

Size Distribution of Unharvested Redwood Forests in Mendocino County¹

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Abstract

Late-seral conditions in redwood forests are becoming a management goal on some timberlands. However, published information is rare regarding the structure of late-seral forests upon which silvicultural prescriptions can be guided, or upon which to measure success. Old-growth forests—those perceived to be near or at the successional climax—are the ultimate model. Yet, old-growth forests are a rare commodity in Mendocino County, limited mostly to state parks and small stands on private lands. Their rarity yields a poor sampling of the variation among stands, making historic sources of information valuable. Despite often incomplete information relative to ecologically important but non-commercial vegetation such as hardwoods or the structural complexity of their trees' canopy and boles, historic timber inventories can yield insights to the range of unharvested forests conditions. A 1929 data set derived from timber stands stratified into 20-thousand board feet per acre redwood classes on Caspar Lumber Company lands reveals an inverse J-shaped size frequency distribution based on diameter at breast height (DBH). Across the stand conditions, redwood comprised 67 to 96 percent of the tree density (31 to 51 trees per ac) and 73 to 97 percent of the basal area (116 to 537 ft²/ac); the DBH₅₀ (diameter at which half of the trees were smaller) ranged from 17 to 30 inches DBH; while the DBH₉₀ ranged from 42 to 70 inches. The largest size classes measured were 126+ inches, 78 to 82 inches, and 42 to 46 inches for redwood, Douglas-fir, and grand fir, respectively.

Key words: late-seral, late-successional, old-growth, stand structure, targets, hardwoods

Introduction

To enable setting goals and evaluating management actions, descriptive criteria of late-seral conditions can be important to forest managers in the redwood (*Sequoia sempervirens*) region. Where cut-over forests have been acquired in parks, restoration of more advanced and near-climax stages is a goal (e.g., Chittick and Keyes 2007). Other land managers desire to manage forest stands for late-seral values as well as for other values including commodity production (e.g., Thornburgh 2007). Still other forest land owners who have late-seral forests in a Timber Harvesting Plan can avoid significant impacts under the California Forest Practice Rules (Anon. 2011) if their harvests retain late-seral conditions after harvests.

Whether to establish success criteria for restoration or to consider the maintenance of or the degree of departure from late seral conditions, working definitions are lacking or imperfect. The Forest Practice Rules' (Anon. 2011) definition includes trees greater than 24 in either with or lacking understory trees; an open to dense canopy; a minimum area threshold (20 ac); and the presence of an

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unspecified density of large decadent trees, snags, and large down logs. This definition's lack of specifics may be due to its intended use in many forest types across the state. However, equally important, its ambiguity may be a reflection that late-seral forests are variable. Not only may they vary locally due to site condition and localized disturbance dynamics, the late-seral stands may occupy any point along a successional continuum from mid-seral to climax conditions. Criteria developed specifically for different forest types and regions could enhance the use of the late-seral concept in forest management.

Unharvested redwood forests can be the source of information upon which to develop regional management goals. To the extent they represent near-climax conditions, unharvested forest represent perhaps the ultimate example of late-seral qualities. However, in Mendocino County, current unharvested stands are rare and of generally small acreage, limiting how much variation they may encompass. Despite the focus on economic values of forests, historic information can be mined to yield stand-based information to better understand the range of conditions present in late-seral forests. This paper characterizes the "virgin" forest conditions of conifers on the Caspar Block of the Caspar Lumber Company (Anon. 1929); a management unit that closely approximates the present-day Jackson Demonstration State Forest.

Methods and materials

According to the report (Anon. 1929), the lands inventoried were the "Caspar Block", an area of 23,564 ac of which 18,629 ac were virgin timber. The Caspar Block was in the watersheds of Two Log, Chamberlain, James and Two Rock Creeks, and adjoining parts of the South Fork of Noyo and the Little North Fork of Big River.

