Statement of
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Before the
Committee on Energy and Natural Resources
U.S. Senate
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Concerning
The Federal Government's Role in Wildfire Management, the Impact of Fires on Communities, and Potential Improvements to be made in Fire Operations

Good morning Chairman Murkowski, Ranking Member Cantwell, and Members of the Committee. Thank you for inviting me here today to discuss my research on fire and bark beetle interactions. My name is Sharon Hood, post-doctoral researcher in the College of Forestry and Conservation at the University of Montana. I have lived in Montana since 2001, first working as a fire ecologist with the USDA Forest Service, Rocky Mountain Research Station for 12 years and then earning my PhD from the Organismal Biology and Ecology Program in the Division of Biological Sciences at the University of Montana in 2014. I was a USDA Forest Service term employee while conducting much of my dissertation research. My research focuses on the ecological impacts of fire and bark beetle interactions on coniferous forests. Today, I will focus my testimony on my dissertation research about the impacts of removing wildfire on ponderosa pine resistance to mountain pine beetle, while also drawing from the scientific literature. This research was based on data collected primarily in Montana, but also in Idaho, Oregon, and Utah, and I would like to use it as an example to highlight three main messages.

My main messages are: (1) fire plays an essential role in many of our Nation's forests, (2) management activities in ponderosa pine forests can affect resistance to mountain pine beetle, (3) a combination of basic and applied research on fire and bark beetles is imperative for development of tools for management of our Nation's forests in an ecologically sustainable way.

BACKGROUND

Wildfire and native bark beetles have huge impacts on coniferous forests. These disturbances have shaped forests for millennia, often affecting the same areas. Therefore, while fire and bark beetles each have direct impacts on the species composition and structure of our forests, one disturbance type can also indirectly affect other types of future disturbances. Anthropogenic changes to historical fire regimes have altered flammability, changing the intensity, extent, and effects of subsequent fire in many ecosystems (Ryan et al. 2013). A significant event in the fire history of many western North American forests is the near total cessation of low-severity fires since the late 1800s due to domestic livestock grazing, road building, a reduction in burning by Native Americans, and organized fire suppression (Pyne 1982). These factors have reduced fire frequency and thus greatly impacted fire-dependent forests reliant on frequent, low-severity fires for persistence on the landscape (Pyne 1982, Keeley et al. 2009). Prior to fire cessation, low-severity surface fires burned frequently (<35 years) over an estimated 34% of the total land in the United States (Schmidt et al. 2002). I use the term low-severity fire to describe surface fires that burn through the forest, but generally cause little mortality to larger trees (Hood 2010). Native bark beetles are dominant biotic disturbance agents, capable of causing massive tree mortality in temperate coniferous forests in North America (Raffa et al. 2008). These aggressive bark beetles typically occur at very low population levels, causing limited mortality. However, periodically widespread regional climatic triggers can allow populations to rapidly increase to outbreak levels during which beetles kill large extents of coniferous forests (Raffa et al. 2008). Relative to previously recorded outbreaks in the past century, recent bark beetle outbreaks have been synchronized across western forest landscapes, resulting in extensive tree mortality (Bentz et al. 2009). These recent outbreaks have been attributed to direct and indirect effects of climate change and, in some cases, past land management practices (Bentz et al. 2009, Bentz et al. 2010).

For my dissertation research, I focused on ponderosa pine (*Pinus ponderosa*) defenses against the native mountain pine beetle (*Dendroctonus ponderosae*). As one of the most broadly distributed conifers in North America, ponderosa pine is of huge ecological and economic importance (Oliver and Ryker 1990). Ponderosa pine is adapted to survive frequent, low-intensity/low-severity fire (Hood 2010). Fire exclusion in ponderosa pine dominated forests during the last century has resulted in increased density and forest composition conversions to shade-tolerant species in many areas (Allen et al. 2002, Keeling et al. 2006). Ponderosa pine is host to several plant eating bark beetle species, including the native mountain pine beetle, an aggressive bark beetle that has recently killed trees over 8 million hectares of pine species in the western U.S. and Canada (Meddens et al. 2012). Conifers have an extensive defense system to resist attack from bark beetles. The primary defense is resin, a complex mixture of chemicals, many of which are toxic to beetle metabolism and can affect beetle communication (Raffa 2014). In pines, resin is produced and stored in an interconnected network of vertical (axial) and horizontal (radial) resin ducts (also called resin canals) in the inner bark and wood (Bannan 1936). As bark beetles bore into a tree during attack, they sever resin ducts and this allows resin to flow to the attack site. Copious amounts of resin act as a physical barrier to attacking beetles and is the first line of defense to prevent entry.

