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Fire Effects on Microbial Dynamics and C, N, and P Cycling in Larch Forests of the Siberian Arctic

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Introduction

As the climate continues to warm and dry, wildfire frequency and severity are predicted to increase in high-latitudes. Fires have profound consequences for ecosystem biogeochemical cycling, both directly through the combustion of organic matter and indirectly through changing vegetation dynamics and microclimates. In permafrost ecosystems, large proportions of the terrestrial carbon pool are stored in soil organic matter (SOM), and the slow turnover of this organic matter induces severe nutrient limitation. Wildfires in boreal forests cause substantial loss of carbon (C) and nitrogen (N) through volatilization of soil organic matter, and it has been hypothesized that phosphorous (P) cycling is impacted as well through the transformation and redistribution of P in ash. Fire induced changes in soil microclimate and C, N, and P availability have been shown to have long-term consequences for the soil microbial community and subsequent soil biogeochemical cycling, yet these impacts are poorly constrained and largely unknown for arctic ecosystems.

In this project, we created experimental burn plots in a mature larch forest in the Kolyma River watershed of Northeastern Siberia. The impacts of fire severity on soil C, N, & P cycling and subsequent microbial response were evaluated 1 day, 8 days, and 1 year post-fire to compare short and long-term effects. Microbial response was assessed through C respiration, N and P mineralization, and the activity of 4 extracellular enzymes (EEA) that play significant roles in C, N, & P cycling (table 1). Microbes produce extracellular enzymes to breakdown larger compounds into more usable pieces, and this is often the rate-limiting step of decomposition. Extracellular enzymes represent a significant investment of microbial C and N, and so their production corresponds closely with demand.

