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INSIDE

"Science affects the way we think together."

Lewis Thomas

TOWARD MORE DIVERSE FORESTS: HELPING TREES "GET ALONG" IN A NEW ORGANIZATION

Warren Devine

A researcher clears vegetation away from a seedling as part of a study to better understand competition for light and water in the forest understory.

IN SUMMARY

Interactions among plant species and their growth patterns help shape a forest. Various management practices can enhance forest complexity and in return yield benefits that include enhanced growth of desired species, slowing the spread of root disease, and improved wildlife habitat.

To find effective strategies for increasing forest complexity by shaping stand architecture, Tim Harrington and Warren Devine at the Olympia Forestry Sciences Laboratory conducted three studies related to the impacts of competition among forest plant species. The first effort examined the effects of belowground competition from understory vegetation and overstory trees on the survival and growth of conifer seedlings in mature Douglas-fir forests. The second study examined ways in which precommercial thinning and competition from tanoaks influence the long-term structure of Douglas-fir plantations. The third study identified silvicultural approaches for mitigating threats from black-stain root disease, Scotch broom, and trailing blackberry.

In each case, researchers found that efforts to manage or manipulate competition among plant species—such as well-timed thinning treatments—effectively modified stand structure and curtailed adverse effects on Douglas-fir regeneration in natural forests or plantations. Altering stand structure also expanded habitat opportunities for wildlife and beneficial plants.

Look deep, deep, deep into nature, and then you will understand everything.

— Albert Einstein

Today's forest managers are challenged to meet a range of emerging objectives, from restoring and maintaining native plant communities to optimizing forest ecosystem services and strengthening resilience to environmental stressors. Increasingly, scientists are recognizing that variety in tree age and stand architecture are key ingredients to forest health and biodiversity. No simple formulas exist for creating these features or building them into existing even-aged stands, and given the uniqueness and ever-changing dynamics in managed and natural forests, no one-size-fits-all solutions are likely to surface. However, by carefully studying interactions among plant species and the ways in which their growth patterns help shape forests, silviculturists are piecing together possible strategies for enhancing forest complexity and reaping a range of benefits from the changes.

Tim Harrington and Warren Devine, research foresters with the Pacific Northwest Research Station's Forestry Sciences Laboratory in Olympia, Washington, have focused on these issues. At low-elevation sites around Puget Sound and in southwestern Oregon, they have sought to find effective methods for incorporating new trees into mature forests, increasing the structural complexity of young, planted forests, and reducing the damaging effects of pests.

THE PLIGHT OF UNDERSTORY SEEDLINGS

Foresters have long sought to know the ins and outs of what it takes for conifer seedlings to succeed in the iconic Douglas-fir forests of the Northwest. In these systems, gaps in the canopy are generally infrequent, making light a precious commodity. Although Douglas-fir seedlings can survive in conditions where they only receive 20 percent of full sunlight, without an eventual boost in overhead illumination, they're not likely to develop and thrive. Some managers have used thinning to give saplings a "leg up" in the understory, with varying degrees of success. But the juvenile trees also must contend with a less visible handicap. "Seedling roots occupy the same soil layer as those of overstory trees and understory vegetation, and they all compete for soil water and nutrients," Devine explains. And, under dense canopy, less rain reaches the forest floor during the growing season to recharge the soil, he adds.

KEY FINDINGS

- Belowground competition from the roots of understory vegetation and overstory trees deprives conifer seedlings of soil water and nitrogen, substantially reducing their growth. However, the relative intensity of competition from each forest layer depends on the light environment. In dense, low-light stands, overstory trees are the primary competitor, but as light levels increase, so does competition from understory vegetation.
- Competition from hardwoods early in the development of Douglas-fir stands, combined with precommercial thinning, exerts long-lasting influence on the eventual structure of a stand. With low hardwood densities, conifers become dominant. Moderate hardwood densities promote development of dominant (conifer) and intermediate (hardwood) canopy layers. Under high hardwood densities, a codominant canopy layer of conifers and hardwoods evolves.
- In young stands of Douglas-fir, conifer mortality from black-stain root disease was less where hardwoods were retained, probably because hardwood roots slowed conifer root growth and served as a physical barrier to the spread of disease.
- Retention of scattered logging debris after timber harvest reduced abundance of Scotch broom, facilitating a 30-percent increase in Douglas-fir survival by the fifth year after planting.

