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Reducing Stand Densities in Immature and Mature Stands, Applegate Watershed, Southwest Oregon

Marty L. Main and Michael P. Amaranthus

Abstract

Throughout the Applegate watershed, dense, overstocked, immature stands of mixed conifers and hardwoods and declining stands of mature conifers present significant and complex silvicultural problems. Stand stagnation is common, as is loss of large-diameter conifers from insects and wildfire. Treatments designed to maintain or encourage development of large-diameter conifers have not been tested. In this study, we examined conditions after density management treatments in two adjacent but dissimilar stands: (1) a dense, stagnant, immature stand of 40+-year-old hardwoods and conifers, and (2) a stand of declining mature conifers over a rapidly encroaching understory of hardwoods and conifers. The immature stand received a unique density-reduction treatment retaining both hardwoods and conifers to encourage long-term survival and growth of its coniferous component. The density-reduction treatment in the mature stand focused on removal of the competitive influence from overstocked, suppressed understory trees and maintaining existing large-diameter conifers. Precommercial thinning greatly reduced stand density and increased quadratic mean diameters in the immature stand. Before precommercial thinning, Pacific madrone (*Arbutus menziesii* Pursh) dominated, even though it regenerated at the same time as Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco). Following precommercial thinning, relatively equal numbers, sizes, and basal areas of Douglas-fir and madrone were retained. Several light thinnings may be necessary to foster development of vigorous Douglas-fir that can release and ultimately grow into large-diameter mature trees. In the mature stand, the combination of commercial and precommercial thinnings produced a reduced stand density designed to improve overall stand vigor. Trees per acre and basal area were greatly reduced in all diameter classes less than 24 inches but were not reduced in diameter classes greater than 24 inches.

Keywords: Applegate watershed, basal area, commercial thinning, competition, Douglas-fir, large-diameter conifers, Pacific madrone, precommercial thinning.

MARTY L. MAIN is a forester, Small Woodland Management Services Inc., 1305 Butte Falls Hwy., Eagle Point, OR 97524; and MICHAEL P. AMARANTHUS is a research biologist, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, P.O. Box 440 Grants Pass, OR 97526.

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Introduction

Treatments designed to maintain or encourage development of large-diameter conifers have been mainly untested, particularly at lower elevations and on harsh sites in the Applegate watershed of southwest Oregon. Dense, overstocked, immature stands of mixed conifers and hardwoods are not only common in the Applegate watershed, but also present significant and complex silvicultural problems, particularly if development of mature stands of conifers is desired. Stand stagnation is common, with reduction in growth and vigor, as well as increased likelihood of damage from insects and wildfire. Precommercial thinning in these immature, mixed species, natural stands demands much more complicated decisionmaking processes than uniformly spaced single-species plantations.

Existing mature conifer stands are threatened by bark beetle attack throughout the lower elevations of the Applegate watershed, and large-diameter conifers are being lost at increasing rates. Enhancing vigor of mature leave trees through harvest-related reductions in stand density is not nearly as dependable, or as immediate and dramatic, in mature stands as in younger stands (Williamson and Price 1971). This study examines stand conditions before and after density management treatments in the Applegate watershed of southern Oregon in two adjacent but dissimilar stands: (1) a dense, stagnant, immature stand of 40+-year-old hardwoods and conifers, and (2) a stand of declining mature conifers over a rapidly encroaching understory of hardwoods and conifers. The immature stand received a unique density reduction treatment retaining both hardwoods and conifers to encourage long-term survival and growth of its coniferous component; the mature stand was commercially and precommercially thinned with the aim of maintaining large-diameter conifers. Specific objectives for the immature stand included reducing stand density, increasing tree quadratic mean diameters, and developing relatively equal numbers, sizes, and basal areas of Douglas-fir (Pseudot*suga menziesii* (Mirb.) Franco) and Pacific madrone (*Arbutus menziesii* Pursh). In the mature stand, specific objectives of commercial and precommercial thinnings included reducing stand density and basal area, especially in the understory with retention of larger overstory diameter classes. Long-term objectives are to develop a mixed stand of large-diameter conifers and hardwoods and may require several density management treatments.