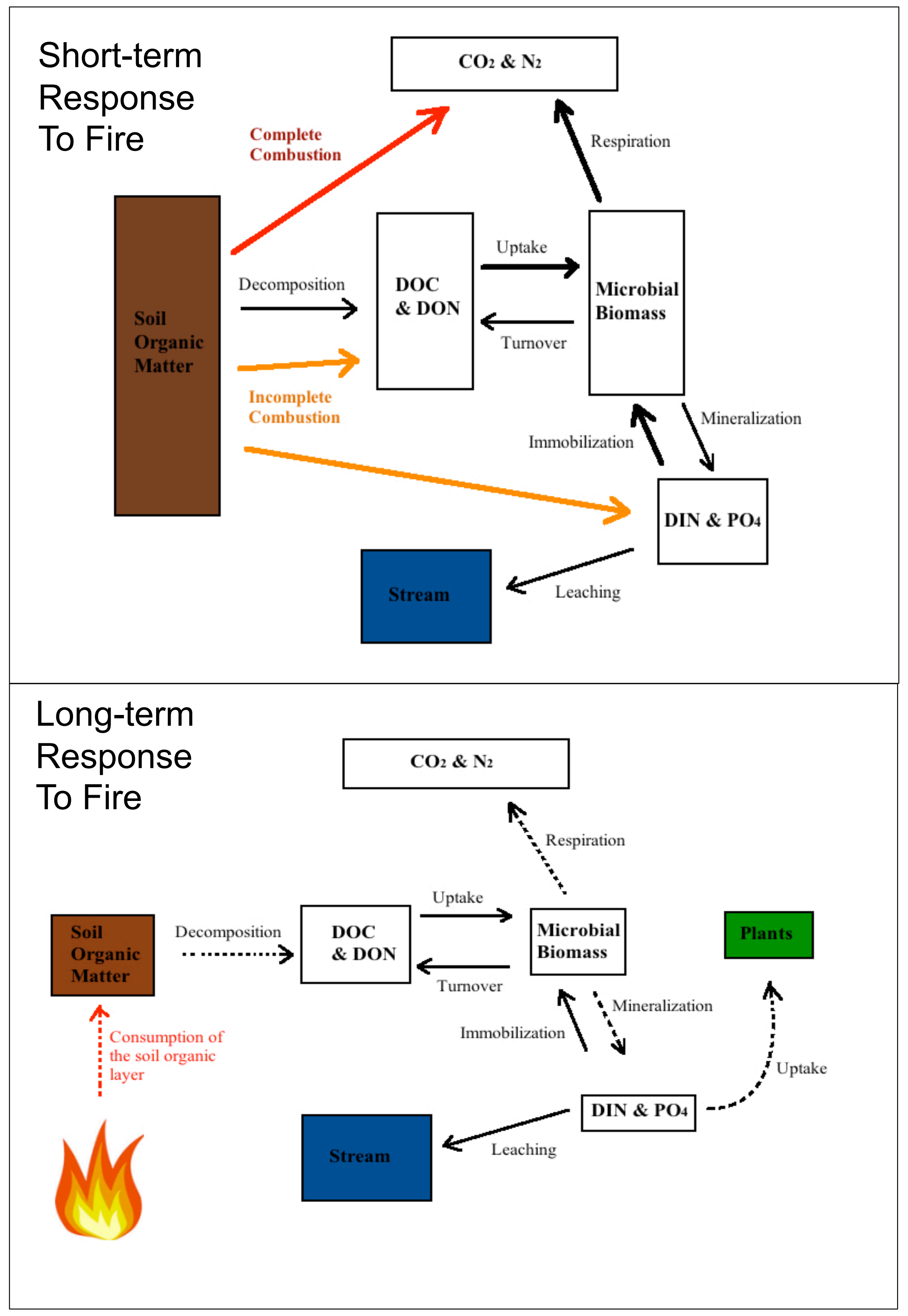

Figure 1. Conceptual models of the short-term (top) and long-term (bottom) effects of fire on soil microbial processes. Dashed arrows denote decreases, solid arrows increases, and thin arrows no change, and the direct effects of fire are in organge and red.

Acknowledgements

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Figure 2. Landscape view of a typical larch forest in Northeastern Siberia

Figure 3. Example of a severely burned plot

We hypothesize:

1) Fire severity will increase dissolved C, N, & P availability in the short-term by breaking down SOM during combustion (figure 1).

2) C & N availability will decrease over the long-term through the consumption of the organic layer (figure 1).

3) Since P is not lost in the gaseous phase, it will have a greater fertilization effect, inducing a reduction in phosphatase and increase in C and N acquiring enzymes.

4) Fire severity will lower microbial biomass resulting in less respiration.

