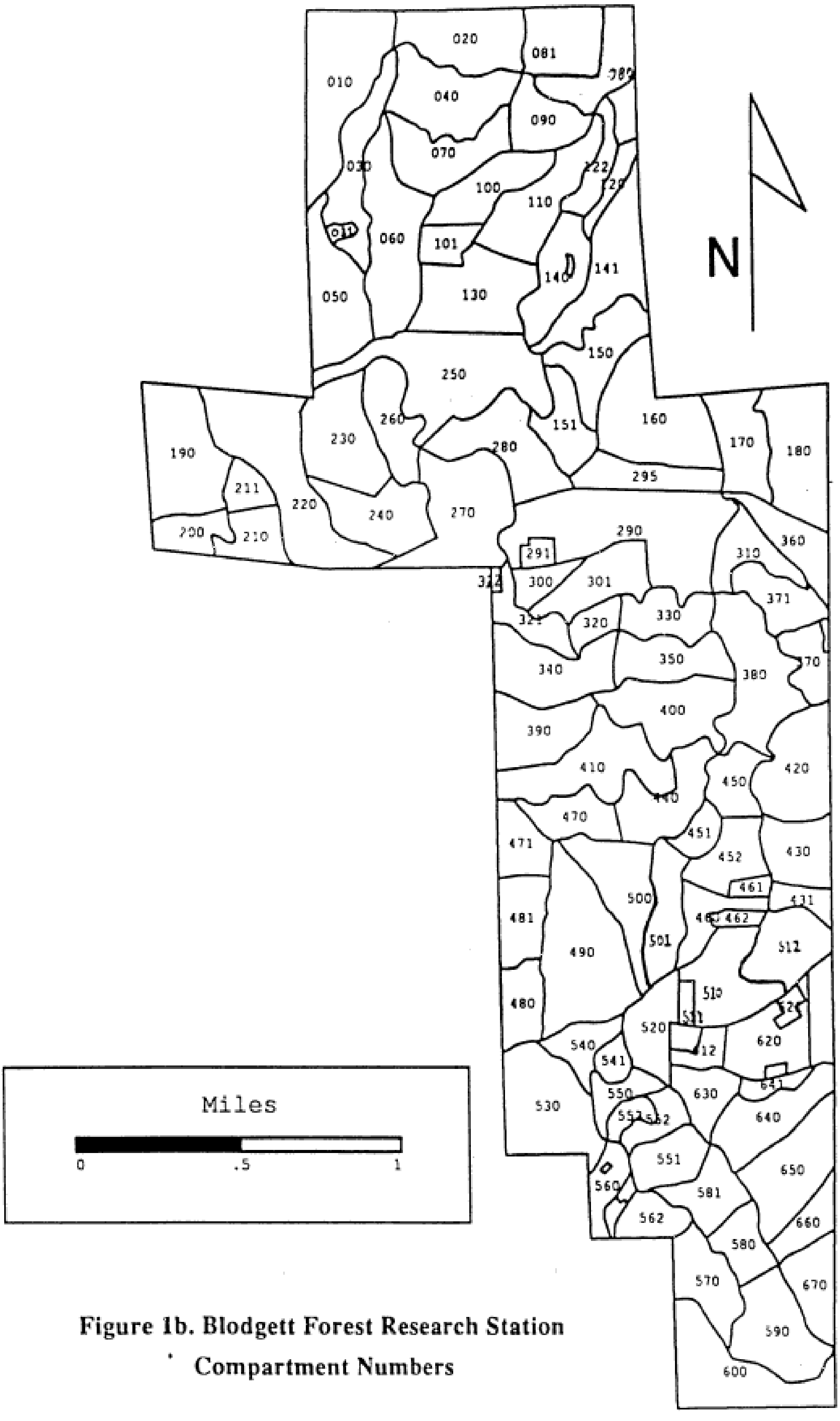

Figure 1b. Blodgett Forest Research Station Compartment Numbers

categories: uneven-aged management, even-aged management, administrative reserve, ecological or old-growth reserve, and research reserve. Within each of these categories there are one to several different management prescriptions as set forth in the Forest's guiding document "Policy for Use of Blodgett Forest Research Station, June 1, 1987 (editorial revisions April 5, 1989)".

1) Uneven-aged Management There are approximately 1086 acres in 26 compartments assigned to uneven-aged management. There are two regeneration methods -- group selection and single-tree slection. The desired residual stand structure has been defined as having a diminution quotient of 1.2 and a growing stock level of 120 to 180 sq ft /ac and maximum tree diameter of 30-36 inches.

a) Group selection Fourteen compartments (734 ac, Table 1) have been assigned to group selection. One- to two-ac groups comprising 10-15 percent of the area within each compartment are removed with a cutting cycle of approximately 10 years. Two entries have been made in most compartments in the 1970s, 1980s, and 1990s. In addition, compartments 50 and 420 had entries in the late 1950s and early 1960s. Competing vegetation has been controlled using cattle grazing, herbicide application, and mechanical removal.

Table 1. Group selection compartments and number of acres.

Compartment #	Acres
10	58.7
50	44.5
60	56.2
180	49.4
190	53.7
270	56.9
340	41.3
350	30.9
380	55.6
400	41.9
420	43.2
490	72.3
500	40.2
562	17.3
570	30.3
590	42.0
Total	734.4

b) Single-tree selection Eight compartments (318 ac, Table 2) have been assigned to single-tree selection. Single trees or very small groups of less than 0.2 ac are removed with a cutting cycle of approximately 10 years. Most compartments have had two entries in the 1970s and 1980s. In compartments 160, 230, 420, and 500 three entries have been made beginning in the late 1950s.

Competing vegetation has been controlled by cattle grazing and occasional herbicide application.

Table 2. Single-tree selection compartments and number of acres.

Compartment #	Acres
101	11.7
110	42.0
130	50.0
160	56.8
230	44.5
410	49.4
470	21.0
471	19.2
670	22.9
Total	317.5

2) Even-aged Management There are approximately 1,045 acres in compartments assigned to even-aged management. Three regeneration methods are used: shelterwood, seed-tree, and clearcutting. The expected rotation age is 60 to 90 years with the longer rotation providing a vegetation structure with larger trees.

a) Shelterwood Applied to four compartments (97 ac, Table 3). In each case, a residual stand of about 15 trees per acre totalling approximately 50 ft^2/ac basal area is used to provide shelter and seed for regeneration. The residual stand is removed in approximately 8-10 years, that is, after the establishment of the new stand.

Table 3. Shelterwood compartments, acres within each compartment, and the year harvested.

Compartment #	Acres	Year Harvested
80	20.5	1973 prep*, 1986 seed[+], 1994 overwood[x]
81	33.2	1973 prep, 1986 seed
280	43.3	1979 seed, 1986 overwood
Total	97.0	

* The prepartory step is used to prepare the shelter-seed trees to be wind firm and large crown seed producers.

[+] The seed step removes the majority of the trees leaving the shelter-seed trees.

[x] After a new stand is established under the shelter-seed trees the shelter-seed trees or overwood are removed (in approximately 8-10 years).

b) Seed-tree Applied to one compartment (Table 4). A preparatory partial harvest was done to isolate the intended seed trees to encourage wind firmness. At final harvest, five to six well-distributed trees per acre of good form, representing the appropriate species mix, were retained to provide seed. The seed trees were cut after establishment of regeneration, usually about 7 years. Based upon a regeneration analysis additional seedlings were planted to augment natural regeneration.

Table 4. Seed tree compartments, size, and year harvested.

Compartment #	Acres	Year Harvested
301	27.8	1983 seed⁺, 1986 overwood*

⁺ The seed step removes the majority of the trees leaving the seed trees.

* After a new stand is established under the seed trees the seed trees or overwood are removed (in approximately 3-5 years).

c) Clearcutting Forty nine compartments (864 ac, Table 5) are designated to the clearcutting regeneration method. In the year after harvest, the compartments are planted to a stocking of at least 340 seedlings per acre, targeting an even distribution in the number of seedlings for each of the five major native conifers. Hardwoods (pricipally oak and tanoak) are regenerated by coppice.

Table 5. Clearcutting compartments, acres within each compartment, and the year harvested.

Compartment #	Acres	Year Harvested
30	34.0	
31	3.7	65
70	39.6	
90	25.9	
100	27.8	
141	45.1	90
150	32.7	
151	22.9	82
170	32.1	
200	18.5	80
295	22.9	
320	10.5	
321	17.3	80
322	1.2	80
330	22.2	91
360	21.6	84
370	16.7	84
371	22.5	85
372	1.0	84
431	9.9	88
450	20.3	
451	9.3	69
480	19.2	91
481	20.4	75
501	24.0	86,87
511	4.9	83

512	31.0	93
530	54.9	
540	16.1	
541	7.4	
550	11.7	
551	21.6	
552	12.4	
553*	7.4	85
560	13.6	84
561*	1.2	68
563*	3.1	78
564	0.6	83
580	20.4	
581*	22.9	69
611*	5.6	64
612*	10.5	78
620*	29.0	85
621	4.3	88
622	1.2	88
623	11.5	
624	10.0	90
640*	34.0	85
641*	7.4	77
Total	864.0	

* Converted from brushfields

3) Ecological or Old Growth Reserve There are approximately 349 acres in 12 compartments set aside as ecological or old growth reserves (Table 6).

Table 6. Ecological or old growth reserve compartments and number of acres.

Compartment #	Acres
210	15.4
220	61.8
221	1.0
290*	96.4
291	4.9
300	9.9
310	22.8
390*	32.8
510*	35.1
521	3.0
600	48.2
630	17.9
Total	349.2

*Principally old growth; the remainder are 70-80 year old young growth

4) Administrative Reserve There are approximately 125 acres in five compartments set aside as administrative reserves to protect visual and cultural values as well as structures and other physical improvements (Table 7).

Table 7. Administrative reserve compartments and number of acres.

Compartment #	Acres
142	1.0
211	10.5
250	85.2
291	4.9
520	22.9
Total	124.5

5) Young Growth Reserve There are 355 acres in 15 compartments assigned as young growth reserves (Table 8). Young growth reserves are intended to be harvested 90 years after they are regenerated. Following harvest the compartments will be regenerated to an appropriate mix of the six principle tree species. During the rotation no silvicultural activites, such as thinning or herbicide use, will occur.

Table 8. Young growth reserve compartments and number of acres.

Compartment #	Acres
20	41.4
40	44.5
120	7.4
121	6.8
122	14.8
140	31.1
240	37.7
260	30.2
430	26.6
452	25.3
460	17.3
461	4.9
462	6.2
650	45.7
660	14.8
Total	354.7

Soils

There are four main soil types found within Blodgett Forest. Three of the soil types, Musick, Holland, and Bighill, are developing in place on granite parent material. The four type, Cohasset, is developing in place on andesite parent material. Each can be characterized as well drained sandy-loam that are 3 to 6 feet with low to moderate erosion hazard rating on slopes less than 30 percent (California Code of Regulations, Title 14). Exposed mineral soil on slopes over 30 Percent is subject to high hazard for sheet and surface rill erosion. There are three other soil types that occur within the forest - Jocal, Aquecept, and Crozier. The major soil types have the capacity to grow the principal conifers of the area (excluding incense-cedar) to 90-100 feet in 50 years and are considered Dunning (1942) Site I.

Climate

The climate at Blodgett Forest is characterized by cool wet winters and warm dry summers. The mean annual precipatation from 1962 to 1995 was 62.3 inches, 78 percent of which falls in the five months, November to March (Table 9). The maximum annual precipatation during that period was 108.7 inches in 1981-1982 and the minimum was 26.6 inches in 1976-1977. During the winter about 35 percent of the precipitation falls as snow, averaging about 100 inches per year. The average minimum temperature in January over the period was 33°F and the average maximum temperature in July is 83 °F. Frosts can occur in any month but are rare from June to September.

Table 9. Average maximum and average minimum temperature (°F) and average precipitation (inches) at the BFRS weather station 1962 to 1995[1].

Month	Average Maximum °F	Average Minimum °F	Average Precipitation (inches)
January	46	33	11.14
February	48	33	9.30
March	50	34	9.21
April	56	37	5.14
May	67	45	2.03
June	75	52	0.83
July	83	59	0.34
August	83	59	0.33
September	76	54	1.19
October	64	46	3.93
November	50	37	8.53
December	46	33	10.37

C. Forest Inventory

Over the years as forest condition and management objectives have changed, various methods have been used to assess vegetation on the Forest. Today, there is a forestwide

[1] From: Schurr, F.G. 1995. Unpublished Report. Blodgett Forest Research Station, Georgetown, CA.

system of permanent plots and a variety of resources (timber, regeneration, ground cover, fuel, and wildlife) are monitored on a continuing basis. Initially, there was a single plot established by George Sudworth in 1899, and this was followed by four forestwide inventories in 1934, 1946, 1955, and 1973.

1) Sudworth's 1899 Plot

Within George Sudworth's field records written in 1899 (U.C. Forestry Library) is a short note describing the stocking of a plot that is now within Blodgett Forest. He measured one 1/4-ac plot listing the diameters of all trees by species (Figure 2a,b). His description reads:

> "Average height of all very near 150 ft. Clear 30-35 ft. Average number of logs = 6. Abundant reproduction of all species 1 - 12 years old. Low (illegible word) Rosaceous shrub forms close ground cover in main; tree seedlings about margins of plot -- dense. All fire marked 15-years back. Average conditions for region. Humus 1 1/2 in. deep. Soil sandy loam with rock."

This plot represents a stand of 108 trees per acre having a surprisingly high total basal area of 930 ft^2/ac. This density is more than double the approximately 400 ft^2 /ac shown for high site land in Dunning and Reineke's (1933) yield tables for 150-year-old young-growth mixed conifer in the Sierra. The proportion of basal area by species in Sudworth's plot was white fir 48.5%, ponderosa pine 19.4%, incense-cedar 13.1%, sugar pine 9.9%, and Douglas-fir 9.1%. The largest eight trees per acre, those between 48 to 54 inches dbh, were all white fir and ponderosa pine, but all five species were represented in diameters greater than 44 inches. Apparently there were no trees between 10 and 16 inches dbh. There was only one standing dead tree on the plot, a 23-inch dbh white fir. Using local volume tables the volume for the plot was 55,380 bd.ft. or 221,520 bd.ft./ac.

If these data represent average conditions, the original stands on the Forest must have been very dense with many large, old trees. However, Sudworth documented conditions on typical timber stands but he did not report the actual area occupied by commercial timber stands. One might have expected that the dense canopy plus the occurrence of fire and grazing would have resulted in little ground cover or regeneration, however Sudworth reports abundant regeneration.

2) 1900 to 1933

The area that is now Blodgett Forest was owned by several private individuals and companies during this period. The area was extensively logged by ground skidding cables from steam engines with railroad access and other means. The University of California has no inventory or harvest records from this period and perhaps none exist.

