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Forest Restoration at Redwood National Park: a Case Study of an Emerging Program

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Abstract

For more than 30 years, Redwood National Park has been working to establish a Forest Restoration Program to rehabilitate its impaired, second-growth forests. This case study outlines the Park's history of using silviculture as a restoration tool, which began in 1978 after the Park's expansion. The most recent effort was the 1,700 acre South Fork of Lost Man Creek Forest Restoration Project where two silvicultural prescriptions were used. Low thinning on ridge-top sites reduced basal area by 40-percent, and wood generated was sold as forest products. Crown thinning on steep mid-slope sites reduced basal area by 25-percent, and the wood was lopped-and-scattered. Permanent plots were established before thinning and were re-assessed after thinning. Data were analyzed to determine whether the silvicultural prescriptions altered stand structure and species composition to promote redwood dominance. Before thinning, Douglas-fir dominated stand density. Both prescriptions shifted composition in favor of redwood. The ridge-top prescription resulted in 191.3 percent more redwood trees/acre than Douglas-fir, and 80.2 percent more redwood basal area, making redwood the dominant species. The mid-slope prescription resulted in 4.3 percent more redwood trees/acre than Douglas-fir, but Douglas-fir had 5.9 percent more basal area. This project is the Park's first successful attempt at large-scale forest restoration.

Key words: crown thinning, low thinning, monitoring restoration, redwood, silviculture

Introduction

Today over 50,000 acres of second-growth forests occur within Redwood National Park. These forests have developed into dense stands characterized by deficient redwood (*Sequoia sempervirens* [Lamb. ex D. Don] Endl.) composition, low tree vigor, homogeneous structure, and little bio-diversity (Chittick and Keyes 2007, Teraoka and Keyes 2011). This case study outlines the Park's 30 year history of forest restoration planning and how the history culminated in the South Fork of Lost Man Creek Forest Restoration Project.

Redwood National Park was created in 1968 to preserve intact, old-growth redwood ecosystems. Under the Redwood National Park Expansion Act of 1978, 48,000 acres were added to protect the Park from encroaching logging activities. The expansion included 38,000 acres that had been logged, so the new law mandated a program of rehabilitation to restore these lands. This marked the beginning of the Park's forest restoration planning efforts.

In 1978, the Park established a 200 acre experimental thinning referred to as the Holter Ridge Thinning Study. The area had been clearcut in 1954, was dominated by Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco), and averaged 1,000 trees/acre 24 years after clearcutting (Chittick and Keyes 2007). A low thinning had been

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conducted to determine its effects on tree growth, forest composition, and understory vegetation (Chittick and Keyes 2007). This marked the first time that trees were cut down at Redwood National Park as a restoration effort. National Park Service executives, however, disagreed with the notion that thinning could be used as a restoration tool; others expressed frustration that the Park was cutting down trees on land removed from timber production. Finally, a moratorium on thinning second-growth forests in the Park was established in 1979, and the Park's first attempt at forest restoration came to an end.

In the 1990s, the listing of the northern spotted owl (*Stix occidentalis caurina* [Merriam]) as a threatened species made forest management on public lands a contentious issue and led to the development of the Northwest Forest Plan. Research began on ecosystem management practices that could maintain timber production while protecting, and creating, spotted owl habitat. Redwood National Park used this shift in paradigms to revive forest restoration planning, which resulted in a 40 acre experimental thinning in 1995 referred to as the Whiskey 40 Thinning Study. The area had been clearcut in 1962 and averaged 2,200 trees/acre 33 years after clearcutting. The thinning had been conducted in part to promote redwood composition (Stuart and Cussins 1994) and to demonstrate potential management for a larger forest restoration program.