Methods

Site Description

The study site is a 10-acre area about 0.25 mile west of the town of Applegate (Sec. 21, T. 38 S., R. 4 W.) on the first hillside bench above the flood plain of the Applegate River. Slope percentage is 0 to 10 and the aspect is southerly. Elevation is 1,000 feet above sea level and annual precipitation is 22 inches. Soils are the Manita loams series—a relatively deep, moderately drained soil formed in colluvium weathered from altered sedimentary and extrusive igneous rocks. The surface soil is dark reddish brown and about 11 inches thick. The upper 9 inches of the subsoil is reddish brown clay loam. The lower 30 inches is reddish brown clay impermeable to most root development.

Before treatment, the study site was dominated by two distinct stand types. The first was an immature, dense stand of 30- to 44-year-old mixed conifers and hardwoods that regenerated after a stand replacement wildfire in the early 1950s. The same fire underburned the adjacent mature timber type, as evidenced by common fire scars on larger trees. The immature stand was significantly overstocked (over 2,200 stems per acre), with primarily Pacific madrone and Douglas-fir (table 1). Growth of individual stems throughout this type was suppressed, particularly so for the Douglas-fir, which had a quadratic mean diameter of only 2.6 inches (as compared to 4.2 inches for Pacific madrone). Stand density index was 417, high for a stand at age 100. Site index, 50-year base age, was 70-75 for both Douglas-fir and ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) (Hann and Scrivani 1987).

Table 1—Douglas-fir, Pacific madrone, and ponderosa and sugar pine trees per acre, basal area, quadratic mean diameter, stand density index, and relative density index before and after precommercial thinning in the immature stand

	Douglas-fir		Madrone		Pine[b]		Total,	Total,
Measure[a]	Before	After	Before	After	Before	After	before	after
Trees/acre	1,070	382	1,100	341	50	16	2,220	739
BA (ft^2/acre)	42	40.8	106.2	43	3	2	151.2	85.8
QMD (inches)	2.6	4.5	4.2	4.8	3.2	5.8	3.5	4.7
SDI							417	217
RDI								0.4

[a] BA= basal area, QMD= quadratic mean diameter, SDI= stand density index, and RDI= relative density index.
[b] Ponderosa and sugar pines.

The second stand type was a rapidly declining stand of mature mixed conifers and hardwoods (table 2). This mature type was comprised of four primary age classes of conifers: 110 to 115 years, 95 to 100 years, 75 to 80 years, and 30 to 44 years. The three oldest age classes comprised the declining overstory conifers—Douglas-fir 16 to 30 inches in diameter at breast height (d.b.h.), and to a lesser extent ponderosa pine and sugar pine (*Pinus lambertiana* Dougl.) (table 3). The youngest age class began after the wildfire in the early 1950s that was survived by the overstory trees. The 30- to 44-year-old understory was dominated by 1 to 9 inches in d.b.h. Douglas-fir and Pacific madrone. Openings within the mature overstory were densely stocked with the young Douglas-fir and Pacific madrone.

Table 2—Number of trees, basal area, Scribner volume, stand density index, relative density index, mean crown ratio, and crown closure before and after thinning in the mature stand

Measure	Before thinning	After thinning
Trees per acre	383	177
Basal area (ft^2 per acre)	180	101
Scribner volume (bd. ft. per acre)	22,455	10,929
Stand density index	340	183
Relative density index	0.641	0.345
Mean crown ratio (crown %/100)	0.388	0.458
Crown closure (percent)	84.1	30.8

Table 3—Number of trees, basal area, cubic foot volume, and Scribner volume per acre for each diameter class before and after thinning in the mature stand

	Trees/ acre		Basal area/ acre		Cubic foot volume/acre		Scribner volume/acre	
Diameter	Before	After	Before	After	Before	After	Before	After
Inches	- - - *No.* - - -		- - - *ft²* - - -		- - - *ft³* - - -		- - - *Bd. ft.* - - -	
0-4	152.8	76.4	3.3	2.9	40	3.3	0	0
4-6	743.0	28.5	13.3	4.2	292	88	0	0
6-8	67.2	28.5	16.7	7.1	388	167	0	0
8-10	0	0	0	0	0	0	0	0
10-12	10.3	0	6.7	0	152	0	519	0
12-14	10.8	7.1	10.0	6.7	279	175	989	574
14-16	22.0	5.5	26.7	6.7	912	196	3686	736
16-18	14.5	8.3	23.3	13.3	838	422	2845	1130
18-20	13.8	8.8	26.7	16.7	985	535	3995	1908
20-22	4.1	1.3	10.0	3.3	420	115	1919	414
22-24	8.0	6.8	23.0	20.0	942	699	4096	2873
24-26	2.9	2.9	10.0	10.0	456	380	2093	1584
26-28	1.7	1.7	6.7	6.7	314	253	1542	1106
28-30	.8	.8	3.3	3.3	161	131	812	602
Total	383.1	176.6	180.0	100.8	6,177	3,194	22,455	10,929