Figure 2a. 1899 DBH Distribution by Species

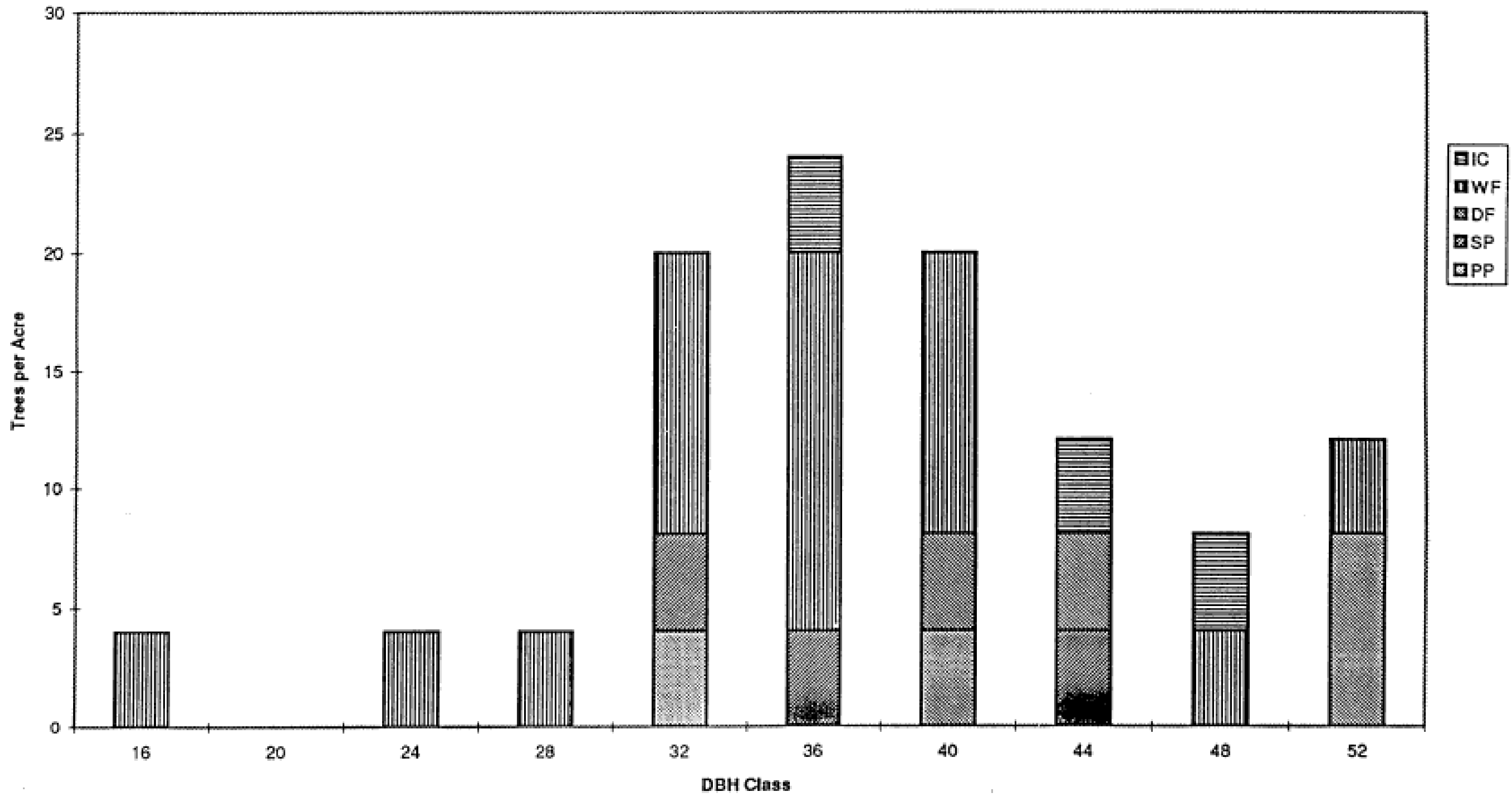

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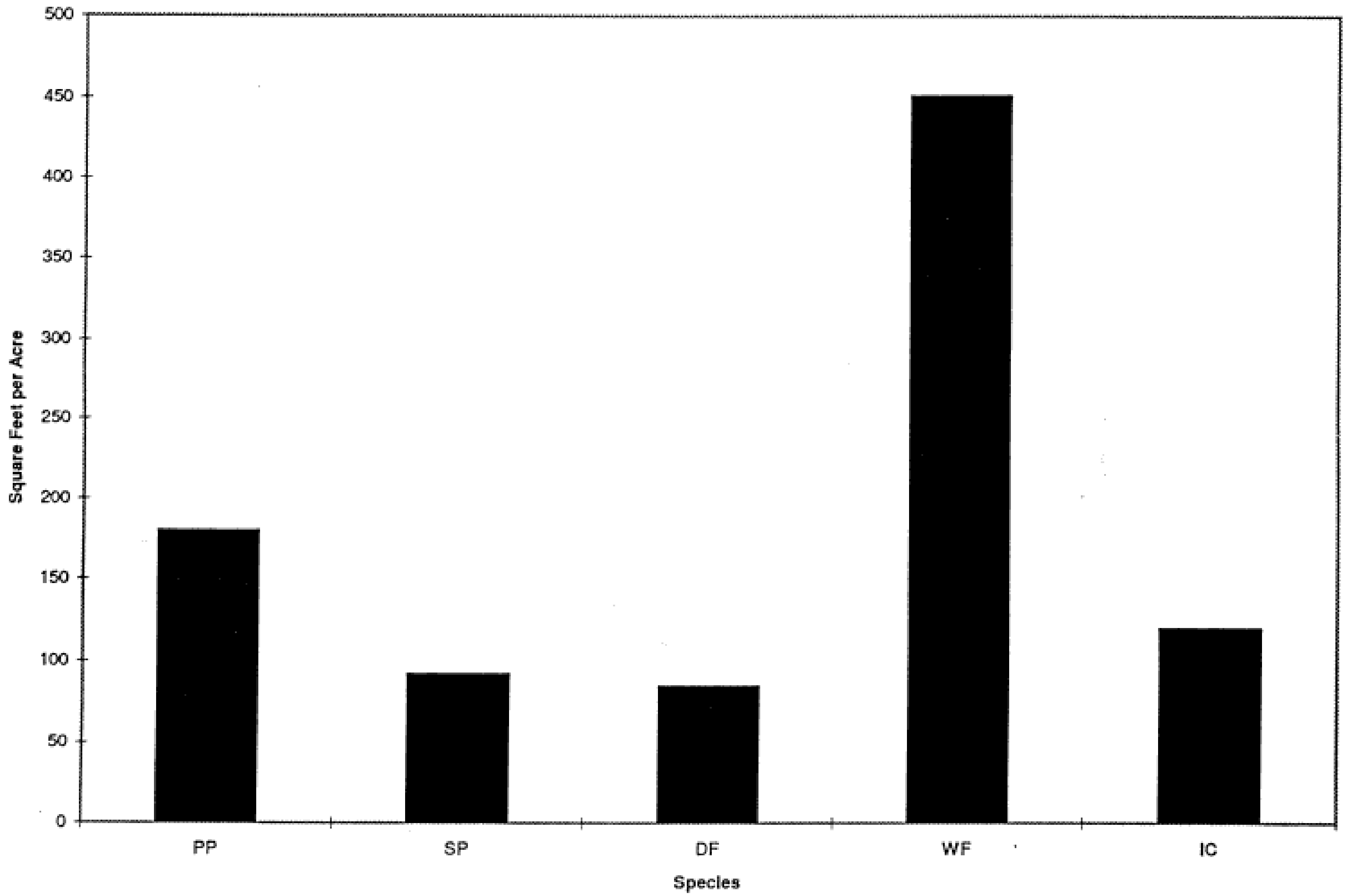
Figure 2b. 1899 Basal Area (sq.ft.) by Species on one 1/4 acre plot in BFRS



3) <u>1934 to 1956</u>

The first measurements done by the School of Forestry were plots installed by Professor Percy Barr in 1933 to study growth and yield of high density young ponderosa pine. In 1934-35, 1946, and 1955 under the direction of Barr, surveys of young growth were conducted on those areas not covered by brush or in residual old growth (1934 and 1955 inventory summaries are shown in Table 9). These restocking surveys consisted of a strip inventory (5% in 1934 and 1955, and 10 % in 1946) of trees greater than 6 inches dbh. By 1933, 2,060 acres (75.5%) of the Forest were in young growth, 588 acres (21.5%) were in brush and 82 acres (3.0%) were in residual old growth (Fig. 3).

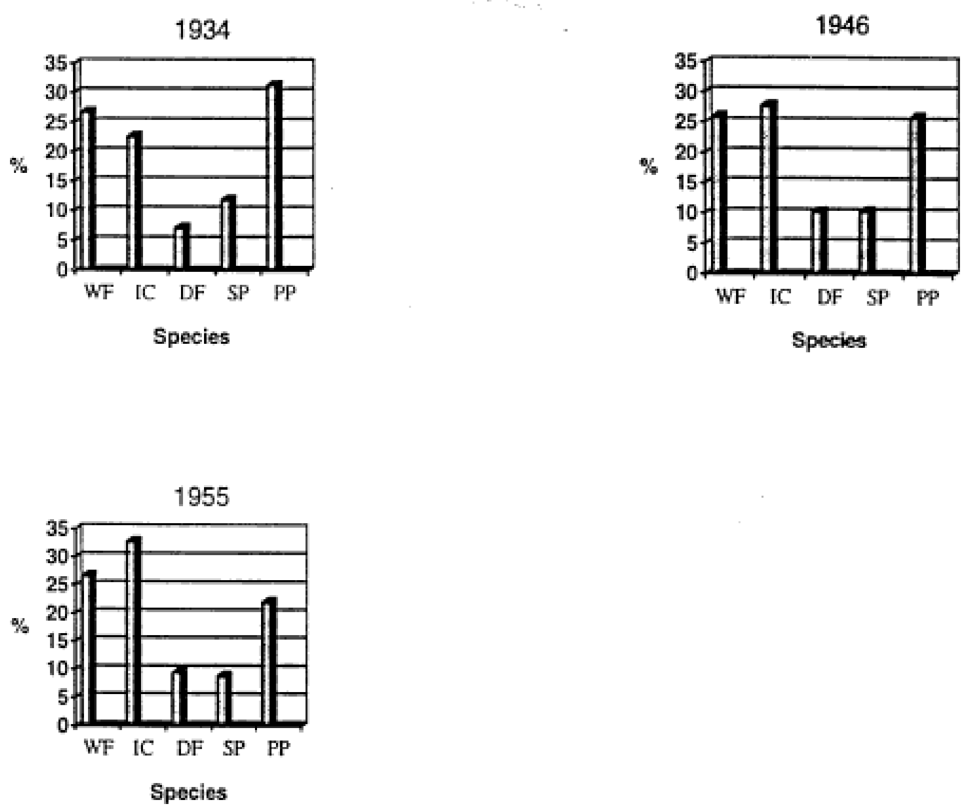


Figure 3. Percent species composition for number of trees greater than 8 inches dbh for the 5 principal conifer species in 1934, 1946, and 1955.

We can see in Figure 3 that the proportion of stems greater than 8 inches of sugar pine and ponderosa pine was declining in Blodgett Forest during the period from 1934 to 1955 while the proportion of incense-cedar and Douglas-fir was increasing. Such a shift is probably due to the differential survival of the more shade tolerant species in the understory. We would conjecture that the pines in the overstory were not dying but rather that understory incense-cedar and white fir were surviving and growing into the 8 inch class at a greater rate than the pines.

4) 1957-1973

In 1957, Michigan-California Lumber Company exercised part of their option, reserved at the time of their donation to UC, to remove all trees on the Forest greater than 24 in dbh. This resulted in 1.26 MM bf being harvested on several 40-acre units on the eastern boundary of the forest. At this time, access was still limited to the summer months when the only road, leading to a CCC-constructed house, was trafficable. However, the young growth had reached merchantable size and this, together with previously unmerchantable old growth, created an opportunity for the University to conduct timber sales that would raise the necessary capital to permit management of the property. A basic road system was devised and the Forest was divided into an initial set of compartments. Annual timber sales were commenced and the proceeds used to construct an internal net of roads, to build structures, and to provide electric power that would provide the necessary support for research. Over time, the compartment structure was refined and in the mid 1960s, a preliminary management plan was developed in which the Forest was divided into compartments allocated to even- and uneven-aged management with ecological reserves.

In 1973 there was a stratified random sample inventory of the entire Forest designed to give a forestwide estimate of stocking, growth, and volume (see Table 9). This inventory was not designed to give accurate estimates by compartment.

5) 1974 to 1994

The first system of permanent, comprehensive forest inventory plots was started in 1974 and completed by 1980. The original plot system (those located in uneven-aged compartments in 1974 and 1975) consisted of 1/20 acre circular plots located on 3 chain intervals along N-S and E-W transects. Transects were located randomly until 20 plots were located within a compartment. Since 1975, the inventory system has been modified to a 6-chain grid of 1/10 acre plots. [Compartments that were inventoried in 1974 and 1975 were reinventoried using the current system, locating the grid to correspond to the location of the original plots as much as possible]. There are approximately 700 1/10 acre plots forestwide. On even-age regenerated compartments, the number of plots was quadrupled (3-chain grid) to assess regeneration stocking and growth using plots 1/100 ac in size. In 1994, nearly half of the plots on the Forest were remeasured. A projected total volume has been estimated for the Forest as of 1994 (Table 9).

There have been four distinctly different inventory systems used at Blodgett each of which involved considerably different designs. The inventories of 1934 to 1955 used a systematic strip method in areas of reproduction. The inventory of 1973 used a stratified random design of the entire forest. The inventory of 1974 and 1975 used random location of 1/20th acre circular plots in the uneven-aged management units. The inventory 1976 to present used systematic location of 1/10th acre plots on a 6-chain grid. These plots are permanent plots intended for periodic remeasurement.

D. GROWTH and DEVELOPMENT

Measurements on the Forest, beginning with Sudworth's 1899 single plot through successive inventories to the end of the summer in 1994, permit a unique comparison of stand dynamics and growth under alternative systems of management. In particular, comparisons can be made between even- and uneven-aged compartments in terms of age and size structure (height and diameter) and species distribution. The extensive nature of the forest inventories enables relatively precise estimates to be made of volume growth by species on a forestwide basis. By selecting compartments, within each system of management, having similar silvicultural prescriptions it is possible to evaluate the effect of choice of management system on growth, yield, and establishment of regeneration.

The following series of tables presents results from inventory data and harvest records. Table 10 depicts the results of forestwide inventories showing how volume per acre has changed over time since the entire forest was cut over at the beginning of the century. Inventories in 1934 and 1955 did not include brush areas and old growth forest areas within Blodgett, which represented 588 and 82 acres, respectively.

It should be noted that inventory volume is the gross volume measured and does not include deduction for defect or breakage while harvest volume reported is the net volume which is the gross volume minus defect volume and breakage. Current experience at Blodgett suggests that net volume is 5 - 8 percent less than gross volume. This makes growth estimates of compartments where there has been harvest somewhat conservative.

