Determining sensitivity to fire-induced embolism in SW Oregon forest trees using a lab-simulated heat plume experiment.

Javin deMello-Folsom, Mark DeGuzman, and Aaron R. Ramirez

RAMIREZ LABORATORY

REED COLLEGE FOUNDED IN 1911

Introduction

Prescribed fire is integral for maintaining healthy forest ecosystems and preventing high-intensity wildfires. However, trees in such managed systems can still experience shoot dieback and plant mortality following prescribed fire events. One potential mechanism for this mortality is heat plume-induced damage to the vascular tissue of plant stems, which results in a loss of hydraulic function (West et al. 2016). Two forms of damage to plant hydraulic systems can occur during a fire. Embolism can occur when water is rapidly drawn from the leaves in response to low exterior vapor pressure created by the hot, dry air surrounding a fire (a.k.a. a heat plume). Additionally, heat from a fire can directly deform and, in turn, impair xylem tissue within a stem. While recent discoveries have shed light on the emerging topic of heat-plume induced vascular damage, little is known about the differences between species sensitivity in sites actively undergoing prescribed fire management. The goal of this study was to compare the sensitivity of species native to SW Oregon forests and compare lab-based measurements to values collected from burned and unburned sites in the field.

Hypotheses:

(1) Tree species native to SW Oregon will exhibit varying sensitivity to heat plume-induced vascular damage.

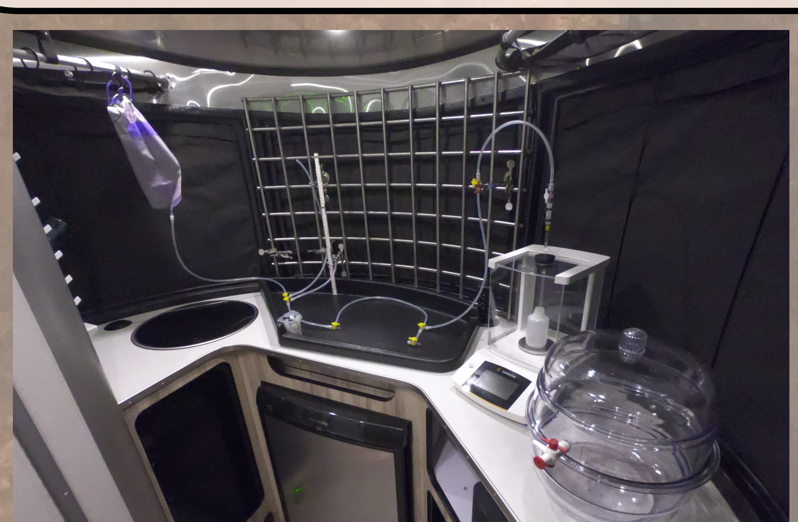
(2) Embolism formation will be associated with observed losses in hydraulic conductivity.

Methods

Laboratory:

- Seedlings of *C. decurrens*, *P. lambertiana*, *P. menziesii*, *P. ponderosa*, and *Q. kelloggii* grown in greenhouse
- Plants physiologically screened to select the healthiest for sampling
- Treated plants placed in oven at 100℃ for 6 minutes and physiological data gathered again post-treatment
- Stems from control and treated plants excised and measured for hydraulic conductivity using a gravity-induced flow setup
- Excised stems rehydrated overnight using a vacuum chamber and then remeasured to assess percent loss of conductivity (PLC)

A Black Oak (*Q. kelloggii*) seedling placed within a customized laboratory oven used to simulate a 100℃ heat plume.



System used for measuring hydraulic conductivity (Ks). This mobile set-up allowed for determination of these traits in the field using the BioBasecamp (see ReedMobileLab.com)

Field:

- *Q. kelloggii* stem segments were collected from individuals in areas treated with controlled burning (treated) and adjacent areas (control) within the Ashland watershed.
- Excised stems measured for hydraulic conductivity using gravity-induced flow setup.
- Stems rehydrated for 1 hour and then remeasured.

