Intensive Management of Stump-Sprout Reproduction In Coppice-Regenerated Coast Redwoods

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Introduction

The habit of coast redwood (*Sequoia sempervirens* (Lamb. ex D. Don) Endl.) to regenerate naturally from epicormic basal sprouts (stump sprouts) after severe damage or removal of the main stem has contributed greatly to the species' renewal and has been responsible for the regeneration of many of the region's second-growth redwood stands. However, unmanaged stump sprouts generated by the harvest of second-growth redwood stands contribute to an aggregated, patchy spatial distribution of tree stems within regenerating third-growth stands. This concentration was not problematic with sprouts from old-growth stumps due to large size of the stumps and the resulting distance between sprouts, but it will be increasingly problematic for sprouts from the smaller second-growth stumps that are much closer in proximity. This concentrated, unmanaged condition might be most effectively and efficiently ameliorated by the control of stump sprout densities at an earlier age than has previously been considered. A reconsideration of traditional concepts of stand thinning and a new consideration of the intensive silvicultural control of redwood sprout reproduction is warranted. With this paper we present an argument for an innovative silvicultural approach to the management of third-growth redwood coppice-generated forests.

Redwood Renewal in Context

Redwoods occur in a limited range defined as a very narrow Pacific coastal strip that is 450 miles long and 5-35 miles wide (Roy 1966). Despite the small range, the species constitutes a vital share of the California timber economy. The redwood region's fertile soils, combined with a moderate climate of plentiful precipitation, results in forests of high productivity and tremendous growth rates. For example, one celebrated plot in a second-growth stand first measured in 1923 achieved a periodic annual increment of 5,000 bf/acre, and had by 1995 (age 137) accrued a basal area of 935 ft^2/acre and a volume of 343,000 bf/acre (Fritz 1945, Allen 1996). Moreover, redwood's natural decay resistance makes the species desirable for wet and outdoor environments and returns high per-volume prices (Wilcox 1996). With sawlog prices commonly approaching or exceeding $1,000/mbf (nearly double the value of Douglas-fir), the species is favored by foresters far above its associates. And unlike Douglas-fir, there is nearly no market competition from other states and countries in North America.

On most commercial redwood timberlands, the main regeneration method for redwood is by clearcutting in blocks that are constrained in size by the California Forest Practices Act to 20 acres (ground-skidded) or 40 acres (cable-yarded) (California Department of Forestry and Fire Protection 2002). Logging of virgin redwood forests on a grand scale began with the 1849 California gold rush and rapidly became one of coastal California's main industries. Selective logging of old-growth redwood forests was predominant by the 1940s, and reached its peak in the 1950s-1960s (O'Dell 1996). Yet an economy based on the utilization of smaller, primarily even-aged second-growth forests emerged and grew as the region's old-growth forests declined. By 1986, approximately 63 percent of the original redwood range was in second-growth status (Fox 1996). As these second-growth forests have reached maturity in recent decades, an increasing proportion of the redwoods are now in third-growth status.

Natural regeneration of redwood from seedfall has always been of concern to the region's foresters due to low seed viability rates. Seed crop years are not infrequent (Boe 1968), but even during those years of high seed production years, seed crops are up to 85 percent infertile (Olson et al. 1990); the germination rate of sound seed is high (Boe 1961), but the occurrence of defective seeds is very high. Concern over redwood's regeneration potential, together with a concern over the size and quality of second-growth logs, resulted in dim expectations for the redwood timber economy following logging of virgin forests. Reflecting upon the state of redwood regeneration at the end of the 19th century in *National Geographic Magazine*, one observer lamented,

When the timber has been cut there is no sign of reproduction from seed. In many localities sprouts are growing from stumps in the cut areas, but even this form of reproduction is limited. Indeed everything appears to indicate that for some reason…with the clearing away of the present forests the end of the species as a source of lumber will be at hand (Gannett 1899).

In the same issue, a second author fatalistically reported,

The reproduction of the species is said to be very low. Cut-over areas show no evidence of reforestation with the same species. Thus hemmed in by inimical climatic conditions and unable to maintain its stand, its extinction seems assured at no very remote period (Leiberg 1899).

But those fears were never realized. Stands of redwood developed from the brushy thickets of sprouts emerging from virgin stumps, mills retooled to accommodate smaller log sizes, and fears about the quality of second-growth redwood sawnwood were allayed. Still, as a hedge against risks, cutover redwood forests even as late as the 1950s-1960s were aerially seeded with mixtures that included alternate species such as Douglas-fir and Sitka spruce. Today, however, redwood is the unambiguous reforestation species of preference wherever site quality is permitting, and commercial nurseries are developing redwood seedlings of greater drought tolerance that, it is hoped, will expand redwood plantings beyond the species' current geographic range.

Due partly to redwood's limited potential for natural regeneration from seedfall, and largely to California's stringent reforestation requirement of full restocking within two years following harvest, most redwood forest managers today rely on artificial regeneration with nursery seedlings to ensure successful reforestation. However, stump sprouts are also heavily depended upon to contribute substantially to full stocking. One survey revealed that stump sprouts comprised the majority of stems in fully-stocked stands following harvest and reforestation (Lindquist and Palley 1967). When they are grown together, sprouts outpace planted seedlings, so planted seedlings are generally used to interplant between distant stumps.

