

Holter Ridge Thinning Study, Redwood National Park: Preliminary Results of a 25-Year Retrospective¹

Andrew J. Chittick² and Christopher R. Keyes³

Abstract

Redwood National Park is comprised of large areas of overstocked stands resulting from harvest of the old-growth stands in the late 1940s to the 1970s. The Holter Ridge Thinning Study was initiated in 1978 to address this problem and examine the effects that thinning to varying spacing would have on forest development. Densities following thinning in 1979 ranged from 150 to 790 stems/acre with the controls ranging from 1170 to 3410 stems/acre. Mortality from 1979 to 2003 showed a positive relationship to the number of stems/acre post thinning. The number of redwood sprouts was positively related to the number of redwoods thinned. The percent cover of herbaceous and shrub species showed a negative exponential response to stand density while the change in percent cover from 1984 to 2003 for the shrubs also had a negative response to stand density. Stand structure differed between the control plots and the thinned plots. The control plots showed no stratification of the canopy, but the thinned groups showed stratification into an upper-canopy composed of redwood and Douglas-fir and a lower-canopy of redwood and tanoak. After twenty-five years the thinned stands show the initial signs of a mature forest while the controls still exhibit intense competition.

Key words: density, old-growth, redwood, restoration, second-growth, structure, thinning

Introduction

Upland second-growth forests located within Redwood National Park exhibit a high potential value for restoration of old-growth associated characteristics. When Redwood National Park was expanded in 1978, over 51,000 acres out of 106,000 acres was cutover second-growth forest. These resulting second-growth forests now contain an extremely high density of trees, disproportionate amounts of Douglas-fir and tanoak, stagnated growth and development, and a homogeneous vertical and horizontal structure. Understory vegetation consisting of herbaceous, shrub, and tree species is generally excluded from dense second-growth forests within Redwood National Park with similar negative impacts on wildlife. The length of time until these second-growth forests re-establish new cohorts and become multi-age stands could be several hundred years. That silvicultural treatments can alter a stand's successional pathway to increase near-term old-growth-associated characteristics has gained increasing attention in recent years.

¹ This paper was presented at Redwood Science Symposium: What does the future hold? March 15-17, 2004, Rhonert Park, California.

² Graduate Student, Dept. of Forestry and Watershed Management, Humboldt State University, P.O. Box 4761, Arcata, CA 95518. email: andy@mattole.org

³ Assistant Professor of Forestry, Dept. of Forestry and Watershed Management, Humboldt State University, 1 Harpst St. Arcata, CA 95521. email: christopher.keyes@humboldt.edu

The Holter Ridge Thinning Study, located within Redwood National Park, is an experiment initiated in 1978 to determine what effects a low thinning with varying levels of stand densities has on the growth and composition of overstory trees (Veirs 1986). Its purpose is to determine how restoration thinning can alter a successional pathway to more closely resemble the pre-existing vegetation of old-growth forests. The study consists of a 200 acre, ~50-year old stand of second-growth coastal redwood (*Sequoia sempervirens* [D. Don.] Endl.)/Douglas-fir (*Pseudotsuga menziesii* [Mirbel] Franco)/tanoak (*Lithocarpus densiflorus* [Hook and Arn.] Redh.). The stand was harvested in 1954 using the seed tree method; an average of 1 redwood seed tree per acre was left and the stand regenerated from natural seeding (Veirs 1986). Pre-treatment stand densities averaged more than 1000 trees/acre, with some plots having 3000 trees/acre, according to Veirs' (1986) initial observations in 1978. Second-growth redwood/Douglas-fir ratios were also observed to be 1:1 on more xeric sites and 12:1 on mesic sites. Old-growth stands nearby were found to be predominantly redwood with densities ranging from 10 to 35 trees/acre for redwood and one to four trees/acre for Douglas-fir—considerably different than the second-growth that is now present (Veirs 1986). Other associated tree species present include western hemlock (*Tsuga heterophylla* [Raf.] Sarg.) and madrone (*Arbutus menziesii* Pursh.), and understory shrubs consisting of salal (*Gaultheria shallon* Pursh.), rhododendron (*Rhododendron macrophyllum* D. Don), evergreen huckleberry (*Vaccinium ovatum* Pursh.), red huckleberry (*Vaccinium parvifolium* Sm.), and swordfern (*Polystichum munitum* [Kaulf.] C. Presl) (Veirs 1986).