Table 10. Forest-wide inventories 1934 to 1994

Year	Acres	MBF	MBF/Acre
1934	2061^{+}	26,183	12.70
1955	2061^{+}	37,816	18.35
1973	2817*	63,941	22.68
1994^{x}	2817*	82,467	29.27

$^{+}$ Area excluding old growth and brushfields - Total Forest area = 2731 acres

* Area excluding roads - Total Forest area = 2895 acres

^{x} Volume estimated prior to 1994 harvest

Table 11 summarizes the volume harvested from the forest for period between inventory summaries.

Table 11. Harvest volumes during periods between inventories, 1933-1994.

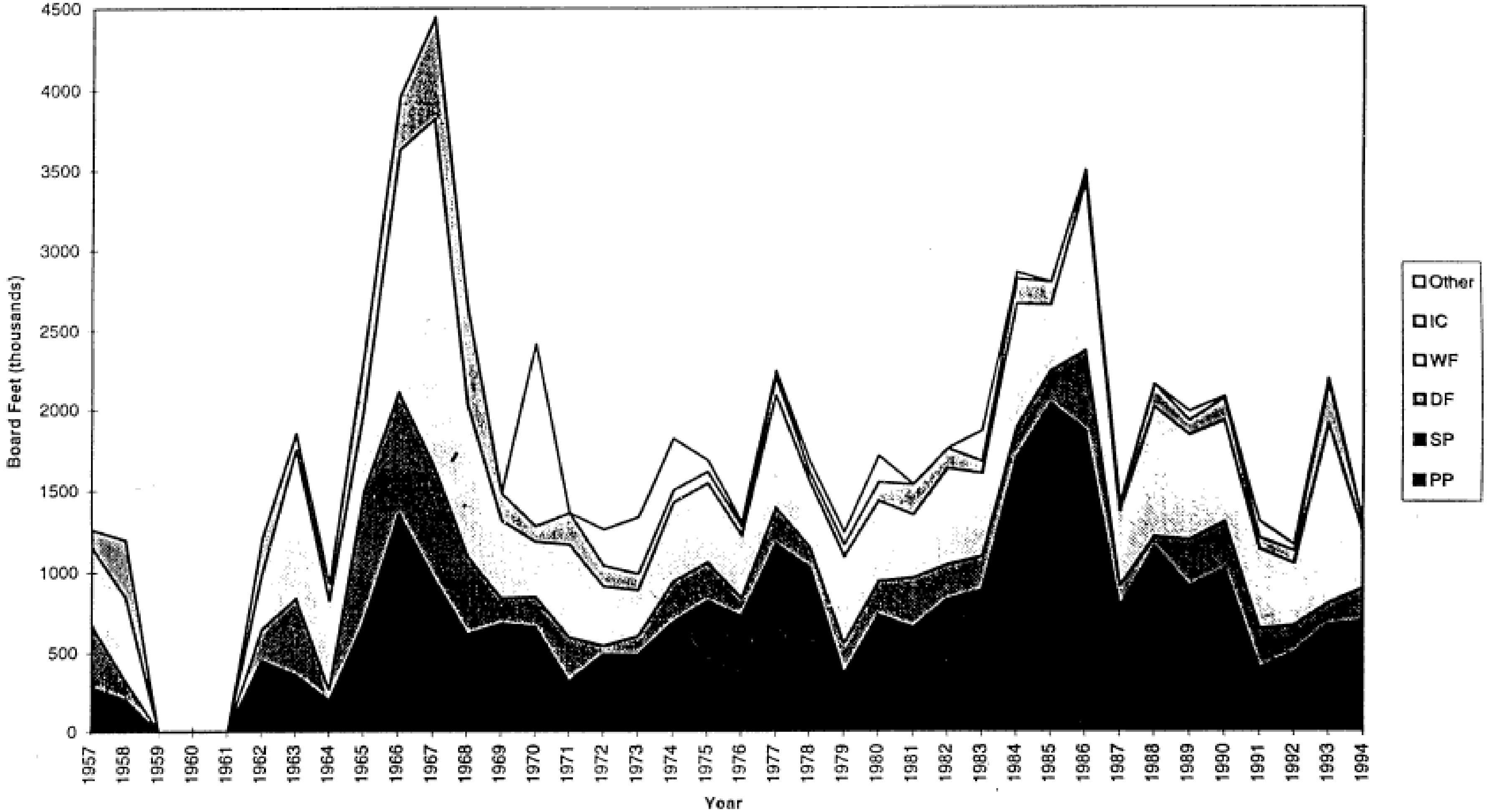
Harvest Period	Harvest Volume (MBF)
1934-1956	0
1957-1973	27,700*
1974-1994	39,757

* There was no harvest from 1959-1961

Tables 10 and 11 show that, since 1934, the Forest has increased in stocking from 26,183 MBF (12.7 MBF/ac) to 82,467 MBF (29.27 MBF/ac). This growth occurred despite the fact that over the 37-year period from 1957 to 1994, 67.4 MMBF was harvested. In terms of growth, from 1934 to 1955, when no harvests occurred, average growth was 269 bd ft/ac/yr; from 1955 to 1973, growth averaged 787 bd ft/ac/yr; and from 1974 to 1994, growth averaged 986 bd ft/ac/yr. In 1994 the reserve compartment area was 424 acres and had 24,434 MBF or 57.7 MBF/ac. If we exclude the reserve compartments from volume estimates then the average 1994 volume on the 2,393 acres is 24.0 MBF/ac and growth for the 38 year period 1955 to 1994 was 868 bf/ac/yr; including the reserve compartments the growth for the period was 894 bf/ac/yr. This indicates that growth increased as stocking increased, and that the Forest is capable of sustaining a growth of over 800 bd ft/ac/yr. Over the past 39-year period, harvests are equivalent to approximately 68.7% of growth, consequently growing stock on the Forest is steadily increasing despite harvesting approximately 1.775 MBF per year. In addition, average diameter on the forest is increasing to include 30- to 40-inch trees and small and large harvest units have created a patchwork of age classes, thus forest structure is becoming more diverse.

Timber harvest volume by species from the Forest for 1957 to 1994 is shown in Figure 4. Many of the high and low levels in harvest volume is a result of accommodating research projects. The Figure shows large volumes harvested in 1966-67 which were associated with the financing of the purchase of the Bacchi Property inholding. The period from 1984 to 1986 had increased harvest in order to accommodate several clearcut research projects. About 40 percent of the volume harvested consists of ponderosa pine and sugar pine and the bulk of the remainder (33 percent) consists of white fir. "Other" harvest species shown in Figure 4 includes hardwoods (primarily black oak) and undifferentiated fuelwood harvest.

Figure 4. Net Volume of Timber Harvest (Mbf)



Comparison of Even- and Uneven-Aged Silvicultural Prescriptions

To compare the effects of even- and uneven-aged systems on forest productivity, compartments have been chosen within each silvicultural treatment (totaling approximately 1/4 of the Forest) that have had similar history of inventories and harvesting entries from approximately 1974 (Tables 12, 13 and 14). Gross growth per acre per year (G+H/Yrs) is computed by subtracting the inventory volume at time one from that of time two, adding any volume cut in the intervening period, and then dividing by the total time period in years. Mortality, defect, and breakage was ignored as a component of gross growth.

Harvest volume is the scaled net volume removed from the compartments prorated over the entire comparment areas, while inventory volume is the gross volume estimated from the system of permanent plots within the compartment. Ideally, harvest volume, as a proportion of total compartment volume within group cut compartments, would be the same as the proportion of permanent plots harvested. This is not likely to be the case and the estimated gross growth per acre may be significantly different from the true gross growth.

Table 12. Comparison of **board foot growth** (Scribner MBF) and harvest on selected compartments.

Group Selection Compartments 270 and 380 (112.5 acres)

Year	# plots	PP	SP	DF	WF	IC	BO	Other	Total	G+H/Yrs
74-75 Inv	32	3.09	1.46	1.97	4.52	0.72	2.98		14.75	
Harvests		3.30	2.44	1.30	3.41	0.79		0.20	11.43	
94 Inv	34	5.91	3.66	4.25	7.01	1.60	2.64	0.12	25.17	1.09

Single-tree Selection Compartments 160 and 410 (106.2 acres)

Year	# plots	PP	SP	DF	WF	IC	BO	Other	Total	G+H/Yrs
80 Inv	22	6.46	4.40	4.21	4.31	0.41	2.67	0.03	23.15	
Harvests		2.24	1.03	.98	1.96	0.13			6.34	
94 Inv	27	7.95	3.68	4.84	6.41	0.69	2.67		27.19	0.71

Even-aged, thinned from below - Compartments 40, 90, 120, and 140 (108.9 acres)

Year	#plots	PP	SP	DF	WF	IC	BO	Other	Total	G+H/Yrs
76-78 Inv	33	6.81	1.52	1.44	4.96	2.94	2.37	0.23	20.27	
Harvests		2.26	0.78	0.71	1.03	0.47			5.25	
94 Inv	33	8.19	1.78	3.62	9.58	3.66	2.69	0.60	30.12	0.89

Even-aged with overstory removal - Compartments 30, 70, 100, 530 (156.2 acres)

Year	#plots	PP	SP	DF	WF	IC	BO	Other	Total	G+H/Yrs
77-78 Inv	46	4.45	1.00	2.23	3.21	3.45	4.13	0.07	18.55	
Harvests		4.21	0.93	1.35	1.79	1.18		0.05	9.51	
94 Inv	53	2.79	1.92	2.60	3.63	3.28	1.58		15.78	0.40

Even-aged, Clearcut - Compartment 481 (20.4 acres)

Year	#plots	PP	SP	DF	WF	IC	BO	Other	Total	G+H/Yrs
75 Harv		6.01	1.75	5.38	5.45	0.57		0.78	19.95	
89 Inv	18	2.07		0.42	0.01		0.10		2.60	0.19

Even-aged, Clearcut - Compartment 321 (17.3 acres)

Year	#plots	PP	SP	DF	WF	IC	BO	Other	Total	G+H/Yrs
80 Harv		2.65	7.95	8.12	2.99	1.24	2.67	0.25	25.88	
94 Inv	5	0.59						0.99	1.58	0.11

Reserve (Uncut) - Compartments 20 and 220 (103.2 acres)

Year	#plots	PP	SP	DF	WF	IC	BO	Other	Total	G+H/Yrs
76 Inv	28	10.93	1.08	8.39	6.93	6.57	2.90	0.02	36.81	
94 Inv	29	20.23	2.72	16.91	11.78	9.78	2.41	0.12	63.96	1.51

Reserve (Uncut) - Compartments 290 and 600 (144.6 acres)

Year	#plots	PP	SP	DF	WF	IC	BO	Other	Total	G+H/Yrs
81 Inv	25	13.08	6.36	3.46	8.50	3.99	0.82	0.19	36.40	
94 Inv	35	16.60	5.40	9.71	13.12	4.40	1.00	0.40	50.63	1.09

Table 13. Comparison of **cubic foot growth** and harvest on selected compartments.

Group Selection Compartments 270 and 380 (112.5 acres)

Year	PP	SP	DF	WF	IC	BO	Other	Total	G+H/Yrs
74-75 Inv	609	287	477	1122	273	666	7	3441	
Harvests	658	551	328	843	303		107	2790	
94 Inv	903	610	859	1475	505	588	48	4987	216.8

Single-tree Selection Compartments 160 and 410 (106.2 acres)

Year	PP	SP	DF	WF	IC	BO	Other	Total	G+H/Yrs
80 Inv	1193	807	954	946	317	772	17	5088	
Harvests	441	188	224	469	115			1301	
94 Inv	1263	614	1094	1296	371	746	13	5503	122.5

Even-aged, thinned from below - Compartments 40, 90, 120, and 140 (108.9 acres)

Year	PP	SP	DF	WF	IC	BO	Other	Total	G+H/Yrs
76-78 Inv	1126	265	378	1054	1029	631	205	4688	
Harvests	371	132	193	237	164			1097	
94 Inv	1191	290	799	1658	1068	674	219	5905	136.1

Even-aged with overstory removal - Compartments 30, 70, 100, 530 (156.2 acres)

Year	PP	SP	DF	WF	IC	BO	Other	Total	G+H/Yrs
77-78 Inv	802	185	531	686	970	965	103	4242	
Harvests	763	180	328	412	325		71	2080	
94 Inv	464	352	572	690	897	372		3348	69.8

Even-aged, Clearcut - Compartment 481 (20.4 acres)

Year	PP	SP	DF	WF	IC	BO	Other	Total	G+H/Yrs
75 Harv	781	273	800	852	116		430	3253	
89 Inv	682	80	165	17	27	110		1081	77.2

Even-aged, Clearcut - Compartment 321 (17.3 acres)

Year	PP	SP	DF	WF	IC	BO	Other	Total	G+H/Yrs
80 Harv	345	1240	1208	469	252	647	139	4300	
94 Inv	751		82	87	12		377	1309	93.5

Reserve (Uncut) - Compartments 20 and 220 (103.2 acres)

Year	PP	SP	DF	WF	IC	BO	Other	Total	G+H/Yrs
76 Inv	1895	204	1605	1292	1548	586	140	7271	
94 Inv	2912	442	2848	1846	2003	491	223	10764	194.1

Reserve (Uncut) - Compartments 290 and 600 (144.6 acres)

Year	PP	SP	DF	WF	IC	BO	Other	Total	G+H/Yrs
81 Inv	2151	1061	670	1443	763	293	181	6560	
94 Inv	2412	852	1456	2066	945	331	219	8281	132.3

Table 14. Comparison of **basal area growth** (ft^2/ac) and harvest on selected compartments.