While the methods are described in the inventory, the description is limited. In summary, Caspar Lumber Company had preexisting cruises organized by 40 ac units. However, stand conditions frequently covered such small areas and were so important to deriving an accurate inventory that evaluating the timber values based on the 40 ac units would not have shown the actual situation clearly. To solve this problem, overlapping aerial photographs, complimented by the cruise information were used to create a map of "economic types". Then "more than 200" one quarter ac sample plots separated by 5 chains were sampled. Neither the starting point(s) nor the orientation of the sampling frame is specified. A sample of trees was cored, and the thickness of the bark recorded; however, the report is not clear if the size distributions calculated included or excluded bark thickness. The plots were not laid out to achieve any specified level of sampling within or among the "economic types". Rather, a plot was assigned to its economic type based on where the plot fell on the map. The report does not provide a count of plots by economic type, except that there were "a large number of sample areas in each type".

The "economic types" to which virgin stands were assigned was based upon the quantity of redwood/acre as derived from company cruises adjusted to agree with the company's cutting experience (*table 1*).

Table 1—*Identifiers, definitions of economic types, and possible percentage of sample plots.*

Identifier	Redwood volume Board ft/Acre thousands (M)	Area (Acres)	Percent of Samples
80+	more than 80	431	7
60 – 80	between 60 and 80	528	3
40 – 60	between 40 and 60	2643	10
20 – 40	between 20 and 40	7120	44
<20	less than 20	7907	36

A map in the inventory (Anon. 1929) displays the geographic distribution of assigned economic types, roads, watercourses, and ridges. Also included are 61 numbered points that are neither identified on the map index nor the body of the report. These may reflect location information (possibly start points) for the plot sampling frame. To approximate the sampling distribution if it was based on these points, I calculated the percentage of points by the “economic type” in which they were placed (*table 1*).

Results

When the plot data for all conifers is grouped within economic types, each displays an inverse J-shaped curve (*fig. 1a*). Generally the curves are ordered according stand type, with the density of trees in the 80+ type greatest and that of the <20 type least. The ordering by stand type is most notable in the larger size classes. In the 14 to 22 in size class, the <20 type had the greatest density among the types. The size class distribution of redwoods (*fig. 1b*) also was ordered similarly among types, but with density of the 80+ types greater than the other in all size classes. Notably, the curve shows the smallest size class of redwood in the 80+ type being denser relative to the larger size classes than those of the other types, despite the presumably more heavily shaded understory in the 80+ stand. The largest redwood was in the 126 in size class, and was found in the 80+ type. Among types, the Douglas-fir (*Pseudotsuga menziesii*) size class distribution (*fig. 1c*) ranged from inverse J-shaped curves for the lowest economic types to flat curves for the highest types. The density of Douglas-fir in the latter types was very low, and much lower than for the lowest economic types. The largest Douglas-fir measured was in the 78 in size class of the 20–40 type. Grand fir³ (*Abies grandis*) also exhibited flat to declining size class distributions (*fig. 1d*), and there was no apparent relationship between their density and the economic types. Although not common in any type, grand fir was not recorded in the <20 type and was most common in the 60–80 type. The largest grand fir (42 in size class) was measured in all but the 60–80 type.

Total tree density ranged from 30 to 51 trees/ac (calculated values are rounded to the nearest whole number), increasing from the lowest to the highest economic type. Redwood comprised 67 to 96 percent of the trees in each type, with the highest economic type substantially greater than the other types. Graphs of cumulative percent of tree density by DBH class can enable a rapid assessment of the proportion of trees in a stand either greater or less than a given DBH. For instance, among the types, the median density of trees ranged from 18 to 30 in DBH, and 90 percent of

³ The inventory identifies the third conifer species as white fir without its specific epithet. White fir is not known from the vicinity, and the intended species was most likely grand fir.