Results

Table 1 - Mean pre-treatment physiological screening data showing the variation in overall health among each of the 5 species within both the control and treated groups. Traits sampled for include native photosynthetic rates (A_{max}), stomatal conductance (gsw), leaf water potential (Ψ_{leaf}), and chlorophyll fluorescence (yield). Values represent the mean (± 1SE). For both and control and treated data *n* = 5-9.

	Control				Treated			
Species	A_{max} (µmol (CO^2) m^{-2} s^{-1})	gsw (mmol (CO^2) m^{-2} s^{-1})	Ψ_{leaf} (MPa)	Yield (Fv/Fm)	A_{max} (µmol (CO^2) m^{-2} s^{-1})	gsw (mmol (CO^2) m^{-2} s^{-1})	Ψ_{leaf} (MPa)	Yield (Fv/Fm)
C. decurrens	6.2 ± 0.6	126 ± 19	-0.65 ± 0.08	0.75 ± 0.01	5.5 ± 0.2	147 ± 15	-0.74 ± 0.06	0.76 ± 0.01
P. lambertiana	3.7 ± 0.6	74 ± 10	-0.79 ± 0.07	0.75 ± 0.01	4.1 ± 0.6	73 ± 11	-0.69 ± 0.06	0.76 ± 0.01
P. menziesii	6.4 ± 0.8	120 ± 16	-0.94 ± 0.06	0.72 ± 0.01	5.5 ± 0.5	90 ± 8	-0.91 ± 0.06	0.73 ± 0.01
P. ponderosa	5.2 ± 0.4	95 ± 10	-0.62 ± 0.10	0.77 ± 0.01	5.4 ± 0.4	100 ± 6	-0.73 ± 0.11	0.76 ± 0.01
Q. kelloggii	10.8 ± 1.0	120 ± 15	-1.15 ± 0.10	0.75 ± 0.01	11.0 ± 1.2	117 ± 18	-1.29 ± 0.12	0.74 ± 0