Group Selection Compartments 270 and 380 (112.5 acres)

Year	PP	SP	DF	WF	IC	BO	Other	Total	G+H/Yrs
74-75 Inv	23	10	20	49	26	20	1	149	
Harvests	25	24	14	37	27		4	132	
94 Inv	25	18	29	57	35	18	2	184	8.36

Single-tree Selection Compartments 160 and 410 (106.2 acres)

Year	PP	SP	DF	WF	IC	BO	Other	Total	G+H/Yrs
80 Inv	40	28	37	36	27	27	1	195	
Harvests	15	6	9	19	10			59	
94 Inv	36	20	41	46	31	25	1	200	4.53

Even-aged, thinned from below - Compartments 40, 90, 120, and 140 (108.9 acres)

Year	PP	SP	DF	WF	IC	BO	Other	Total	G+H/Yrs
76-78 Inv	35	9	16	42	65	21	11	199	
Harvests	12	4	8	10	11			45	
94 Inv	31	9	30	54	67	22	10	224	3.86

Even-aged with overstory removal - Compartments 30, 70, 100, 530 (156.2 acres)

Year	PP	SP	DF	WF	IC	BO	Other	Total	G+H/Yrs
77-78 Inv	28	7	21	26	60	30	6	178	
Harvests	27	7	13	17	20		4	88	
94 Inv	15	12	21	25	59	12		143	3.12

Even-aged, Clearcut - Compartment 481 (20.4 acres)

Year	PP	SP	DF	WF	IC	BO	Other	Total	G+H/Yrs
75 Harv	18	7	20	25	7		17	93	
89 Inv	88	9	24	3	5	6		135	9.64

Even-aged, Clearcut - Compartment 321 (17.3 acres)

Year	PP	SP	DF	WF	IC	BO	Other	Total	G+H/Yrs
80 Harv	8	33	30	14	14	21	6	125	
94 Inv	71		8	14	2		30	125	8.93

Reserve (Uncut) - Compartments 20 and 220 (103.2 acres)

Year	PP	SP	DF	WF	IC	BO	Other	Total	G+H/Yrs
76 Inv	59	7	51	43	84	16	8	268	
94 Inv	75	13	75	55	95	14	12	339	3.91

Reserve (Uncut) - Compartments 290 and 600 (144.6 acres)

Year	PP	SP	DF	WF	IC	BO	Other	Total	G+H/Yrs
81 Inv	68	31	20	45	45	10	15	235	
94 Inv	70	23	37	61	55	12	9	267	2.46

Tables 12-14 show that:

1) The reserve (uncut) stands are growing at the rate of 132 to 194 ft^3/ac/year (1,090 to 1,510 bd ft/ac/yr and 2.5 to 3.9 ft^2/ac/yr basal area). These stands have a current stocking of 267 to 339 ft^2/ac and a volume of 8,281 to 10,764 ft^3/ac. Growth percent, based on cubic volume growth for the period 1974 to 1994, is 2.0 to 2.7 percent. Normal yield table values (Dunning and Reineke 1933) for basal area and volume for young growth mixed conifer forests (age 80 yr and site index 100) are 321 ft^2/ac and 18,600 ft^3/ac. The relatively low growth of reserved stands compared with normal yield table values is probably due to a number of reasons. Sites chosen by Dunning and Reineke as a basis for their normal yield tables had an incense-cedar component of approximately 5 percent whereas the proportion of slower growing cedar on the Forest is about 30 percent. In addition Dunning and Reineke's plots did not include black oak as does Blodgett. Another major reason for stands on the Forest appearing to have lower volume than those in normal yield tables is that board foot volumes in Dunning and Reineke are based on International rule which provides estimates of volume that are about 20 percent higher than those estimated using Scribner rule which is now commonly used in the Sierra and on Blodgett Forest.

2) Stands managed under group selection, in which the stands have been cut using small groups and with trees between the groups being thinned from below, show a growth rate of 216 ft^3/ac/yr which is similar to the better set of reserve stands. Absolute growth in group selection areas, similar to even-aged areas, is likely to be comparatively low due to the time necessary for regeneration in the harvested groups to develop substantial volume. Growth efficiency in terms of cubic volume is a high 6.3 percent which is undoubtedly associated with higher individual tree growth at a stocking level that is half that of the reserve stands. Also, the two group selection compartments considered here had relatively low stocking in 1974 (149 ft^2/ac). This, coupled with the amount of basal area removed between 1974 and the present (132 ft^2/ac) is likely to have contributed substantially to the relatively high stand increment (8.4 ft^2/ac/yr).

3) Stands managed under single tree selection show a growth rate of 123 ft^3/ac/yr and growth efficiency in terms of cubic volume growth is 2.5 percent. Both of these values are substantially lower than for group selection. This difference is probably mostly associated with the level of harvest in the group selection stands being double that in the single tree selection stands. This has the effect of lowering the value of "growth + harvest" over the period.

4) Stands managed under the even-aged system are divided into three groups: a) those that have received thinnings from below and have not yet been clearcut, b) those that have received thinnings featuring thinning from above and not yet been clearcut, and c) those that have been clearfelled and regenerated. Table 13 shows, not surprisingly, that stands thinned from below under an even-aged system are

performing similarly to those managed under single tree selection. Stands having overstory removal are growing at a lower rate due probably to the time needed to transfer growth potential to the smaller, younger, and possibly initially partially suppressed trees in this transition to an even-aged structure. Those stands that were clearcut and replanted naturally have lower growth over the period due to the lesser growth in even-aged stands during the regeneration and stand closure stage relative to stands that are fully stocked. However, growth in diameter and height of trees on the planted stands in the Forest are greater than that shown in Oliver and Powers (1978) tables for unmanaged ponderosa pine plantations. In general, computer simulations indicate that average volume increment from clearfelling and planting coupled with weeding and precommercial will equal or exceed other management styles, but group selection and thinning from below (CT and STS) can also show good growth efficiency and comparable productivity over an entire rotation.

E. Regeneration

Regeneration surveys (including both natural regeneration and planted seedlings) were carried out Forestwide in 1994 and summarized for each of the following management types: group selection, single tree selection, even-aged and thinned from below, even-aged with overstory removal, even-aged and clearcut, and reserve.

a) Seedlings (0 to 4.5 ft tall)

The total number of seedlings forestwide, disregarding recent clearcuts, ranged from 1,381 /ac within young growth reserves to 3,321 /ac in commercially thinned stands (Table 15).

Table 15. Number of seedlings per acre by species and managment type.

	PP	SP	DF	WF	IC	BO	HW	SW	Total
Management	Seedlings per Acre								
Group Selection	140	170	98	398	423	1525	121	0	2875
Single Tree	355	90	138	379	445	1271	140	0	2818
O'story Removal	139	43	166	334	546	1456	123	0	2807
Even-age, thinned	68	45	189	482	450	1637	447	3	3321
Y-G Reserve	6	36	53	369	142	272	478	25	1381
O-G Reserve	26	50	200	647	1185	479	612	82	3281

i) Managed Compartments

The most abundant species in all treatment areas is California black oak which constituted from 49 to 53 percent of all seedlings. The next most abundant were the shade-tolerant species incense-cedar (14 to 19 percent) and white fir (12 to 15 percent). The more intolerant ponderosa and sugar pines combined constituted only 1 to 13 percent (average 9 percent) of all species and Douglas-fir 3 to 6 percent. Given that the desirable number of seedlings needed for management is approximately 300/ac, in all management types there is more than adequate numbers of each species for maintaining stands with the proportion of species existing in the original stand.

ii) Reserves

Table 15 shows that the reserve compartments differ markedly in the total number of seedlings, 1,381 in the young-growth reserve and 3,281 in the old growth reserve. This is due to differences in stand structure where the former is composed of a more closed canopy, and the latter contains some larger old growth trees and gaps in the canopy. The young-growth reserves have seedlings of white fir, black oak, and other hardwoods (principally tanoak) as the most abundant species (27, 20, and 35 percent. respectively) whereas the most abundant species in the old growth reserves are incense-cedar (28 percent) and white fir (22 percent). The other notable difference in the reserve compartments compared to managed compartments is the higher proportion of other hardwoods (23 percent vs. 7 percent in the young growth compartments) and the presence of other softwoods (2 percent vs. virtually none in young-growth reserves).

Observations show that planted regeneration under shelterwoods, group selection, and clearcutting, often being planted two year old seedings, grows much more rapidly than natural regeneration.

Figure 5 shows the relative abundance of seedlings by species and management type. Incense-cedar and white fir are consistently well represented, having no less than 10 percent each, of all seedlings for all management types.

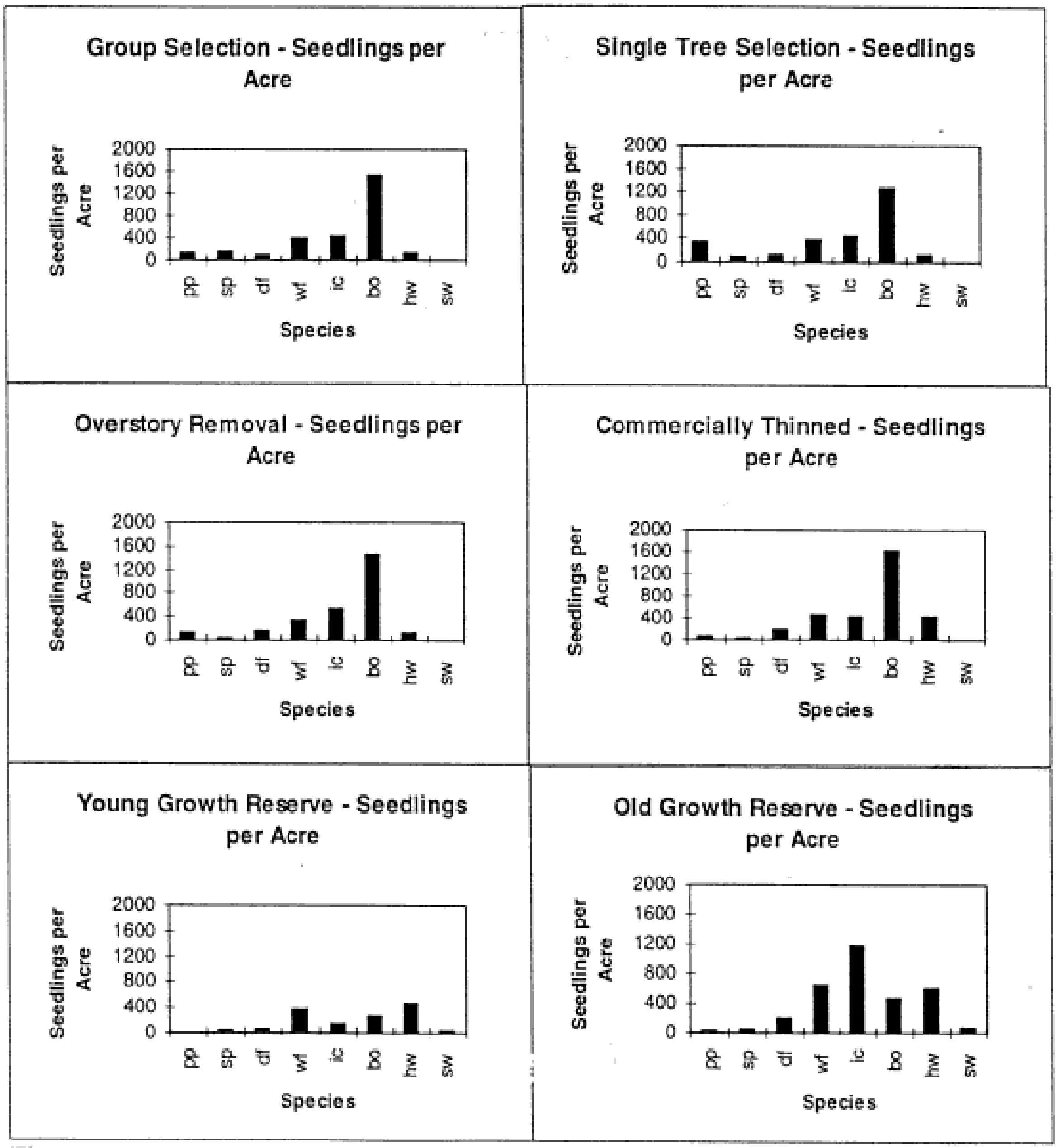


Figure 5. Number of seedlings per acre by species and management type.

b) Saplings (0.0 - 4.0 in dbh)
As shown in Table 16, the total number of saplings ranged from 155 in the even-aged, overstory removal compartments, to 277 in the single tree selection areas.

Table 16. Number of saplings per acre by species and managment type.

Management	PP	SP	DF	WF	IC	BO	HW	SW	Total
	-----------------------------				Saplings per Acre				--------------------------------
Group Selection	8	2	19	83	63	2	64	0	241
Single Tree	22	2	26	112	100	5	10	0	277
O'story Removal	7	10	10	49	44	10	23	2	155
Even-aged Thin	0	3	50	58	55	37	26	0	229
Y-G Reserve	8	3	19	108	53	3	47	6	247
O-G Reserve	3	9	6	85	79	0	26	9	217

i) Managed compartments
The most abundant species in this size class of regeneration were white fir (25 to 40 percent) and incense-cedar (24 to 36 percent). Together, these two species constituted 65 percent of all saplings in all managed compartments combined. Other hardwoods were 14 percent of the total (4 to 27 percent), Douglas-fir 12 percent (6 to 22 percent), and the more intolerant sugar and ponderosa pines combined were 6 to 11 percent). In marked contrast to the situation in the seedlings size class, California black oak saplings constituted only 6 percent of the total (1 to 16 percent), indicating high mortality and browsing in comparison with conifer species.

ii) Reserves
The most abundant species in the reserve compartments were white fir (42 percent) and incense-cedar (28 percent). California black oak saplings were almost non-existant, and Douglas-fir and the pines each constituted 5 percent of the total. Unlike the case with seedlings, the distributions of saplings by species in the young growth and old growth reserves were quite similar.

The distribution of saplings by treatment type is shown in Figure 6.

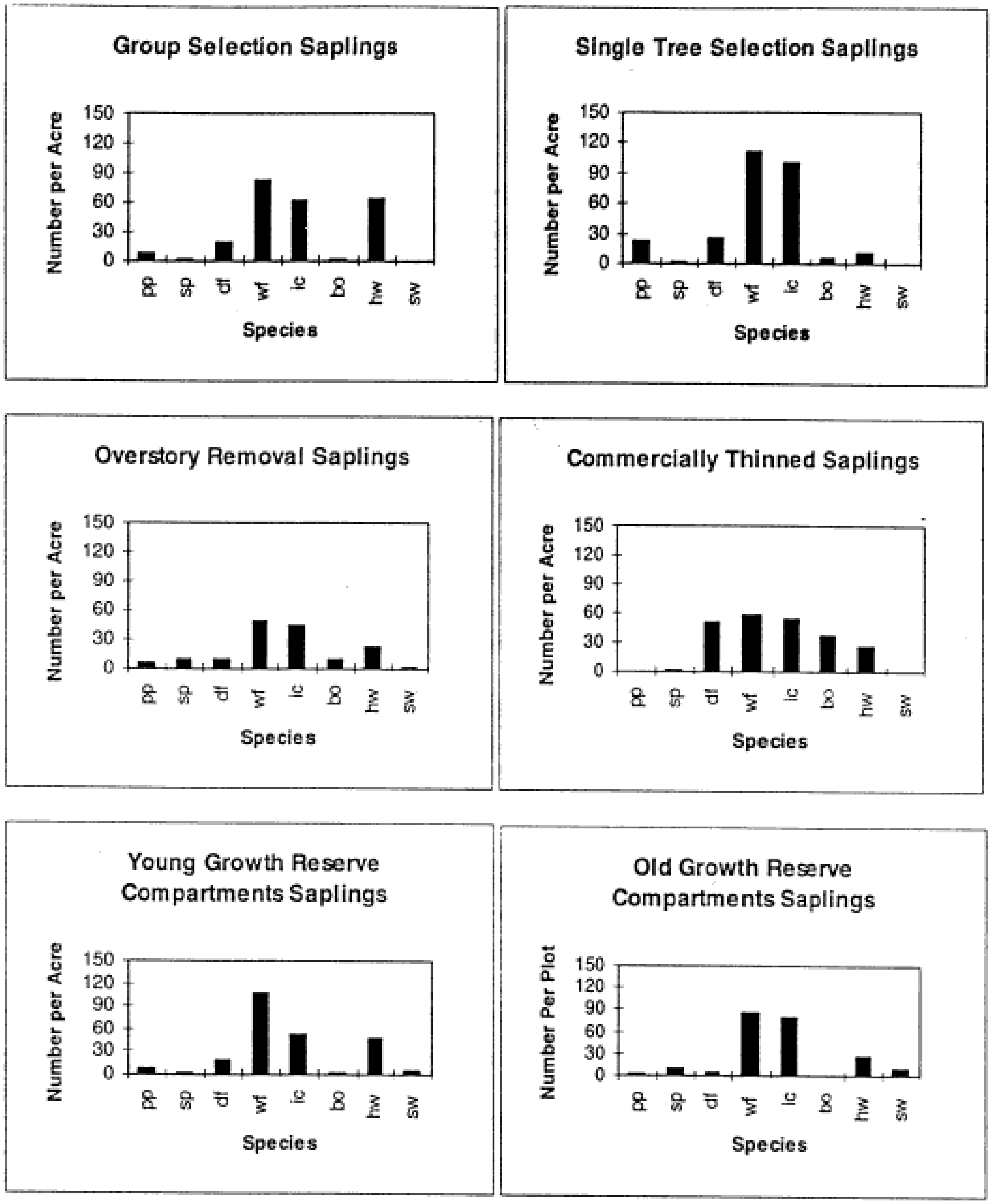


Figure 6. Number of saplings per acre by species and management type.