A funding opportunity to support forest restoration came about when a neighboring timber company planned to log over 500 acres of old-growth stands that were acquired as a land swap connected to the creation of Redwood National Park. Because the marbled murrelet (*Brachyramphus marmoratus* [Gmelin]) was a newly listed threatened species, the timber company proposed to mitigate their logging by providing the Park $1.7 million for thinning. The Park quickly drafted a forest restoration plan (United States 1996) and it was distributed for public review in 1996. A local environmental group responded with a legal challenge, arguing the plan lacked cumulative effects analysis on marbled murrelets from the timber company's proposed logging and failed to state where the Park planned to thin. The Park's plan could not be approved and the mitigation dollars were not accepted; thus, the Forest Restoration Program was once again put on hold.

This unsuccessful planning effort, however, increased public awareness of the Park's impaired forests and increased public support for forest restoration. In 1999, the Park's General Management Plan (United States 1999) was approved, and provided the compliance needed to revive the Forest Restoration Program. To build momentum for the program, a park-wide forest inventory was conducted to describe the range of resource conditions and to use the data to prioritize areas for treatment. In addition, the Whiskey 40 Study was revisited in 2002 and the Holter Ridge Study was revisited in 2003 to aid managers in prescribing future silvicultural practices for restoring forests. The results from both studies were similar in that they both showed that residual trees responded well, there was a significant increase in biodiversity, and the overstory composition was unaffected as Douglas-fir continued to dominate because thinning intensities were too conservative or too much redwood was removed (Chittick and Keyes 2007, Teraoka and Keyes 2011).

Based on the assessment of the Park's second-growth forests, the South Fork of Lost Man Creek drainage was chosen as the first major forest restoration project (United States 2009). Planning began in 2004 and the plan was approved in 2009. The plan's objectives were in part to reduce stand density to promote redwood composition, initiate understory vegetation, and promote vigorous tree growth. To address logistic, economic, and regulatory constraints, five silvicultural prescriptions were used; the two most prominent prescriptions are discussed in this case study. Regardless of prescription, Douglas-fir was primarily targeted for removal. On ridge-tops, where slopes were less than 30 percent, low thinning was used to reduce the stand basal area by 40 percent, and the Park sold the merchantable timber, a byproduct of the restoration, to the contractor that conducted the restoration work. Non-merchantable wood was sent to a cogeneration power plant. On mid-slope sites, where slopes exceeded 30 percent, crown thinning reduced the stand basal area by no more than 25 percent, and felled trees were lopped-and-scattered. Crown thinning removes trees in the dominant and co-dominant crown classes to benefit trees of the same crown classes. This method was used on mid-slope sites to benefit redwood and reduce stand density while only cutting a few trees. Since logs were not extracted from mid-slope sites, the accumulation of cut wood was a major constraint.

Methods

For this analysis, a subset of preliminary data was used from the project's monitoring effort, which began in 2009. Data collected after thinning were analyzed to determine whether the two prescriptions immediately altered stand structure and species composition to promote redwood dominance.

The South Fork of Lost Man Creek Project comprises 1,700 acres. Most of the area was clearcut in 1954; the rest was clearcut in 1962. The latitude/longitude is N41^{o} 17 W123^{o} 58. Elevation ranges from 800 ft to 2,200 ft, and annual precipitation averages 65 inches.

Species and diameter at breast height (dbh) of live trees larger than 10.5 inches dbh were recorded in six 3/5-acre square plots. A 1/40-acre square subplot was nested at each corner of the 3/5-acre plot (four subplots per 3/5-acre plot). In the 1/40-acre subplots, the same data were recorded for trees 4.5 to 10.5 inches dbh. Plots were re-inventoried immediately after thinning. Three plots represented the thinning at the ridge-top site and averaged 15 percent slope. Three plots represented the thinning at the mid-slope site, and averaged 50 percent slope. Both sites were on northwest-facing aspects and were adjacent to each other. Means and standard deviations for stand density (trees/acre, basal area/acre) and quadratic mean diameter (QMD) were calculated for both inventory phases. Diameter distributions were plotted for both inventory phases. Data for western hemlock (*Tsuga heterophylla* [Raf.] Sarg.) and grand fir (*Abies grandis* [Dougl. ex D. Don] Lindl.) were grouped and named "Other" species.