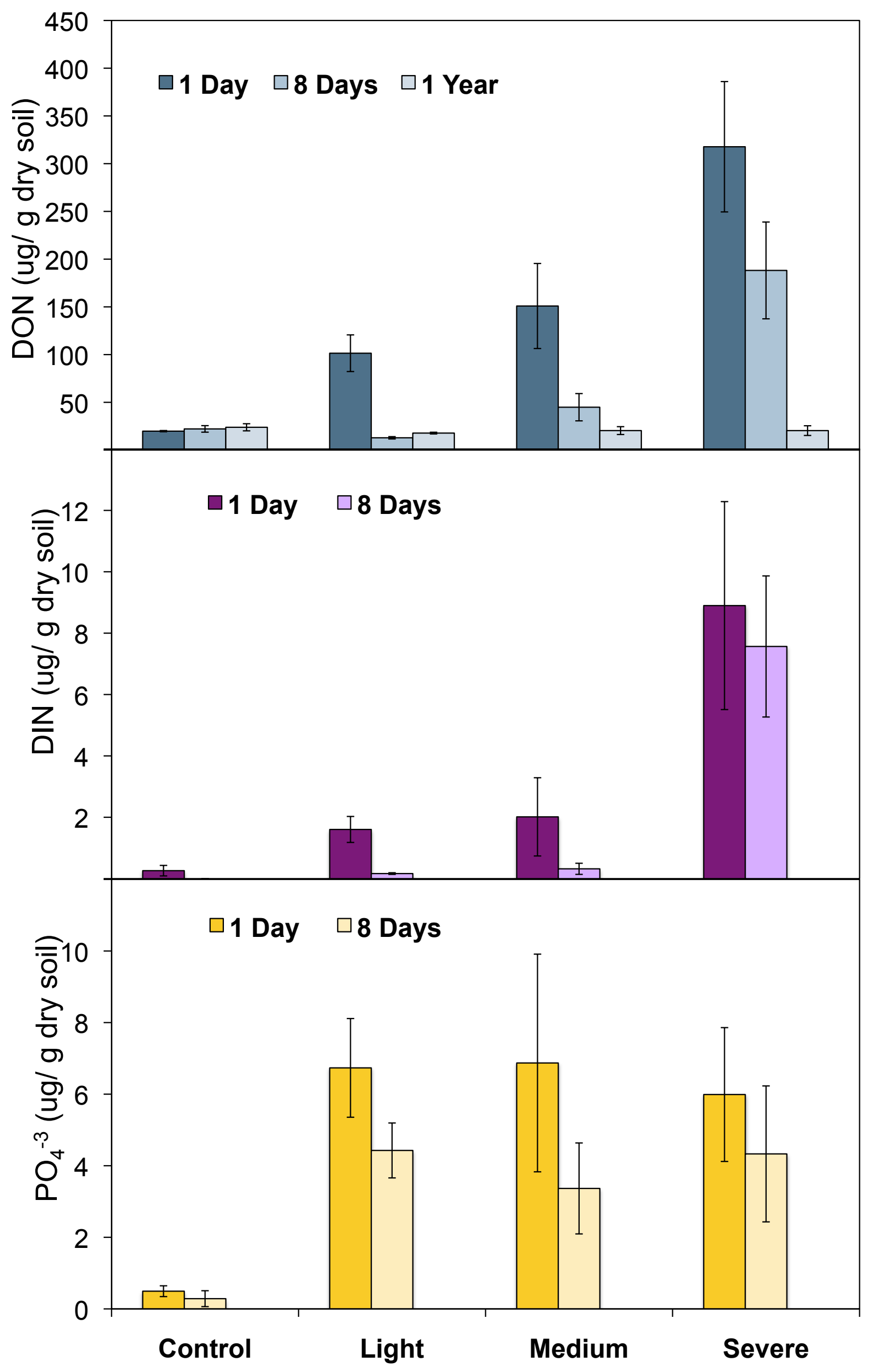

Figure 4. Average values for DON, DIN, and PO_4 in organic layer extracts Error bars are standard error.