I had three overarching research questions, each of which is briefly presented here. (1) Are resin ducts a good measure of resistance to bark beetles? (2) Does fire influence resin duct production? (3) How do management practices affect individual tree defense and scale up to affect forest resistance to a mountain pine beetle outbreak? This research provides new information on the physiological relationship between tree growth and defense, and how fire impacts these defenses to ultimately impact forest resistance to bark beetle attacks.

RESEARCH

(1) Are resin ducts a good measure of resistance to bark beetles?

Resin ducts represent the production and storage capacity of resin in the tree. While resin is the main defense, it is an extremely variable trait. This complicates efforts to characterize the defense potential of trees (Gaylord et al. 2011). Therefore, resin ducts may be a better measure for defense than resin flow because duct measurements are repeatable and imprinted every year when trees deposit new wood and produce annual growth rings. This leaves a permanent record of changes in defense production over time. I compared resin ducts between pairs of trees – those that died from a mountain pine beetle attack and those that survived the attack. Trees that survived the attack had larger ducts and more area of the growth ring in ducts than trees that died from the attack (Fig. 1) (Hood et al. 2015). These results are supported by other studies in several pine species, which consistently show that trees with higher resin duct production and/or larger ducts are more likely to survive beetle attacks (Kane and Kolb 2010, Gaylord et al. 2013, Ferrenberg et al. 2014, Hood et al. 2015) and drought (Heres et al. 2014).

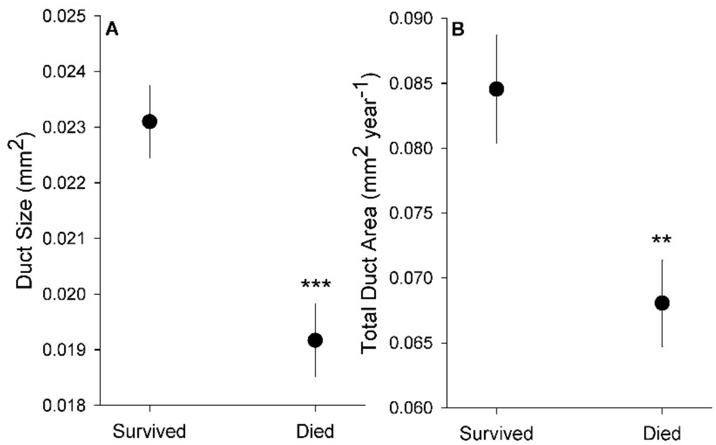

*Figure 1. Resin duct (A) average size and (B) total duct area of ponderosa pine that died and survived attack by mountain pine beetle. ** P < 0.01; *** P < 0.001 From: Hood et al. 2015.*

I further investigated the relationship between resin flow and resin duct characteristics to establish the important biological link that more ducts translate to increased resin flow for the tree to defend itself from bark beetle attacks. Of several different measures, the best predictors of resin flow were average resin duct size (for example, one large pipe transports more water than many small pipes) and total resin duct area, both of which increased with tree growth rates (Fig. 2). However, growth rate alone did not predict resin flow. While slower growing trees invested more in resin duct defenses per unit area of radial wood growth, the total amount of duct production was lower and they produced less resin. These results indicate that forest management that encourages healthy trees with larger resin ducts should increase resistance to bark beetles because resin ducts are a reliable, good measure of resistance because they are positively related to resin flow (Hood and Sala In Review).