Results

Thinning on ridge-top site

Prior to treatment, the ridge-top site's stand density consisted of 566.1 trees/acre and 366.7 ft^2/acre basal area (*table 1*). The majority of the stand consisted of three species: Douglas-fir, redwood, and tanoak (*Lithocarpus densiflorus* [Hook. & Arn.] Rehder). Before thinning, redwood and Douglas-fir had similar average diameters, both larger than tanoak. Douglas-fir dominated stand density in terms of trees/acre and basal area. However, redwood dominated the 22 inch diameter classes and greater (*fig. 1*, *t*op). The thinning reduced stand basal area by 38.4 percent (the target reduction was 40 percent), reduced the number of trees by 46.7 percent and increased stand QMD by 6.3 percent, demonstrating the thinning was successfully implemented as designed (*table 1*). All removals were in the 4 to 20 inch diameter classes (*fig. 1*, bottom), with a QMD of 9.9 inches for all removed trees.

Table 1—*Stand conditions before and after thinning at the ridge-top site expressed in number of live trees/acre, basal area (ft^2/acre), species composition (%), and quadratic mean diameter (QMD, inches) for redwood, Douglas-fir, tanoak, and other species.*

	Trees/acre			**Basal Area (ft^2/acre)**			**QMD (inches)**
	Mean	**SD**	**%**	**Mean**	**SD**	**%**	
Before Thinning							
Redwood	167.2	55.4	29.5	132.5	18.7	36.1	13.9
Douglas-fir	221.1	80.0	39.1	185.9	31.8	50.7	14.0
Tanoak	177.2	134.8	31.3	47.3	38.2	12.9	7.6
Other	0.6	1.0	0.1	1.0	1.7	0.3	17.9
Total	566.1	69.9	-	366.7	14.3	-	11.2
After Thinning							
Redwood	150.6	50.4	49.9	125.6	16.2	55.6	14.6
Douglas-fir	51.7	24.2	17.1	69.7	21.2	30.8	18.9
Tanoak	98.9	74.4	32.8	29.6	27.4	13.1	8.0
Other	0.6	1.0	0.2	1.0	1.7	0.4	17.9
Total	301.7	46.4	-	225.9	19.3	-	11.9

The thinning increased redwood composition relative to Douglas-fir (*table 1*). Prior to thinning, there were 32.2 percent more Douglas-fir than redwood and Douglas-fir had 40.3 percent more basal area than redwood. Immediately after thinning, there were 191.3 percent more redwood than Douglas-fir and redwood had 80.2 percent more basal area than Douglas-fir.

Stand QMD increased by 6.3 percent after thinning. This small boost in stand QMD was associated with leaving redwood virtually uncut and retaining approximately half of all the tanoaks in the smallest diameter classes (*fig. 1*). Douglas-fir represented 64.1 percent of the total number of trees removed and 82.5 percent of the total basal area removed. The removals concentrated on smaller diameter Douglas-fir (*fig. 1*); thus, its increase in QMD was 35.0 percent (from 14.0 to 18.9 inches), while redwood and tanoak QMD increased by 5.0 percent and 5.3 percent, respectively.

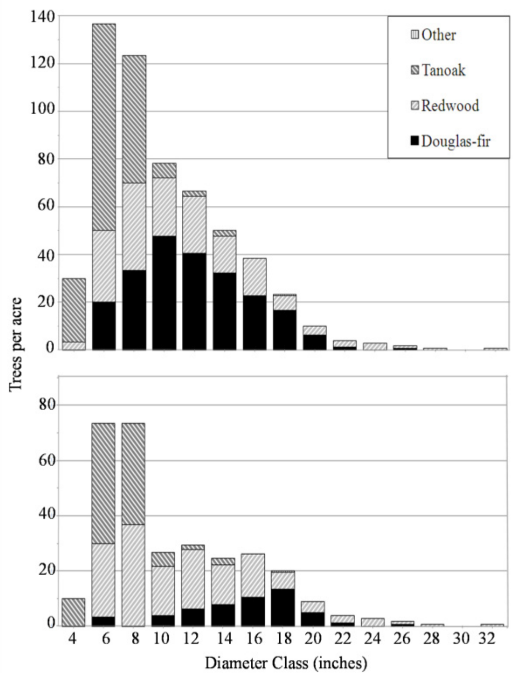

Figure 1—Diameter distributions at the ridge-top site stacked by species immediately before thinning (top) and after thinning (bottom).

