



**ASSESSING THE RELATIVE IMPORTANCE OF RADIAL GROWTH AND RESIN  
DUCT DENSITY IN PONDEROSA PINE RESISTANCE TO BARK BEETLE ATTACK**

*A 2013 Climate Change Research Proposal Submitted to the Climate Change Studies Program and the College  
of Forestry and Conservation*

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Wednesday, March 20, 2013

**ABSTRACT.** Drought stress and rising average global temperatures due to climate change are likely to result in significant shifts in conifer ecosystems, including potentially increasing the severity, frequency, and duration of bark beetle outbreaks (Raffa *et al.* 2008). Though insect outbreaks are among the most common disturbances in conifer ecosystems, affecting over 20 million hectares and costing in excess of \$1 billion annually, the physiology underlying tree defense against outbreaks is poorly understood (Ayres and Lombardero 2000). Given the potential for climate change to exacerbate the severity of bark beetle attacks, it is imperative that more research be done to elucidate mechanisms of tree resistance and defense. I am interested in researching two components of defense against bark beetles in ponderosa pine: the relative importance of radial growth and resin duct density in fending off bark beetle attacks and how climate affects tree investment in these two processes. Developing a better understanding of both tree defense strategies and how climate alters tree physiology will be essential to predicting the consequences of climate change for this ecologically and economically important species and developing appropriate management strategies.

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## BACKGROUND

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In many forests, regular bark beetle outbreaks are disturbances agents essential to maintaining ecosystem health. However, substantial evidence suggests that insect outbreaks have intensified due to climate change (Logan *et al.* 2004, Logan and Powell 2001). Bark beetle outbreaks cause changes to forest structure, forest community composition, primary productivity, carbon storage, and often interact with wildfire and other disturbances to alter ecosystems (Raffa *et al.* 2008). Climate change has the potential to increase host stress and alter numerous aspects of the beetle's life history including its range and synchrony. The impacts of climate change coupled with fire suppression policies that result in unnaturally dense stands have the potential to lead to beetle outbreaks of unprecedented severity, which has implications for ecosystem dynamics, forest carbon balance, and the economic and recreational value of these forests.

Ponderosa pines employ numerous strategies to defend against bark beetles, other insects, and pathogens. Ponderosa pine defense strategies can be broken into two categories: inducible and constitutive. Inducible defenses are stimulated by the presence of an insect or pathogen. Constitutive defenses, which can be mechanical or chemical, are maintained by the tree even in the absence of a pathogen or insect. Mechanical constitutive defenses, such as tough bark or spines, provide a physical barrier to attack. Chemical constitutive defenses are chemical compounds the tree synthesizes and stores for generalized defense. Resin ducts are one type of mechanical constitutive defense in conifers. Resin ducts store resin, the release of which is a critical component of the tree's defense against attack. The greater the density of resin ducts, the greater the flow of resin (Blanche *et al.* 1992, Lombardero *et al.* 2000). Density of resin ducts would thus seem to be an important factor in successful defense against bark beetle attack. Kane and Kolb found that measures of resin duct formation were a more reliable indicator of resistance to bark beetle attack than growth measurements (2010). Kane and Kolb's research thus indicates that resin duct density is an important component of ponderosa pine defense; replication of these results would provide more evidence of the importance of resin duct density in determining tree resistance to bark beetle attack.

Ponderosa pines, like all living organisms, must make trade-offs between numerous critical physiological processes, including growth, defense, reproduction, and storage. Beyond the constraints imposed by limited resource availability, production of many defense structures and compounds relies on the same metabolic pathways, precursors, and intermediates as growth structures (Herms and Mattson 1992). Thus, it seems logical that heavy investment in growth limits investment in defense and vice versa. Although this makes sense *a priori*, research on the nature of this trade-off—or on whether such a trade-off even exists—has had mixed results. Specifically, studies on the relationship between radial growth (*i.e.* the increase in tree radius over time) and resin duct characteristics come up with positive correlations (Kane and Kolb 2010, Fahn and Zamski 1970, Rosner and Hannrup 2004), negative correlations (Reid and Watson 1966, Blanche *et al.* 1992) or no correlation (Wimmer and Grabner 1997). Understanding the nature of the relationship between resin duct density and radial growth is important in determining resistance to bark beetle attack.

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## OBJECTIVES AND HYPOTHESES

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I am interested in the cost of investment in two different processes—growth and defense—in the context of two disturbances, one anthropogenic and the other natural. I want to ask first, whether a trade-off exists between growth and defense, and secondly, how climate and management strategies influence that investment. My specific hypotheses are:

**H<sub>1</sub>:** There is a trade-off for conifers between growth and defense. Specifically, I predict that resin duct density will be negatively correlated with radial growth.

**H<sub>2</sub>:** Investment in defense is more critical to defense against bark beetles than growth. Specifically, I predict that resin duct density will be a better indicator of attack success than radial growth or any other growth measurement.