The coastal redwood's longevity and ability to persist in shade, combined with the relative shade intolerance of Douglas-fir and fire exclusion, indicates that Douglas-fir can be expected to decrease in dominance over time (Oliver and Larson 1996, Roy 1966). Without the use of silvicultural activities or disturbance, the redwood/Douglas-fir ratio of second-growth forests and associated structure may eventually approach those of old-growth stands over thousands of years. However, the development of multi-age structures associated with old-growth redwood forests will be stagnated in the near-term as a result of decreased growth owing to high densities and disturbance exclusion (Franklin and others 2002). In stands with low initial densities, characteristics similar to a maturing forest may be achieved at a younger age than the dense stands (Franklin and others 2002). The primary limiting factor for understory vegetation in coast range forests is the amount of light reaching the forest floor which thinning can directly alter (Bailey 1996). Thinning of dense stands has been shown to increase species richness, diversity, density, and cover of understory vegetation (Bailey and others 1998, Bailey and Tappeiner 1998, Thysell and Carey 2001). The research indicates that understory vegetation possesses the ability to persist in severe shade following canopy closure and flourish upon opening of the canopy (Halpern 1988, Halpern and Franklin 1990, Halpern and Spies 1995).

Methods

This study is located in Redwood National Park on Holter Ridge in the headwaters of Lost Man Creek, a tributary to Prairie Creek, principally in the area known as the Holter Ridge Thinning Study. Map coordinates are Sections 20 and 21, T11N, R2E, Humboldt Meridian, Tectah Creek, California Quadrangle (approximately 41°, 18'N, 123° 57'W).

The thinning study established by Veirs (1986) consists of three treatments and a

control with each treatment divided into two parts depending on conifer spacing (10 ft to 12 ft and 16 ft to 18 ft), treatment of hardwoods (10 ft to 12 ft with hardwoods cut or included in spacing), or treatment of the slash (10 ft to 12 ft with slash lopped or not lopped). Actual densities following thinning range from 150 to 790 stems/acre (17 ft to 7.5 ft spacing) in the thinned units with 1170 to 3410 stems/acre in the controls. Diameter cut limits were 18 inch dbh for redwood sprouts, 10 inch for free standing redwoods, and 12 inch for Douglas-fir. In all units the numbers of redwood stump sprouts were to be thinned to 30 to 50 percent of the dominant sprouts.

Four 1/10-acre circular plots were systematically established for each treatment subunit including the control for a total of 28 plots. The plots were arranged along two pre-determined bearing lines with two plots randomly located on that line. Each tree was measured for: species, diameter at breast height, diameter at one foot above ground (stump height), crown width in each cardinal direction, height to base of live crown, total tree height, and notice of any damage or anomaly. Trees cut during thinning were measured for stump diameter and regressions were used to reconstruct the stand prior to thinning. From each plot center two photographs were taken in each of four cardinal directions. Re-measurements were conducted in 1984 following the same methods and included percent cover of the understory vegetation by species.

In 2003, using stem maps, azimuth, and distance, each tree was relocated and measured for: species, diameter at breast height, height to base of live crown, total tree height, and notice of any damage or anomaly. For understory vegetation percent cover by species was ocularly estimated into modified Braun-Blanquet cover classes with percent covers of: 0.001 to 0.01 percent, 0.01 to 0.1 percent, 0.1 to one percent, one to five percent, five to 25 percent, 25 to 50 percent, 50 to 75 percent, and 75 to 100 percent. Any seedling/sapling regenerated since thinning was counted by species with a seedling defined as a tree below 4.5 inches in height and a sapling as over 4.5 inches.

Regression analysis was used to predict the relationship of the independent variable in question to density immediately following thinning (stems/acre). In certain cases the relationship fitted best with an exponential curve or logarithmic transformation.

Large discrepancies existed between the initial intended treatments and the resulting densities following treatment. In order to observe differences in stand structure between densities I created three groupings based on density: Control, Mid-Density, and Low-Density.