F. Regeneration in Groups as a function of Distance from Edge

A survey was made of the effect of edge of residual stand on the growth of regeneration within the group. Seven groups were evaluated in 1994 that were comparable in slope and aspect. They were all harvested between 1982 and 1986. All groups had received site preparation after harvesting and were planted to mixed conifer species. Natural regeneration occurred in all groups and the differences in growth of these two types of regeneration are mostly separated by dividing the regeneration into size classes.

Figure 7 shows the abundance of seedlings a) less than 3 feet tall, and b) greater than 3 feet tall as a function of distance from the edge. Both diagrams show, as would be expected, fewer numbers of regeneration close to the edge of the stand, particularly in terms of the taller regeneration which shows the competitive effects of edge trees. The smaller-sized regeneration shows the greatest number in the zone 17 to 33 feet from the edge which probably is associated with favorable microclimate and increased seed fall -- particularly partial shade and lower evaporative stress. As distance from the edge increases, the smaller-sized regeneration become less frequent towards the center of the group. The larger-sized regeneration shows uniform abundance from a distance of 33 to 92 feet from the edge. The variability in numbers of saplings from 117 to 167 feet from the edge and near the center of the group is due to a rapid decline in sample size and no trend should be deduced from this portion of the data.

In Figure 7 it can be seen that the shade-tolerant incense-cedar has highest numbers of small-sized (< 3 ft tall) regeneration in the shaded micro-environment provided by the edge trees. White fir, surprisingly, does not show this same trend. The intolerant ponderosa pine shows relatively uniform abundance of small-sized regeneration with increasing distance from the edge, however the number of larger-sized saplings (> 3 ft tall) increases markedly with increasing distance from the edge.

Based upon the number of seedlings and saplings found of each species it appears there is sufficient stocking of all species to meet any likely target species mix. Thinning activities can be tailored to produce the desired mix.

Given edge trees of approximately 100 ft tall, it can be concluded that:

1) the close edge of approximately 1/4 to 1/3 of tree height is unfavorable to the establishment of regeneration of all species except perhaps for California black oak and sugar pine.

2) group diameter greater than of one tree height is sufficient to obtain adequate numbers of regeneration of all species.

3) to obtain greatest numbers of large regeneration of ponderosa pine, group diameter should be a minimum of two tree heights.

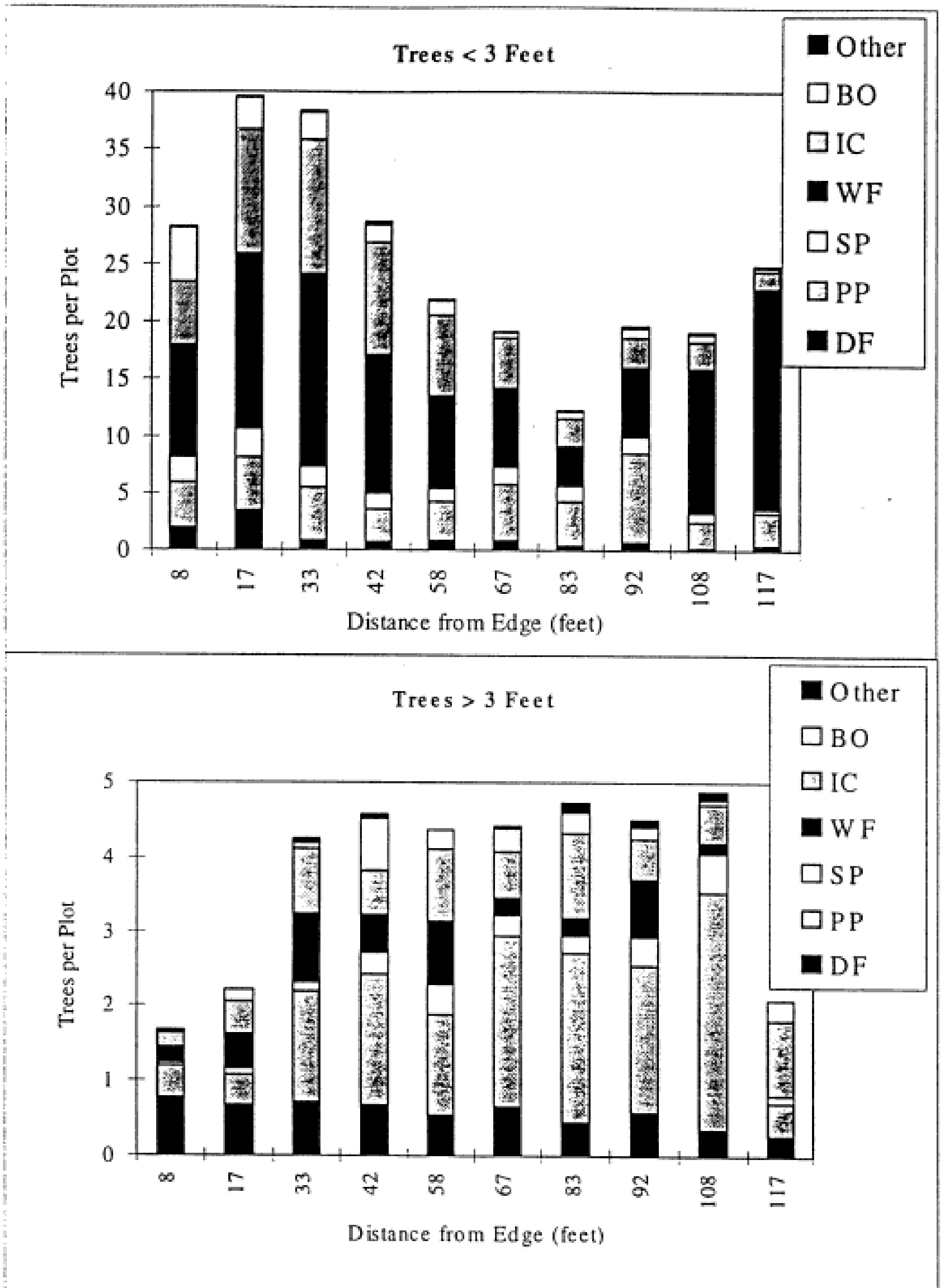


Figure 7. Number of seedlings less than 3 feet tall and seedlings greater than 3 feet tall per plot (1/200 acre) by distance from group edge (feet) for Douglas-fir (DF), ponderosa pine (PP), sugar pine (SP), white fir (WF), incense-cedar (IC), California black oak (BO), and all other tree species (Other).

G. Diameter Distribution

The distribution of breat height diameters of trees in a stand gives an indication of the structural diversity of the stand. Since tree diameters are well correlated to tree heights, the diameter distribution provides information on both horizontal and vertical distribution. This structure is important to wildlife and is an indication of survival of trees in the various age classes. An examination of tree diameters in Blodgett shows how the different management schemes affect structure (Table 17 and Figures 8 to 11).

We can see from Figures 8 to 11 that management has resulted in a classic J-shaped distribution, except for clearcut compartments. The management or silvicultural activities at Blodgett removes trees greater than 40 inches in diameter, eliminating the largest classes. The uneven-aged and commercial thinning compartments all had increases in the larger size classes while the overstory removal compartments had a reduction in the larger classes, as would be expected. Comparing the results of these different management approaches in 1994, we see that both the uneven-aged methods resulted in a distinctly J-shaped distribution with considerable numbers of larger trees (more than 3 trees per acre greater than 30 inches). The two thinning strategies, commercial thinning and overstory removal, produced a more linear distribution of diameters. This is result is expected as the uneven-aged managed stands need a considerable number of stems for future recruitment into the larger diameter classes, while the thinning approaches intend to concentrate volume growth on the residual, larger trees for future clear felling.

Table 17. Number of trees per acre by diameter class (in.) by management type in Blodgett Forest Research Station and for 8 plots measured by Sudworth in 1899 in the mid-Sierra mixed conifer.

Diameter Range (in.)	Sudworth Old Growth	Single-Tree Selection		Group Selection		Commercial Thinning		Overstory Removal		Clearcut	Old Growth Reserve		Young Growth Reserve	
	Inventory Years													
	1899	80	94	74-76	94	76-78	94	77-78	93-94	89,94	80,81	94	76	94
	Trees per Acre													
10-15	4.5	51.4	57.8	26.6	42.4	50.8	59.7	45.2	61.7	19.7	47.5	47.6	47.5	59.8
15-20	8.5	23.2	21.9	15.9	23.2	16.6	24.8	17.2	21.7	2.37	26.7	25.3	26.8	27.6
20-25	10.0	13.2	13.3	5.31	13.5	8.23	15.2	9.35	6.79	0	10	15.6	23.6	23.3
25-30	15.5	6.82	7.04	1.56	7.06	3.23	7.27	5.87	4.34	0	9.17	6.18	8.93	12.8
30-35	15.5	1.36	2.59	0.31	2.65	1.77	3.03	2.61	1.89	0	2.92	8.24	2.86	9.66
35-40	12.0	0	1.11	0.31	0.59	0.61	1.52	0.43	0.75	0	2.08	2.06	1.79	2.36
40-45	11.0	0	0	0	0.29	0.3	0	0.43	0	0	2.08	2.35	0.71	1.97
45-50	10.5	0	0	0	0	0	0	0	0	0	0.83	0.59	0	0
50-55	6.5	0	0	0	0	0	0	0.22	0	0	0	0.29	0.36	0
55-60	3.5	0	0	0	0	0	0	0	0	0	0.83	0.29	0	0.34
50-65	1.0	0	0	0	0	0	0	0	0	0	0	0	0	0
65-70	1.5	0	0	0	0	0	0	0	0	0	0	0.29	0	0
70+	1.5	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	101.5	95.98	103.74	49.99	89.69	81.54	111.52	81.31	97.17	22.07	102.11	108.79	112.55	137.83

Diameter Range	Trees per Acre													
>10"	101.5	96.0	103.7	50.0	89.7	81.5	111.5	81.3	97.2	22.1	102.1	108.8	112.6	137.8
>20"	88.5	21.4	24.1	7.5	24.1	14.1	27.0	18.9	13.8	0	27.9	35.9	38.2	50.4
>30"	62.5	1.4	3.7	0.6	3.5	2.7	4.6	3.7	2.6	0	8.8	14.1	5.7	14.3
>40"	35.5	0	0	0	0.3	0.3	0	0.7	0	0	3.8	3.8	1.07	2.3

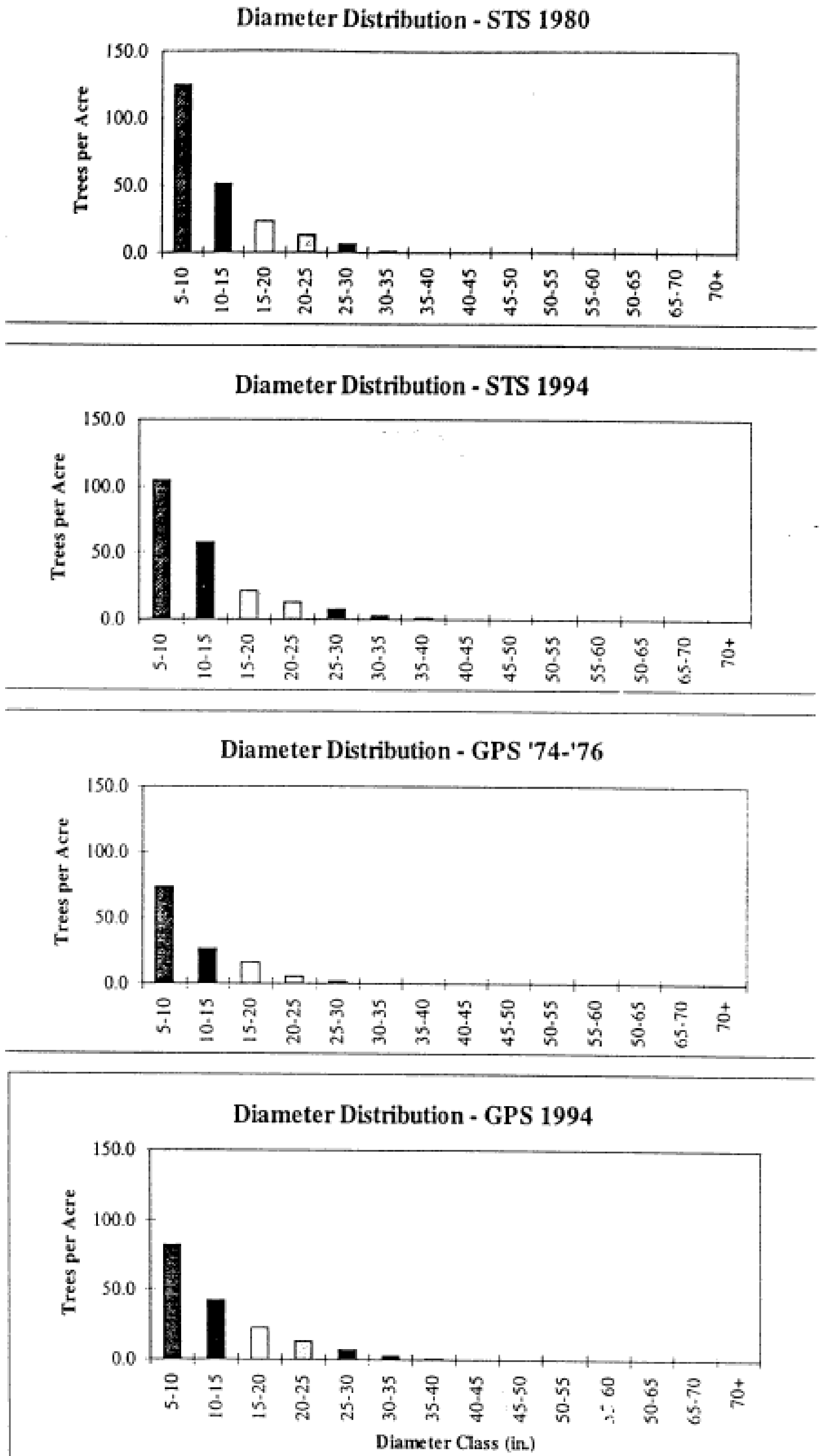


Figure 8. Trees per acre by diameter class for selected single-tree selection (STS) and group selection (GPS) compartments at BFRS by year.