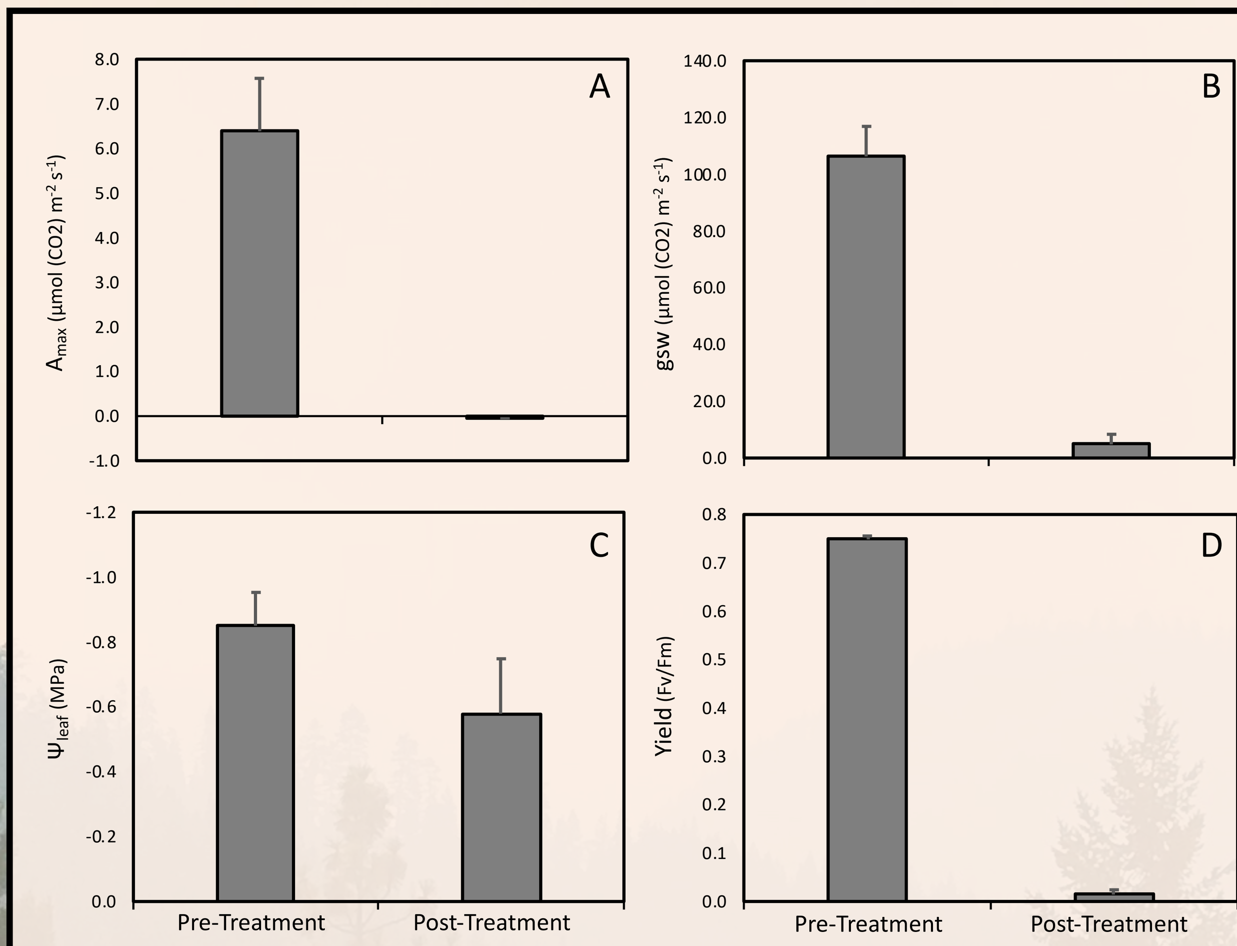


Figure 1 – Effects of the simulated heat plume treatment on physiological traits across 5 species native to SW Oregon mixed evergreen forests. Traits included are photosynthetic rate (A), stomatal conductance (B), leaf water potential (C), and chlorophyll fluorescence (D). Each bar represents the mean (± 1SE). For pre-treatment *n* = 82 and for post-treatment *n* = 41).