**H<sub>3</sub>:** Duct density will be positively correlated with growing season temperatures whereas radial growth will be positively correlated with spring precipitation, based on research indicating this relationship for Scots pines in the Alps (Rigling *et al.* 2003).

**H<sub>4</sub>:** Trees in stands that have not been thinned and have had fires suppressed will display lower resin duct density and less radial growth than trees in stands that have been thinned or burned.

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## METHODS

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For this project, I plan to work closely with my advisor, Dr. Anna Sala, and my off-campus partner, Sharon Hood, an ecologist at the Rocky Mountain Research Station. Sharon Hood is also a graduate student in Dr. Sala's lab, and much of my proposed research would be closely aligned with her doctoral work investigating the effects of fire and water stress on ponderosa pine resistance to bark beetles. In particular, my research would complement her work examining the role of resin ducts in tree resistance to bark beetle attack.

The first component of my proposed research would examine the relative importance of two fundamental physiological processes in ponderosa pines—defense and growth—and the extent to which preferential investment in either of these processes influences the likelihood of a tree being successfully attacked by bark beetles, via the comparison of radial growth and resin duct density in paired ponderosa pine samples. The second component of my project would entail assessing the effect of climate on investment in growth and defense by comparing historical climate data to tree ring growth and resin duct density. To test my hypotheses, I would like to use a paired-study design, using cores from attacked and unattacked trees in close proximity to one another to compare the importance of growth rates and resin duct formation in resisting attack. This pairwise design will help to ameliorate noise in the data set due to spatial environmental variability and the increased likelihood of attack associated with neighboring trees having been attacked. The methodology for much of the study, including several of the growth and defense measurements to be taken, will be similar to that developed by Kane and Kolb (2010).

The study site for this research is part of the Fire-Fire Surrogate Study located at Lubrecht Experimental Forest. The site is made up predominantly of ponderosa pine and Douglas-fir, with the majority of trees aged 80-90 years. The site consists of three randomized 36-ha blocks. Each of these blocks is broken into four 9-ha units; one unit has been thinned, one unit has been burned, one unit has been thinned and burned, and the final unit has been left unaltered (the control). Sharon Hood has already collected fifteen pairs of cores from attacked and unattacked trees in the control units. Fifteen pairs from the burned and thinned plots will be selected for analysis based on the following criteria: (1) attacked and unattacked trees are no farther than 6 meters apart, and (2) diameter at breast height for the paired trees is within +/- 2.5 cm. Two cores from bark to pith will be taken from each individual. If time allows at the end of the field season, I will also collect cores from the plots that have been thinned and the plots that have been burned for analysis.

After collection, cores will be left in the lab to dry for two weeks, sanded, mounted, and turned into high-resolution images using WinDendro<sup>®</sup>. Images created in WinDendro<sup>®</sup> will then be used to assign annual ring boundaries and measure ring width. This data will be cross-dated and the strength of cross-dating will be assessed with COFECHA. Further measurements to be collected include annual latewood to earlywood ratios, number of resin ducts, resin duct density, and resin duct diameter. Resin ducts will also be qualitatively assigned to latewood, earlywood, or transition wood. Data analysis will be a major component of this project, and the relationship between variables will be examined on four scales: individual trees, paired trees, treatment blocks, and the entire data set. To assess the impact of climate on growth and defense, the correlation between growth and defense data and annual precipitation, annual average temperature, seasonal precipitation, and seasonal average temperature will be assessed. Climate data used will be obtained from the Greenough Hill DOT weather station. Additionally, the regional Palmer Drought Severity Index (PDSI) from the National Climate Center will be used to test the impact of climate.

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## CONCLUSION

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Climate change is already reshaping ecosystems and will continue to do so in the future. Insect outbreaks are anticipated to intensify under future climate change scenarios. Although bark beetle attacks are an integral disturbance agent in ponderosa pine forests, the intensification of these attacks could have very severe ecological and economic consequence. This project would address trade-offs between defense and growth in ponderosa pine, add to a growing body of research addressing the mechanisms of tree defense against beetle attacks, and contribute to our understanding of how climate change might alter ponderosa pine susceptibility to bark beetle attack. Understanding these processes will be essential to crafting management strategies that effectively address the convergence of these two disturbances in ponderosa pine ecosystems.

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## LITERATURE CITED

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**PROJECT TIMELINE**

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| <b>APRIL</b>             | Continue to familiarize self with primary literature; refine and finalize methods for study.  |
| <b>MAY</b>               | Process cores from control sites; collect and mount cores from thinned plots.   |
| <b>JUNE-JULY</b>         | Collect and mount cores from burned plots, begin data analysis for cores from thinned plots and controls.                                     |
| <b>AUGUST</b>            | Process cores from burned plots, continue data analysis. If time allows, collect cores from thinned and burned plots.                         |
| <b>SEPTEMBER-OCTOBER</b> | Process cores from burned plots; complete data analysis, including testing correlation of climate variables to different growth measurements. |
| <b>NOVEMBER-DECEMBER</b> | Synthesize results of research in a final paper.  |