Stand Treatments

The immature stand was precommercially thinned in winter 1993 with the short-term objective of improving stand vigor and maintaining and promoting vigorous Douglas-fir and (where present) ponderosa pine. The long-term objective was to produce a mixed stand of large-diameter conifers. Leave tree selection was determined by close examination of crowns and existing stand densities. Tree stems selected for removal were severed with a chain saw and left on the soil surface. The stagnant and suppressed nature of the stand and the dominance by Pacific madrone prevented an abundance of vigorous Douglas-fir from existing in the overstory canopy. Thinning to improve individual tree performance, regardless of species, was the priority, and leave trees selected were the most vigorous trees in the stand regardless of size or location. Tree vigor was subjectively estimated through examination of individual crown ratio, crown denisty, needle color, and leader growth. All factors being equal, conifers were selected as leave trees over Pacific madrone.

The mature stand was harvested in May 1993. Draft horses were used to remove logs from the site, and damage to remaining leave trees was minimal. About 50 percent of the standing volume was removed from the mature stand. The harvest was intended to be strictly a stand improvement entry, maintaining as many large and healthy trees as possible. Considerable mortality had already occurred in the overstory trees as a result of stand overcrowding, drought, and bark beetle infestations. Leave trees selected were the most vigorous trees in the stand regardless of size or location.

Leave tree selection was determined by close examination of the crown form and ratio and numerous corings to determine growth patterns in the last 20 years. Throughout the stand, radial growth had dramatically decreased in the previous 5 years. Although basal area reduction was an obvious objective of the thinning, a careful adherence to spacing guidelines was not followed. Forcing this mature stand into some pre-designated preferred spacing was not an objective. Rather, a generalized basal area reduction was implemented with the primary objective of retaining healthy overstory trees, even if they naturally occurred in a clumpy pattern.

In conjunction with commercial thinning in the mature stand, an understory thinning of precommercial size classes was performed to reduce understory stocking levels and overall stand densities. Thinning was particularly heavy in the vicinity of the residual mature leave trees, although scattered healthy understory saplings were retained as well. Healthy Pacific madrone also were retained at light stocking levels.

Field Measurements

Pretreatment measurements in both the immature and mature stands were taken in November 1992. In the immature stand, five areas were randomly selected from a systematic grid as center points for installation of 1/50-acre measurement plots. Data collected included d.b.h. in 1-inch size classes by tree species. In the mature stand, six 20-basal-area-factor (BAF) plots were installed with species and d.b.h. of each basal area tree measured. In addition, the healthiest dominant site tree on each plot had the following data collected: age, d.b.h., height, diameter, radial growth, and basal area.

Posttreatment measurements in both the immature and mature stands were taken in summer 1994. Growth and yield plots were installed and measured in both the immature and the mature stands. Measurements included tree species, d.b.h., height, radial growth, and crown ratios within a 20-BAF variable plot, along with two nested subsamples (7.78-foot-in-radius plot for trees 0 to 4 inches d.b.h.; 15.56-foot-in-radius plot for trees 4.1 to 8.0 inches d.b.h.) in which species and diameter of all "in" trees were recorded. Plot centers were identical in the pretreatment and post-treatment surveys in the mature stand; new plots were randomly selected after treatment in the immature stand.

A variable plot cruise using a relaskop also was installed in the mature timber type. Six 20-BAF prism plots were measured with information on species, d.b.h., merchantable height, and grade recorded for all "in" trees. Minimum merchantability was 16 feet long and 5 inches in diameter. Trees with less than 30 board feet were not included in the cruise. Volumes for individual trees were determined from local volume tables (Scribner Formula Rule, 32-foot logs) derived from Medford District, Bureau of Land Management, information.