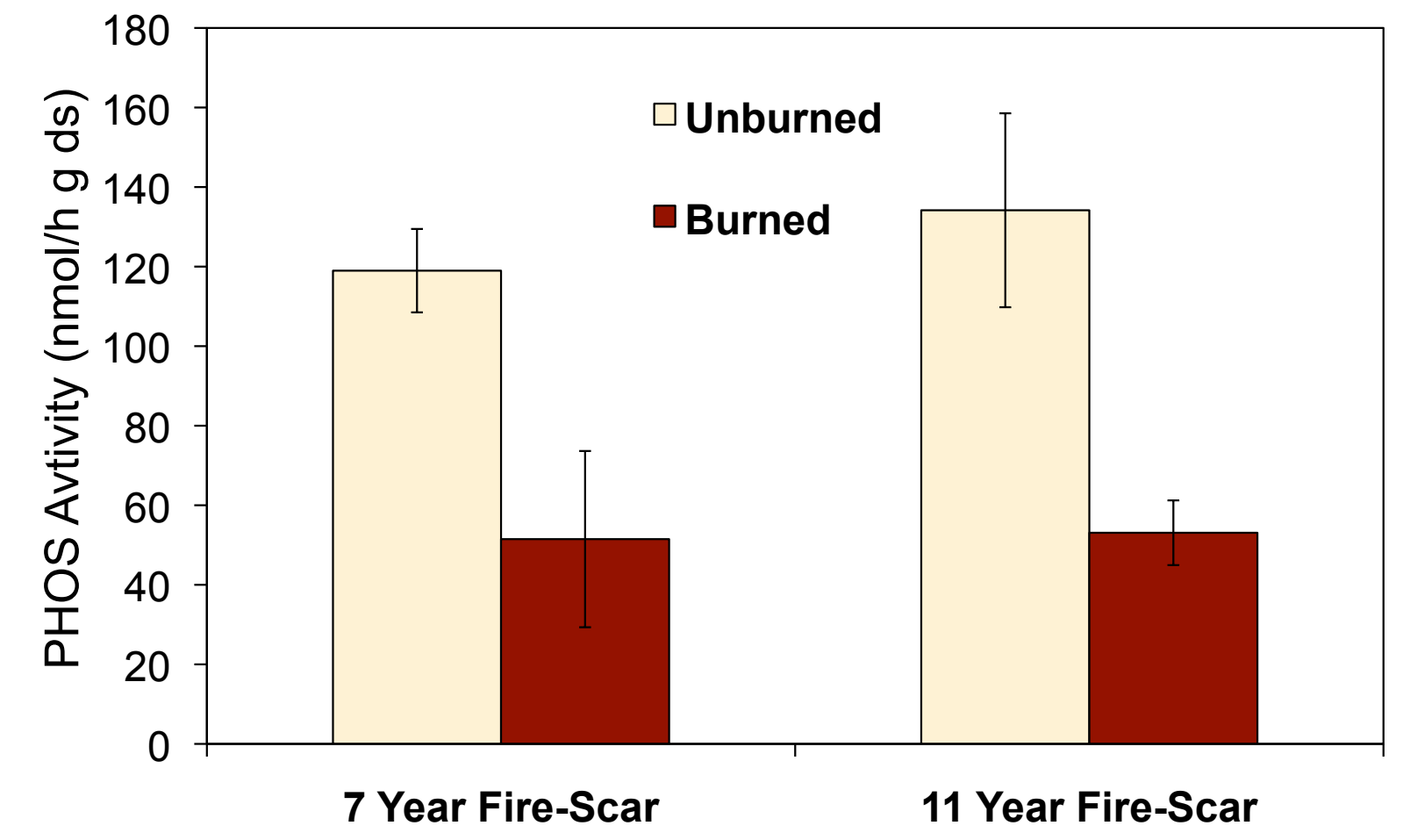

Figure 5. Average EEA for PHOS from the organic layer of nearby natural fire-scars and adjacent unburned areas. Error bars are standard error.