Coppice-Regenerated Redwood Forests

Redwood is the only North American conifer species of any commercial value that is regenerated largely under variations of the traditional coppice system. Redwood sprouting occurs rapidly and prolifically following burning or cutting of the main stem. Regardless of season, sprouts commonly materialize 2-3 weeks after stem removal from stumps and root crowns, often exceeding 100 per stump (Olson et al. 1990). So persistent was the sprouting by old-growth stumps that many prospective ranching attempts in the redwood empire during the 19th century were abandoned. Sprouts outgrow planted seedlings during the initial years, reaching heights of 2-6 feet within a year of emergence.

Second-growth forests that emerged from the sprouts of virgin stumps yielded useful log sizes because they were distantly spaced; the sprouts were distantly spaced because the stumps were very large, and because the stumps themselves were distantly spaced. Structures of virgin redwood forests varied, but overstory densities were often less than 100 stems per acre (Fujimori 1977, Sugihara 1992, Van Pelt and Franklin 2000). Sprouts in many cases therefore had sufficient space on at least two sides to reduce intra-stump sprout competition, to enable expressions of dominance among them, and to facilitate their differentiation into crown classes.

In contrast, stumps of the second-growth redwood forest are located with many nearby neighbors, especially where they were successfully interplanted with redwood seedlings. At diameters that are typically 24 inches or less, second-growth stumps are also substantially smaller and younger than were the virgin redwood stumps. Sprouting frequency has been shown to be greater among smaller stumps than larger stumps (Neal 1967). Moreover, among those stumps that do sprout, sprout density (sprouts per area of stump circumference) is greater for stumps of younger, smaller trees rather than older, larger trees (Powers and Wiant 1970).

Taken together, these factors are resulting in the following condition: the third-growth coppice-generated redwood forest is initiating in aggregated conditions at spacings that are substantially lower than was previously common. It is therefore not realistic to assume that unmanaged third-growth sprouts will develop in the same way and produce products of comparable size and quality as the previous generation of redwood forests. It is more reasonable to expect that some form of density management will be necessary to remediate the high initiating densities of third-growth coppice-regenerated redwood forests.

Complications of Dense Redwood Stands

The dense concentration of third-growth stems in an aggregated spatial pattern potentially diminishes wood qualities, log sizes, and stand yields. Crowded stems grow together as single logs, embedding bark, branches, and other debris within the wood of the butt-log. The close proximity of redwood stump sprouts establishes a need for thinning at an early age to promote growth and minimize losses to mortality; such thinnings rarely yield logs of value and are conducted as pre-commercial thinnings. If thinning is delayed until stems reach a merchantable dimension, growth and yields suffer.

The primary issue of concern, however, is in the area of forest protection. Coppice-regenerated stems growing in dense conditions fail to develop the stem and root capacity necessary to weather the strong seasonal winds that frequent the redwood range; furthermore, the stems develop asymmetrical crowns that exacerbate this instability. As such stands develop, they become increasingly unstable with height:density ratios that increase their susceptibility. Foresters have also noted that commercial thinning sprout clumps often results in wind damage to residuals on the leeward side of stumps when windward-side stems are removed. This threat of blowdown is greatest for those sprouts emerging from the tops and sides of stumps (rather than from the root crown). Fundamentally, such sprouts are mechanically weak and susceptible to wind. Even in the absence of strong winds, it is not uncommon for mature sprouts located high upon the stump to simply peel off eventually under their own weight.

Pre-commercial thinning that retains windward stems and stems emerging from the root collar can ameliorate this condition. However, pre-commercial thinning appears to attract cambium-feeding black bears, whose effects have been increasingly observed with dismay within the past decade. Black bears tear long vertical strips of the fibrous redwood bark to consume the cambium beneath, most often from the bases of young trees (10-30 years; 6-10 inches dbh)(Olson et al. 1990). In mixed stands, redwood is preferentially targeted over other species, including Douglas-fir (Glover 1955, Russell et al. 2001). Cambium-feeding bears typically target the largest trees in a stand, may girdle trees completely, and often return to the same stand repeatedly. A recent study of the activity revealed positive associations of bear damage with recently harvested stands and with stands of pole-sized trees (Russell et al. 2001). This is a relationship that managers corroborate; bears appear to be drawn to young redwood stands immediately following pre-commercial thinning.