Results

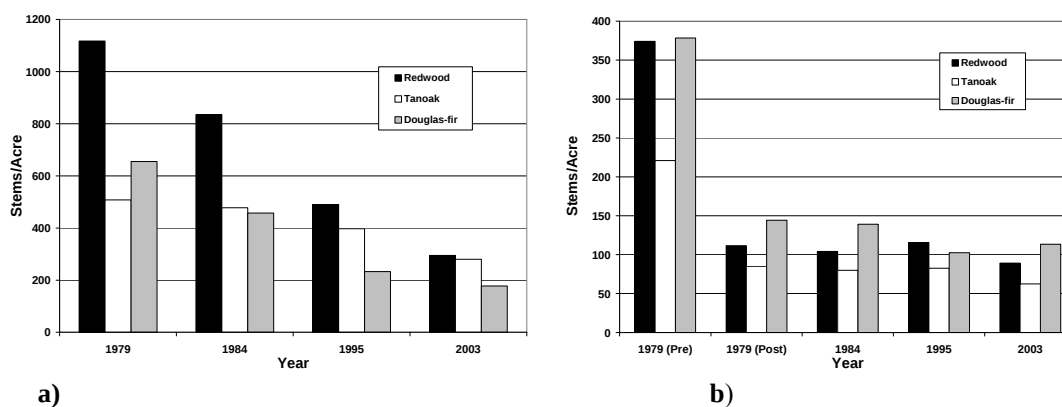
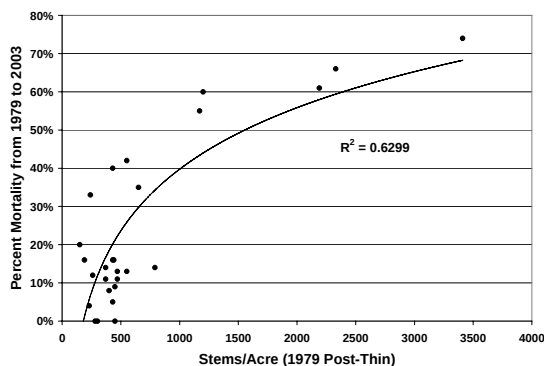
Several aspects of stand description were used to analyze the development of the stands over time: mortality, sprouting, understory vegetation, and stand structure. Densities for 1979 and 2003 for all stems and stems >4 inch dbh for control, mid-density, and low-density plots are given in *table 1*.

Table 1—Stems/acre for control, mid-density, and low-density by year and diameter.

	Stems/Acre (1979)	Stems/Acre >4 inch dbh (1979)	Stems/Acre (2003)	Stems/Acre >4 inch dbh (2003)
Control	2050	552	870	560
Mid-Density	475	302	350	313
Low-Density	200	167	200	183

Mortality

The change in species composition in the control plots is marked by a large reduction in the number redwoods and Douglas-fir relative to tanoak (*fig. 1a*). In 1979 redwood had 1110 stems/acre where Douglas-fir and tanoak had 655 and 507 stems/acre respectively, but by 2003 they had 295, 178, and 280 stems/acre respectively. The change in species composition for the low and mid-density plots is given in *figure 1b*. While redwood and Douglas-fir were equal in density prior to thinning, immediately following thinning redwood was slightly less than Douglas-fir (112 and 144 stems/acre respectively). This species composition in the thinned stands was then maintained throughout the study period. The number of stems/acre post thinning accounted for 63 percent of the variation in total mortality (*fig. 2*).

**Figure 1**—Change in stems/acre by species for (a) Control plots and (b) Low- and Mid-Density plots.**Figure 2**—Regression of percent mortality for all species on all plots from 1979 to 2003 and density (stems/acre) using a logarithmic transformation.

Sprouting

The sprouting response of redwood from thinning ranges from zero to 3160 sprouts/acre while the number of redwoods thinned ranges from zero to 970 stems/acre. The largest ratio of the number of sprouts to number of redwoods thinned was 5:1. The number of redwoods thinned/acre accounted for 45 percent of the variation in the number of sprouts/acre (*fig. 3*). The sapling to seedling ratio had a median value of 2:1 and a range from 5.2:1 to 0.4:1. Average height of saplings was estimated at eight to 12 ft.

