Low Thinning and Crown Thinning of Two Severities as Restoration Tools at Redwood National Park[1]

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Abstract

Interest in the restoration of second-growth forests has continued to increase in the redwood region, which has further increased the importance of evaluating restoration-based silvicultural strategies. This study assessed the short-term effectiveness of four silvicultural treatments (two silvicultural thinning methods, low thinning and crown thinning, and two basal area retentions, 80 percent and 45 percent) as forest restoration tools via analysis of relative basal area growth at Redwood National Park. Prior to treatment, the second-growth stand had more than 1,600 trees ha^{-1} and 70.0 m^2 ha^{-1} basal area and consisted primarily of two species, Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) (the dominant species) and redwood (*Sequoia sempervirens* (D. Don) Endl.). Growth was enhanced for all treatments with 5-year net basal area gains of 28.4 percent for the low-retention crown thinning, 28.1 percent for the low-retention low thinning, 23.3 percent for the high-retention crown thinning, 19.1 percent for high-retention low thinning, and only 14.2 percent for the control. We conclude that all four thinning treatments improved tree growth; but among them, the low-retention treatments were most effective in accomplishing restoration objectives, while the high-retention low thinning was least effective. Increasing the array of silvicultural tools that Redwood National Park can use may prove helpful in accomplishing restoration goals in future projects.

Keywords: ecological restoration, forest stand dynamics, second-growth, *Sequoia sempervirens*, silviculture

Introduction

Approximately half of Redwood National Park is comprised of young, second-growth forest. Managers at Redwood National Park are using silvicultural treatments to adjust species composition, increase tree growth, and improve stand vigor to promote old forest characteristics (Teraoka 2012,Teraoka and Keyes 2011). Low thinning, the removal of trees in the lower crown classes to benefit trees in the upper crown classes (Smith et al. 1997), has been utilized by the park as the primary silvicultural method. Because the largest trees are retained, low thinning mimics the patterns of mortality in even aged stands (Chittick and Keyes 2007, Teraoka and Keyes 2011), thus accelerating a process that would naturally occur.

Many of the park's second-growth stands were initiated via aerial seeding of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) at high densities (Teraoka and Keyes 2011). Empirical growth and yield studies of second-growth stands have shown that Douglas-fir outpaces redwood (*Sequoia sempervirens* (D. Don) Endl.) in height growth during the early to middle stages of stand development (Lindquist and Palley 1963, Wensel and Krumland 1986), thereby promoting Douglas-fir to a dominant canopy position (Plummer 2008, Teraoka and Keyes 2011). The capacity of Douglas-fir to outpace redwood in height growth and sustain canopy dominance is an impediment to the restoration of redwood dominance that silvicultural restoration treatments should seek to mitigate. Analysis at a nearby site with similar conditions revealed that early thinning in young, dense, second-growth stands benefitted redwood proportionately more than Douglas-fir, thereby elevating its capacity for dominance (Plummer et al. 2012).

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Should Redwood National Park consider altering stand trajectories by utilizing silvicultural methods other than those currently being employed? Is simply accelerating the natural pattern of mortality via low thinning the best restoration-based silvicultural tool, or would another thinning method better facilitate restoration objectives? How does thinning severity interact with thinning method to promote old forest characteristics? To further investigate these questions, we analyzed the park's A-972 Forest Restoration Study, a thinning experiment that was conducted in 2008.

Methods

The study area is located approximately 4 km south of Orick, California and 2 km from the Pacific Ocean (fig. 1). The legal description is Rodger's Peak U.S. Geological Survey quadrangle SW1/4 NW1/4 and NW1/4 SW1/4 Sec.16, T. 10N. R.1E. H.B.M. Elevation is 300 m. Annual precipitation averages 178 cm. Slope ranges from 0 to 30 percent. The stand was clearcut in 1968 (prior to park acquisition), followed by broadcast burning and aerial seeding. Species composition is comprised of Douglas-fir, redwood, Sitka spruce (*Picea sitchensis* [Bong.] Carr.), western hemlock (*Tsuga heterophylla* [Raf.] Sarg.), and red alder (*Alnus rubra* Bong.). Understory vegetation is nearly absent, but small pockets of ferns, rubus, and ericaceous species occurred before treatment, in 2008, throughout the study site.