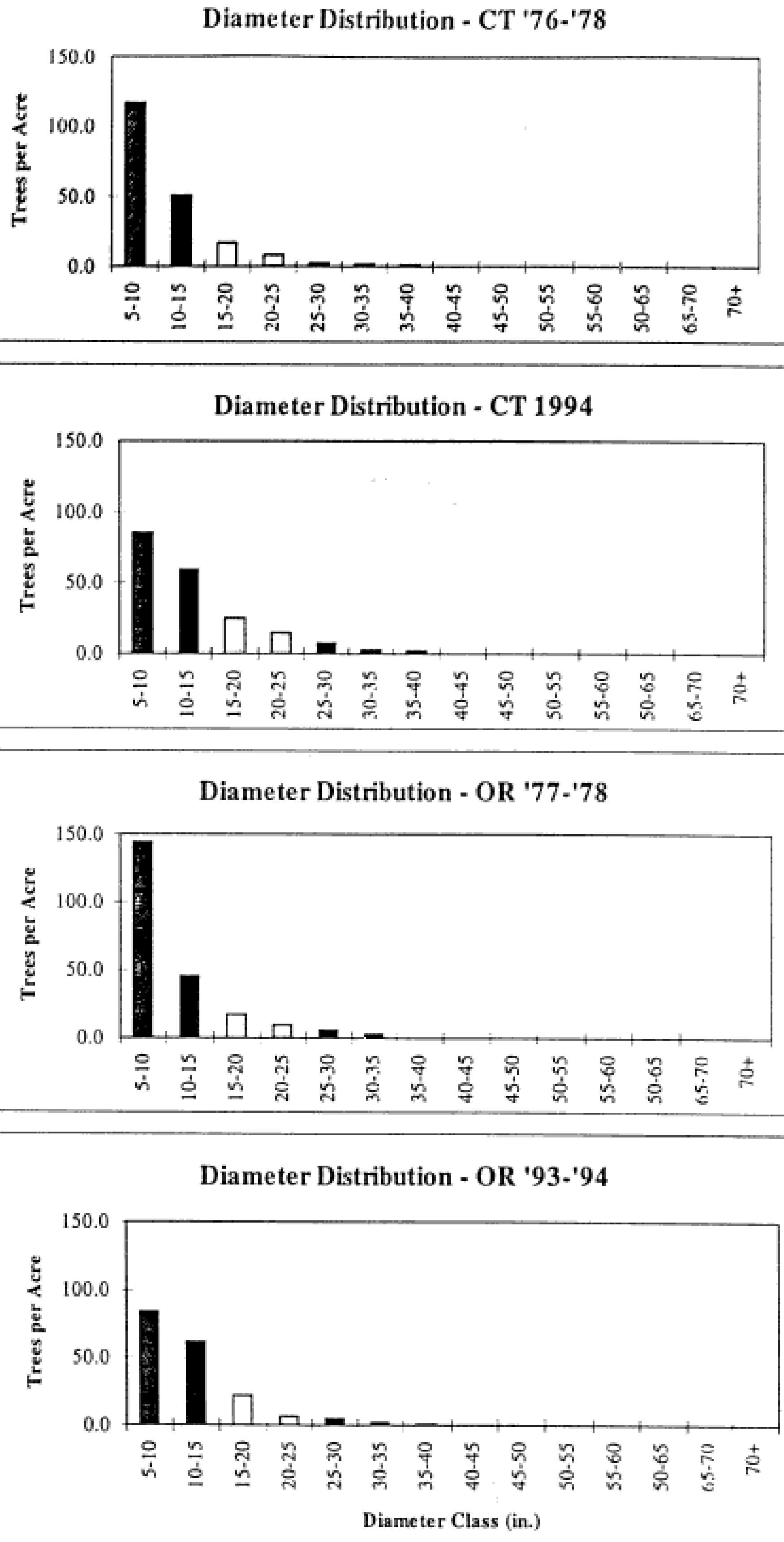


Figure 9. Trees per acre by diameter class for selected commercial thinning (CT) and overstory removal (OR) compartments at BFRS by year.

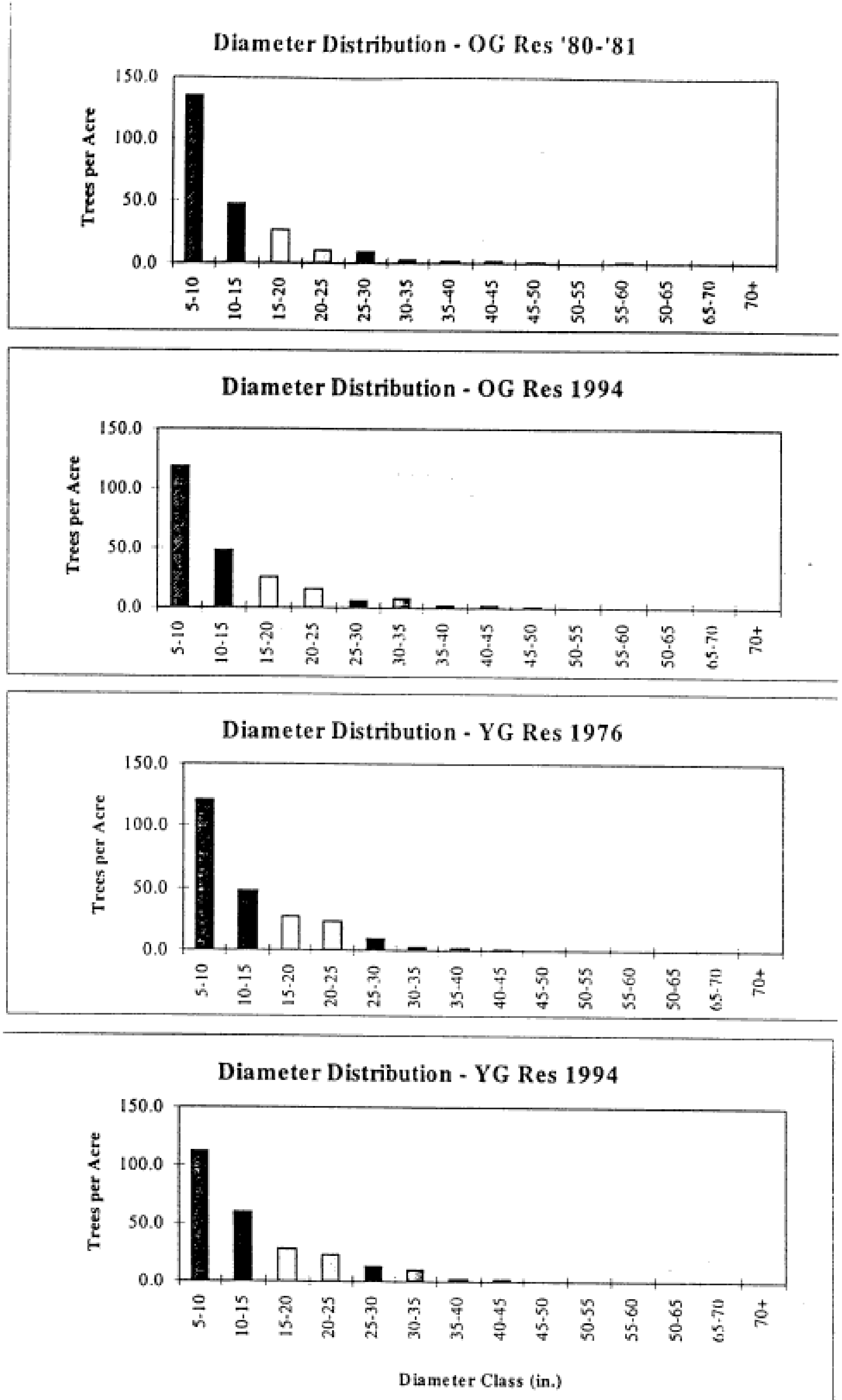


Figure 10. Trees per acre by diameter class for selected old growth reserve (OG Res) and young growth reserve (YG Res) compartments at BFRS by year.

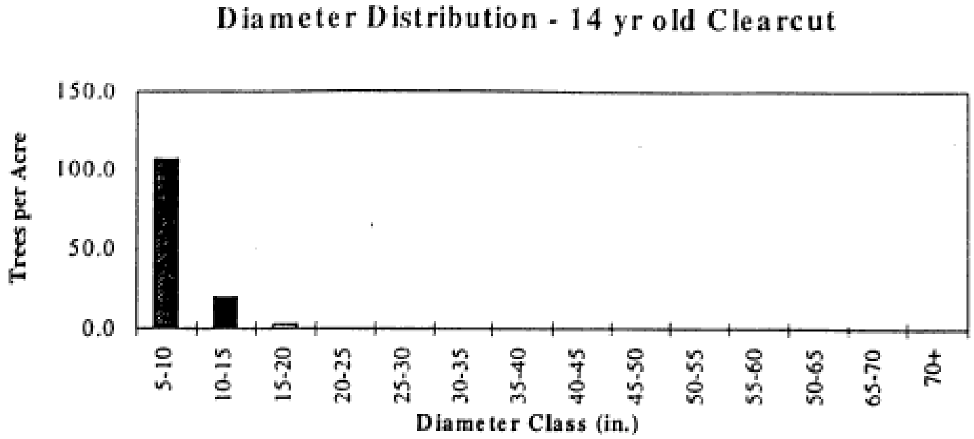


Figure 11. Trees per acre by diameter class for selected clearcut compartments at BFRS by year.

One issue facing forest managers today is the management, protection, and restoration of late seral old growth forests. We know from early reconnaisances of the Sierran region that much of the forests were late seral with wide open stands of large trees (McKelvey and Johnston 1992). If we are to reconstruct these late seral forests then we must have some idea as to their structure and target such structure for it is unlikely that we could ever let natural forces in the absence of pre 1850 fire regimes reconstruct these stands.

Comparing the distribution of diameters found by Sudworth (1899) to those measured at Blodgett we see a marked difference (Figures 8-12). Sudoworth measured diameters of trees greater than 11 inches on 1/4 acre plots (Table 17). He took some 50 plots throughout the Sierra, and eight of these were in the mixed conifer in the mid-Sierra.

The plots Sudworth measured at the turn of the century had few small trees while at Blodgett there are nearly 100 trees per acre just in the 5 to 10 inch class and nearly 50 trees in the 10-15 inch class. Sudworth's plots averaged more than 60 trees per acre greater than 30 inches in diameter. So these stands had many large trees, few small trees, and an open forest floor. This is a large difference in structure that will not be easy to duplicate through management. In the reserve stands, though they are adding trees to the larger diameter classes, there are no mechanisms for eliminating the abundant small trees. As well, the uneven-aged managed compartments require maintenance of a considerable proportion of small trees for recruitment into the larger classes, so neither of these strategies will come close to approximating the stands of the turn of the century for perhaps a hundred years. An examination of eight plots measured by Sudworth in 1899 in the mid-Sierra mixed conifer (Figure 12) shows that the average number of trees per acre greater than 11 inches was 101 (Table 17) and the average number of trees per acre greater than 30 inches was 63. These plots had an average of 720 sqft/ac basal area and a quadratic mean diameter of 38.9 inches for trees greater than 11 inches diameter.

Perhaps biomass thinning of 5 to 10 inch DBH trees in commercially thinned stands could result in stands that approach the size distribution of the plots measured by Sudworth in about 30 to 40 years. Free to grow trees on high site lands can add 4 inches in DBH per decade.

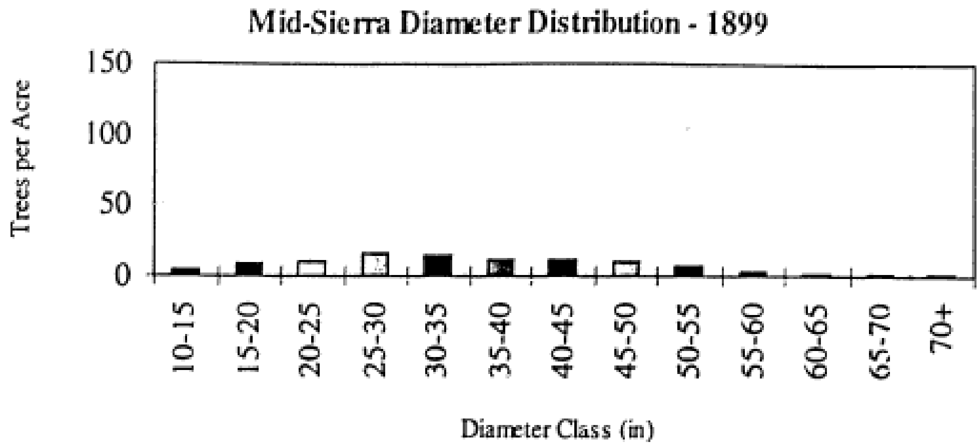


Figure 12. Trees per acre by diameter class for eight 1/4-acre plots measured by Sudworth in the mid-Sierra mixed conifer in 1899.

H. Snags

Standing snags were recorded in Blodgett Forest as part of the permanent plot inventory system since 1976. For each standing dead tree recorded on a plot the species, dbh, height, bark condition, time since death, and presence of bird nesting cavities. Table 18 shows the average number of snags greater than 4.5 inches at breast height per acre, the average diameter at breast height, and the average height of the snags by treatment type for selected compartments in 1994 (Compartment 481 was measured in 1989, 14 years after clearcutting). Management practices at BFRS do not include the making of snags. The snags observed on the permanent inventory plots occur naturally or are a result of harvest damage.

We can see in Table 18 that even though most snags were retained during harvest in the clearcut units, they had the lowest number per acre (6.5/ac) compared to the other treatments.

The young growth reserve compartments had the highest snag density (64.7/ac) as these stands are going through the stem exclusion phase. The old growth reserve compartment (C290) has a more diverse structure and less competitive pressure resulting in lower snag density (44.8/ac). Incense-cedar represents about half of all snags in the compartments shown in Table 18.

Table 18. Snag densities per acre (tpa), average snag diameter (dbh), and average snag height (tht) by treatment for the BFRS in 1994.