Results and Discussion

Immature Stand

Precommercial thinning reduced stand density and increased quadratic mean diameters for all tree species (table 1). Average number of stems per acre declined dramatically from 2,220 to 739. After thinning, quadratic mean diameter increased over 70 percent for Douglas-fir but only 14 percent for Pacific madrone. Quadratic mean diameter was over 60 percent greater for Pacific madrone compared to Douglas-fir before thinning but only 6 percent greater after thinning. Basal area was twice as great for Pacific madrone as for Douglas-fir before thinning and approximately equal after thinning. Equal numbers of Douglas-fir and madrone were retained after precommercial thinning.

Precommercial thinning to retain both conifers and hardwoods is an emerging approach to management of immature stands consistent with objectives of ecosystem management in the Pacific Northwest (USDA and USDI 1994). But selecting leave trees in naturally regenerated stands with dominant hardwoods is a more complex process than precommercial thinning strategies in single-species conifer plantations with predesignated spacing guidelines. In this study, leave trees were selected primarily by a subjective assessment of overall tree vigor regardless of species. Conifers were preferred, however, when all other factors were equal. Pacific madrone, even though regenerated at the same time as the Douglas-fir, dominated most of the immature stand, with associated Douglas-fir lightly to severely suppressed and overtopped. Large-scale removal of madrone would have shocked the Douglas-fir trees because most Douglas-fir had high height-to-diameter ratios, minimal crowns, extensive shade needles, and subsequently low vigor. In addition, removal of structural support maintained by adjacent hardwoods often results in numerous Douglas-fir tipping over.

This precommercial thinning treatment was viewed as an initial entry to begin stabilizing the stand, with the long-term objective of producing a mixed stand of madrone and large-diameter conifers. Achieving this objective will have to be a careful, long-term process with at least two and perhaps more thinnings before Douglas-fir are ready to be fully released. In the interim, a relatively high number of Pacific madrone were maintained. Characteristics used for selecting and retaining Pacific madrone included healthy, vigorous crowns; lack of disease, defect, and evidence of suppression; and, particularly, their position of providing shade (growing with crowns to the south of a preferred Douglas-fir) or structural support for preferred Douglas-fir. Pacific madrone with straight boles, a minimum of forking, and few limbs also were retained for future commercial value (limited markets with very high prices for large high-quality Pacific madrone logs already exist). Selecting for higher quality Pacific madrone may have future economic benefits in a developing hardwood lumber market. Retaining mixed stands of hardwoods and conifers may have numerous other benefits, including improved soil physical, chemical, and biological properties; reduced likelihood of stand-replacing insect or disease infestations; improved wildlife habitat; and possibly greater cubic-foot volume growth than single species stands (Amaranthus and Perry 1989, Amaranthus and others 1990, Fried and others 1990, McComb and others 1986, Hunter and Aarsen 1988, Perry and others 1987, Velasquez-Martinez 1990).

Conditions similar to the immature stand treated in this study are quite common in low and mid elevations of the Applegate watershed and are a challenge when development of large-diameter conifers is a primary objective. Pacific madrone, once established, is much better adapted than conifers to infrequent but intense disturbances, including intense wildfire or harvests. The ability of madrone to rapidly sprout new growth from its base is an advantage over conifers in such scenarios, and once established, Pacific madrone is much more drought tolerant than native conifers. Given the tendency of madrone to regenerate from seed and grow quite slowly, its thin, easily destroyed bark, and its affinity for maximum sunlight, it would have been much less common in a regime of frequent, low-intensity wildfire. Frequent disturbances of reduced intensities offer significant advantages to mature, thicker barked, and larger sized Douglas-fir and ponderosa pine and tend to leave large portions of established canopies intact.

It is suspected that the Pacific madrone in the immature stand will release and grow faster initially than the released conifers. In our experience, thinning in similar dense, low-elevation Pacific madrone stands in southern Oregon produces immediate and large response, much larger than typical responses from conifers in similar scenarios. It is likely that a second thinning concentrating on removal of more Pacific madrone will be needed within a short time to continue encouraging conifer growth on the site. By the time of the next thinning, conifer crown elongation and densification, increased percentage of sun needles, and bole stability should allow further release. Seven hundred and thirty-nine total trees per acre is still far too many to remain on the site for vigorous growth in the future.