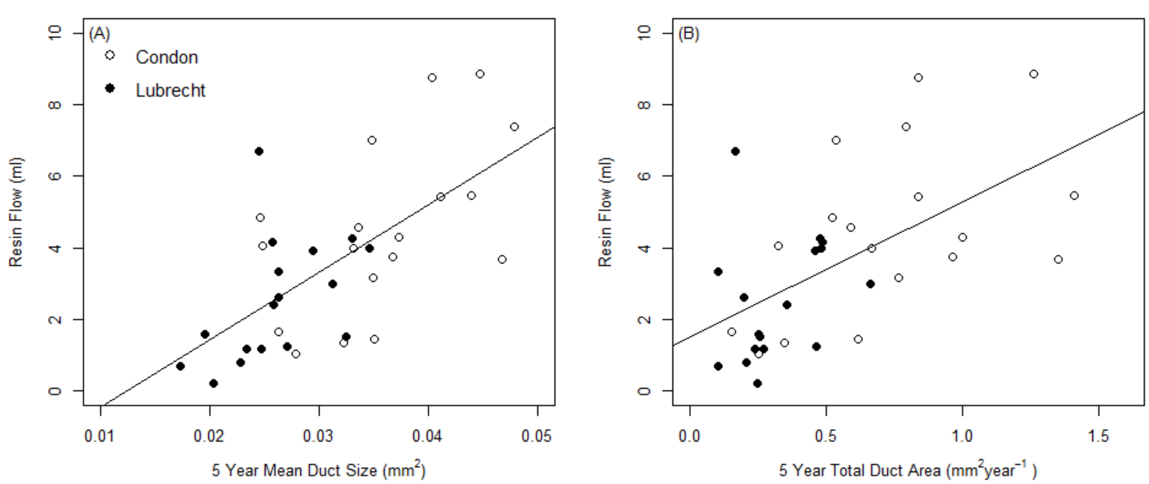

Figure 2. Average monthly resin flow as a function of (A) 5-year mean duct size ($F_{1,10}$ = 12.47, P = 0.0054; site: $F_{1,10}$ = 0.04, P = 0.8388) and (B) 5-year total duct area ($F_{1,10}$ = 7.38, P = 0.0217; site: $F_{1,10}$ = 0.49, P = 0.5002). From: Hood and Sala, In Review.

(2) How does fire influence resin duct production?

Based on previous research showing low-severity fire increases resin flow (Perrakis et al. 2011), I hypothesized that low-severity fire increases resin ducts in ponderosa pine to better resist bark beetle attack, and that lack of low-severity fire relaxes resin duct defenses in forests dependent on frequent, low-severity fire. I measured resin ducts using tree cores with crossdated chronologies (i.e., wood samples for which I knew the calendar year of each annual ring and the year of each fire occurrence) in several natural ponderosa pine stands before and after an individual wildfire and also before and after an abrupt decrease in fire frequency in the 20th century. Low-severity fire increased resin duct production (Fig. 3) and resin duct production declined when fire ceased (Fig. 4) (Hood et al. 2015). These results demonstrate that low-severity fire can increase resin-duct related defenses against bark beetle attacks and that excluding fire decreases tree defenses over time.

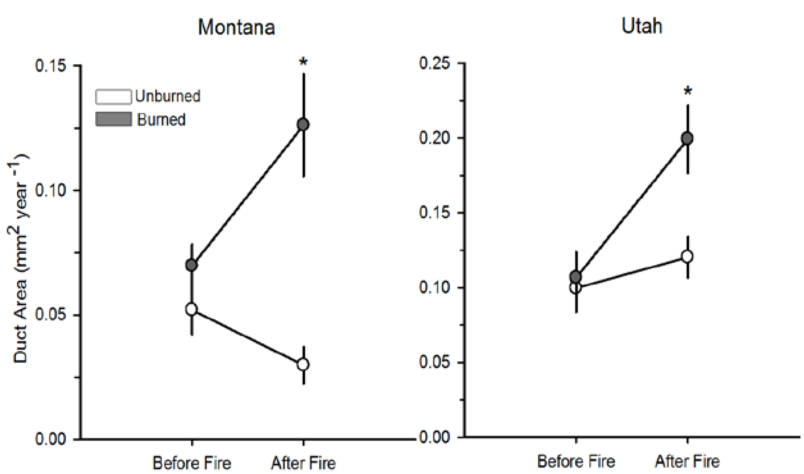

Figure 3. Average total resin duct area (mean ± SE) for burned and unburned ponderosa pine trees before and after wildfire at Montana and Utah sites after accounting for ring area. One-tailed significance values indicate duct area increased after fire on burned trees. From: Hood et al. 2015.

