**Title:** The effect of multiple short interval fires on community and functional trait-based regeneration in boreal Alaska

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## Abstract:

Fire is a major driver of forest structure, composition, and age in boreal landscapes across spatial and temporal scales. Repeat short-interval fires in Interior Alaska (occurring within 50 years or less) are a departure from historic norms of fire intervals and drive ecological transitions from conifer-dominated to deciduous-dominated forests. The impact of short-interval reburning and its subsequent effects on overstory composition and structure on understory plant communities remains unknown. Here, we investigate how multiple short-interval fires alter understory plant communities via changes in stand structure and light availability in an reburned upland stand boreal Interior Alaska that contains a mosaic of burn perimeters from fires that occurred once, twice or three times in short-intervals (>30 years). We quantified understory community composition, including abundance of nitrogen-fixers, and compare estimates of species richness and cover across reburn history. Finally, we examine whether canopy structure and light availability mediate or accelerate the impact of repeat reburning on regenerating plant communities. This work informs our ability to predict and manage impacts of repeat burning in boreal Interior Alaska forests and expands on our understanding of disturbance-driven ecological change in high-latitude boreal environments.

## Introduction

The boreal ecoregion is the largest forest ecosystem on the planet (Kuusela 1992) but contains relatively low vegetation diversity (Hart and Chen 2006). Understory plant communities in the boreal ecoregion are the primary source of plant diversity and act as a major forest ecosystem driver (Nilsson and Wardle 2005), shaping nutrient cycling (Webr and Vancleve 1981, Brumelis and Carleton 1989), wildlife (Gunnarsson et al. 204) and longer-term canopy succession trends (Messier et al. 1998). Despite their role in long-term forest dynamics, understory plant communities in the boreal remain less understood than their overstory counterparts, particularly in the context of recent shifts in modern fire regimes across the boreal. Rapidly warming temperatures across high latitudes have led to an increase in the frequency and severity of boreal wildfires (Balshi et al. 2009), amplifying short-interval fires across the region (Buma et al. 2021, *in prep*). Fire in the boreal is strongly linked to patterns of community composition and plant functional traits, but the impact of increased fire frequency on understory plant community dynamics remains unclear (Whitman et al. 2018).

Fires alter understory plant community composition by altering canopy cover which mediates understory microclimates (Hart and Chen 2006, Ma et al. 2010). [lots more to add]

To better understand the effects of multiple-short interval fires on ecosystem processes of modern boreal forest systems, it is necessary to 1) characterize the structure, composition, and functional traits of regenerating understory plant communities in reburned areas and 2) determine whether reburned areas support understory plant communities that differ significantly from similar communities regenerating in stands with different fire histories.

This study evaluates patterns of understory plant community and functional trait regeneration across a gradient of reburns to investigate post-fire community regeneration and successional trends following multiple short-interval fires. To characterize community structure and drivers of that community structure, we compare understory plant species diversity, understory community composition and abundance of regeneration traits across varying fire histories. We ask the following research questions: 1) what understory plant communities are present in regenerating reburned stands?, and 2) Does light availability, canopy structure or composition interact with fire history to alter overall diversity, community evenness and richness in reburned stands? We hypothesize that fire history will have the largest effect on diversity in reburned stands, overwhelming the effects of site conditions like canopy openness, topography, and solar radiation. Furthermore, we anticipate that single fires or reburns may lead to an initial increase in diversity in understory plant communities, but that communities will become less diverse with additional reburning. Finally, we hypothesize understory communities emerging in reburned stands will become more dissimilar to communities regenerating after single fires, and that communities will continue to become more dissimilar with additional reburns.

## Methods

#### Study design

To examine the effects of short-interval disturbances on plant communities, we established a network of 26 plots in Interior Alaska within a mosaic of unburned, burned and reburned stands.

Figure X. Map of study locations.

#### Field sampling

We sampled understory and overstory communities in field campaigns during the summer of 2018, 2019 and 2021. We counted vegetation above diameter breast height (DBH, 1.37 m) in 400-m2 sample spaces within each plot, though in denser stands, sample spaces were limited to 100m2 or 200 m2 randomly selected subsamples. For each individual above DBH, we recorded species, diameter at breast height (cm), canopy health (%) and the dominant corresponding understory species. We recorded seedlings and shrubs below DBH in 10 1-m2 subsets at each plot, and classified individuals above DBH but under 2.5 mm in diameter as saplings. Given the sensitivity of biodiversity metrics to sample size (Maurregan 2013), sample size was constrained specifically to a maximum of 400 m2  sub-samples of overstory vegetation and 100 m2 of understory vegetation.

We recorded species present and percent cover of understory vegetation within 5 1-meter2 subsamples within each plot and identified species according to regional guides (Mackinnon et al. 2004, Laursen and Seppelt 2010, Hulten 1968). When individuals were unidentifiable to the species level, the genus level was used. Due to difficulties in identifying moss species consistently across plots, we describe all moss data at the genus level.

To capture canopy openness as it relates to light availability, we took skyward hemispherical photographs at the center of each plot. Pixels were classified as “sky” or “non-sky” using Gap Light Analyzer (GLA) software, which was then used to quantity canopy openness (Frazer et al. 1999).

#### Data analysis

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To examine the specific drivers of community diversity in understories of upland reburned stands, we use multivariate regression models with Simpson’s diversity index as a dependent variable, and number of fires, organic layer depth (as a metric of disturbance severity), solar insolation, slope, and canopy openness as independent variables. Simpson’s index was calculated for upland and lowland plant communities according to reburn history using the ‘vegan’ package in R (Oskanen et al. 2017). This index provides a measure of diversity that considers both species richness and evenness of abundance by measuring the probability that two individuals randomly selected from an area will belong to the same species (Magurran 2013). Simpson’s diversity index was selected over the commonly used Shannon diversity index due to the stability of Simpson’s index at lower sample sizes (Magurran 2013, Gimaret-Carpentier et al. 1998). This model was used to compare the effect sizes and confidence intervals of the independent variables to evaluate the main drivers of diversity between a predefined set of frequency, severity and topographic characteristics.

To evaluate how plant communities in reburned stands differ according to reburn history or topographic context, we used presence/absence data of individual species to calculate Jaccard’s similarity index. Jaccard’s index uses the size of intersection and the size of the union of two finite sample sets to evaluate similarity (Magurran 2013). Once-burned species communities will be pooled and treated as one community. Jaccard’s index on its own is often a descriptive metric: to provide a quantitative estimate of community difference across reburns, we calculated Jaccard’s index comparing each plot experiencing either 2 or 3 fires to the pooled one-burn community. This approach produced a distribution of differences created from comparing each twice-burned plot index to the pool of once-burned plots. That distribution of differences is compared between 1-burn vs 2-burn and 1-burn vs 3-burn, providing a specific quantitative measure of whether additional reburns drives converging or diverging communities.

## Results

### Species composition

### Species cover

### Species richness

### Nitrogen fixers

### Canopy structure / light availability

## Discussion

## Acknowledgements

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