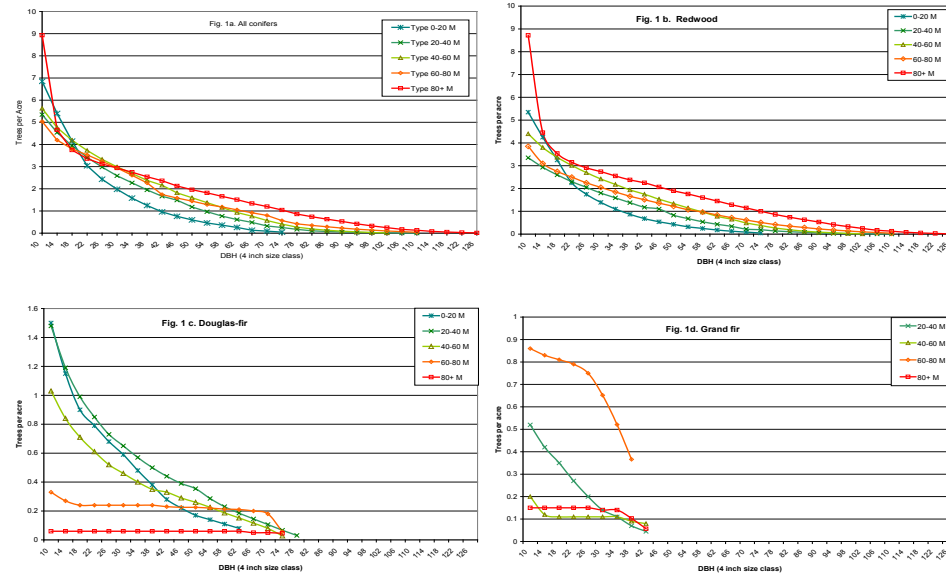


Figure 1—Conifer density (trees per acre) by size class and stand type in virgin forests of the Caspar Block, 1929; a=all conifers, b=redwoods, c=Douglas-fir, and d=grand fir.

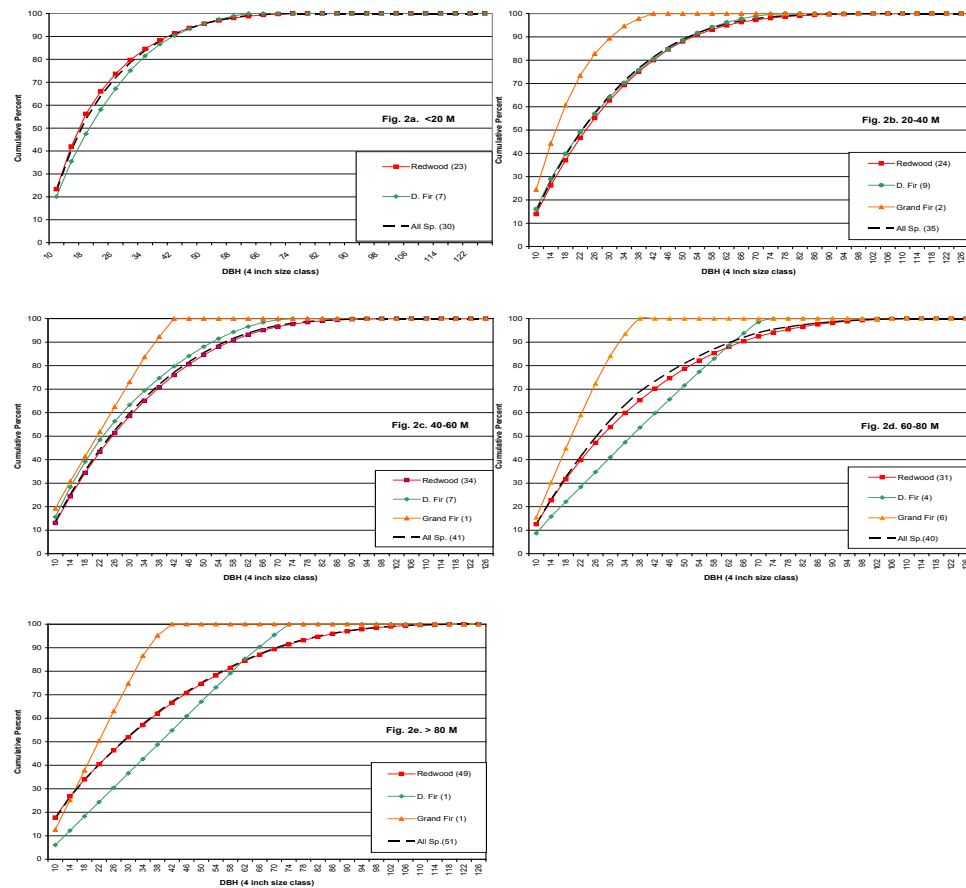


Figure 2—Cumulative percent of conifer trees by diameter class and species in virgin forests of the Caspar Block, 1929; stand types a) <20 M, b) 20-40 M, c) 40-60 M, d) 60-80 M, and e) 80+ M. Species-specific density is given parenthetically by stand type.

the trees were less than 42 to 74 in DBH (*fig. 2a to 2e*). The values of both the median and 90 percent DBH increased with economic type. The similarity between the cumulative DBH curves for redwood and all conifers (*fig. 2a to 2e*) displays how the former dominates this metric of the stand condition.