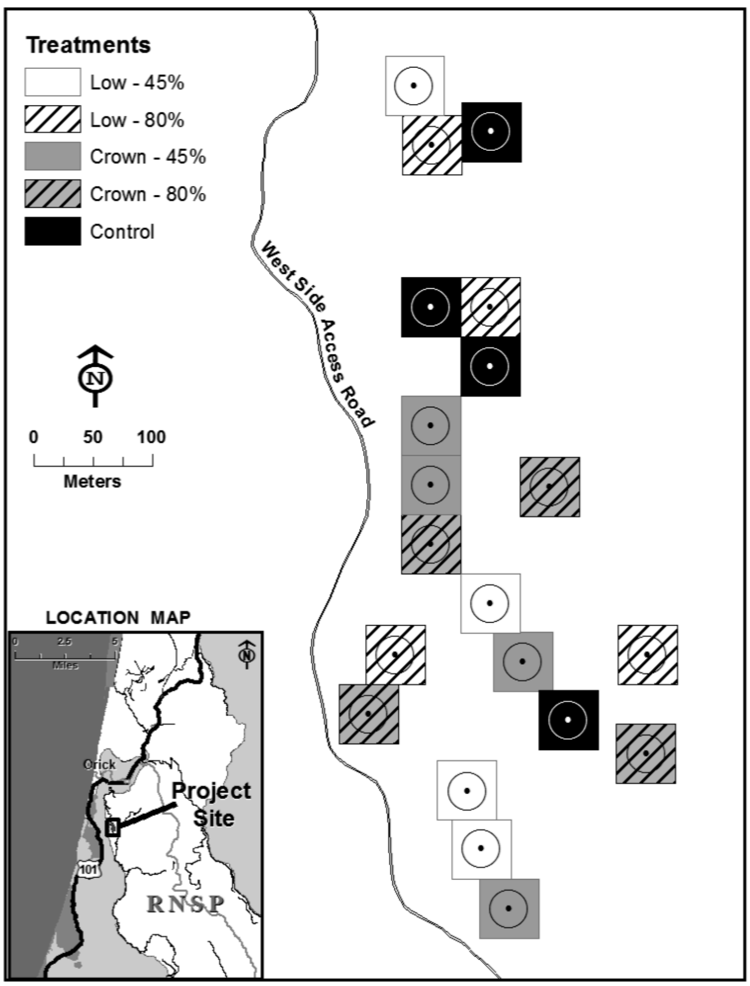

Figure 1—Location map and arrangement of treatment units and plots in the A-972 Study Area. Circles within the square units represent 0.08-ha monitoring plots.

In fall of 2007, 20 square units (0.25 ha) were established in the 40-year-old stand (fig. 1). Species and diameter at breast height (DBH; 1.37 m) of live trees were recorded for all stems greater than 10 cm DBH within a circular fixed-radius monitoring plot (0.08 ha) located at the center of each unit. Five groups were created: an untreated control and four thinning treatments. The four treatments consisted of two silvicultural thinning methods — low thinning (the removal of trees in the lower crown classes to benefit trees in the upper crown classes) and crown thinning (the removal of trees in the upper crown classes, primarily co-dominant trees, to benefit trees of the same crown classes) (Smith et al. 1997) — each with two basal area retentions of 80 percent and 45 percent. In meeting each unit's retention target, Douglas-fir was primarily targeted for removal, and clumps of redwood stump sprouts were thinned. All wood was lopped-and-scattered. The five groups are summarized as follows (abbreviated naming conventions in parentheses):

1. Low thinning with a 80 percent retention of basal area (L80)
2. Low thinning with a 45 percent retention of basal area (L45)
3. Crown thinning with a 80 percent retention of basal area (C80)
4. Crown thinning with a 45 percent retention of basal area (C45)
5. Control

Treatments and controls were randomly assigned to the units and replicated four times each (fig. 1). In the winter of 2007 to 2008, treatments were applied to the units totaling 4 ha of thinning.

Plots were resampled immediately after treatment, and again in 2013. Means of stand density (trees ha^{1} [tph] and basal area) were calculated for each measurement period. Relative stand basal area growth of the surviving trees and standard errors were calculated for all species combined, for redwood only, and for Douglas-fir only. Relative stand basal area growth used here was calculated as the total net stand basal area growth that occurred after thinning divided by the stand basal area immediately after thinning at the beginning of the 5-year growth period. Relative stand basal area growth was analyzed via one-way ANOVA and Tukey's post-hoc test using a pre-set alpha of 5 percent to determine whether differences in relative stand basal area growth among groups had occurred as a result of the treatments and the passage of time.