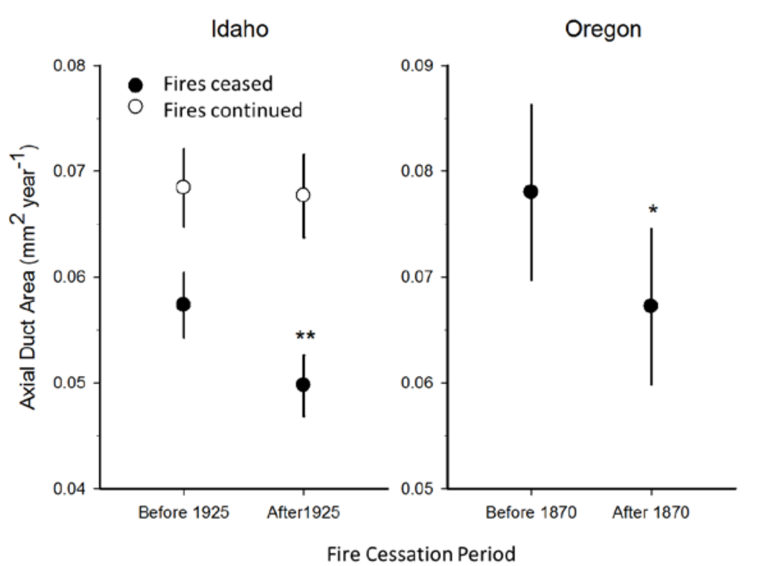

Figure 4. Ponderosa pine resin duct area (mean ± SE) before and after fire cessation in Idaho and Oregon. We defined fire cessation as the period following the last recorded fire at a site, determined from tree-ring reconstructions. The Idaho site was divided into two areas: open circles are sites where fires continued in the 20th century, solid circles are sites where fires ceased in the 20th century. One-tailed significance values indicate duct area decreased when fires ceased after 1870 in Oregon and after 1925 in Idaho. From: Hood et al. 2015.

(3) How do management practices affect individual tree

defense and scale up to affect forest resistance to a mountain pine beetle outbreak?

I investigated susceptibility to mountain pine beetle attack and forest resilience in a fire-dependent ponderosa pine forest as a function of stand structure resulting from the absence of frequent, low-severity fire during the 20th century, and subsequent management treatments to mitigate the negative effects of lack of fire. I capitalized on an existing study of fire and stand density treatments (Fiedler et al. 2010) implemented approximately 5 years prior to a naturally occurring mountain pine beetle outbreak to explore how tree-level defense and stand structure contribute to bark beetle attack success and ultimately forest resilience from a natural disturbance. While the effects of forest management on bark beetle attack patterns have been widely studied, virtually no studies with replicated thinning and fire treatments exist that were subsequently subject to a widespread bark beetle outbreak. This offered a unique opportunity to explore the ecological effects of disturbance interactions with far-reaching management implications for the resiliency of fire-dependent coniferous forests.