	Acres		PP	SP	DF	WF	IC	BO	TO	Oth	Tot
Group Selection	107	tpa	1.2	2.0	1.4	8.9	6.1	2.3			22.1
Comps 270 and 380		dbh	9.0	12.5	11.0	12.1	9.5	18.3			11.8
		tht	41.8	34.5	28.3	38.4	20.8	27.1			31.6
Single Tree Selection	113	tpa	2.0	1.8	1.2	6.7	21.2	12.0		1.4	46.4
Comps 160 and 410		dbh	9.6	13.0	16.3	10.8	6.0	8.4		22.5	8.5
		tht	33.5	44.6	18.2	33.8	20.8	35.4		13.8	28.2
Commercial Thin	106	tpa	3.4	0.7	0.3	6.9	9.1	2.5	1.6	0.9	25.5
Comps 40, 90, 120,		dbh	13.1	7.4	14.1	8.0	8.9	11.2	9.1	6.5	9.4
and 140		tht	23.3	29.3	11.0	37.8	25.4	35.5	24.4	18.0	29.1
Overstory Removal	152	tpa		0.3	0.5	3.2	12.6	1.4	0.6	0.8	19.5
Comps 30, 70, 100,		dbh		5.4	4.5	9.5	6.9	10.4	5.6	6.6	7.7
and 530		tht		20.0	41.8	39.8	22.8	26.1	12.8	25.8	26.1
Clearcut		tpa	0.3	1.2	0.3	3.3	0.5	1.0			6.5
C321 1994	17	dbh	4.6	3.8		8.8	19.7	11.9			8.9
C481 1989	20	tht	18.0	13.0		13.9	25.0	33.5			18.6
YG Reserve	99	tpa	4.6		1.8	8.5	41.2	0.6	7.3		64.0
Comps 20 and 220		dbh	11.3		8.7	12.8	7.8	39.3	5.6		8.8
		tht	34.6		35.7	55.8	29.7	28.5	33.9		34.3
OG Reserve	93	tpa	2.0	3.4	1.3	9.5	13.4	0.9		1.3	31.7
Comp 290		dbh	12.1	18.5	8.0	10.7	7.2	13.0		6.6	10.0
		tht	43.7	67.9	28.6	33.1	24.7	52.3		25.6	34.1

All snags greater than 4.5 inches DBH were recorded on permanent inventory plots. However, Cunningham et al. (1985) report that snags should be at least 33 cm (13 in.) at breast height and 6 m (20 ft.) tall with at least 40 percent bark cover to be suitable for wildlife nesting. Balda (1975) suggests that suggests that densities of such snags should be at least 6.5/ha (2.6/ac) to maintain cavity nesting birds at natural levels in Arizona ponderosa pine forests. Reynolds et al. (1985) also suggests 6.5 snags per hectare for nesting birds, but defines snags as those greater than 20 cm (7.9 in.) and greater than 2.6 m (8.6 ft.) tall in Colorado forests. In Figure 13 we can see that small diameter snags represent the greatest proportion of all snags. Table 19 shows the number of snags greater than 8 inches DBH and greater than 12 inches DBH by treatment type.

Only the overstory removal and clearcut treatments resulted in fewer snags per acre, ones greater 12 inches DBH, than is recommended in other studies. We would surmise that overstory removal tends to remove trees likely to become snags, especially the larger ones, thus resulting in few large snags. Clearcut areas on the other hand leave no trees for large snag recruitment. Even if numerous large snags are left during logging, snag attrition will result in fewer snags over time. Morrison and Raphael (1993) found that 67 percent of the snags in unburned Sierran forests fell in a ten year period. Recruitment for that same period was greater than attrition and they found a net increase in snag density over the ten year period 1978 to 1988.

Table 19. Number of snags per acre greater than 8 inches DBH and greater than 12 inches DBH by treatment type at BFRS in 1994.

Treatment	Number Snags per Acre > 8 inches DBH	Number Snags per Acre > 12 inches DBH
Group Selection	13.4	8.0
Single Tree Selection	17.0	7.3
Commercial Thinning	11.0	5.9
Overstory Removal	5.9	1.9
14 Year Old Clearcut	2.7	0.9
Young Growth Reserve	23.9	11.6
Old Growth Reserve	15.5	7.7

There are a large number of snags per acre less than 12 inches DBH in all but the clearcut compartments. Looking back at Section G of this report we see that the distribution of live trees is similar to that the dead snags, but there about 5 to 10 times as many live trees as dead standing ones.

Since the group selection compartments have only been entered 2-3 times the majority of the area has been treated much the same as the single tree selection area and we would expect similar numbers of snags per acre. However, we see very few snags in the 4.5 to 8 inch class in the group selection compartments. If we look back at page 31 we see that in the mid 1970s the group selection compartments, for whatever reason, had relatively few trees per acre in the 5-10 inch category, providing few trees as recruitment for snags in the small size class in the mid 1990s.

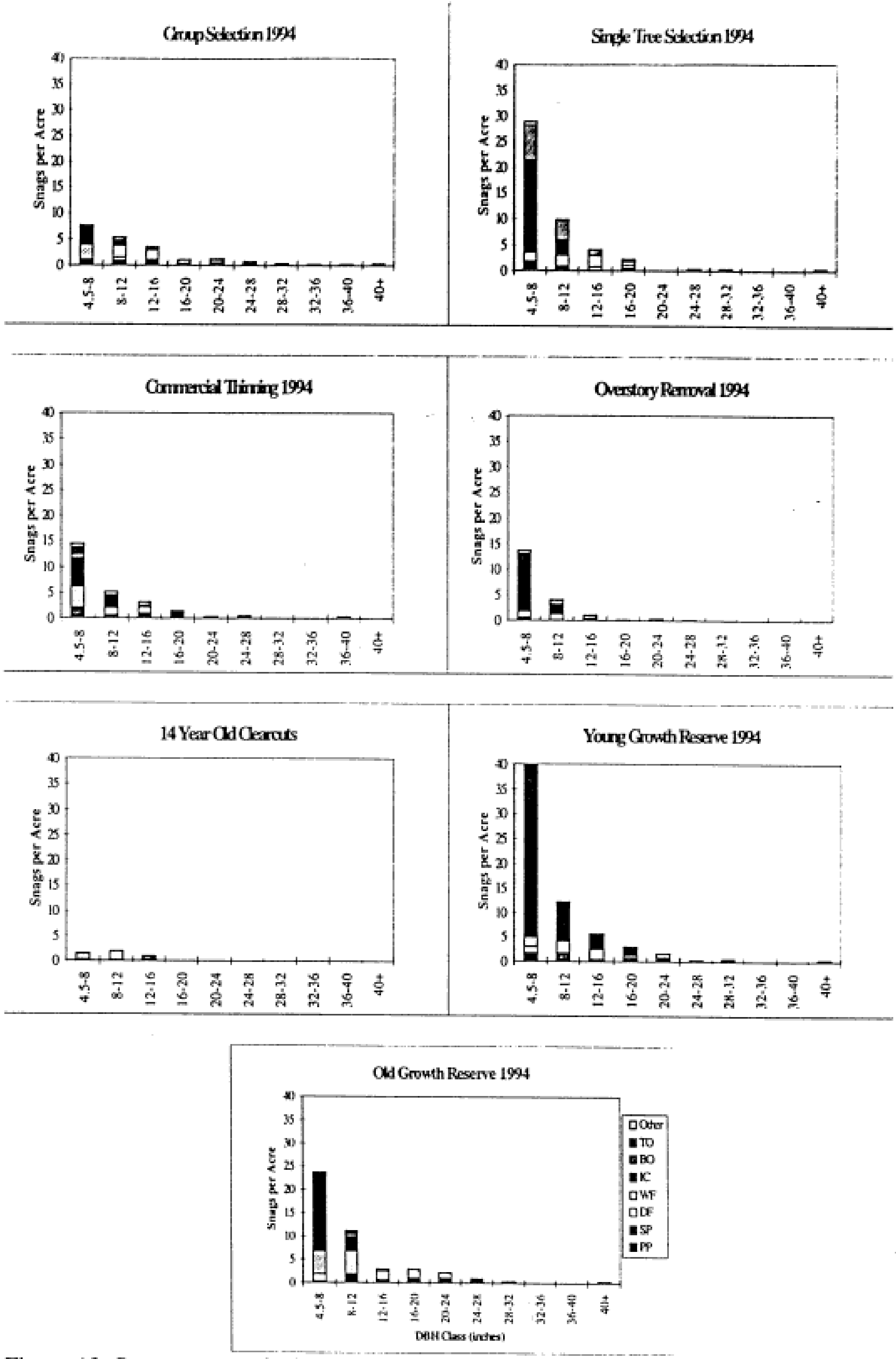


Figure 13. Snags per acre by DBH size class by treatment type at BFRS.

I. Fuels

Tables 20 and 21 show that the amount of light and heavy fuels in any given treatment area depends primarily on management or silvicultural method. Clearcutting and planting resulted in 1/3 less fuel than other treatments. The least amount of fuels were removed in the individual tree selection method compared to the other partial harvest methods. All treatments retained adequate amounts of duff layer needed for soil protection. As expected, both young-growth and old-growth reserve areas had the most amount of fuel material, however except for clearcut and planting, the differences were small. Understandably, overstory removal compartments had significantly less material greater than 10 inches in diameter compared to the other "thinning" and uneven-aged management compartments, as the intent of overstory removal is to capture mortality, thereby removing material greater than 10 inches in diameter that would otherwise be deposited on the forest floor.

These impacts on fuels were made without a deliberate intent to achieve particular fuel conditions. And over the years, the amount of fuels removed in preparation for plánting in clearcut and group selection areas have become less, recognizing their value in preventing soil surface movement and providing habitat. With the identification of specific goals of retaining medium to light fuels on site, quite different results of fuel retention could be obtained.

Table 20. Sample size, (n) fuel depth in inches, and standard error by fuel type and management type[1].

Mgmt*	n	Duff Depth	SE	Litter Depth	SE	Woody Fuel Depth	SE
		---Inches---					
GPS	211	1.66	0.29	1.39	0.18	6.51	1.77
ITS	86	2.06	0.35	1.34	0.17	5.66	1.23
OR	110	1.37	0.26	1.16	0.14	4.95	0.68
CC	21	1.32	0.31	2.07	0.27	4.63	0.84
CT	167	1.71	0.46	1.64	0.39	7.22	2.71
OG	60	2.43	0.42	1.00	0.13	4.81	0.84
YG	99	2.08	0.42	1.86	0.31	5.81	1.53
Avg.	-	1.78	0.36	1.46	0.23	6.06	1.62

Table 21. Fuel weight in tons per acre and standard error (SE) for duff and woody fuel diameter class in inches and by rotten (R) and sound (S) by management type[1].

Mgmt*	Duff	SE	0-.25	SE	0.25-1.0	SE	1.0-3.0	SE	>3.0	R3-10	R11-20	R >20	S3-10	S11-20	S>20	Total
	---Tons/Acre---															
GPS	19.57	3.45	0.32	0.06	1.81	0.26	3.27	0.66	12.36	1.09	2.66	2.11	2.71	1.77	1.29	37.34
ITS	24.29	4.15	0.25	0.04	1.68	0.23	3.30	0.69	13.47	1.77	3.43	0.76	3.29	2.56	1.66	42.99
OR	16.11	3.07	0.25	0.04	3.45	0.26	3.41	0.69	7.64	1.36	1.62	0.00	3.01	1.64	0.00	30.86
CC	15.54	3.65	0.11	0.04	0.96	0.32	1.47	0.67	4.36	1.46	0.63	1.55	0.73	0.00	0.00	22.44
CT	20.17	5.46	0.25	0.07	1.63	0.58	2.16	0.92	14.02	1.82	4.09	2.60	3.00	1.58	1.10	38.23
OG	28.71	5.01	0.59	0.06	2.60	0.26	2.29	0.44	13.02	0.74	2.47	2.62	2.60	1.79	2.65	47.21
YG	24.52	4.96	0.29	0.06	1.82	0.38	1.90	0.55	11.76	1.90	1.81	2.30	2.81	2.94	0.00	40.29
Avg	21.00	4.25	0.30	0.06	2.04	0.35	2.74	0.70	11.92	1.46	2.73	1.81	2.83	1.91	1.01	37.99

*Management types: GPS=Group selection, ITS=Individual tree selection, OR=Overstory removal, CC=Clearcut, CT=Commercially thinned, OG=Old growth reserve, YG=Young growth reserve

[1] From: Gregoire, R. 1995. Unpublished Report. Blodgett Forest Research Station, Georgetown, CA.

J. Shrubs and Forbs

Over the past 30 years of management of Blodgett Forest, the understory vegetation on many compartments has been manipulated to provide a temporary advantage to regenerating conifers. Treatments have included underburning, herbicide applications, grazing, hand weeding, mechanical cutting, and mixtures of treatments. For the past 20 years, records have been kept on the amount of ground cover vegetation present on the Forest.

Vegetation treatment in any particular year may have only covered a portion of a compartment to meet research or management objectives. Therefore, treatments in successive years were conducted to treat additional untreated areas within a compartment rather than to re-treat previously treated areas.

Understory vegetation was recorded by species for each permanent plot within the Forest. Table 22 shows mean understory vegetation percent cover by management type and by compartment. Shrubs represented 12 percent cover forest wide. Four species, each nearly equally represented, comprised 62 percent of the total shrub cover, deerbrush (*Ceanothus integerrimus*), greenleaf manzanita (*Arctostaphylos patula*), bush chinquapin (*Castanopsis sempervirens*), and tanoak (*Lithocarpus densiflorus*). Table 22 shows the results of remeasurements in 1993-1994 showing the average amount of ground cover by silvicultural treatment and method of control of ground vegetation.

Table 22. Mean shrub, herb, and total cover (percent), basal area (ft^2), year of last harvest, vegetation treatment and year, and number of plots by compartment management type and compartment number for compartments measured from 1992 to 1994.