Results

Prior to treatment, there were no significant differences between groups for total number of trees (p = 0.725) or basal area (p = 0.674). Collectively, the stand averaged about 1,600 trees ha^{-1} and 70.0 m^{2} ha^{-1} basal area; both stand density metrics were dominated by Douglas-fir with lesser amounts of redwood (fig. 2).

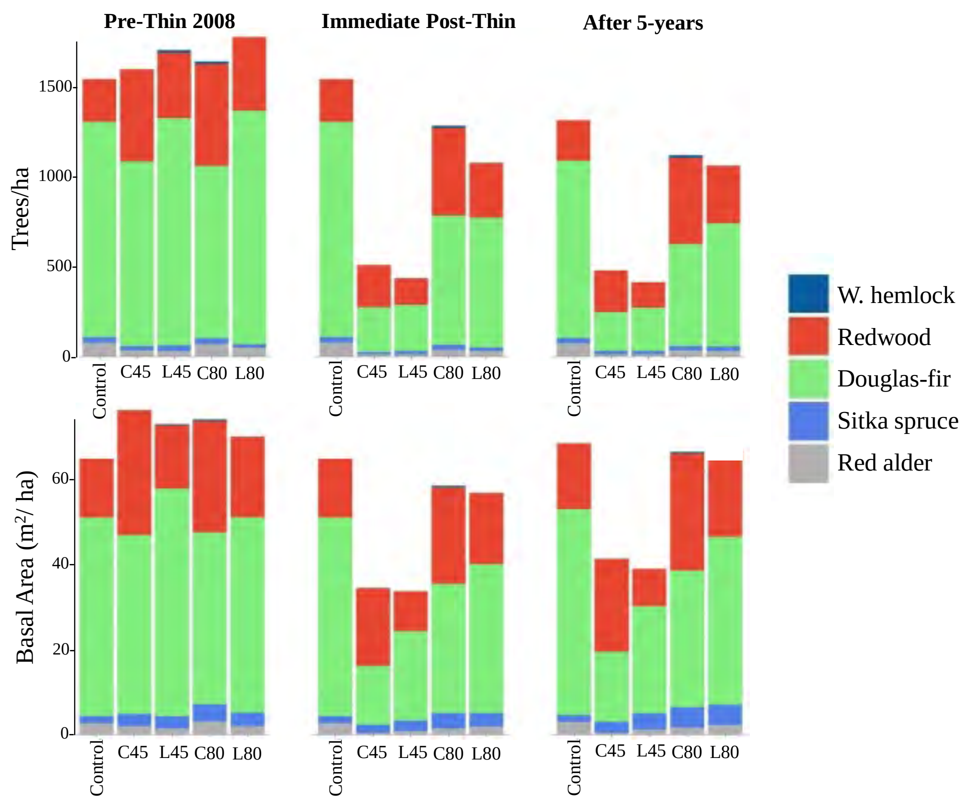

Figure 2—Number of trees per hectare (top) and basal area (bottom) for each group by species: before thinning (2008; left), immediately after thinning (2008; middle), and 5 years after thinning (2013; right).

Implementation of the low thinning treatments proved to be slightly more severe as compared to the crown thinning treatments at the same retention targets (fig. 2). Low thinning required the removal of relatively higher number smaller-diameter trees as opposed to crown thinning, which required the removal of a relatively lower number of larger-diameter trees.

Stand basal area growth for all species was apparent 5 years after treatment for all groups, with net basal area gains of 28.1 percent for L45, 28.4 percent for C45, 23.3 percent for C80, 19.1 percent for L80, and 14.2 percent for the control (fig. 3). Basal area growth for treatments C45 ($p < 0.001$), L45 ($p < 0.001$), and C80 ($p = 0.001$) were significantly greater than the control. Basal area growth for the L80 treatment ($p = 0.05575$) was not significantly different than the control. There were no differences in terms of basal area growth between treatments of the same basal area retentions (C45 - L45, $p = 0.9999$; C80 - L80; $p = 0.2140$). Both C45 ($p = 0.00454$) and L45 ($p = 0.00568$) were significantly different than L80.