"It's common knowledge that shade and root competition limit growth in the understory, but the difference in effects from these factors hasn't been thoroughly explored," Harrington notes. To gain a better understanding of the importance of root competition on Douglas-fir seedlings in a mature forest with a dense canopy, Devine and Harrington conducted experiments in stands 60 to 80 years old on Fort Lewis Military Reservation near Olympia. Prior to the study, periodic thinning had been carried out; nonetheless, light levels in the stands averaged about 26 percent of full sunlight—approaching the lower limit of seedling shade tolerance.

The researchers excavated trenches around small plots—each populated by a few Douglas-fir seedlings—and tested different levels of root competition from nearby overstory trees and understory herbs and shrubs. Trenches were lined with plastic to prevent regrowth of roots. In other plots, all shrub and herbaceous vegetation was repeatedly clipped to eliminate root competition from these species.

Onsite sensors continuously monitored soil water in the plots throughout the study. As well, the researchers routinely measured

Warren Devine

Researchers trench the perimeter of a plot containing Douglas-fir seedlings to exclude competition from overstory tree roots at a study site in Fort Lewis, Washington.

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amounts of nitrogen, potassium, and phosphorus in the needles of seedlings. After 2 years, the results were telling: seedlings in plots free of overstory tree roots had significantly more needles, buds, and branches, and retained their needles longer than their competition-handicapped cousins. In previous research, Harrington found that with higher light levels from reduced overstory densities, the understory plants competed with conifer seedlings for soil water. But significantly, this didn't turn out to be true at Fort Lewis. "We found that root competition from understory vegetation had negligible effects on seedling growth in the low-light conditions. Rather, the main competition for soil water came from overstory trees," Devine says. The results also showed a strong correlation between soil water content and nitrogen concentrations in needles of the seedlings. "Because processes that make nitrogen available require water, excluding tree roots meant seedlings could take up more nitrogen for growth," he explains.

This suggests that reducing the amount of understory vegetation in high-density, low-light stands isn't likely to yield much benefit to Douglas-fir seedlings. "A more effective approach for supporting seedling growth is to reduce the number of overstory trees, to curtail root competition and bring in more light," Devine says. "However, as overstory density is decreased and more light makes it to the forest floor, the impacts of understory plant competition increase, so gaps in understory vegetation also become necessary if young conifers are to thrive."

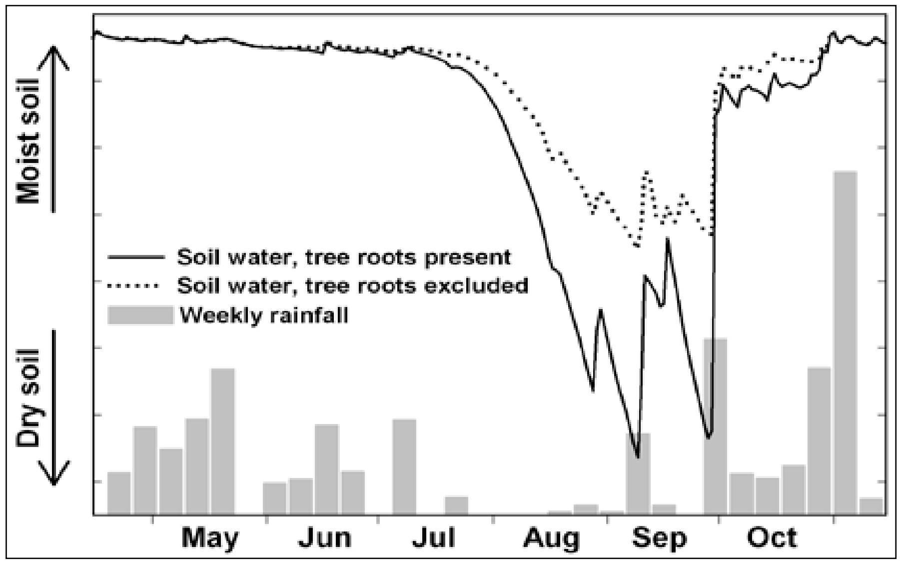
BALANCING CONIFER NEEDS WITH HARDWOOD BENEFITS