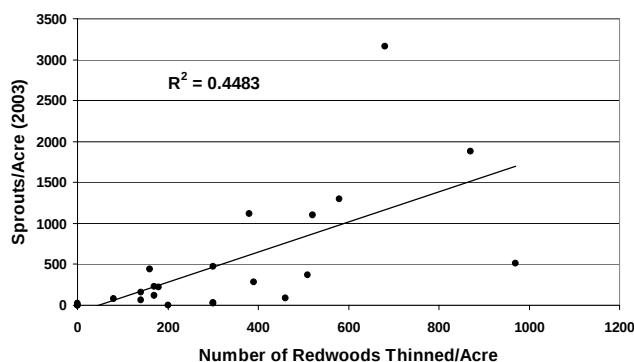


Figure 3—Regression of the number of redwoods thinned/acre in 1979 and the number of sprouts/acre in 2003.

Understory Vegetation

Percent cover of understory herbaceous and shrub species when compared to stems per acre post-thinning yielded an $R^2 = 0.77$ (*fig. 4*). Herbaceous and shrub vegetation on the control plots ranged from zero to 20 percent cover but all of the thinned plots had at least 45 percent cover with a high of 95 percent cover. The percent change in the shrub vegetation from 1984 to 2003 is shown in *figure 5*, with the number of stems/acre post thinning accounting for 51 percent of the variation. For the control plots there was either no change or a decrease over the 25-year period while the thinned plots showed increases of up to 75 percent from 1984 levels.

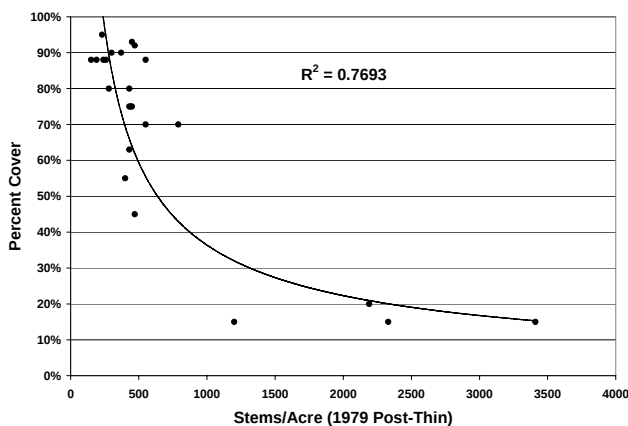


Figure 4—Regression of percent cover of herbaceous and shrub species in 2003 and density (stems/acre) with an exponential transformation.

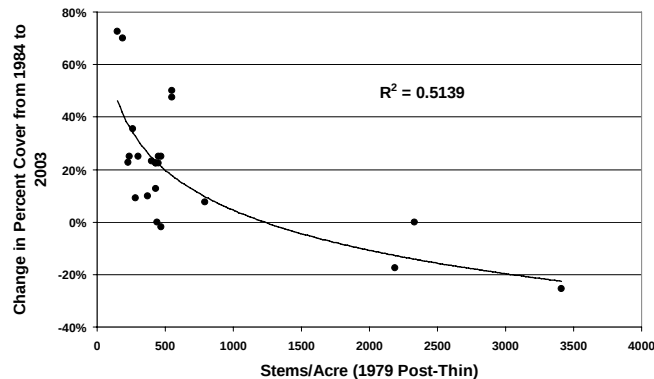


Figure 5—Regression of change in percent cover of shrubs from 1984 to 2003 and density (stems/acre) with a logarithmic transformation.

Stand Structure

Diameter distributions for all densities are given in *figure 6*. The Control plots in 1979 (*a*) exhibit a reverse-J distribution but in 2003 (*d*) there are a large number of trees in the <10 inch dbh classes with relatively few dominants. This is seen in the height distribution for 2003 (*fig. 7a*) where there are a large number of tanoak and redwood that comprise the suppressed/intermediate classes and the dominant/co-dominant classes are mostly Douglas-fir. There is no clear stratification by height class for the Controls.

The diameter distribution for the Mid-Density plots immediately following thinning (*fig. 6b*) show a gradation of redwood and tanoak in the lower classes to redwood and Douglas-fir in the larger classes. In 2003 (*e*) they show a similar but more pronounced stratification by species with Douglas-fir having a normal distribution in the upper diameter classes and a greater range than the control. The height classes in *figure 7b* show two distinct strata: a lower-canopy strata consisting of tanoak and redwood ranging from 10 feet to 70 feet in height and an upper-canopy strata with the majority of those being Douglas-fir followed by redwood.