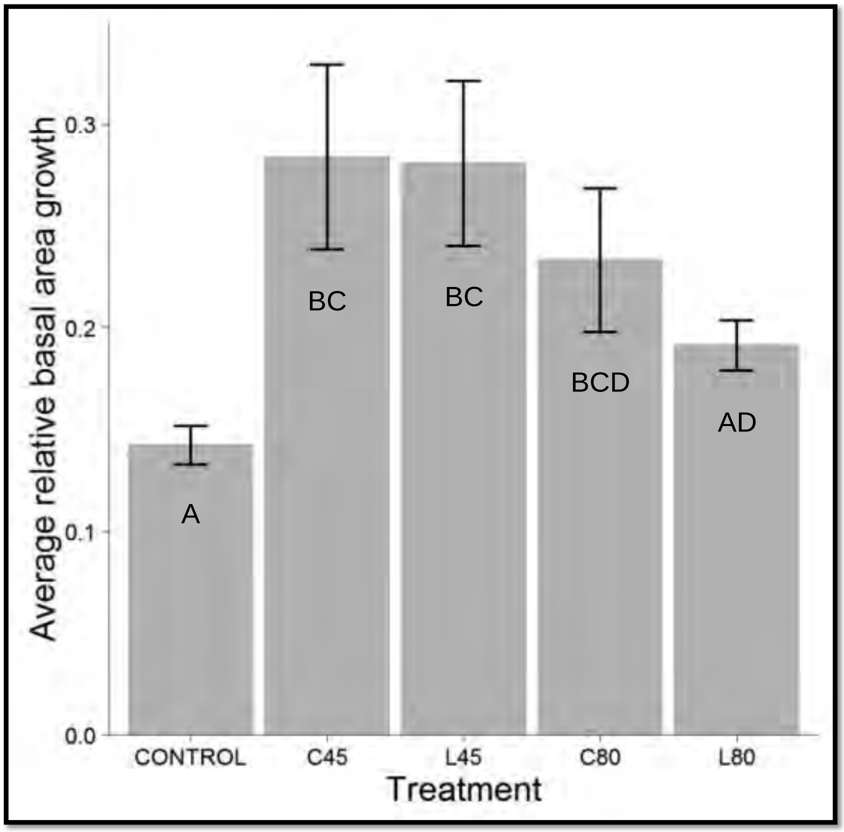

Figure 3—Average relative stand basal area growth and one standard error per treatment for trees of all species for the 5-year post-treatment period. Different upper case letters within the bars represent significant differences among the means when one-way ANOVA and Tukey's post-hoc test were performed at a pre-set alpha of 5 percent.

Basal area growth for Douglas-fir had net 5-year gains of 25.6 percent for L45, 24.2 percent for C45, 17.4 percent for C80, 16.6 percent for L80, and 12.9 percent for the control. Redwood had more relative basal area growth than Douglas-fir over the 5-year period, with net basal area gains of 31.3 percent for L45, 30.2 percent for C45, 26.9 percent for C80, 24.6 percent for L80, and 17.3 percent for the control (fig. 4). Pairwise comparisons between groups for individual tree species produced results similar to that of all species combined. Redwood basal area percent increase appeared to respond more positively to thinning compared to Douglas-fir ($p < 0.001$) across all treatments, yet it also out-paced Douglas-fir in the untreated control (fig. 4).