Conifers reign virtually supreme in Northwest forests, but, given suitable conditions, shade-tolerant hardwoods such as tanoak are capable of establishing a foothold and thriving. Following timber harvests within tanoak's range, the species commonly regenerates from clumps of sprouts on residual stumps, growing vigorously and competing with conifer seedlings. In his doctoral research, begun in 1983 at two Douglas-fir plantations in southwestern Oregon, Harrington investigated how well conifer seedlings developed under a gradient of tanoak densities. After 11 years, conifer saplings had grown best where tanoak was absent, although surprisingly, their survival didn't vary significantly among hardwood densities.

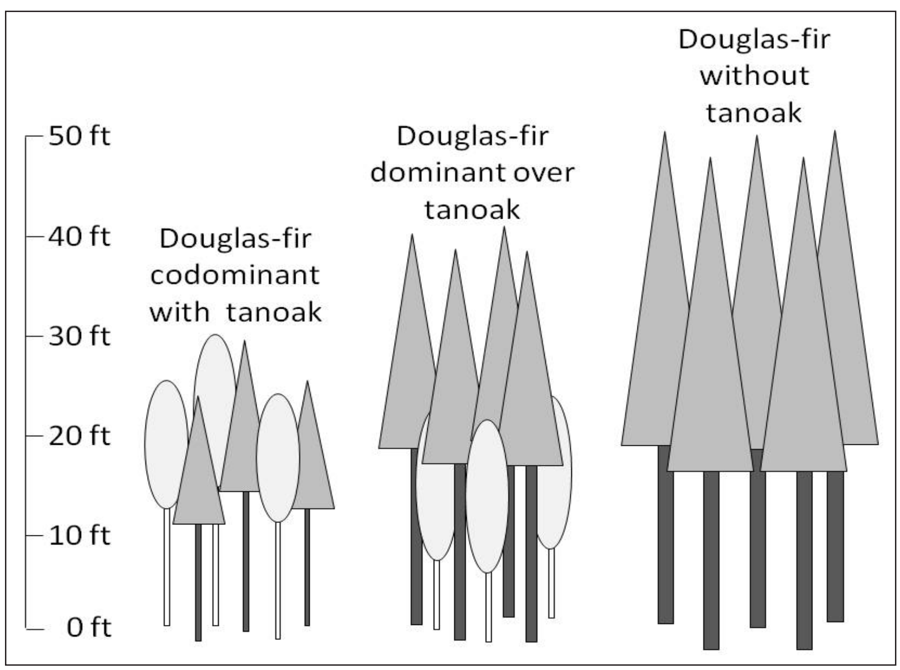
Competition aside, the tanoak's prolific production of acorns makes it an important species for mast-feeding wildlife such as deer, bear, and rodents, Harrington notes. Thus, if managers are aiming for a mixed-conifer-hardwood forest, finding the "sweet spot" between maintaining enough tanoaks to support wildlife and controlling their competition effects on conifers would be a boon for biodiversity.

