The Effects of Fire Intensity on Trees and Productivity

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Key Findings

Study A

- Increasing FRED dose on lodgepole pine seedlings resulted in significant decreases in net photosynthesis four weeks after the burn. The higher the FRED dose, the greater the decrease in photosynthesis, when compared to the pre-burn photosynthesis values (Figure 1).

Study B

- For both western larch (Figure 2) and lodgepole pine, increasing FRED dose resulted in increased crown scorch and decreased net photosynthesis at four weeks post-fire.
- Mortality of both species one year post-fire also increased with increasing FRED dose, with all seedlings of both species exposed to 1.2 MJ m^{-2} dying within four weeks post-fire.

Keywords. FRED dose, fire intensity, net photosynthesis, fire severity, fire behavior, post-fire impacts, fire effects, peak FRFD dose, crown scorch, tree mortality.

The production of this science brief was supported by the National Science Foundation through award DMS-1520873. The research described in this brief may have had other funding sources, which are acknowledged in the appropriate foundational publications.

Climate change is projected to exacerbate the intensity of heat-waves and drought, leading to greater incidences of large and high-intensity wildfires in forested ecosystems. While commonly-used remotely-sensed spectral assessments can provide useful information about the areal extent of fires and resultant changes in vegetation cover, current assessments provide little to no direct information regarding burn severity, including the physiological status of trees or other vegetation after fires. This limits our collective understanding of fire effects on ecosystems and the effectiveness of land management methods.

To address this gap in our understanding, researchers at the University of Idaho conducted multiple prescribed and laboratory burn experiments to illuminate the effects of various fire intensities (technically, Fire Radiative Energy Density, or FRED, doses) on fire severity and the recovery of seedlings native to the Pacific Northwest region of the United States. Researchers began studying differing fire intensity treatments within a climate-controlled combustion laboratory by establishing 1 m^2 fuelbeds that burned at three different FRE doses: 0.4 MJ m^{-2}, 0.8 MJ m^{-2} and 1.2 MJ m^{-2}. Productivity of the surviving seedlings was measured four weeks post-fire and, in later experiments, 12 months post-fire. Later experiments also analysed prescribed burns as well as laboratory burns. This science brief synthesises key findings from these experiments, and highlights implications for land management.

Study A: Impacts of FRED dose on net photosynthesis

In one study, researchers burned 1 m^2 fuelbeds in the laboratory, and measured fire severity as the change in net photosynthesis (M_{mol} CO_2 m^2 s^{-1}) of 2.5 year-old lodgepole pine (*Pinus contorta*) seedlings between pre-fire and four weeks post-fire (Smith et al. 2016). They found that increasing the FRED dose led to decreases in net photosynthesis four weeks later (Figure 1).

Study B: Impacts of FRED dose on mortality in western larch and lodgepole pine seedlings

In another study, researchers evaluated whether spectral indices common in vegetation stress and burn severity assessments could accurately quantify post-fire physiological performance of

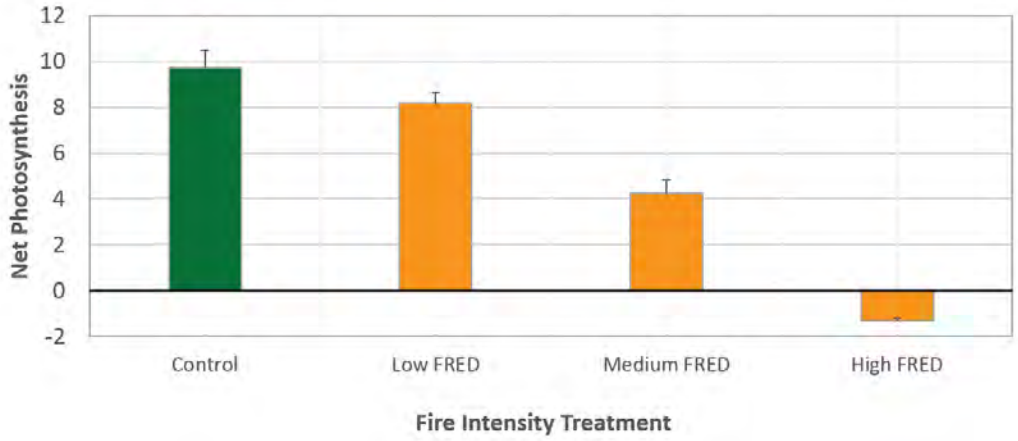

Figure 1. Net photosynthesis (measured in Mmol CO_2 m^2 s^{-1}) of lodgepole pine seedlings measured four weeks after burning in a lab (orange bars), compared to the unburned control (green bar). These results are for three different fire radiative energy density (FRED) doses (0.4 MJ m^{-2}, 0.8 MJ m^{-2} and 1.2 MJ m^{-2} are low, medium and high FRED, respectively). Error bars represent the standard error (SE). Data obtained from Table 2 in Smith et al. (2016).