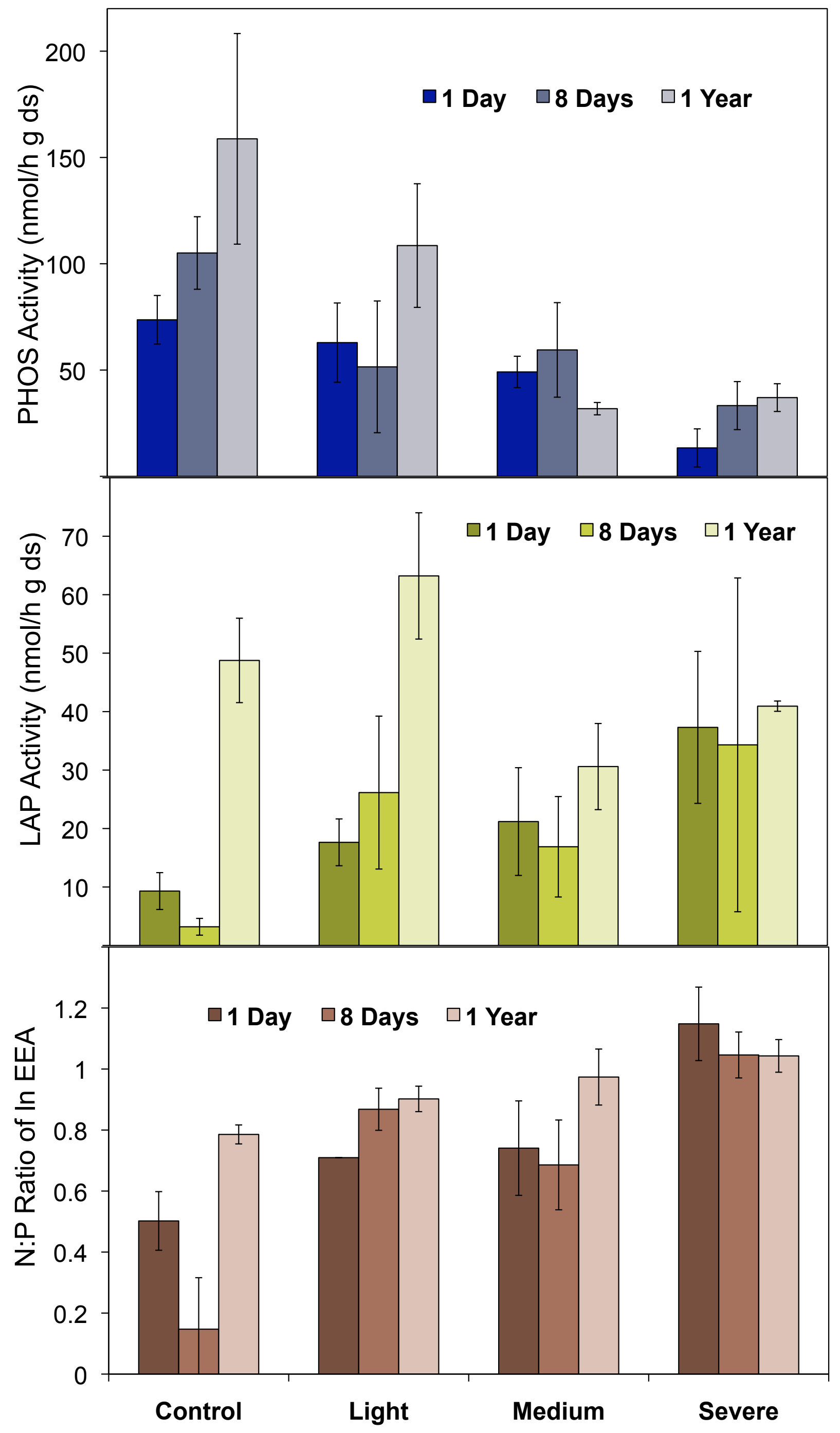

Figure 6. Average EEA from the organic layer for PHOS (top), LAP (middle), and N:P of resource acquisition (bottom), calculated as ln(LAP)/ln(PHOS). Error bars are standard error.