Mature Stand

The combination of treatments, commercial thinning harvest coupled with a precommercial thinning, effectively reduced stand density and improved the likelihood of maintaining large-diameter conifers in the stand (table 2). Trees per acre were reduced by more than 55 percent, and basal area and stand density index were reduced by 45 percent. Canopy closure declined from 84 percent before thinning to 31 percent after thinning. Average crown ratio increased nearly 20 percent after thinning as a result of removing the majority of trees with low crown ratios. Reducing stand density and selecting trees with more developed crowns was particularly important because vigor of the mature timber had declined significantly and experienced a large reduction in radial growth within the last 5 years. Bark beetle infestation was already occurring in the stand, and there was considerable recent mortality in the larger diameter overstory trees. Although mature trees could have been removed to achieve the same desired reduction in basal area, as has been typical of many "high-grading" types of timber harvests in the Applegate watershed in the past, that would not have met the desired objective of trying to maintain as many large-diameter conifers as possible. Further, it would fail to capitalize on the release potential of these larger trees that typically had radial growths exceeding those of the smaller size classes in the stand.

Trees per acre and basal area were greatly reduced in all diameter classes less than 24 inches (table 3). Trees per acre and basal area were not reduced in diameter classes greater than 24 inches. Trees in the larger size class, above 20 inches in diameter, were removed only if they were rapidly declining, were insect or disease infested, or were not expected to survive. Removal of 45 percent of the basal area in the suppressed, intermediate, and codominant size classes should reduce competition for soil moisture and nutrients in this stand and provide growing space and additional site resources for the preferred larger diameter trees. Younger, immature trees may use more site resources than older mature timber of equal or greater basal areas as a result of the greater percentage of sapwood in younger stems. Heartwood in older timber accounts for a large increase in basal area but contributes less competitive influence.

The significance of maintaining and promoting mature stands of large-diameter conifers through basal area reductions is becoming an increasingly important management concept. Mature stands, particularly at lower elevations, have become increasingly uncommon, and thereby represent a significant and highly desirable biological and ecological component of the Applegate watershed. Less commonly discussed are the economic justifications for retaining healthy, higher quality mature timber. In the rapidly developing global economy, large high-grade conifers have become more valuable. Results of timber cruises afer thinning indicate that 68 percent of the Douglas-fir leave tree volume is a sawmill grade 2, with the remainder in lower quality sawmill grades 3 and 4. In 1994, stumpage value for sawmill grade 2 Douglas-fir logs was 24 percent higher than sawmill grade 3 logs and 48 percent higher than sawmill grade 4 logs. Some of the timber, if it can be retained in the stand, will soon develop into a special mill grade with a current stumpage value 23 percent higher than sawmill grade 2 Douglas-fir logs. Similar grade differentials can be extrapolated for the ponderosa pine in the stand. It is expected that price differences between lower and higher quality logs will only expand in future years as worldwide availability of larger, slower growing mature trees diminishes. In addition, larger trees allow higher values per unit of volume and subsequent reduced management costs. Developing stand management strategies that extend rotations or retain large-diameter conifers can add volume as higher quality saw logs, which will maximize value rather than just volume per acre.

Stand management strategies that retain large-diameter conifers may not reduce volume production in the long term. Curtis (1992, 1994) suggests that mean annual increment curves are quite flat near and beyond formerly predicted culmination ages and that extending rotations may not, in reality, reduce volume production. Density control can even further extend culmination of mean annual increment in many cases. Curtis and Marshall (1993) describe an 81-year-old stand, commercially thinned at age 48, that has produced 1.25 times the cubic volume of two 40-year rotations, and with much higher quality logs than those produced in the two 40-year rotations. Lengthening of rotations or retaining large-diameter conifers in stands also may reduce conflicts with other amenities, wildlife, and other public values.

The condition of the mature stand before thinning is an example of the shift away from historical conditions in southern Oregon forests. Dense understory vegetation was less abundant before fire suppression activity began early in the 20th century. In the absence of frequent, light to moderate intensity fires, coniferous stands have become increasingly overstocked with understory vegetation that would have been partially or totally removed by underburns (Agee 1993). This dense understory vegetation often contains a high proportion of hardwoods and represents significant competition for site resources. In effect, particularly at lower elevation sites, large-diameter overstory conifers are being "killed from below." Age classes in the mature stand were separated by about a consistent 20-year interval (113-117, 95-100, 75-80) until about 80 years ago and the advent of fire suppression. Since that time, a single major fire event has occurred (in the early 1950s) and produced the stand replacement event that led to the development of the immature stand. With the developing understory fuels in the mature stand adjacent to the dense thicket of the stagnating hardwoods and conifers in the immature stand, the entire area had developed high risk for a stand-replacing wildfire event.