The Low-Density plots show a single-modal distribution following thinning (*fig. 6c*) but are bi-modal in 2003 (*f*). The first mode consists mostly of tanoak and redwood with significant portions of in-growth of sprouts into those diameter classes. The second mode is comprised of Douglas-fir and redwood and consists of dominant/co-dominants. The height distribution (*fig. 7c*) shows a strong component of Douglas-fir and redwood dominants in the 80 feet to 120 feet range with tanoak and redwood dominating the 10 feet to 60 feet strata.

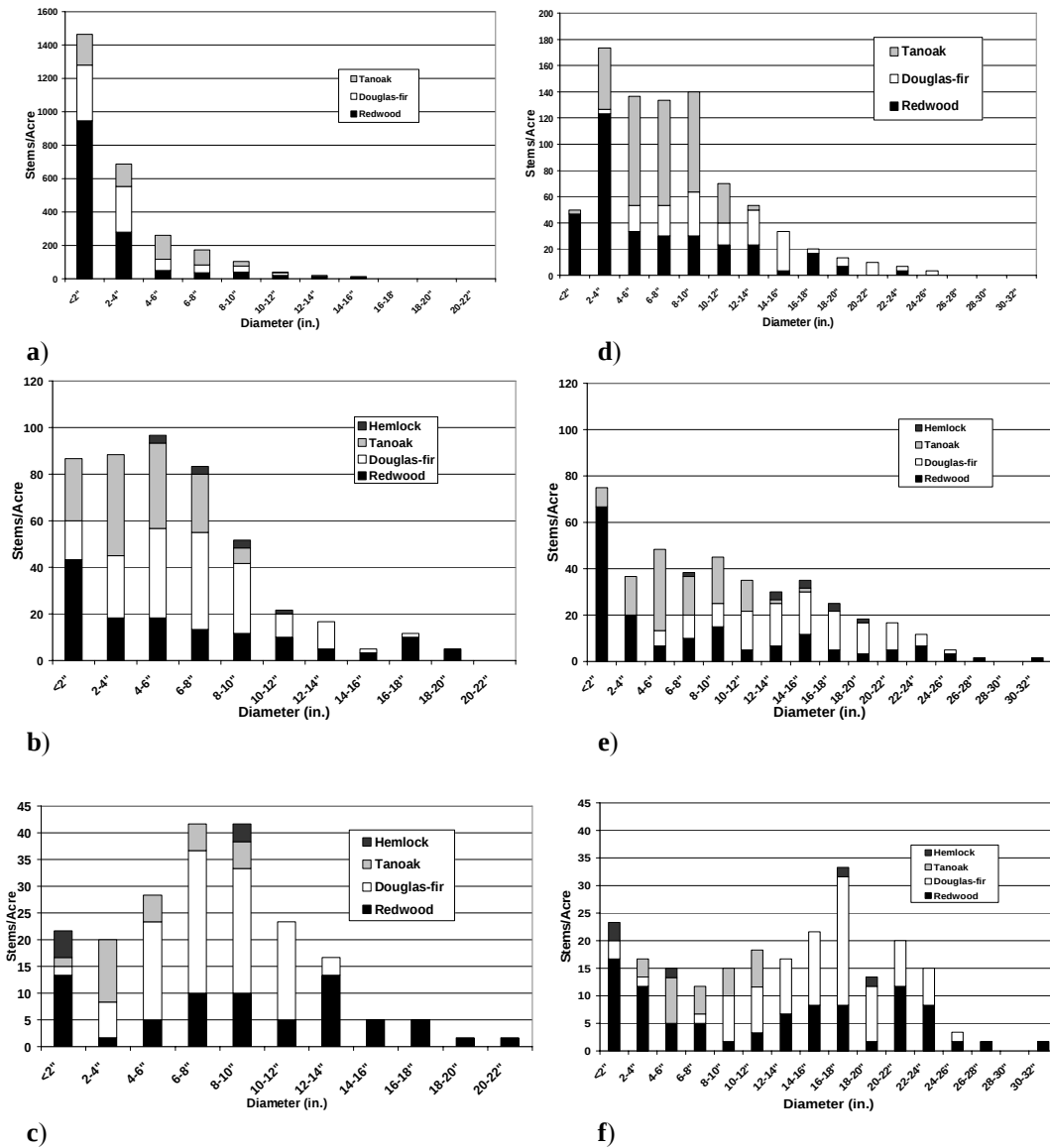


Figure 6—Diameter distributions in 1979 (post-thinning): (a) Control (b) Mid-Density (c) Low-Density and in 2003: (d) Control (e) Mid-Density (f) Low-Density.