	Comp.	Last Harvest	Vegetation Treatment* and Year	# Plots	Shrubs	Herbs	Total Cover	Basal Area
					Cover (%)			ft^2/ac
Group Selection								
	50	84	H 89,86,84,83	10	18.2	2.0	20.2	211
	60	89	H 92,90	14	1.1	2.3	3.4	197
	180	86	H 89	11	1.5	1.1	2.6	201
	260	76	-	9	21.7	1.6	23.3	214
	270	87	G, H 89	19	3.9	0.3	4.2	218
	350	92	G	8	0.0	0.0	0.0	288
	380	85	G, H 91,89	15	7.2	3.1	10.3	150
	420	92	G, H 84	12	10.0	4.4	14.4	174
	490	93	G	21	25.5	11.1	36.6	171
	570	88	G, H 82	9	1.1	0.0	1.1	206
	590	87	G, H 91	9	20.3	1.7	22.0	201
Weighted Average							13.7	197.4
Single Tree Selection								
	110	82	H 87,84	13	0.8	4.5	5.3	187
	160	83	-	16	16.9	3.4	20.3	204
	230	93	-	13	9.7	8.3	18.0	226
	295	91	-	8	3.1	0.0	3.1	218
	410	86	G, H92,87	11	1.1	0.5	1.6	195
	470	89	G	7	2.9	0.7	3.6	208
	471	91	G, H 91	5	0.0	0.0	0.0	185
	670	85	G, H 91	5	18.0	6.0	24.0	175
Weighted Average							10.4	202.3
Commercial Thinning								
	40	85	-	12	10.3	0.6	10.9	220
	90	85	-	8	4.8	2.5	7.3	225
	120	80	-	3	33.0	18.3	51.3	200
	121	80	-	3	40.7	3.6	44.3	226
	122	80	-	2	23.5	2.0	25.5	266
	140	85	-	10	12.9	13.2	26.1	223
	580	85	G	6	37.8	3.9	41.7	226
Weighted Average							23.6	223.5
Overstory Removal								
	30	81	-	13	21.5	4.9	26.4	193
	70	89 (90 pct)	-	8	3.1	0.0	3.1	168
	100	84	H 88	9	4.9	5.4	10.3	146
	170	86	B 82	10	11.8	2.0	13.8	191
	530	81	G, H 90	23	3.0	0.9	3.9	175
	540	87	G, H 90	4	33.8	15.0	48.8	150
	552	84	G	2	33.0	18.5	51.5	144
Weighted Average							14.3	173.8
Clearcut								
	321	80	G,H83,82, W 83,82,81	5	9.6	0.6	10.2	125
	560	84	G, H 90,86	3	11.7	0.0	11.7	216
Weighted Average							10.8	159.1
Young Growth Reserve								
	20	84	-	9	5.6	0.0	5.6	364
	220	13	-	20	3.1	1.7	4.8	322
	520	66	G	7	4.3	11.3	15.6	343
	630	-	G	4	12.5	0.0	12.5	279
	650	85	G, W 75	12	68.4	0.2	68.6	140
Weighted Average							23.6	314.3
Old Growth Reserve								
	290	-	-	27	9.8	2.3	12.1	292
	390	-	-	7	0.0	0.0	0.0	323
	600	-	-	8	24.4	0.6	25.0	216
Weighted Average							12.5	282.7
Shelterwood								
	440	87	G	11	2.2	3.7	5.9	259

B= burned; G= grazed; H= herbicide application; W= Mechanical weeding; - = No treatment

*Vegetation treatments often covered only a portion of a compartment in order to meet research objectives

Table 23. Control of understory vegetation under different silvicultural regimes (data from 44 compartments)

	Understory Cover (%)		
	Shrubs	**Herbs**	**Total**
No Shrub Treatment			
Group	21.7	1.6	23.3
Single Tree	11.4	4.4	15.8
Thinning	23.3	6.3	29.6
Reserve	6.0	1.5	7.5
Herbicide			
Group	6.2	1.8	7.9
Single Tree	0.8	4.5	5.3
O'Removal	4.9	5.4	10.3
Grazing			
Group	18.5	8.0	26.5
Single Tree	2.9	0.7	3.6
O' Removal	33.0	18.5	51.5
Shelterwood	2.2	3.7	5.9
Grazing + Herbicide			
Group	7.7	1.9	9.2
Single Tree	4.9	1.7	6.6
O'Removal	7.6	3.0	7.2
Underburning			
O'Removal	11.8	2.0	13.8

Table 23 shows that without any treatment, the amount of understory vegetation in managed compartments is approximately 16 to 30 %. This amount of cover can be compared with the level of approximately 30 % which is the threshold level above which growth of conifer saplings is markedly reduced (Oliver 1984). The relatively low level of 7.5 % cover in untreated reserve compartments is due to their having high stocking levels of 290 to 360 ft^2/ac. The effectiveness of herbicides is shown by compartments with this treatment having understory vegetation cover of between 5 and 10 %. As might be expected, cattle grazing results in the most variable amount of control with cover ranging from 4 to 52 %. The use of a combination of grazing plus spot herbicide kept understory cover to 7 to 9 %. Underburning, with average ground cover of 14 % was not as effective as other methods of control (except grazing) but still satisfactory. It should be noted that, in all methods of shrub and herb control, substantial amounts of understory vegetation have been retained. The management goal in vegetation control is not to eliminate all ground cover but to reduce it below a 20 to 30 % level.

K. Discussion and Conclusions

The permanent plot system and silvicultural practices in Blodgett Forest Research Station were not established or applied in a manner designed to test hypotheses and draw inferences. For example, residual stocking levels, choice of thinning prescriptions, conditions of fuels, or regeneration characteristics, all vary among compartments due to differences in past history and existing stand conditions. Consequently, in applying each cutting method on several compartments, variable stand conditions among compartments necessitates differences in treatment specifications. This makes it is impossible to make precise, quantitative statements on the effects of silvicultural treatments on stand characteristics. The problem is made more complex when attempting to compare the effects of alternative silvicultural approaches, forestwide. In addition, the Forest has only been managed for approximately half of a 60- to 70-year rotation; consequently it is too early to draw definitive conclusions. However, some limited general observations on stand growth and development can be made based upon 60-years of harvest and inventory records and time-series measurements on permanent plots for 20 years.

Extrapolation from Blodgett Forest to broad areas of the Sierra Nevada

Care must be taken in generalizing from data obtained from Blodgett Forest and in extrapaolating to other parts of the Sierra. All silvicultural methods used at Blodgett may be applied throughout the Sierra. However, the results, particularly of growth, must be extrapolated to other areas with caution because Blodgett Forest: 1) is located on high site quality land (Site Class IA and I (Dunning 1942) capable of producing at least 165 ft^3/ac/yr), 2) is on relatively flat ground (no cable yarding required), 3) has relatively small compartments (less than 90 acres), and 4) has a high degree of technical competence and supervision of silvicultural activities. In the Sierra Nevada, approximately 7 % of private forest industry lands (196,000 ac) and 3 % of public lands (222,000 ac) are of similar site quality (Hiserote *et al.* 1986, Colclasure *et al.* 1986, and Lloyd *et al.* 1986). Consequently, results from Blodgett Forest are directly applicable to perhaps 420,000 acres in the Sierra. Considering just those lands sufficiently productive in the Sierra Nevada to warrant active forest management (Site Quality III and above), Sites I and Ia lands represent 9 % of the total forest area (7 % of National Forest lands and 14 % of private industrial lands). On lands that are less productive and steeper than Blodgett Forest, stands will respond more slowly to treatment, silvicultural operations will be more difficult to apply, and overall volume production and economic return will be lower and less cost effective.

1. Overall Conclusions

Because the whole Forest was heavily cut-over between the turn of the century and 1927, three overall conclusions are:

a) in the space of 21 years from 1934 to 1955, unmanaged, cutover, relatively poorly stocked, but highly productive sites can gain in board foot volume at a rate of 1.8 % per year.

b) forest development over the next 37 year period from 1956 to 1993 supported an active timber harvest in which about 68% of the growth was removed while, at the same time, allowing the forest to build up growing stock while increasing stand vigor and health. Board foot volume accrued at 2.7% per year during this period.

c) the use of a variety of silvicultural harvesting and regeneration methods has demonstrated that a wide diversity of stand structural types can be developed.

2. Timber management

- Forest Practice Rules - Blodgett Forest is managed in a similar manner to lands managed by small private landowners. Taxes are paid, timber harvest plans prepared and submitted to the State for approval, and all standards of the State forest practice rules are met or exceeded. All operations, maintenance, and salaries of Blodgett Forest personnel are funded from revenue obtained from timber sales.

- Growth - Forestwide, from 1934 to 1994, the average volume increased from 12,700 bd ft/ac to 29,270 bd ft/ac (24,000 bd ft/ac excluding reserve compartments).
  Over the 39-year period 1955-1994, over the 2,895 ac Forest:
  a) total volume harvested averaged 1,775,000 bd ft/yr.
  b) approximately 69 % of growth was harvested.
  c) standing volume increased from 18,350 bd ft/ac to 29,270 bd ft/ac.
  d) an average of 614 bd ft/ac/yr was logged.
  e) including reserve compartments (424 acres), growth plus harvest averaged 894 bdft/ac/yr.
  f) excluding reserve compartments, growth plus harvest was 868 bf/ac/yr.
  g) over the last 10 to 15 years, well stocked 70- to 100-year-old stands (>200 ft^2/ac) are growing at the rate of nearly 1,000 bd ft/ac/yr.
  h) long-term productivity appears to be relatively independent of cutting method as long as there is sufficient stocking that is relatively free to grow.

- Retention of Pines - Successive forestwide inventories in 1933, 1946, and 1957 (before any harvesting was done) show that, as stands go through the stem exclusion phase, sugar pine and ponderosa pine combined decline from 40 to 30 percent of all stems. They did not survive as well as the more shade tolerant incense-cedar and white fir. Inventories since 1957 show that, except in areas clearcut and planted, pine seedlings and saplings in the Forest are fewer in number compared to the more shade tolerant white fir and incense-cedar. Also, the naturally-regenerated pine does not seem to be surviving well into the sapling stage. Under natural conditions, pines are probably maintained in mixed conifer stands by frequent, low intensity fires which reduce the number of competing shade-tolerant species. In single-tree and group selection managed stands where wildfires are suppressed, the retention of pines in the overstory seems possible through substantial investments in selective precommercial and commercial thinnings, vegetation management, selective harvesting, and prescribed burning.

- Choice of Group Size - Current planning is tending to favor the use of either group or single tree selection systems for regenerating mixed conifer stands. A major issue is how to determine optimal group size. There are engineering issues of the space needed to fall and yard in a safe manner while minimizing damage to residual trees. Silviculturally, groups size should be chosen such that the microclimate created favors the shade tolerance characteristics of the desired mix of regenerating trees, shrubs or grasses. Experience at Blodgett has shown that reduced growth occurs in groups near the stand edge. Towards the center of .5 to 1.5 acre groups, growth of intolerant pine regeneration is greater than that of fir and cedar. Naturally regenerated or planted shade tolerant species will be favored near the stand edge or in groups of small size.

- Snags - Group and single tree selection methods and commercial thinning can retain and recruit snags of sufficient size at or above levels necessary for cavity nesting wildlife. In carrying out clearcutting or overstory removal, all existing snags are retained at harvest except those constituting a hazard to personnel. However, 10-years after harvest, most of these snags have fallen due to natural decay processes. Past prescriptions for clearcutting and overstory removal have not retained large live trees to become snag replacements.

- Fuels - In managing mixed conifer stands, the choice of treatments and the manner of their application affects the distribution of light, medium and large dead woody material. This material has value for wildlife habitat, nutrition, soil cover, and to protect against soil erosion. This material also constitutes fuel and contributes to fire hazard. Knowledge is needed, therefore, on the extent to which alternative silvicultural treatments affect the quantity of this material. A major difficulty in evaluating treatment effects is that standards of silvicultural practice change over time. In particular, clearcutting, site preparation, and planting conducted in the early 1980s removed, by design, considerably more dead and down woody fuel compared with other silvicultural methods. Currently, post harvest site treatment practices are designed to leave the medium to large woody material which is now recognized as desirable for wildlife habitat and to protect the surface soil from erosion.

- Cattle grazing and herbicides can be effective in reducing shrub competition with conifers. Cattle grazing produces highly variable reduction in shrub competition. Certain shrub species are very thoroughly controlled, such as deerbrush (*Ceanothus integerrimus*), while other shrubs, such as the unpalatable gooseberry (*Ribes spp*), are not controlled at all. Herbicide use, being more target specific, is more consistently effective in reducing shrub and hardwood competition to specified levels.

- Shrubs are effectively suppressed to a level of less than 12% when conifer crowns form a closed canopy and basal areas reach approximately 250 ft^2/ac.

3. Sierran Issues and Alternative Management Scenarios

- Biodiversity. The compartment design on the 2,895-acre Forest has resulted in a diverse landscape consisting of a mosaic of age classes, stand structures, and species composition. The Forest has allocated approximately 1,052 acres to uneven-aged management, approximately 985 acres to even-aged management (including 125 acres of shelterwood and seed tree regeneration), approximately 355 acres to young growth reserves (gradually, over 90 years, clearfell and plant, no other management), and approximately 349 acres to no-cut ecological reserve. Such an allocation provides a spectrum of habitats from early seral (newly clearcut) to mid seral (reserve compartments) while at the same time over 600 bf/ac/yr has been harvested forestwide over the last 37 years. The Forest provides, therefore, an indication of what might be obtainable on a landscape basis where the management goal was to provide diversity of stand structures to attain forest health, diversity of wildlife habitat, and sustainable timber yields.

- Fire Hazard Reduction. Since wildfire suppression policies were introduced earlier in the century, there has been a significant accumulation of dead, woody fuels in Sierran forests. On Blodgett Forest there is most dead, woody fuel accumulation in the unmanaged reserve and uneven-aged managed stands, and less in clearcut and planted areas and overstory removal compartments. Small diameter trees in both managed and reserve stands provide ladder fuels that could allow fires to reach tree crowns. These ladder fuels were less common in those areas of late seral stands at the turn of the century due to the paucity of small diameter trees. In these stands, it is conjectured that wildfires were commonly restricted to ground fires of low intensity.

  There has been no experience at Blodgett Forest in the creation or management of late-seral, low fire hazard areas because of the small size of the Forest and because sufficient time has not elapsed for the development of very large-sized trees. Experience suggests, however, that fuel management and stand structures can be developed, in time, using a combination of thinning and underburning that would reduce the likelihood of catastrophic wildfires.

- Pre-EuroAmerican Stand Conditions
  The USDA Forest Service and other groups are developing plans having the goal of returning much of the the Sierra Nevada to within the range of "pre-Euro-American conditions". These conditions have not been identified in terms of species composition, age classes, or stand structures. The best descriptions of stand conditions in the 1800s are those of John Muir, plots established by Sudworth in 1899 - 1901, and early photographs such as those evaluated by Gruell (1994). Although these descriptions may not be "average" they are representative of at least a portion of the Sierra Nevada that consisted of open, park-like conditions and late-seral stage stands. In addition to these stands, the Sierra is most likely to have had mosaics of stands of varying age class, density, and species composition.
  An examination of Sudworth's field notes, describing eight 0.25-ac plots measured in 1899 in the mixed conifer type in or near Blodgett Forest, showed that there was an average of 101 trees per acre greater than 11 inches dbh and 63 trees per acre greater than 30 inches dbh. Average basal area stocking was 720 ft^2/ac. Stands were uneven-sized but not necessarily uneven-aged, and there was limited regeneration.

  There has been no direct experience at Blodgett Forest that provides a silvicultural prescription on how to produce late-seral stage stands having attributes similar to "pre-EuroAmerican" conditions. Experience at Blodgett suggests, however, that it is possible, on high site quality lands, to accelerate the growth of well-spaced trees to create stands having elements of a late seral condition (i.e. mosaics of large, well-spaced trees, gaps containing smaller trees and shrubs, large snags and downed woody material, and multi-layered canopies). Silvicultural prescription could favor a sufficient pine component by thinning and underburning. Experience suggests that, on productive sites, such stands can be developed from bare ground in 100 to 150 years. Similar approaches could be taken on sites of lower productivity, however the time taken to obtain stands having elements of late-seral structure would be longer.

L. Acknowledgments

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