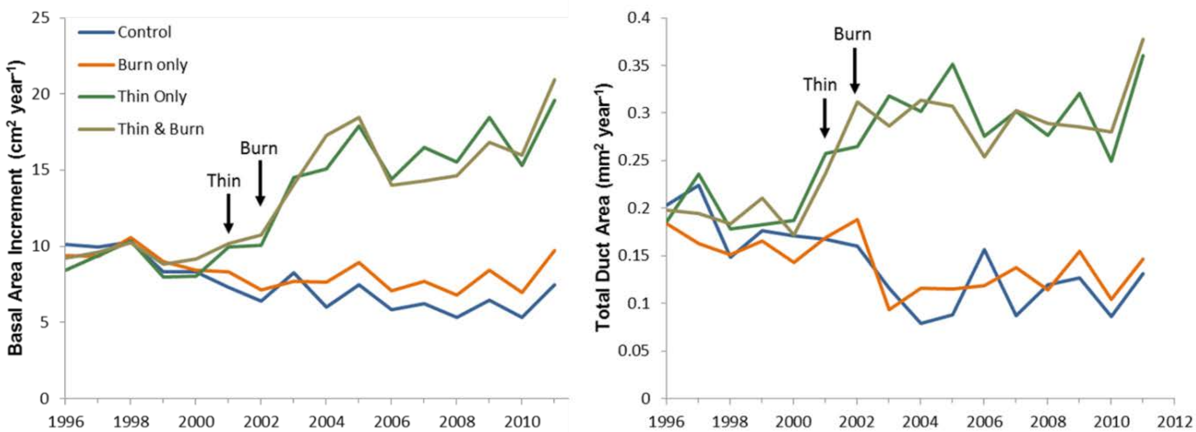

Figure 5. (A) Yearly mean basal area increment (i.e., annual wood production) and (B) total duct area by treatment. Arrows denote year of thinning (Winter 2000-2001) and prescribed burns (Spring 2002).

Annual tree growth and resin duct size and production increased after the thinning, with and without burning, and remained higher than the control and burn-only throughout the length of the study, 11 years post-treatment (Fig. 5). We attribute the minimal resin duct production in the burn-only treatment to the fact that prescribed fires were conducted in the spring, while natural fires in this region typically occur in the late summer or fall. Mortality from mountain pine beetle was markedly different between treatments: in the control approximately 50% of the ponderosa pine > 10 cm diameter was killed in the outbreak compared to 20% in the burn-only, and almost no mortality in the thin-only and thin-burn treatments (Fig. 6). The high mortality in the control caused a shift in species dominance to Douglas-fir (*Pseudotsuga menziesii*) (Fig 7). The large Douglas-fir component in both the control and burn-only due to fire exclusion, coupled with the high pine mortality from mountain pine beetle has likely reduced resilience of this forest beyond the ability to return to a ponderosa pine-dominated system in the absence of further disturbance or management. These results suggest that excluding frequent fire from this system has greatly decreased resistance from bark beetle outbreaks. This study, also supported in the scientific literature, shows that management treatments that reduce tree density and remove shade-tolerant species can increase resistance to bark beetles in the short-term (Hood 2014). An important caveat is that these treatments were conducted before the bark beetle outbreak began;

therefore, we do not know if they would be effective if implemented during an outbreak. In the long-term, frequent, low-severity fire in this system is necessary to prevent the growth of shade-tolerant species such as Douglas-fir (Allen et al. 2002, Keeling et al. 2006) and to repeatedly stimulate resin-duct defenses against bark beetles (Figs. 3 and 4).

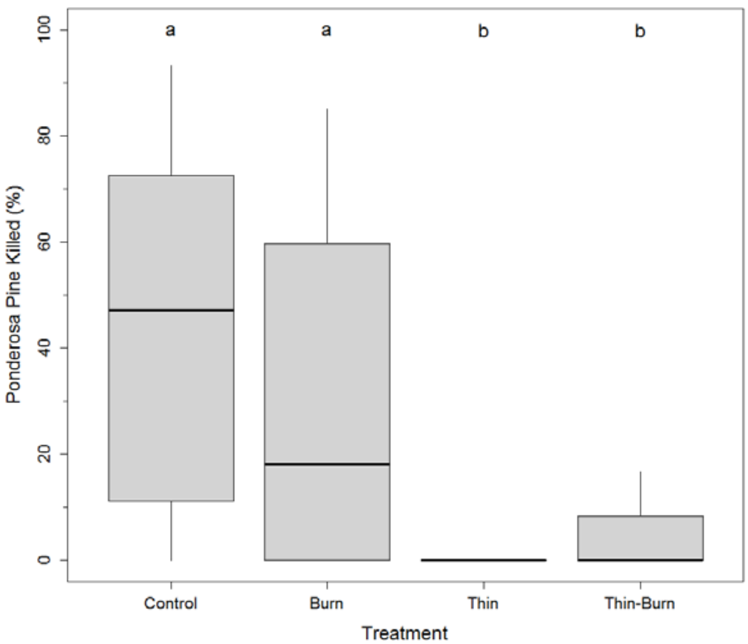

Figure 6. Percent of ponderosa pine killed by mountain pine beetle between 2005 and 2012. Different letters indicate mortality is significantly different between treatments (α = 0.05). Boxes denote first and third quartiles, lines the median, and whiskers the 1.5 inter-quartile range (IQR).