Thinning on mid-slope site

Prior to treatment, the mid-slope site's stand density consisted of 391.7 trees/acre and 364.3 ft^2/acre basal area (*table 2*). The majority of the stand consisted of two species, Douglas-fir and redwood. Tanoak occurred in the stand, but was a minor component. Before thinning, redwood and Douglas-fir had similar average diameters. Although Douglas-fir and redwood had similar compositions, Douglas-fir represented most of the stand density in terms of trees/acre and basal area. However, redwood dominated the 20 inch diameter class and greater (*fig. 2*, top). The thinning reduced stand basal area by 11.0 percent (the target reduction could not exceed 25 percent), reduced the number of trees by 14.0 percent and had virtually no effect on stand QMD. The thinning was successfully implemented as designed; however, the reduction in basal area was low. All removals were in the 4 to 18-inch diameter classes (*fig. 2*, *bottom*), with a QMD of 11.5 inches for all removed trees, and concentrated on Douglas-fir. Douglas-fir represented 68.7 percent of the total trees/acre removed and 87.9 percent of the basal area removed.

The thinning had minor effects on redwood composition relative to Douglas-fir (*table 2*). The thinning virtually inverted the proportions of Douglas-fir to redwood in terms of number of trees, but failed to do so in terms of basal area, although it brought balance to the overall basal area composition. Prior to thinning, there were 11.4 percent more Douglas-fir than redwood, and Douglas-fir had 27.2 percent more basal area than redwood. Immediately after thinning, there were 4.3 percent more redwood than Douglas-fir, but Douglas-fir had 5.9 percent more basal area than redwood, which was an improvement to the pre-thinning condition.

Table 2—*Stand conditions before and after thinning at the mid-slope site expressed in number of live trees/acre, basal area (ft²/acre), species composition (%), and quadratic mean diameter (QMD, inches) for redwood, Douglas-fir, tanoak, and other species.*

	Trees/acre			Basal Area (ft²/acre)			QMD (inches)
	Mean	SD	%	Mean	SD	%	
Before Thinning							
Redwood	160.6	34.3	41.0	148.0	51.2	40.6	13.0
Douglas-fir	178.9	41.4	45.7	188.3	16.5	51.7	13.9
Tanoak	36.1	42.8	9.2	9.0	9.4	2.5	6.8
Other	16.1	10.0	4.1	18.9	4.2	5.2	14.7
Total	391.7	43.1	-	364.3	50.2	-	13.1
After Thinning							
Redwood	147.2	34.7	43.7	145.0	55.0	44.6	13.4
Douglas-fir	141.1	46.0	41.9	153.5	27.9	47.3	14.1
Tanoak	32.8	37.3	9.7	8.4	8.6	2.6	6.9
Other	15.6	9.2	4.6	17.8	5.5	5.5	14.5
Total	336.7	20.5	-	324.7	63.8	-	13.3