Basal area ranged from 116 to 536 ft²/ac, increasing substantially with an increase in economic type. Redwood comprised about 73 percent of the basal area in the lowest two economic types, 85 percent in the 40-60 and 60-80 economic type, and 97 percent in the 80+ type. Compared to the cumulative percent of trees by DBH class, the curves for cumulative percent of basal area by DBH class (*fig. 3a to 3e*) portrays relatively “s” shaped curves. The trace of redwood cumulative basal area by DBH class was most similar to that for all trees, showing the dominance of redwood as a determinant of basal area in these forests. The DBH of median basal area ranged from 36 to 66 in, while that at which 90 percent of the basal area was less ranged from 61 to 98 in. Both increased with economic type.

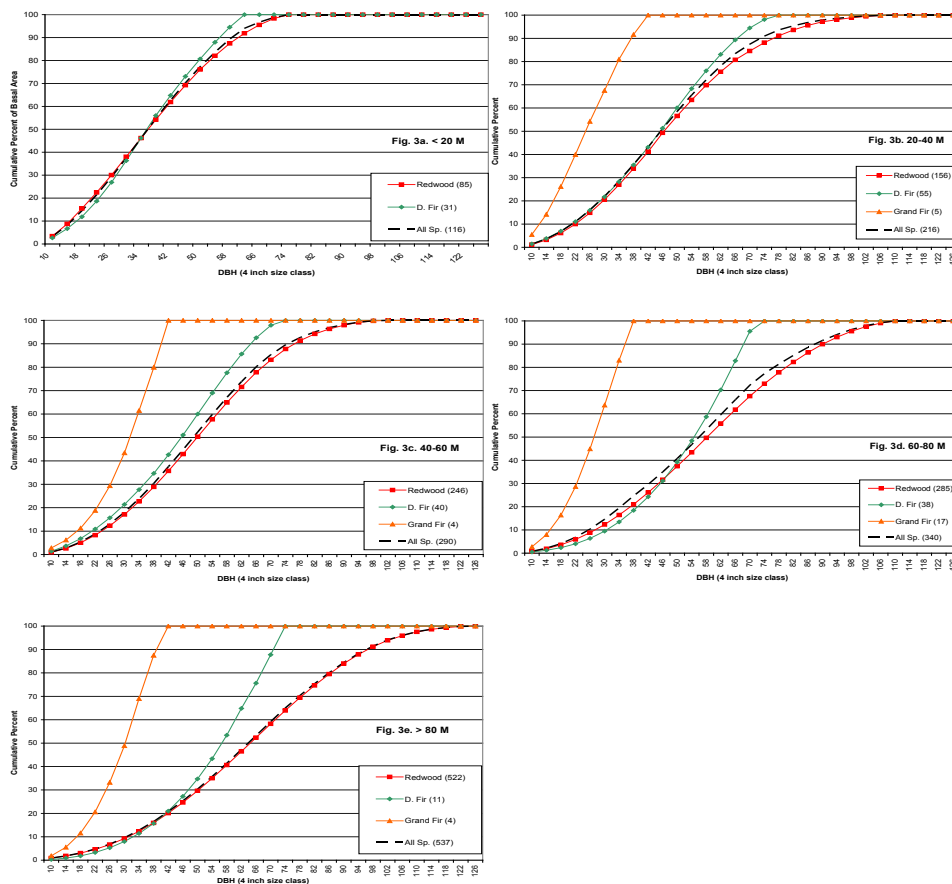


Figure 3—Cumulative percent of conifer basal area by diameter class and species in virgin forests of the Caspar Block, 1929; stand types a) <20 M, b) 20-40 M, c) 40-60 M, d) 60-80 M, and e) 80+ M. Species-specific total basal area is given parenthetically by stand type.