The preharvest mature stand provided an example of a diameter distribution typical of uneven-aged stands—a reversed J-shaped curve (table 3). A Q-quotient (a ratio that compares the number of stems between adjacent diameter classes) of about 1.4 existed in this stand (a slightly lower quotient in the lower diameter classes and a slightly higher Q-quotient in the diameter classes greater than 14 inches). It is suspected that many of the prefire exclusion era stands in the Applegate watershed were uneven-aged, particularly those where fire return intervals were short and at low elevations. If a return to some degree of historical conditions is desirable, then restoration and ultimate maintenance of uneven-aged stands, at least on a portion of the landscape, is needed. The harvest in this stand provides one example of combined treatments that maintained the uneven-aged nature of the stand, although the Q-quotient was reduced slightly. Of critical importance in uneven-aged management is the management of the understory species, precommercial thinning, and release treatments. It should be noted that typical prescriptions and harvest practices that either remove the overstory to release the understory (a practice of often questionable value due to the poor quality and vigor of the understory) or remove the entire stand, in effect, shift stands rapidly toward even-aged conditions and away from the historical conditions of more uneven-aged stands.

Stand dynamics, species, and structures are far different in stands controlled by infrequent, intense disturbance than by frequent, low-intensity disturbances. In the Applegate area, shifting stands toward less frequent but more intense disturbances has contributed to the following changes: (1) more stands in the stand initiation or stem exclusion (precommercial) development classes; (2) the severely overstocked condition of these stands, with subsequent impacts on growth and vigor; (3) and resulting potential for damage or mortality from bark beetles and the likelihood of killing mature conifers from below with unchecked encroachment of understory vegetation; (4) the much higher percentage of hardwoods in the developing stands, which will continue to increase (given their advantage of stump sprouting) if the recurring cycle of intense disturbance is not broken; and (5) the decreased likelihood of establishment and growth of shade-intolerant but otherwise well-adapted species such as ponderosa pine (Agee 1993, Oliver and Larson 1990).

Conclusions

A strategy for developing large-diameter conifers in immature stands at low to middle elevations in the Applegate watershed includes precommercial thinning as an initial entry to begin stabilizing overstocked and stagnating stands, with the long-term objective of producing a mixed stand of hardwoods and mature conifers. This will have to be a careful, long-term process with at least two thinnings, and perhaps more, before conifers are ready to be fully released. In the interim, a relatively high number of hardwoods are maintained. Precommercial thinning should reduce stand densities and increased quadratic mean diameters for all tree species. Where hardwoods dominate the stand their density and basal area should be gradually shifted to conifers. Precommercial thinning to retain both conifers and hardwoods is a newly emerging approach to management of immature stands in the Pacific Northwest. Selecting leave trees, however, is a more complex process than the traditional precommercial thinning strategies in single-species stands.

A strategy for maintaining large-diameter conifers in existing mature stands focuses on commercial and precommercial thinning of understory vegetation. Trees per acre and basal area are greatly reduced in the smaller diameter classes. The objective includes improving overall vigor of large-diameter trees and maintaining larger diameter classes unless they are rapidly declining, insect or disease infested, and unlikely to survive. Density reduction of understory conifers and hardwoods is critically important to maintain larger diameter conifers in the lower elevations of the Applegate watershed. Developing stand management strategies that extend rotations and retain healthy large-diameter trees not only has biological and ecological benefits for dependent species but also adds economic value by producing higher timber values and quality saw logs.

In effect, both harvest activities and fire suppression have greatly reduced the abundance and distribution of large-diameter conifers and increased the likelihood of severe disturbance by wildfire, on both the stand and landscape levels. Maintaining this level of risk is highly undesirable and investment in reducing this risk would seem prudent, if not imperative. It will be a considerable challenge to manage immature and mature stands to develop and maintain large-diameter conifers in low- to mid-elevation areas in the Applegate watershed. This study and increased research and monitoring of other areas will provide an opportunity for long-term assessment and understanding of stand management in the Applegate watershed.

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