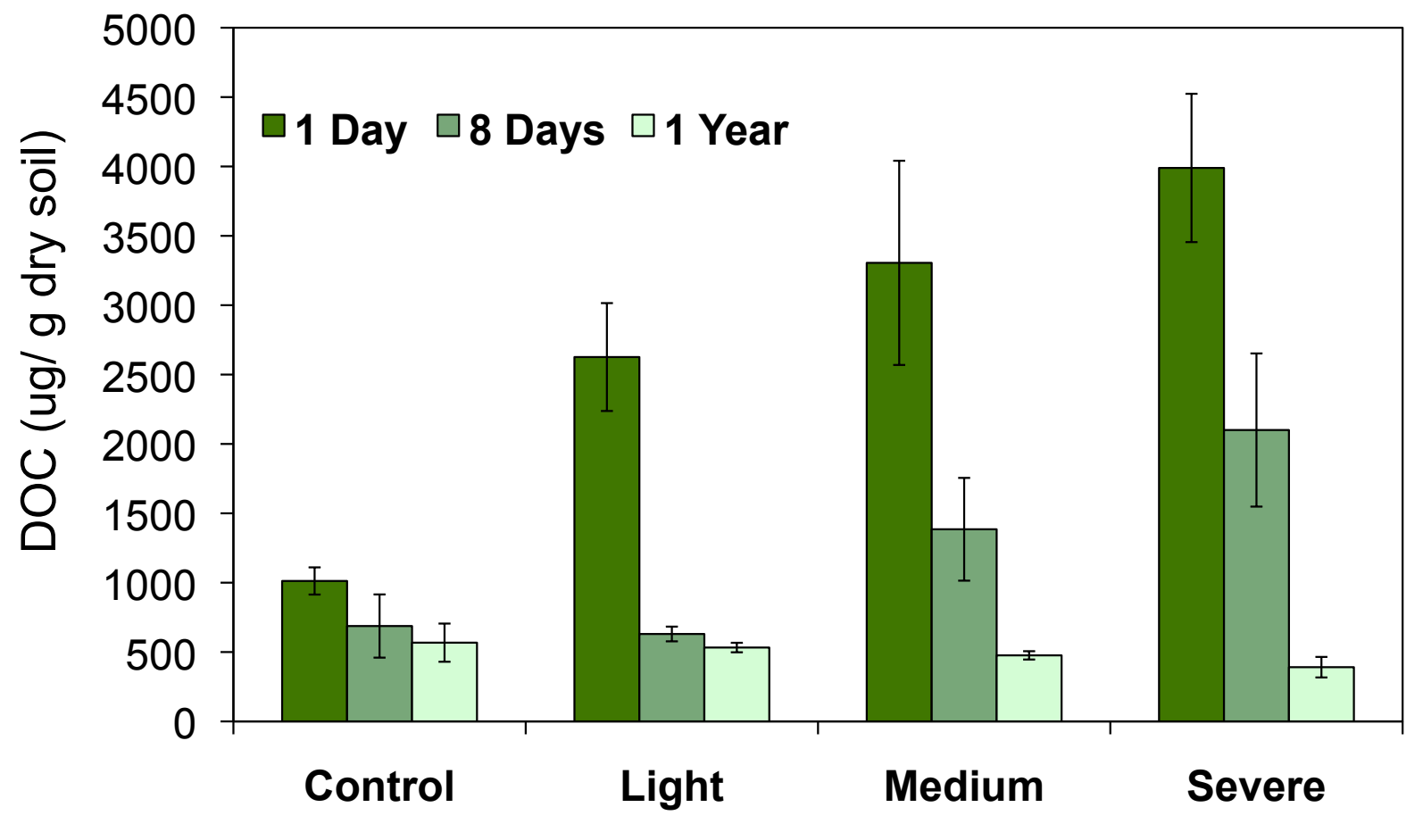

Figure 7. Average DOC from organic layer extractions. Error bars denote standard error.