Harrington stumbled upon an accidental opportunity for exploring possible means to that end when he returned to his study sites 10 years after the conclusion of his dissertation. As he describes it, "The plantations had been thinned around age 17 to favor the largest diameter trees, which included tanoak in some places, as well as Douglas-fir. Different stand structures had developed, and I was curious to see if the effects of my original treatments were still detectable." For the next several years he tracked the growth of the sites' trees, herbs, and shrubs to determine whether his earlier manipulations of the vegetation had set the stage for the stand profiles more than a decade later.

Combined with the earlier results, the data set spanned 23 years. It revealed that three types of arboreal architecture had emerged:



In the low-light conditions at the Fort Lewis study site, overstory trees, rather than understory vegetation, competed most strongly with Douglas-fir seedlings for water.



The level of hardwood control soon after planting Douglas-fir in southwestern Oregon caused three distinct stand structures to develop after the stands were thinned at age 16 to 17 years. Depending on the initial density of tanoak, three distinct stand structures emerged 8 years later, as shown above.

pure stands of Douglas-fir, mixed stands of Douglas-fir and tanoak (forming a single canopy layer), and two-storied stands of dominant Douglas-fir and intermediate tanoak. "It showed that by retaining tanoak at various densities, you can manage competition and force different structures to develop," Harrington explains. "The thinning treatments had widened the extremes in tree growth with respect to both tree size and volume, pushing stands to either pure Douglas-fir or mixed stands, which grew more slowly because of competition." Areas that had more than 10 percent of tanoak cover at the outset of the original study averaged nearly 50 percent coverage by year 23. "This suggests that if you help the hardwoods to stay dominant, they maintain a big stake in the canopy and contribute to one continuous layer," he says.

Furthermore, comparisons between the year-1 and year-23 abundances of herbs, shrubs, and tanoaks "confirmed that vegetation control early in stand development, and the subsequent development of tanoak cover, were dominant forces shaping the eventual abundance and species composition of understory vegetation," Harrington says. Although the research didn't include surveying of wildlife on the sites, he suspects there's been a payoff in biodiversity. "Many species of wildlife respond to edges in forest environments, so this factor and the diverse stand structures have likely created more habitat opportunities for a variety of animals," he concludes.

BATTLING INVADERS

The plantation research yielded another serendipitous finding. Black-stain root disease plagues young, commercially raised Douglas-fir, and its spread is increased by insects that feed on the green slash left after thinning conifers. During the years following thinning at the study sites, Douglas-fir began dying from the fungal disease. However, Harrington observed that more trees succumbed in plots where tanoak had been eliminated, than where tanoak had been retained. Presence of tanoak—regardless of density—apparently conferred a protective effect against the disease. "The black-stain fungus can move in the soil between roots and spread out from centers of infection, but the roots of tanoak create a barrier because tanoak is immune to the disease," Harrington explains. Also, competition from tanoak roots likely slowed down root growth in their conifer neighbors, thereby buffering them from inoculation by the fungus, he adds.

Of course, fungal disease is but one of the many threats to young forests. Following timber harvests and other disturbances, fast-growing shrubs such as Scotch broom and trailing blackberry often invade the opened-up terrain and compete aggressively with conifer seedlings for space, nutrients, and water. A prodigious producer of seeds that can survive in the soil for decades, Scotch broom can resurge even following repeated eradication efforts.

Woody debris also impacts forest regeneration, through changes in the plant community. "Much research has addressed how debris influences microclimate and soil properties critical to conifer survival and long-term forest productivity," Harrington says, "and the question of whether to leave it in place, pile and burn it, or haul it offsite in preparation for replanting a logged area has been much debated."

