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Ponderosa Pine Biomass Relationships Vary with Site Treatment and Site Productivity

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Fire Science Brief

RESEARCH SUPPORTING SOUND DECISIONS

A selected tree was marked at breast height and one foot, and then felled. The research team then measured the diameters of all the branches and obtained dry weights for the trunk, the branches, and the foliage. Credit: Martin Ritchie.

Ponderosa Pine Biomass Relationships Vary with Site Treatment and Site Productivity

Summary

Allometric equations, which express biomass as a function of tree size, are often used to estimate the amount of fuel in a site's canopy. Most managers assume that one allometric equation per species is sufficient, or that any error introduced by extrapolation is irrelevant. This work showed, however, that the allometric biomass relationship for ponderosa pine likely changes over space and time. The researchers concluded that for maximum accuracy, allometric equations for ponderosa pine should account for stand management history and site productivity. Thinned trees replaced their foliage within about 4 years, and 8–10 years post-thinning, growth had stabilized. This indicates that using allometric equations to estimate fuel loads can result in miscalculation of the potential for active crown fire.

Key Findings

- In ponderosa pine, the relationship between foliage biomass and tree dimensions varies in response to thinning.
- Forest productivity may influence biomass relationships for ponderosa pine trees.
- Stand-level foliage biomass reached pretreatment levels within 5 years post-thinning. Overall fire risk may be lower because ladder fuels were removed, but heavy litterfall rates could still support frequent surface fires.

How does foliage accumulate in tree crowns in response to thinning?

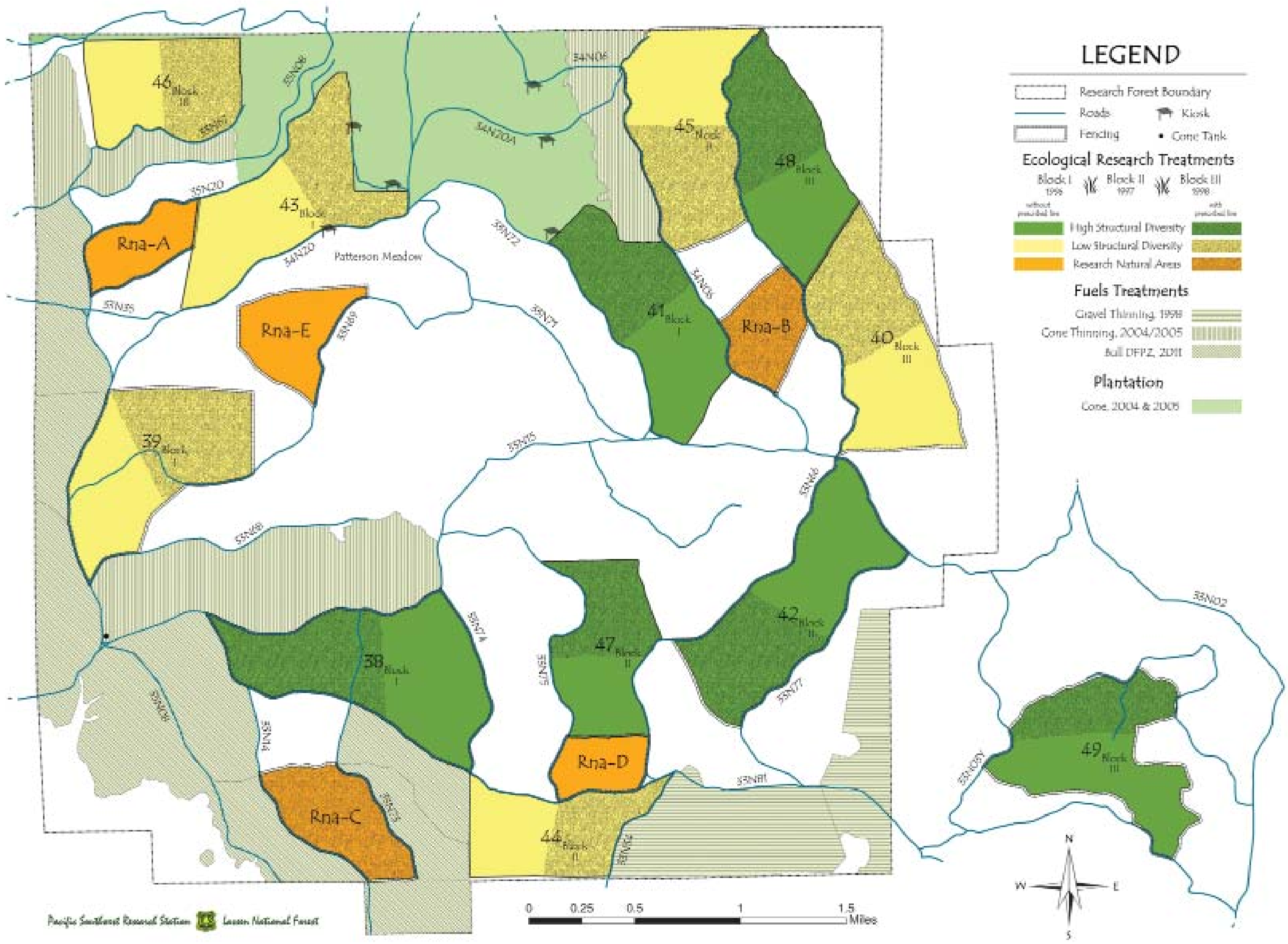
Lately there is greater interest in fuel treatments to reduce the risk of severe fires in the western United States. But we need more practice quantifying the effectiveness and forecasting the longevity of those treatments. If a treatment's associated reduction in risk of severe wildfire is brief, the treatment may not meet managers' goals.