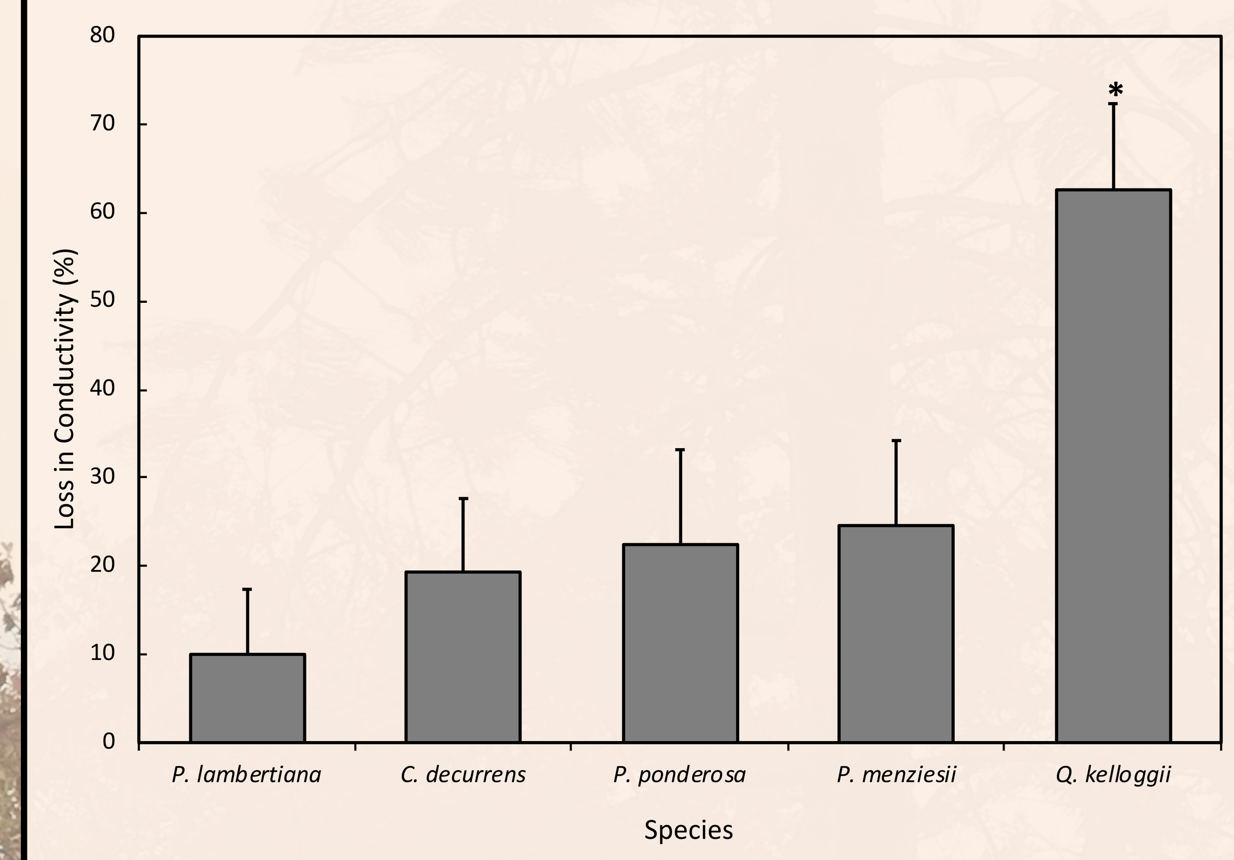


Figure 2 – Percent loss in stem-specific hydraulic conductivity (PLC) due to simulated heat plume-induced embolism of 5 species native to SW Oregon mixed evergreen forests. Each bar represents the mean (± 1SE, *n* = 5-9). * denotes significant difference from PLC of 0 ($P < 0.05$).