Key Findings

Study C

- Unlike in previous lab research on seedlings, there was no dose-response relationship observed between FRED (J m^{-2}) and post-fire mature tree growth in surviving trees.
- However, a clear dose-response relationship between *peak* fire radiative power per unit area (W m^{-2}) and post- fire ponderosa pine radial growth was observed: trees exposed to higher peak doses experienced lower relative growth compared with those exposed to lower peak doses and control trees (Figure 3).

Figure 2. Laboratory burn experiment to evaluate post-fire physiological performance of western larch (*Larix occidentalis*) seedlings. Photos show seedlings before (left) and after (right) a high fire radiative energy density (FRED) burn treatment (1.2 MJ m-2). More details on these seedlings and experiments are found in Smith et al. (2017). Photos: Alistair Smith.

lodgepole pine and western larch *(Larix occidentalis*) seedlings (Smith et al. 2017). Researchers assessed physiological performance by measuring net photosynthesis and crown scorch at four weeks and one-year post-burn. They found that increasing the FRED dose led to increased crown scorch, decreased net photosynthesis, and increased mortality (Figure 2).

Study C: Peak fire radiative power impacts on growth in ponderosa pine

Researchers aimed to also test the effects of FRED dose on adult ponderosa pine (*Pinus ponderosa*) trees one year post-burn (Sparks et al. 2017). Prescribed burns, rather than lab burns, were conducted on nine plots selected to represent a wide range of slopes, aspects, fuel loading and moisture content, and to facilitate a large range of potential fire behavior conditions. They found that FRED dose did not affect post-fire growth of the surviving trees. However, trees exposed to higher peak fire radiative power saw their growth inhibited (Figure 3).

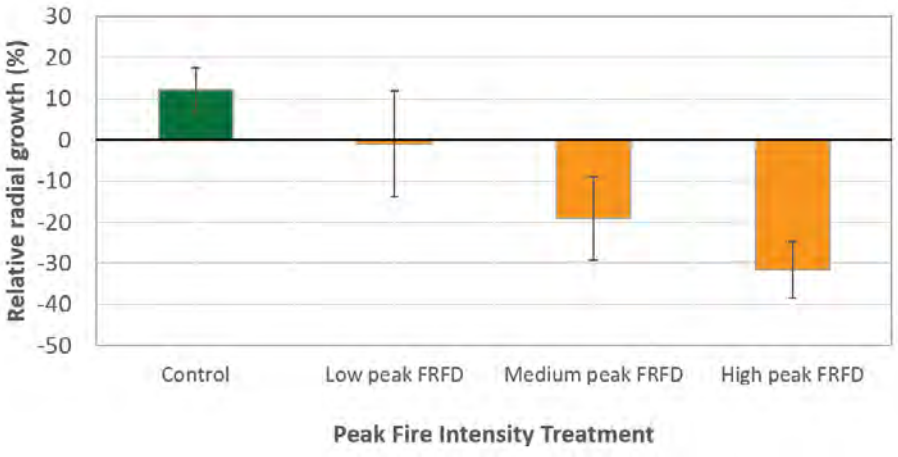

Figure 3. *Pinus ponderosa* relative radial growth (%) by peak fire radiative flux density (FRFD) class (orange bars), compared to an unburned control (green bar). Peak FRFD classes were low (0–5.4 kW m^{-2}), medium (5.5–10.8 kW m^{-2}) and high (10.9–16.3 kW m^{-2}). Error bars represent the standard error (SE). Data obtained from Figure 4b in Sparks et al. (2017).

Management Implications

Though considerable research is still needed to evaluate scaling of the controlled laboratory experiments to landscape-scale fires, greater mechanistic knowledge of how varying heat doses affect tree physiology would be an important tool for researchers and land managers. Prescribed fire practitioners could use this information to guide when and how to conduct treatments to ensure that the heat release remains manageable. Equally, they could potentially use the information on mortality threshold levels to target fire intensities in ways that remove unwanted species. The data could also be useful to managers seeking to conduct rehabilitation treatments following wildfires. Complete mortality thresholds could provide valuable information on the degree of reseeding that may be required for a given species.

Foundational Publications

Smith, A. M., Sparks, A. M., Kolden, C. A., Abatzoglou, J. T., Talhelm, A. F., Johnson, D. M., Boschetti, L., Lutz, J. A., Apostol, K. G., Yedinak, K. M., Tinkham, W. T. & Kremens, R. J. (2016). *Towards a new paradigm in fire severity research using dose–response experiments.* International Journal of Wildland Fire, 25(2), 158-166. https://doi.org/10.1071/WF15130

Smith, A. M., Talhelm, A. F., Johnson, D. M., Sparks, A. M., Kolden, C. A., Yedinak, K. M., ... & Davis, A. S. (2017). *Effects of fire radiative energy density dose on* Pinus contorta *and* Larix occidentalis *seedling physiology and mortality.* International Journal of Wildland Fire, 26(1), 82-94. https://doi.org/10.1071/WF16077

Sparks, A. M., Smith, A. M., Talhelm, A. F., Kolden, C. A., Yedinak, K. M., & Johnson, D. M. (2017). *Impacts of fire radiative flux on mature* Pinus ponderosa *growth and vulnerability to secondary mortality agents.* International Journal of Wildland Fire, 26(1), 95-106. https://doi.org/10.1071/WF16139