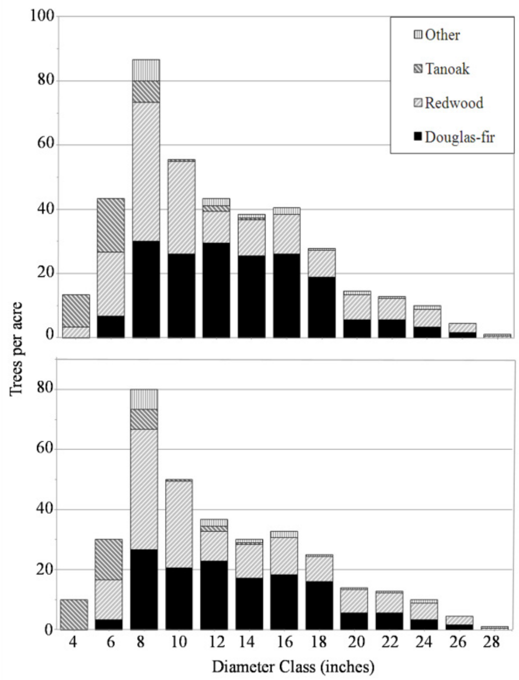

Figure 2—Diameter distributions at the mid-slope site stacked by species immediately before thinning (top) and after thinning (bottom).

Discussion

More than 30 years after the first attempt at establishing a Forest Restoration Program at Redwood National Park, regulatory agencies, the environmental community, and conservation organizations have embraced the idea that thinning young forests can improve ecosystem values. The effects of restoration thinning have been documented throughout the Pacific Northwest (Carey 2003, O'Hara and Waring 2005). Interest in the restoration of young-growth redwood forests has grown in part because the range of old-growth forest continues to decline (Evarts and Popper 2001), fragmented old-growth redwood stands have been deemed inadequate as reserves leading to increased landscape-scale efforts to connect these fragmented old-growth stands (Noss et al. 2000, Porter et al. 2007), and young forests in reserves exhibit declines in vigor and redwood dominance.

Teraoka and Keyes (2011) found that applying low thinning that targets all species for removal can result in a reduction of redwood composition relative to Douglas-fir and an intense low thinning targeting Douglas-fir could better achieve restoration objectives. This issue was addressed in the current case study. At the ridge-top site, the objectives of immediately altering stand density conditions while enhancing redwood dominance was successful because it was intense enough to immediately make redwood dominant. Although redwood dominated the largest size classes after thinning, the largest Douglas-firs were retained and Douglas-fir had the largest increase in QMD. This suggests that a gain in Douglas-fir's competitive potential in the upper canopy classes may occur during subsequent stand development, but this remains to be determined.

At the mid-slope site, the objective of immediately altering stand density conditions while enhancing redwood dominance was not fully met by low-intensity crown thinning; however, stand density conditions and redwood composition were improved. Results may have been more favorable if the basal area reduction was closer to 25 percent. The intent of this prescription was to remove fewer trees, while targeting Douglas-fir in the upper crown classes. Thus, a minor reduction in stand density could be achieved while releasing redwood in the upper crown classes. Regardless of the thinning intensity, all removals focused on redistributing growing space for redwood. Whether the thinning provided redwood with a more competitive position over the course of subsequent stand development remains to be determined.

The lop-and-scatter prescriptions were funded by the Centennial Challenge Initiative and the American Recovery and Reinvestment Act of 2009, which provided the Park $629,084 to thin 1,267 acres, a rate of $497/acre. In contrast, approximately 2.5 million board-feet were removed from 226 acres of ridge-top sites and sold to the contractor, which resulted in the contractor paying the government $221/acre to perform the restoration work. This project has demonstrated that excess wood, a byproduct generated from the restoration work, could be sold to offset the cost of implementing the project without compromising restoration objectives.

The Park is planning its next forest restoration project, which calls for managing 1,200 acres within the Lost Man Creek Drainage. In addition to traditional thinning methods, the Park proposes to implement variable density thinning, which has shown to be effective as a restoration tool in the redwood region (O'Hara et al. 2010, Keyes et al. 2010). In addition to ground-based equipment, the Park proposes to thin intensely on steeper slopes using cable yarding systems, which would allow the Park to remove excess biomass.

The challenge ahead for managers is to develop diverse silvicultural restoration treatments that are founded on the knowledge of forest dynamics in young stands and structural references from old-growth ecosystems, suit a variety of stand conditions, and are appropriate for an array of social and economic constraints.

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