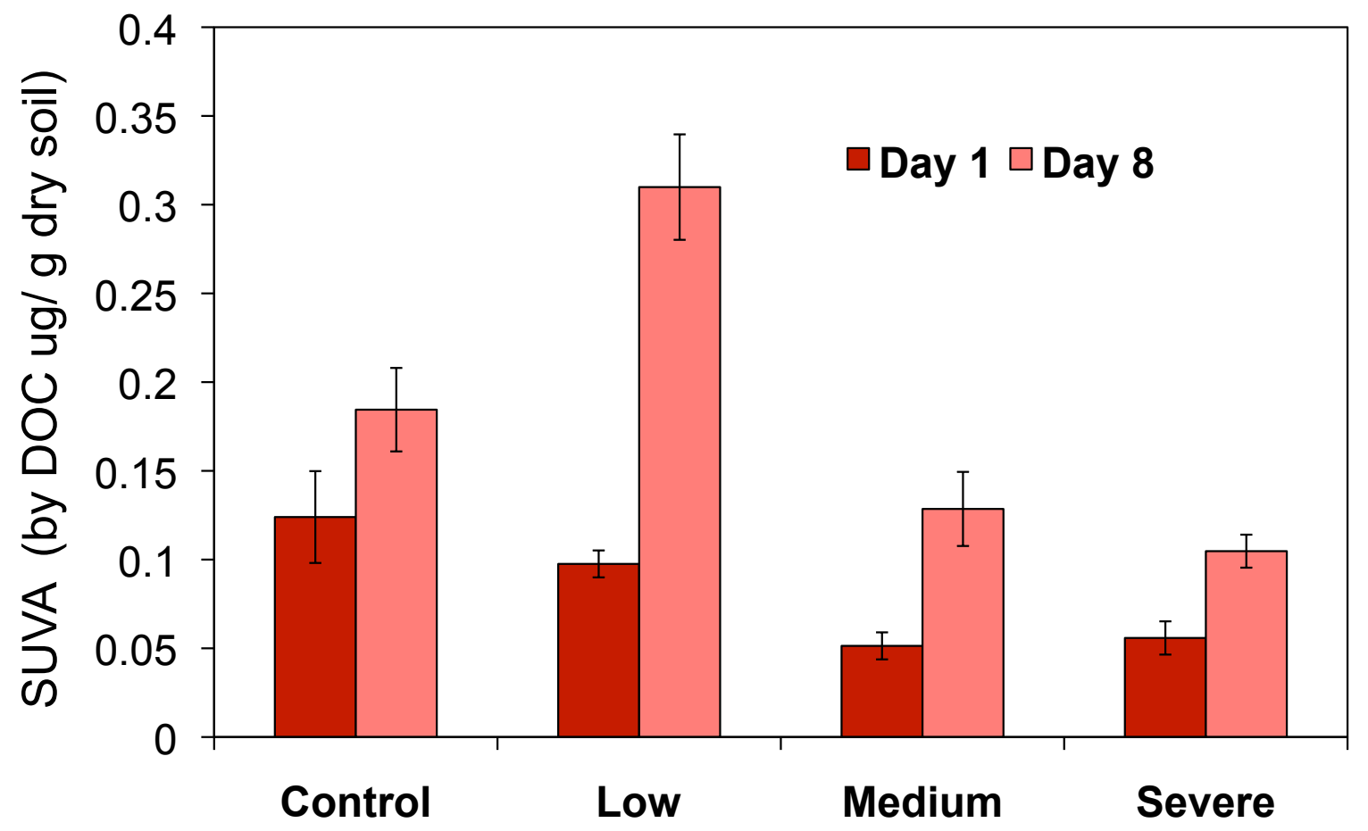

Figure 8. Average $SUVA_{254}$ as calculated from CDOM absorbance at λ = 254 nm from organic layer extractions. Error bars are standard error.