Bear damage has been recognized since the 1950s (Glover 1955), but has increased in either intensity or observation in recent years, and has become a management priority for some ownerships. Their devastating effects led industrial forest ownerships to rate bears and other mammals as the forest health concern of primary importance in the redwood region, above fire, insects, diseases, and alien plants (Stuart 1996). However, options for addressing bear damage that are both effective and socially acceptable are scarce. Direct control of bear populations in the form of animal disposal is a highly restricted activity, and in California is highly controversial. Therefore, silvicultural approaches that minimize the susceptibility of stands to bear utilization may hold the greatest potential for reducing the scale of bear damage

New Silvicultural Treatments for Coppice-Regenerated Redwoods

Taken together, these concerns suggest the high potential value of stand density management at a very early age. Sprout thinning enables coppice-regenerated stands to be shaped to desired spacings and in a manner that favors low, windward sprouts over high, leeward sprouts; importantly, it performs this function before stands become susceptible to black bears. But most prior research in redwood stand density management addresses the commercial thinning or precommercial thinning of coppice-generated stands at age 10 and older (e.g. Boe 1974, Lindquist 2004), or sprout emergence from virgin stumps (Cole 1983, Neal 1967, Powers and Wiant 1970). The potential for managing stump sprouts at a very early age until recently had not been addressed in any comprehensive way. To address this deficiency, we recently initiated a study of redwood sprout ecology and management that is the first to test the operational feasibility of methods for managing the density of sprout reproduction from second-growth stumps (Keyes and Matzka 2005).

Previous research on the sprouting behavior of coast redwood suggests that opportunities exist for intensive sprout reproduction management as an operational practice. Sprout densities are directly influenced by stump size, age, and height (Neal 1967). Past studies in redwood and other species have shown an effect on sprout density and vigor by partial sprout removal, thermal wounding, shading, exposure to hormones, and bark integrity (Powers and Wiant 1970, Finney 1993, Tappeiner 1996).

Our study has been established for the purpose of identifying practical and efficient techniques for the operational control of immediate post-harvest stump sprouting capacity (basal bud management) and early sprout density management. It is being conducted in operationally-harvested stands that are dominated by mature coast redwood trees and are representative of the region's second-growth forests. In this study, differences in the sprouting response of redwood stumps to various treatments designed to debilitate the capacity of stumps to produce sprouts – including varying stump heights, mechanical stump scarification, bud incineration, and mechanical sprout removal – are being quantified. Three separate analyses constitute the project.

In the first study, the effect of overstory density retention levels from thinning on later post-harvest sprout proliferation is assessed. This study tests the hypothesis that thinning prior to harvest can reduce the quantity of stump sprouts when harvest occurs 5-10 years later. It assesses commercial thinning as a form of pre-emergent regeneration density management in the post-harvest, sprout-regenerated stand. The hypothesis is tested by measuring sprout density and sprout height from stumps in stands previously thinned to reduced levels of overstory density (33/66/100 percent density retention).

In the second study, the effectiveness of sprout removal on the height growth response of residual sprouts is assessed. This study tests the hypothesis that sprout growth rates are affected by different levels of sprout removal and post-removal sprout densities. It assesses a new practice of sprout thinning as a form of pre-precommercial thinning. This study is conducted among stumps within 2 years following clearcut harvest with numerous sprouts (tens or hundreds) per stump. The hypothesis is tested by utilizing chainsaws and motorized brush-cutting tools to thin sprout clumps to pre-determined density levels, and then monitoring sprout height and caliper growth.

In the third study, the effects of stump morphology and different methods of stump treatment on sprout densities and spatial distributions are assessed. This study tests the hypothesis that different forms of stump and bud treatment (stump height, bud incineration, mechanical bark removal) exhibit varying levels of effectiveness in achieving sprout density and distribution targets. It assesses a new practice of stump morphology treatment as a form of pre-emergent regeneration density management in the post-harvest, sprout-regenerated stand. The treatments are conducted on stumps immediately following clearcut harvest. The hypothesis is tested by implementing stump treatments based on the previously-described tools, and then monitoring the density and spatial arrangement of sprouts.

The Future of Redwood Coppice Silviculture

Intensive sprout density management as an operational practice has not been codified, but there is ample evidence that it will work, and that it (or something very similar) is necessary. Intensive sprout management offers multiple potential benefits, including:

- Captured volume that is otherwise lost to mortality
- Decreased rotation length to desired product size
- Or, increased product size at desired rotation length
- Improved quality of the lowermost log; reduction in embedded bark and debris
- Selection of most stable and enduring sprouts on a stump
- Reduction of losses associated with high winds
- Reduction of losses associated with cambium-feeding bears

The history of forestry in the redwood empire is one that has been written by engineering technology, biological limits, and societal influences. That history is still being written today. Nearly 80 years ago, The Humboldt Redwood Reforestation Association (1926) refuted popular misconceptions of the futility of redwood renewal, concluding that,

...there is no chance whatsoever that redwoods will become extinct….California can look forward to being perpetually in the redwood lumber business, and at the same time tourists will always have, in addition to parks of virgin trees, great timbered areas in which the grandeur of Nature has been enhanced by the hand of man.

Its since-demonstrated capacity for aggressive regeneration from stump sprouts casts doubt on the notion that redwood's extinction was ever at stake. Yet steps may be taken to develop innovative silvicultural techniques for the management of today's redwood forests to ensure that they continue to yield the quality and quantity of logs upon which the health of the redwood forest products economy depends.

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