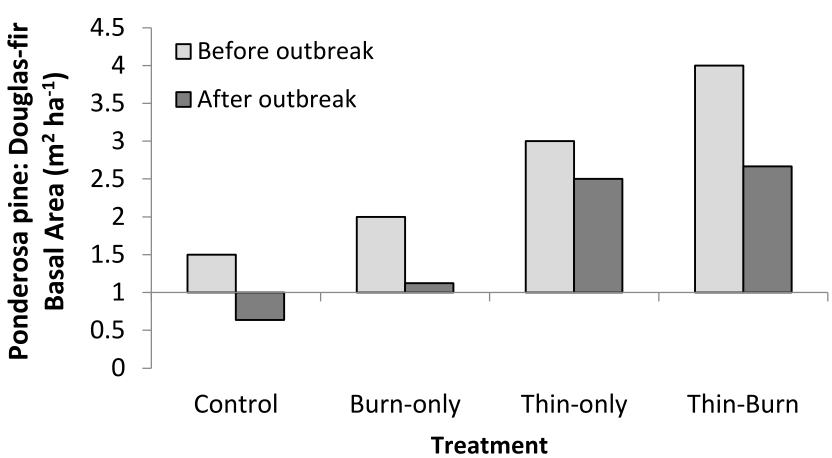

Figure 3. Ratio of host (ponderosa pine) to non-host (Douglas-fir) basal area before (2005) and after (2012) the mountain pine beetle outbreak. Numbers > 1 indicate dominance by ponderosa pine. Numbers < 1 indicate dominance by Douglas-fir.

Conclusions

Based on my research, I hope it is clear that fire plays an essential role in many of our Nation's forests. I focused my testimony on ponderosa pine in dry areas of the Northern Rockies – a forest type where there is strong scientific support that low-intensity, low-severity fire was the dominant fire regime. Other coniferous forests types throughout the U.S. also experienced frequent, low-severity fire prior to European settlement (Hood 2010). My research shows that frequent wildfire stimulates resin duct defenses against bark beetles and that lack of fire decreases resin duct defenses, potentially increasing susceptibility to beetle attack and subsequent mortality. These and other critical ecological effects of fire cannot be replicated by thinning alone. While thinning can be a very useful and sometimes necessary restoration tool, fire is crucial for long-term maintenance of early-successional pine forests through both impacts on forest structure and composition and through stimulation of defenses that can increase resistance to bark beetle attacks. My research shows that thinning, with and without prescribed fire, increased resistance to a naturally occurring mountain pine beetle outbreak. However, thinning with prescribed fire created the most long-term resilient forest to future disturbances because of the additional effects of fire-stimulated defenses and through the beneficial effects of killing understory vegetation.

Finally, I hope my research demonstrates the importance of both basic and applied research in managing U.S. forests. Without basic research, applied research can become greatly hindered because the underlying biological mechanisms are unknown, limiting effective extrapolation of scientific research to other ecosystems or novel climates and leading to a high level of uncertainty. Maintenance of a long-term research site (Fiedler et al. 2010) with periodical monitoring, the Inland Empire Tree Improvement Cooperative ponderosa pine genetic trials, and past archived data were also essential for the research I presented today. My research was dependent on prior research projects conducted by Emily Heyerdahl (USDA Forest Service), Anna Sala (University of Montana), Barbara Bentz (USDA Forest Service), and Eric Keeling (New Paltz State University of New York). Continued funding of basic and applied research is imperative to increase our understanding of how fire and bark beetles interact in order to develop the best possible tools to manage our Nation's forests in an ecologically sustainable way.

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This concludes my prepared statement. I am happy to take any questions you may have.

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