Discussion

Metrics associated with tree size are convenient for describing stand conditions. Because this information is important in assessing the economic value, the methods

have a long history and common understanding among various users. In their literature review of coast redwood forest disturbance dynamics, Lorimer et al. (2009) characterize northern forests from several studies. Veirs (1982, in Lorimer et al. 2009) evaluated nine 2.53 ac plots in near-coastal, intermediate, and xeric slope forests near Redwood National Park. He reported the minimum size to reach canopy status to be 23.6 in, and a mean of 27.7 canopy trees/ ac (range 22.9 to 38.4 > 23.6 in). Redwood comprised 41 to 95 percent of the canopy trees. Basal area averaged 689 ft²/ac (range 455 to 1085 ft²/ac) with redwood accounting for 43 to 97 percent. Lorimer et al. (2009) note that of Veirs' nine sites, only two or three had size distributions that approximate a "negative exponential or rotated sigmoid curve" typical of uneven-aged, old-growth forests. This divergence from the expected size distribution is not explained for the mesic, near-coast sites; but they suggest upland sites may depart due to climatic shifts, limited sample size – and perhaps most importantly – moderate disturbance. The presence of Douglas-fir, a species requiring fire-related disturbance for recruitment was presented as evidence for the disturbance. Sample size is a likely difference between the clear inverse J-shaped curves for each economic type at Caspar and those reported by Veirs. While lots differed in size between the studies, the apparently more numerous plots in the Caspar Block data should have averaged out localized disturbance-induced variation that might overwhelm patterns at few sites.

Dagley and O'Hara (2003) summarize a number of studies on the density of trees in unharvested stands, and found the density is highly variable across the redwood range. They note that differences in methods and definitions complicate comparison. Based on upper canopy trees, the density ranged approximately from 20 to 150 trees/ac, the majority being redwood. Direct comparison of these values to the Caspar Block data is limited. The preponderance of the summarized studies sites were at Bull Creek and Redwood National Park in the northern part of the range while central Mendocino County is in the central part of the redwood forest's range (Sawyer et al. 2000). Also, while considering only canopy tree density may have ecological relevance, determining what constitutes a canopy tree needs clarification. The studies reviewed by Dagley and O'Hara (2003) used unspecified or different DBH criteria. Still, the cumulative distribution graphs (*fig. 2a to 2e*) can facilitate enumeration by whatever DBH class is relevant.

Giusti (2007) presents historic inventory data from lands that became Redwood National Park in Del Norte County. As presented (*fig. 5* of Giusti 2007), unharvested redwood from ARCO, Simpson, and Rellim Timber Companies consistently present an inverse J-shaped curve. Although Giusti (2007) did not fully describe the methods used in these historic inventories, they likely included averaging a large number of samples including upland and riparian areas over the 9,000 ac cruised. In addition, Giusti (2007) also tabulates tree density data from Redwood creek, Little Lost Man Creek, and Bull Creek in Humboldt County. Respectively, trees greater than 40 in averaged 11.3, 12, and 35 trees/ac. The density of trees in the Caspar Block that exceeded this size class ranged from 3 to 18 trees per ac for the < 20M and the 80+ M types, respectively (*fig. 2a to 2e*).

Hardwood associates in redwood/Douglas-fir forest likely common in the Caspar Block area include tanoak (*Lithocarpus densiflorus*), madrone (*Arbutus menziesii*), bigleaf maple (*Acer macrophyllum*), California bay (*Umbellularia californica*), and golden chinquapin (*Castanopsis chrysophylla*). These species, though of limited

economic value have great ecological value. They are often overlooked in timber inventories, even though they may constitute a substantial component of forests. As for conifers, the hardwood content and stand structure of future stands is a direct outcome of present management (Harrington and Tappeiner 2009). Managers who focus on developing large conifers without simultaneously planning for a substantial hardwood component when developing restoration treatments may fail to achieve the broad ecological values of late-seral forests. Unfortunately, information is limited on the hardwood component of unharvested conifer stands upon which to evaluate either the range of natural variation or management goals.