At various clearcut sites Harrington noticed that tenacious plant invaders were much sparser where the debris was left behind. This led him to hypothesize that the method of dealing with debris might indirectly affect the survival and growth of conifer seedlings via its impact on the abundance of nuisance vegetation. So, he analyzed data from existing forest productivity experiments that compared the effects of dispersing, piling, and removing logging debris on the 5-year survival and growth of planted Douglas-fir seedlings at logging sites near Matlock, Washington, and Molalla, Oregon. Scotch broom was the key woody competitor at the first location; trailing blackberry was rampant at the second. At each site, three different treatments were tested. In one treatment, only harvested logs were removed, leaving the branches and treetops in

Tim Harrington

Tim Harrington

The amount of Scotch broom, a nonnative, invasive shrub, was substantially higher 3 years after logging at sites where woody debris had been removed or piled (see top), compared to sites where the branches and treetops were left in place (see bottom).

place; in another treatment, entire trees were hauled off; and in a third treatment, logs were taken, while branches and tops were piled on site.

"By the second or third year of the research, the amount of terrain covered by the key invasive [Scotch broom or blackberry] was substantially greater where debris had been piled or removed," Harrington says. Likewise, the impact on conifer seedlings was dramatic. "As broom cover at Matlock increased to 40 percent, the survival of seedlings decreased by 30 percent," he explains, "and at Molalla, stem growth of the young trees decreased by 30 percent as blackberry cover rose to 80 percent."

The results were significant on several levels, he says. Piling or removing debris exposes mineral soil and opens up more area for colonization by sun-loving invasive plants that exclude native plants. At the same time, it reduces pools of carbon and nitrogen that may be needed for long-term forest productivity and eliminates shade and moisture conservation effects of debris that support a range of plant and animal species. On the other hand, debris left in place decays, releases nutrients, and adds to soil productivity. "This is especially important with low-nitrogen soils, such as glacial till-derived soils in Washington," Harrington says. Furthermore, "Leaving debris saves the cost of removal and enhances opportunities for enriching biodiversity," he contends. He concedes that the practice of retaining debris may increase short-term fire hazard, but says, "It's a matter of scale. Within a couple of years, the risk is probably not much different than at sites where debris had been removed."

The findings from Harrington's and Devine's research have already benefitted working forests. At Fort Lewis, a strategy of thinning canopy trees and creating gaps in the overstory, in combination with manual cutting of the shrub layer, is promoting the growth of natural and planted Douglas-fir and other conifer species. And, in southwestern Oregon, on the Siskiyou National Forest and Medford District of the Bureau of Land Management, managers have begun combining the manual cutting of shrubs with precommercial thinning of conifers and hardwoods—an approach that favors the development of mixed stands with a patchy structure of conifers in dominant or codominant positions with hardwoods.

LAND MANAGEMENT IMPLICATIONS

- In regenerating conifers beneath an existing overstory, creating canopy gaps is essential to providing sufficient light for young trees and decreasing tree root competition. At greater light levels, understory thinning also is necessary for young conifers to thrive.
- Conifer-hardwood stand structure can be shaped by maintaining hardwoods at various densities from early stages in stand development. This results in greater forest complexity, which supports biodiversity, forest resilience, and other multiuse objectives.
- Retaining some hardwood competition in new conifer stands may make the conifers more resilient to black-stain root disease.
- Retaining scattered logging debris after timber harvest inhibits development of invasive species, such as Scotch broom, enhancing conifer regeneration.

"There is unrest in the forest,
There is trouble with the trees,
For the maples want more sunlight
And the oaks ignore their pleas."
— Rush

Tim Harrington

Nine years after treatment, pure stands of Douglas-fir occur where all tanoak was removed, whereas mixed Douglas-fir and hardwood stands occur where some hardwoods were retained. The variation in forest structure and composition stemming from the different treatments likely created diverse habitat for wildlife.

WRITER'S PROFILE

Noreen Parks has been writing about science and the environment for nearly 20 years, frequently covering topics related to forests and their ecology. She lives in Port Townsend, Washington.

FURTHER READING

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SCIENTIST PROFILES

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WARREN DEVINE was a research forester with the Pacific Northwest Research Station from 2002 through 2009; his silvicultural research included conifer regeneration and oak wood-land restoration. He is currently working under contract for the Olympic National Forest on a project that addresses the potential effects of climate change. He received his Ph.D. from the University of Tennessee in 2002.

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