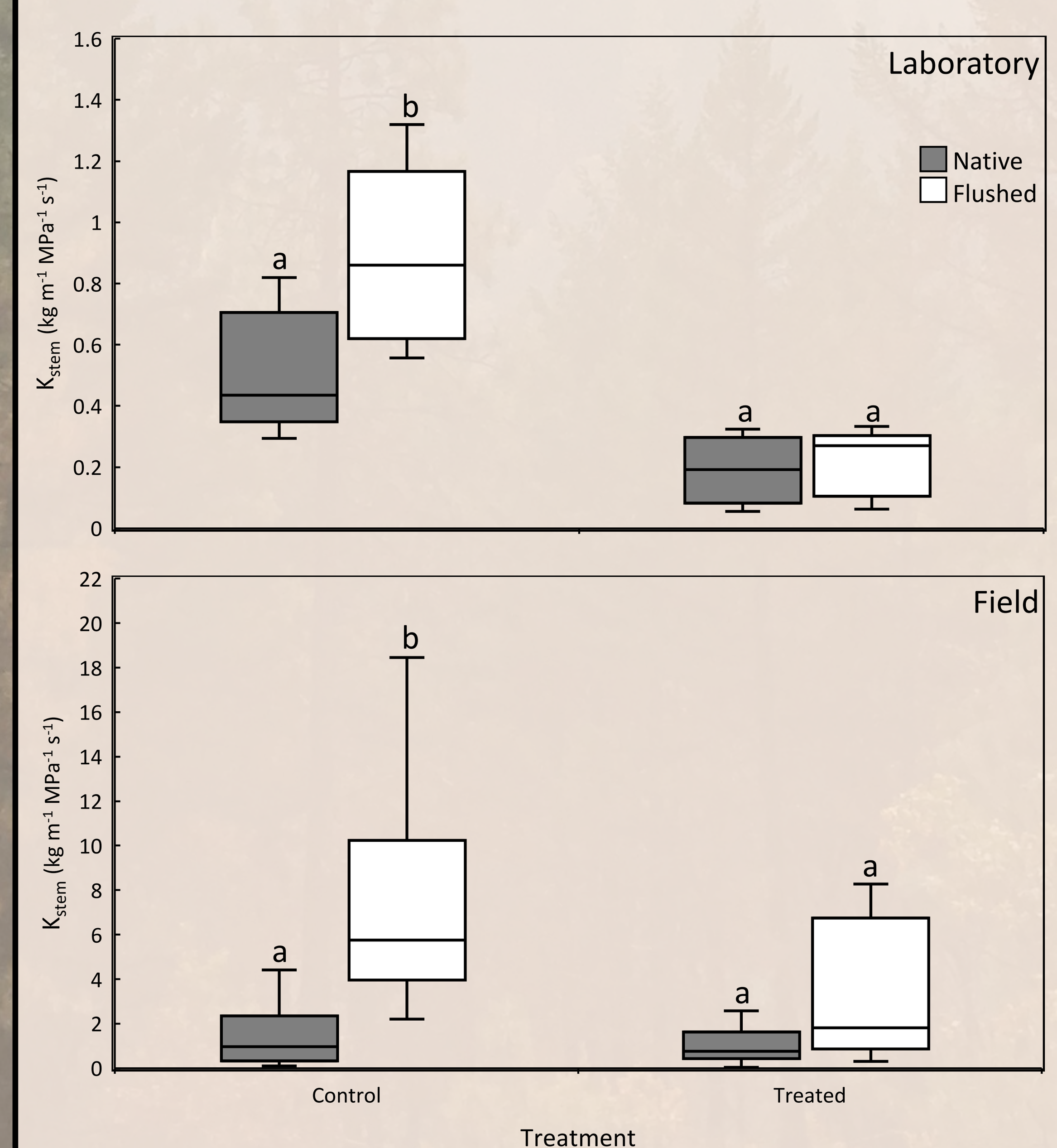


Figure 3 – Stem-specific conductance (K_{stem}, ± 1SE) measured for control and treated *Q. kelloggii* in both the laboratory and the Ashland watershed (field). Native conductance values appear in grey, whereas flushed stem values appear in white and represent the amount of recovery in re-measured stems. Significantly different means (post-hoc Tukey's HSD) are represented with unique letters. For each box within the laboratory data *n* = 5, whereas for the field *n* = 12.

Conclusion

- Low loss of hydraulic conductivity among treated gymnosperms (*C. decurrens, P. lambertiana, P. menziesii, P. ponderosa)*
- High loss of conductivity among the one sampled angiosperm (*Q. kelloggii*).
- Evidence of irreversible vascular damage among treated *Q. kelloggii* in both the laboratory and field as shown by a lack of recovered hydraulic conductivity after rehydration compared to the control.

Further Research:

- Develop methods for simulating heat plume-induced vascular damage across a range of 'real-world' canopy temperatures.
- Determine effects of heat exposure on future drought vulnerability.
- Model fire related vascular damage in SW Oregon Forests.

Acknowledgements:

Thank you to the Environmental Studies Summer Experience (ESSE) Fellowship (Dusenbery Fund) for supporting this project. Thank you also to The Nature Conservancy and the Ashland Forest for providing access to the Ashland Watershed and guidance on the project, especially Dr. Kerry Metlen.

References:

1. Bär, A., Nardini, A. and Mayr, S. (2018). Post-fire effects in xylem hydraulics of *Picea abies*, *Pinus sylvestris* and *Fagus sylvatica*. *New Phytol*, 217: 1484–1493. doi:10.1111/nph.14916
2. Metlen, K., Perchemlides, K., and Borgias, D. (2017). Ashland Forest Resiliency Stewardship Project Monitoring Plan – June 2017. *AFR*
3. West, A. G., Nel, J. A., Bond, W. J., & Midgley, J. J. (2016). Experimental evidence for heat plume-induced cavitation and xylem deformation as a mechanism of rapid post-fire tree mortality. *The New Phytologist*, *211*(3), 828–838. http://doi.org/10.1111/nph.13979