This study was designed to (a) quantify the effects of thinning and prescribed fire on ponderosa pine fuels in the first 5 years post-treatment at Blacks Mountain Experimental Forest (BMEF) in northeast California (see following image); (b) determine the temporal change in stand-level foliage biomass by destructively sampling trees from four sites on the forest (thinned in 1996, 1998, 2005, and untreated); (c) use the Forest Vegetation Simulator Fire and Fuels Extension to simulate the change in fuels and compare with field-derived values.

"We wanted to know how foliage and fuels accumulate in tree crowns and, by extension, on the forest floor, in response to thinning," says Martin Ritchie, research statistician at the Pacific Southwest Research Station. He and his colleagues noted that ponderosa pine trees appeared to rebuild their crowns pretty quickly after thinning. "That would mean," says Ritchie, "that the crown dynamics that people typically assume when estimating biomass actually vary."

Challenging assumptions about biomass relationships

Biomass estimates are often based on predictions for individual trees and their allometric equations. In an allometric equation, biomass is expressed as a function of



Map of treatments at Blacks Mountain Experimental Forest. Credit: Martin Ritchie.

tree size. An allometric equation reflects the relative growth of a part of an organism with respect to the entire organism. Biomass estimates derived from allometric equations are often used to evaluate canopy fuels and subsequent potential for crown fire.

Allometric equations "tend to be very simple," Ritchie explains. "There is an unspoken and unwritten assumption in almost all of them that this process is stationary. It doesn't change in response to external factors like thinning."

But Ritchie's observations in the field led him to believe that this assumption was untrue. "So what I wanted to do," he explains, "is look at trees across a spectrum of different ages since thinning, and see if that relationship varied."

What currently happens, says Ritchie, is someone builds an equation for biomass, as J.K. Brown did in 1978 for ponderosa pine in the Interior West. But, Ritchie continues, "Then those get applied all over the place. They get applied in California and Arizona. People just go grab an equation off the shelf. Our results suggest that may be ill-advised."

There are many reasons why it's important for land managers to properly understand these allometric equations. For example, they help us understand how much canopy fuel is available to burn. They can also be used to estimate the amount of carbon sequestered in a forest, which is a hot topic today. Forests are important "sinks" for carbon, meaning that they absorb carbon dioxide, an important greenhouse gas, into their tissues, making it unavailable in the atmosphere until the wood decomposes.

Thinning, sampling, and statistical analysis

Forestry technicians thinned the experimental plots to a residual basal area—one that in addition to reducing fuels will also serve to reduce tree mortality from bark beetles. All the thinning for this experiment was done from below so that the resulting stand was a homogeneous single canopy layer with pretty wide crown spacing. The technicians removed surface fuels and ladder fuels to create fire-resilient stands, as managers concerned about wildfire do all over the West. They used whole-tree harvesting so little material was left on the forest floor. The control plot had no thinning.

The researchers broke biomass down into three components—that in the main bole or trunk, that in the branches, and that in the foliage. Their sampling was destructive—they cut down sample trees and bucked up the bole and cut branches off and obtained dry weights for the various components. They measured the diameter of every branch on the sample trees and sampled some of them for dry weight.

Then Ritchie built a statistical relationship for individual branches using the data from the dried, weighed, and measured branches. Then he fit models to predict foliage biomass and branch wood biomass as a function of branch diameter at its base. He used the relationship to estimate branch weight and foliage weight for the branches they didn't sample. They also took samples—called cookies—of the bole. These provided wood density data, which Ritchie used to estimate the weight of the entire tree bole. So he then had a total foliage biomass, a total branch biomass, and a total bole biomass for a whole tree. Then he statistically fit simultaneous relationships and ranked the models to select the one best supported by the field data.