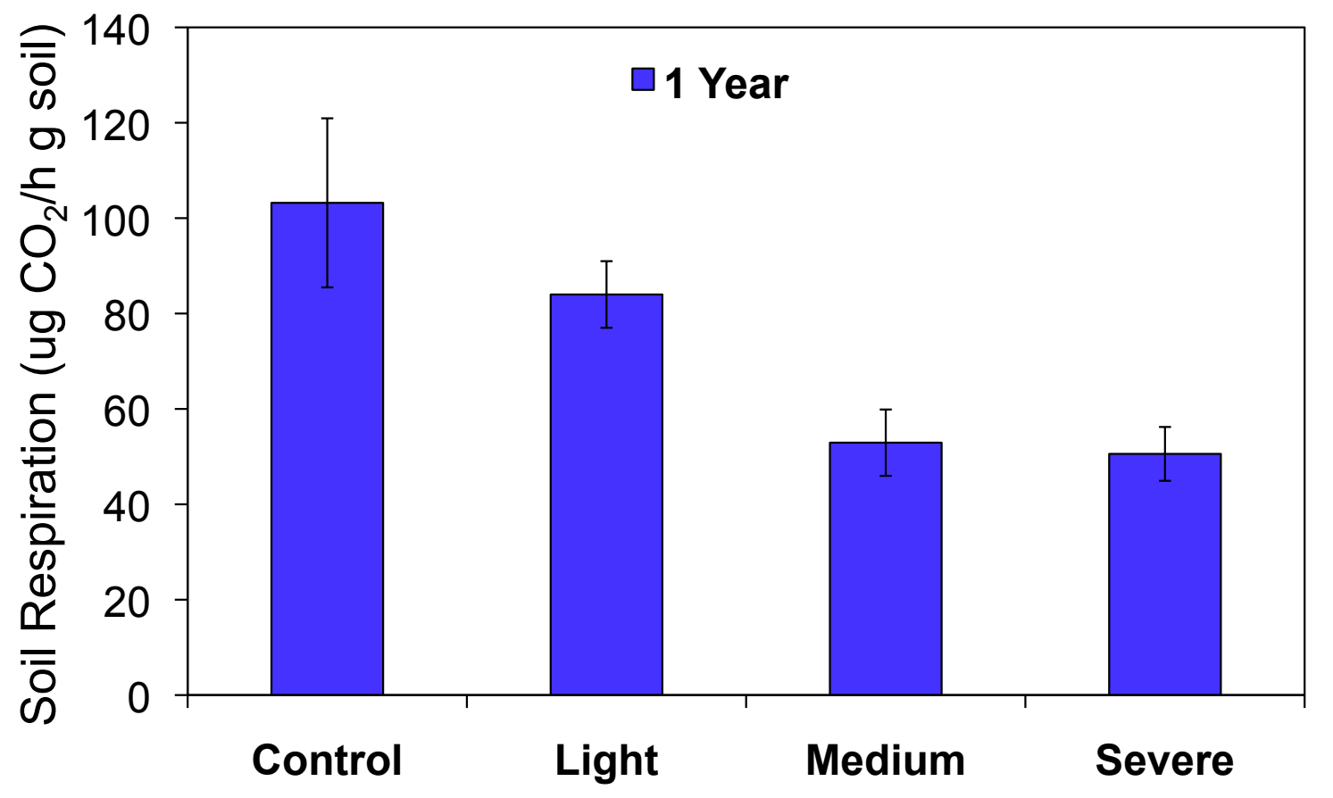

Figure 9. Average soil respiration from *ex situ* incubations 1 year post-fire. Error bars are standard error.

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Extracellular Enzyme	Abbreviation	Function
Phenol Oxidase	POX	Oxidative degradation of lignin
Phosphatase	PHOS	Hydrolyzes phosphate from phosphoesters
B-glucosidase	BG	Hydrolyzes cellulose
Leucine Aminopeptidase	LAP	Hydrolyzes leucine from polypeptides

Table 1. Extracellular enzyme abbreviations used through out the poster and corresponding functions.

Results

The short-term impacts of fire severity:

- Increased organic and inorganic nutrient availability, P more so than N.
- Increased concentrations and lability of DOC.
- Down-regulation of PHOS activity and brief up-regulation of LAP activity
- Spike in phenol oxidase activity in severe burns only, 1 day post-fire only (data not shown).

Long-term impacts of fire severity:

- Decreased soil respiration, likely the result of a smaller microbial biomass
- Continued depressed PHOS activity, also seen in natural fire-scars that are 7 and 11 years old.
- Relative nutrient limitation scales with fire severity, with the most severe fires showing a switch in nutrient acquisition efforts.

Discussion

- In more severe fires microbes are putting less resources into acquiring P. This could allow them to allocate more to C and N acquisition and compete better for N.
- The P released from fires is likely going to fuel plant microbial uptake long after the fact while organic-P accumulates, uncoupling N and P mineralization.
- The decline in soil respiration after the fires could help offset initial C emissions.
- Our results support our hypotheses and the proposed conceptual models (figure 1).

These results suggest that the effects of fire severity on microbial communities have the potential to change both nutrient use and the form and concentration of C being processed and mobilized from larch forest ecosystems. These findings highlight the importance of changing fire regimes on soil dynamics with implications for forest re-growth, soil-atmospheric feedbacks, and terrestrial inputs to aquatic ecosystems.

Methods

Experimental Burn Plots

▪Plots were burned at 4 treatments: control (no burn), low, medium, and severe

▪Soil were sampled from each plot 1 day, 8 days, and 1 year post-fire at 2-3 depths: organic layer, top 10 cm, and bottom 10 cm of mineral soil (mineral soil data not shown).

▪Nearby natural fire-scars and adjacent unburned areas were sampled similarly.

Soil Extractions

▪Soils were extracted with DI water and 2 M KCl and were measured for dissolved organic carbon (DOC), total dissolved nitrogen (TDN), NH_4, NO_3, PO_4, and chromophoric dissolved organic matter (CDOM) absorbance.

Soil Incubations

▪Soil respiration was measured as the rate of CO_2 production from *ex situ* incubations.

▪EEA was measured on soil slurries (in acetate buffer) after approx. 24 hour incubations in deep well microplates.

▪Hydrolytic and oxidative EEA was assayed by absorbance of pnp-conjugated substrates and LDOPA respectively (table 1).