In northwestern California, Bingham and Sawyer (1992) found the density of hardwoods and conifers to be 82 and 24 per ac, respectively, in old stands. Diameters of hardwoods averaged 15 in, while conifer DBH averaged 38 in. Using average density and DBH, the study concluded that the hardwood basal area of the old stands approximated 50 ft²/ac, just over 20 percent of the total basal area.

The most comparable data from the central portion of the Redwood range comes from Montgomery Woods State Reserve (Giusti 2007). Data on tree species inclusive of hardwoods, size, and habitat elements were analyzed from an average of four 0.1 ac plots at 98.4 ft spacing along 14 parallel transects that crossed the alluvial plain and extended into the adjacent upland. These plots collectively characterize a single stand. Unlike the size distributions observed on the Caspar Block, the plot for Montgomery Woods displays a flat, inverse J-shaped curve with redwood and Douglas-fir about equally dominant within each of the 10 in size classes. Twenty one trees/ac exceed 40 inches, with only one tree/ac – a redwood – exceeding 80 in. The flatness of the Montgomery Woods size distribution lead Giusti to conclude that recruitment may be limited on the site. Redwood dominated with nearly 60 percent of the large conifer density, Douglas-fir had the remainder. Importantly, Giusti (2007) found that by density, tan oak made up 85 percent of the less than 10 in DBH size class, 89 percent of the trees in the 11 to 20 in DBH class, and 7 percent of the > 20 in size class. Giusti (2007) does not report basal area directly, but it can be approximated from his data. Using size class mid-points, the stocking of all tanoaks was 83 ft²/ac, and those greater than 10 in DBH accounted for 49 ft²/ac; approximately 15 and 10 percent of the stands total basal area. The Montgomery Woods stand data indicate that both quantitatively and proportionately, tanoaks are a heavy and dominant understory component. The degree to which effective fire suppression since the early 20th century affects the species mix, especially in the smallest size class, is unknown.

The variation among the Caspar Block's economic types may be due to many factors. The absence of plot-specific information prevents statistical analyses of differences between the types or the variance within types. Although the stands were virgin timber, the time elapsed since their last stand-replacing event may be variable; that is, their relative position along the successional continuum is unknown. The species mix may reflect topographic position, with redwood dominant on alluvial sites and a broader mix of conifer species upslope (Lorimer et al. 2009). Topography may well be the driver of processes that acts on tree physiology and disturbance dynamics to yield the differences observed in species composition and biomass across stands types. Topography constrains available moisture and soil characteristics. Both within and among economic class variation can result from disturbance dynamics that vary by topography. Localized disturbance events such as

individual tree fall can lead to substantial variation if sample size is few or the area sampled is small relative to the tree fall impact area. Because succession within late seral forest when scaled to large areas likely proceeds towards an asymptote over long periods, the points in the successional continuum at which a stand is studied can lead to among stand variation. Analysis of the map associated with the inventory (Anon. 1929) may help describe topographic relationships with the economic types.

Stand structure that can be useful for describing late-seral management conditions and goals. However, the Caspar Block and Montgomery Woods studies are too few and of limited geographic range to have confidence in the amount of variation that may exist within regional unmanaged late-seral stands. Publication of historic inventories, despite their probable omission of non-conifer information could yield more useful descriptions of late seral structure. Collecting more comprehensive information on extant stands, while possibly being obscured by decades or more of fire exclusion can also broaden the picture of unharvested stand structures.

Tree size and density are in many ways a caricature of late-seral conditions. Simplistic stand tables fail to recognize or quantify the elements more important to a late-seral forest community. These elements include substantial amounts of the products that accumulate over time: tree decline, decadence, death such as snags (Giusti 2007) and logs (Bingham and Sawyer 1988, Porter and Sawyer 2007); mechanical and fire-induced disturbance such as reiterated branches (Sillett and Van Pelt 2000) and basal hollows (Finney 1996); establishment of epiphytes (Sillett and Van Pelt 2007); and late-seral associated species (Russell and Michels 2010). Forest-type and regional quantification of the elements at the scale of a stand will add substantially to tree size and density criteria to assure that late-seral management achieves ecological goals.

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