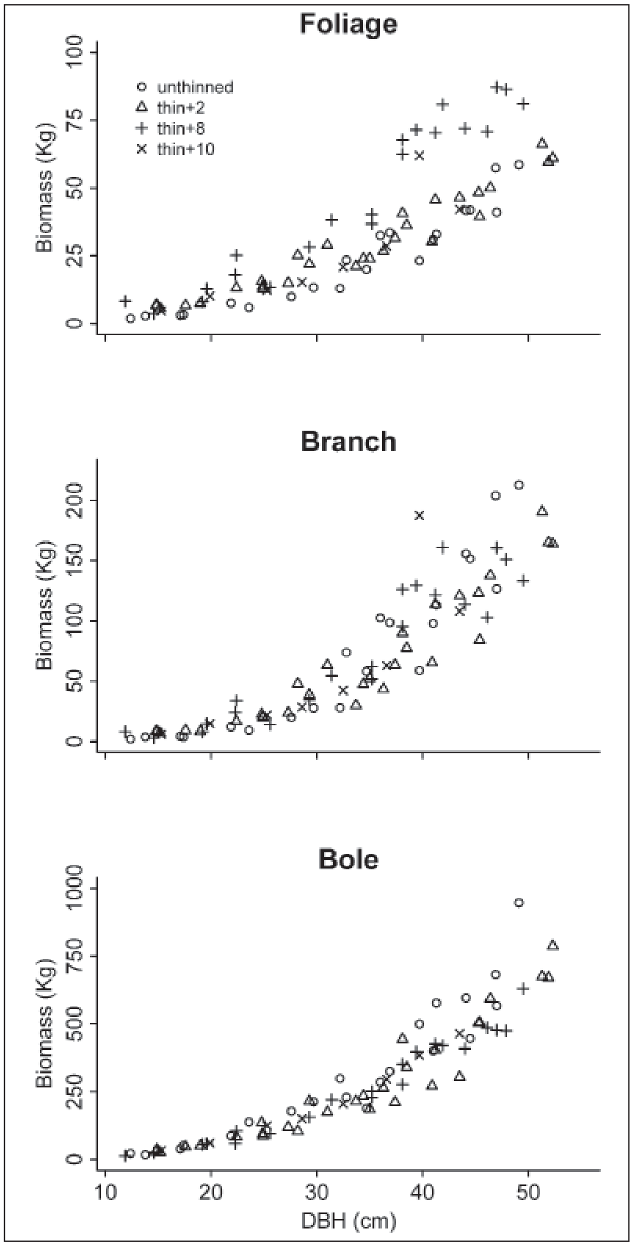
Results show that one-size-fits-all equations are not valid

Separating foliage from a sampled branch.
Credit: Martin Ritchie.

Field measurement of a disk from the tree bole.
Credit: Martin Ritchie.

The authors identified five key findings in the final project report. First was that "trees in thinned areas had much higher levels of foliage after accounting for variability in tree size (diameter at breast height) and crown ratio." Therefore, the relationship used to predict foliage biomass from tree size changes with respect to thinning. This means that using an unchanging allometric equation to estimate foliage biomass in ponderosa pine may produce substantial over- or underestimation error. Whether you end up over- or underestimating depends on whether the equations you're using are based on stands that are thinned or unthinned.

Second, site productivity may have a greater effect on foliage biomass per tree than previously realized. Trees on a site with slightly higher productivity had much higher foliage biomass per tree (see below for more details). However, Ritchie warns that this finding requires further validation at other sites.



Foliage, branch, and bole biomass for sampled trees by diameter at breast height. Credit: Martin Ritchie.

Third, annual foliage production is approximately 27 percent of the total after trees have rebuilt their crowns and growth has stabilized 8–10 years post-thinning. Ponderosa pine produce a very clear bud scar on the branch at the end of each year when they set the bud, so it's easy to identify which foliage grew in which year. It is important to know the amount of foliage produced each year because this becomes the fine surface fuel that allows fire to spread and move through the landscape. In stands with no thinning and stands 2 years post-thinning, about 34% of the foliage is cast off yearly. But 8 and 10 years post-thinning, the percentage is down to 27. However, this is offset because the trees 8 and 10 years post-thinning have more foliage to begin with (a response to thinning) than control trees and trees only 2 years post-thinning. The tree's foliage is replaced within about 4 years post-thinning. During this time the crowns adjust to the increased growing space. After this point, growth tends to stabilize.

Fourth, foliage was retained 4 years on average in unthinned areas and 5 years in thinned stands. This means that there is a short-term reduction in litterfall immediately after thinning, due to both reduced overall crown mass and longer needle retention.

Fifth, 5 years post-thinning, stand-level foliage biomass reached pretreatment levels and the trees had basically replaced their entire crown. So foliage removed through thinning has been recovered in the stand within 5 years, although stand basal area remains below pretreatment levels. However, the threat of crown fire may still be low because of the removal of ladder fuels. Litterfall rates may still allow for spread of frequent surface fires.