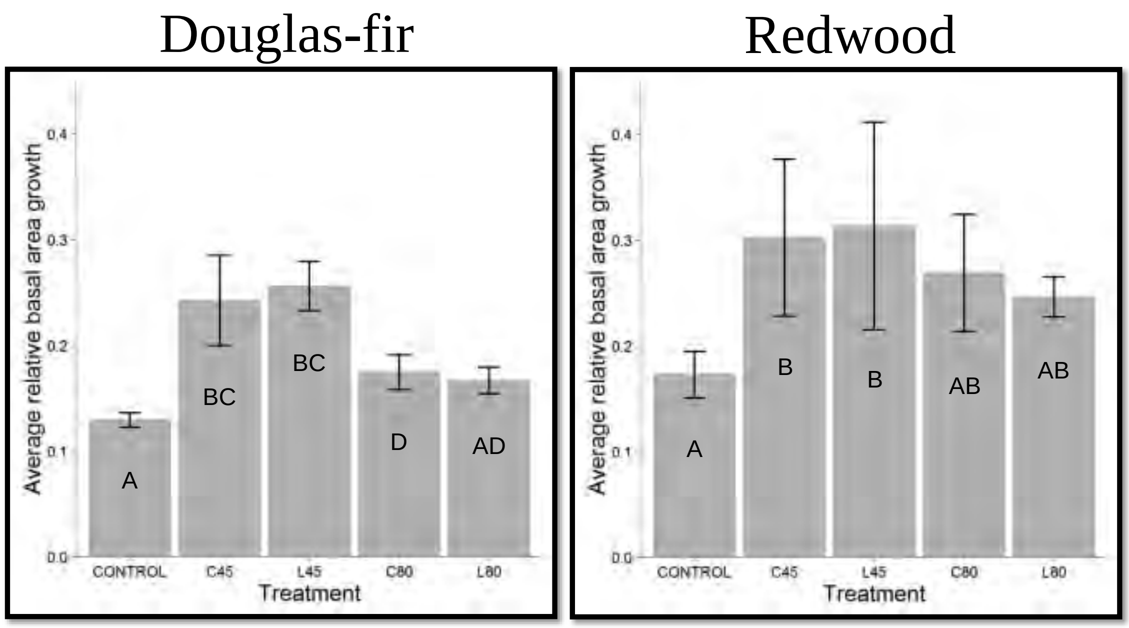

Figure 4—Average relative stand basal area growth and one standard error per treatment for Douglas-fir (left) and redwood (right) for the 5-year post-treatment period. Different upper case letters within the bars represent significant differences among the means when one-way ANOVA and Tukey's post-hoc test were performed at a pre-set alpha of 5 percent.

Discussion

All four thinning treatments improved stand basal area growth over the short-term period relative to the control. The more severe (45 percent retention) thinning treatments were generally more effective in maximizing stand-level growing conditions. Least effective was the low-severity, low thinning (L80) treatment, which produced growth that was just marginally greater than the control.

These results, particularly for the low-severity, 80 percent retention thinning treatments, were consistent with the findings and conclusions made earlier by Teraoka and Keyes (2011), who found that a low-severity low thinning, in the short-term, only weakly altered development patterns in the upper canopy. Our results from this more expansive study further suggest that crown thinning, or more aggressive thinning in general, could be more successful in altering stand development by effectively redistributing growing space to redwoods, and thus could better favor redwood dominance over the course of subsequent stand development.

The heavier thinning treatments were consistent with other growing stock studies that have shown that higher-severity thinning increased relative growth, but the increase was generally offset by the decrease in total yield associated with retention of less growing stock per unit area (Curtis and Marshall 2002, Lindquist 2004, Oliver et al. 1994).

These results lend support to utilizing higher severity thinning treatments, and indicate that other silvicultural methods— such as crown thinning—may be more effective at achieving redwood forest restoration objectives. Having a wide array of forest restoration tools at Redwood National Park’s disposal gives managers greater flexibility in achieving restoration goals. Utilizing higher severity low thinning, other traditional thinning methods, and alternative thinning methods (such as variable-density thinning; Keyes et al. 2010, O’Hara et al. 2010, O’Hara et al. 2012), may prove more effective. Identifying powerful, efficient silvicultural techniques will be key to achieving the park’s forest restoration objectives, as funding constraints and removal of roads makes multiple-entry restoration treatments unfeasible.

It is evident from existing long-term thinning studies in the Pacific Northwest that the main benefits of thinning are not necessarily increased basal area or volume production, but larger and more vigorous trees, enhanced stand stability, the enhancement of floral diversity, and increased aesthetic values and wildlife habitat (Curtis et al. 1997, Curtis and Marshall 2002, Keyes 2011, Webb et al. 2012).

Similar to other long-term thinning studies in the Pacific West, the A-972 study demonstrates the influence that restoration-based silvicultural treatments can have on retained tree growth over a relatively short period. Yet this study serves as a rare thinning study of mixed Douglas-fir-dominated redwood forest of moderate site quality; similarly-designed studies in the redwood region tend to have been located in high site quality, redwood-dominated stands (Lindquist 2004, Oliver et al. 1994, Webb et al. 2012). We intend to conduct further studies at this site to analyze other aspects of the growth-to-growing stock relationship—such as treatment-induced differences in understory dynamics, tree regeneration, and overstory species composition—to better inform forest restoration strategies at Redwood National Park.

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