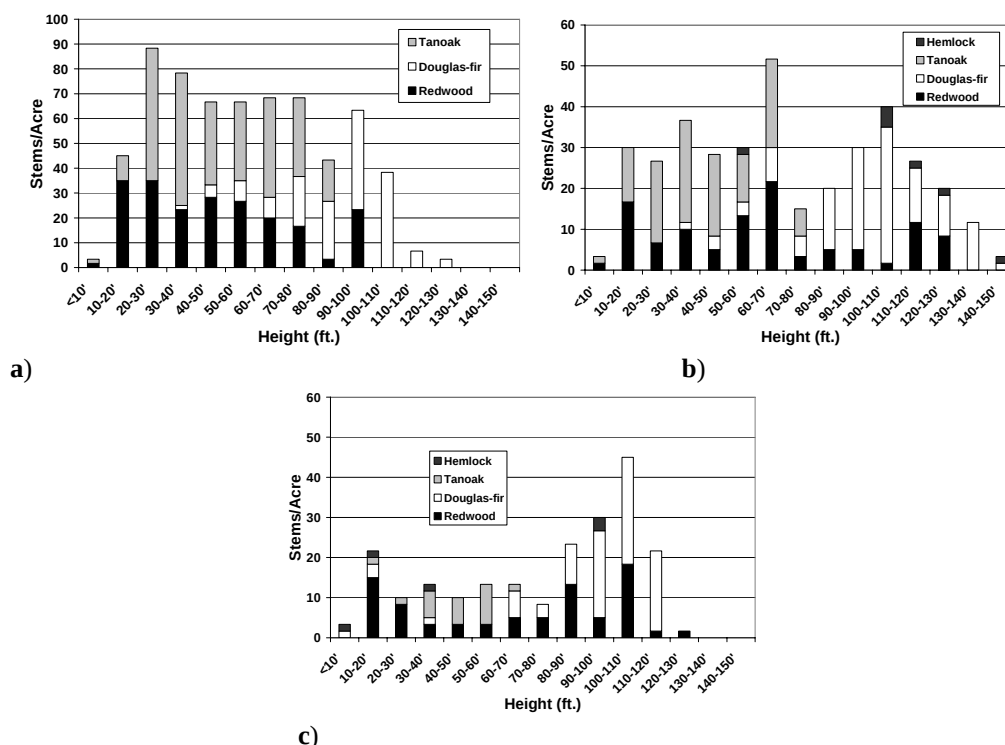


Figure 7—Height distributions in 2003: (a) Control plots (b) Mid-Density plots (c) Low-Density plots.

Discussion

Mortality

The reduction in the numbers of redwoods relative to Douglas-fir and tanoak in the control plots from 1979 to 2003 is due partly to the large number of redwoods comprising the <2 inch dbh class. In the thinned plots, species composition remains unchanged from 1979 to 2003. One of the stated goals in the thinning study was to increase the relative abundance of redwood; the thinning did not accomplish the goal as redwood decreased relative to Douglas-fir and tanoak immediately following the thinning.

Sprouting

Sprouting response of redwood from thinning indicates that there is a high possibility for multiple sprout shoots to persist in the understory with little growth in a moderately-dense overstory canopy. The only observed redwood sprouts to make it into the >4 inch dbh class were on the plots with both large gaps in the canopy and a small number of sprouts competing with each other; otherwise the sprouts had minimal height growth due to competition from the overstory canopy or among shrubs and other sprouts.

Understory Vegetation

Given the exponential nature of the understory vegetation in its relationship to density of overstory trees, it follows that the changes in cover over time should show a similar response. The control stands have fully passed into competitive exclusion of the understory and are expected to continue for the next 50 to 100 years (Franklin and

others 2002). Currently, there are still shrubs present in the controls (~20 percent cover) that can possibly expand into any gaps that open in the canopy. In the thinned stands the understory vegetation has received enough light to expand and maintain itself. Canopy closure is not yet complete in most stands and the understory should persist indefinitely.