What's important is that "although the arrangement of fuels may be different because we've gotten rid of ladder fuels," Ritchie notes, "the actual amount of foliage and the amount of needle cast we're getting every year is very similar to what it was before. The stand recovers very quickly in that regard."

Site productivity matters as well as stand history

The researchers performed all of this work on one experimental forest—Blacks Mountain in northeast California. Ritchie explains that they did this because site productivity was thought to be fairly uniform across the forest. Therefore, they expected site productivity not to be an important factor in this experiment. Instead, they were surprised to find that 8 years post-thinning one stand had a whole lot more foliage per tree than anywhere else in the forest. In attempting to identify a reason for this very obvious difference, they realized that the stand has slightly higher productivity. This suggests, says Ritchie, that there's also a site productivity effect at work in biomass equations. Ritchie hypothesizes that the increase in productivity comes from the site's gentle north-facing aspect, which would allow the snow to melt a bit more slowly, the soil to retain moisture longer, and the growing season to be a bit longer. In this area workers heavily thinned out white fir to favor ponderosa pine. The other areas thinned had less white fir to begin with because they have experienced less fir encroachment than this higher productivity plot.

Ritchie notes that using the allometric biomass equation developed in this area on an unthinned stand in another part of the experimental forest would yield biomass estimates off by almost 100 percent. He also notes that the site productivity differences seen within the experimental forest are minimal compared with those across the range of ponderosa pine, so there is potential for substantial influence of productivity in ponderosa pine.

"If you have a very highly productive ponderosa pine stand on the west side of the Sierra Nevada, say, you could have a very different kind of foliage biomass response or level than you would see, say, on the east side in Oregon or Washington." The lesson is that if you're going to use these allometric equations, you may need to consider site productivity as well as stand history.

Results have implications for scheduling stand treatments

Ritchie explains that the appropriateness of using off-the-shelf biomass equations is important to managers in that "there are increasing numbers of decision support tools, like the Fire and Fuels Extension in the Forest Vegetation Simulator, that use these biomass equations to allow managers to anticipate what the fuel levels are going to be over time in response to their management activities. Those predictions are used in planning treatments, such as timing of thinnings, prescribed fire, etc. By changing these equations, we may find that we need to change the frequency with which stands are treated. Stands may recover more quickly and need to be thinned again, or may need prescribed fire again more frequently because there may be more fuel buildup than other models have predicted in the past."

> *"By changing these equations, we may find that we need to change the frequency with which stands are treated."*

The frequency of treating stands depends on many factors, including site productivity and type and intensity of thinning. So you really can't develop a blanket statement saying you should thin ponderosa pine every X years.

The project final report concludes by noting that for ponderosa pine, site treatments and site productivity should be considered in developing biomass estimates, particularly for the crown. Ritchie summarizes, "A one-size-fits-all foliage biomass model, I would argue, is inappropriate for ponderosa pine." He cautions that allometric equations should be used only for similar sites and treatments. The assumption has been that one allometric equation per species is adequate, or that any error due to extrapolation is small. This work showed, however, that the allometric biomass relationship for ponderosa pine likely changes over space and time. Ritchie notes, however, that branch and bole biomass relationships appear to be less variable, and relationships may be more reliably extrapolated for these measures.

Management Implications

- Managers need to account for thinning responses and site productivity differences if they want to accurately estimate tree biomass for ponderosa pine.
- Canopy foliage biomass and litter fall rates recover to pretreatment levels relatively quickly (approximately 5 years). Crown fire potential may still be low due to the rearrangement of canopy fuels.

Follow-up studies Ritchie would like to see include (a) more biomass sampling using similar methods across the geographic range of ponderosa pine and in stands that are thinned to see if the patterns observed at Blacks Mountain hold elsewhere; and (b) determining whether crown dynamics of white fir respond in a similar way to thinning.

Further Information: Publications and Web Resources

Ritchie, M.W., C.N. Skinner, and J. Zhang. Fuel reduction treatment longevity and crown response in interior ponderosa pine forests of northern California. Final report to Joint Fire Science Project. www.firescience.gov/projects/06-3-3-04/project/06-3-3-04_final_report_1.pdf

Ritchie, M.W. and J. Zhang. *Fuel Reduction Treatment Longevity Research*. Pacific Southwest Research Station. http://www.fs.fed.us/psw/programs/ecology_of_western_forests/projects/biomass/

Scientist Profiles

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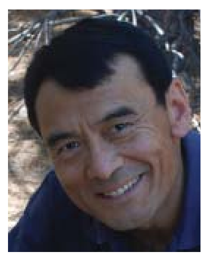

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