Stand Structure

The Control plots show a canopy without any definite strata. The upper canopies (>80 feet) of the Mid- and Low-Density stands have similar height distributions and species composition consisting of Douglas-fir and redwood. The lower canopies (<70 feet) differ between the two densities in the numbers of redwood and tanoak comprising those strata (Mid-Density has 2.5 times the number of stems as the Low-Density). The Low-Density appears to have a simple structure consisting of an overstory composed of dominant trees with very few lower canopy trees. In contrast, the Mid-Density is dominated by mid- and lower-canopy trees that provide for a more diverse structure. As these stands progress in the near future, little ingrowth into the lower canopy is expected to occur until sufficient gaps in the canopy open. Stratification will continue to increase between the upper and lower canopies with redwood and tanoak in the lower strata and redwood and Douglas-fir in the upper strata. Overall, the diameter distribution at age 50 that most closely approximates that of the reverse-J distribution is that of the Mid-Density stands.

Conclusions

Twenty-five years after treatment, the thinned stands exhibit reduced density-dependent mortality compared to the controls, high numbers of sprouting redwoods that remain in the understory, a highly significant increase in the growth of understory vegetation, and a stratification of the thinned plots into two distinct canopy layers. Stand development in the controls remains in competitive exclusion and will so for the next 50 to 100 years while the thinned stands have moved into the maturation stage. The Holter Ridge Thinning Study achieved some of its goal of accelerating stand development towards simulating old-growth characteristics. The use of a low-thinning at the lowest densities resulted in a simple structure not characteristic of old-growth forests. At higher densities the structure was closer to old-growth but had densities considerably higher than the old-growth. The thinning did not significantly alter the species composition towards redwood.

References

- Bailey, J.D. 1996. **Effects of stand density reduction on structural development in western Oregon Douglas-fir forests—a reconstruction study.** Corvallis, OR: Oregon State University. Ph.D. dissertation.
- Bailey, J.D.; Mayrsohn, C.; Doescher, P.S.; St. Pierre, E.; Tappeiner, J.C. 1998. **Understory vegetation in old and young Douglas-fir forests of western Oregon.** *Forest Ecology and Management* 112: 289-302.
- Bailey, J.D.; Tappeiner, J.C. 1998. **Effects of thinning on structural development in 40- to 100-year-old Douglas-fir stands in western Oregon.** *Forest Ecology and Management* 108: 99-113.

- Franklin, J.F.; Spies, T.A.; Van Pelt, R.; Carey, A.B.; Thornburgh, D.A.; Berg, D.R.; Lindenmayer, D.B.; Harmon, M.E.; Keeton, W.S.; Shaw, D.C.; Bible, K.; Chen, J. 2002. **Disturbances and structural development of natural forest ecosystems with silvicultural implications, using Douglas-fir forests as an example.** Forest Ecology and Management 155: 399-423.
- Halpern, C.B. 1998. **Early successional pathways and the resistance and resilience of forest communities.** Ecology 69: 1703-1715.
- Halpern, C.B.; Franklin, J.F. 1990. **Physiognomic development of *Pseudotsuga* forests in relation to initial structure and disturbance intensity.** Journal of Vegetation Science 1: 475-482.
- Halpern, C.B.; Spies, T.A. 1995. **Plant species diversity in natural and managed forests of the Pacific Northwest.** Ecological Applications 5(4): 913-934.
- Oliver, C.D.; Larson, B.C. 1996. **Forest stand dynamics.** New York: McGraw-Hill.
- Roy, D.F. 1966. **Silvical characteristics of redwood.** Res. Paper PSW-RP-28. Berkeley, CA: Pacific Southwest Range and Experiment Station, Forest Service, U.S. Department of Agriculture.
- Tappeiner, J.C.; MacDonald, P.M. 1984. **Development of tanoak understories in conifer stands.** Canadian Journal of Forest Research 14: 271-277.
- Thysell, D.R.; Carey, A.B. 2001. **Manipulation of density of *Pseudotsuga menziesii* canopies: preliminary effects on understory vegetation.** Canadian Journal of Forest Research 31: 1513-1525.
- Veirs, S.D. 1986. **Redwood second growth forest stand rehabilitation study, Redwood National Park: Evaluation of 1978-79 thinning experiments.** Unpublished draft supplied by author. Redwood National Park, Arcata, CA; 34 p.