Examining the success of specific functional traits within given community assemblages occurring after multiple short-interval fires builds a mechanistic understanding of the drivers of successional divergence in boreal Interior Alaska. Here, we investigate community regeneration in two reburned stands with comparable burn histories (1, 2 or 3 fires in <30 years).

Disturbances alter ecosystems by changing biodiversity across communities and scales. Theory suggests frequency and severity of disturbances differ in their effects on ecological diversity (Fraterrigo et al. 2020), leading to uncertainty about how ecological communities may respond to changing disturbance regimes. Empirical research has demonstrated the importance of examining interactive effects between frequency and severity of disturbance (i.e., Thom et al. 2017, Hughes et al. 2007, Castorani et al. 2018). However, the bulk of research on disturbance regime change in systems like the boreal focus primarily on either severity or frequency effects individually (i.e., Hollingsworth et al. 2013, Johnstone et al. 2011). Understanding how diversity and community structure will change with changing disturbance regimes requires investigating the interactive effects of disturbance frequency and severity on biological communities.

Here, we use fires in the boreal as a model system, to examine how changing disturbance frequency and severity interact to alter understory plant communities. The boreal ecoregion is adapted to infrequent severe fires, occurring every 100 or more years under historic norms (Viereck 1973). Dominant boreal plant species are highly adapted to infrequent fire and possess traits enforcing dominance across fire intervals, which promote “ecological legacies” at landscape-scales (Johnstone et al 2010). Furthermore, wetter topographic contexts in the boreal may mediate increases in fire severity while still succumbing to increases in fire frequency (Hayes and Buma 2021). This would suggest that the effects of fire on ecological communities may differ according to fire severity, but not fire frequency.

Community assemblies in the boreal are driven primarily by the interaction between disturbance history, topographic context and site conditions (Hollingsworth et al. 2013, Roland et al. 2013). This interaction occurs across regional, stand and site-level scales (Fig. 1). Out of all species climatically and environmentally tolerant of boreal conditions, local fire regimes select for those with traits most suitable to survive and reproduce through infrequent, severe fires, while topographic conditions like aspect, slope and elevation influence both species distributions and fire occurrence at various scales. At a site-level, solar radiation, seed availability and canopy openness drive diversity in understory communities. Investigating ecological communities in the boreal requires acknowledging the role of complex interacting drivers across the appropriate scale.

Diagram

Description automatically generated

**Fig. 1. Conceptual diagram of factors driving overstory and understory community composition in the boreal.**

### Regeneration strategies in the Boreal

One dominant functional trait shaping communities in the boreal is regeneration strategies: tree species in the boreal regenerate either sexually or asexually (Greene et al. 1999). Sexual reproduction occurs via serotinous or wind-born dispersal strategies, while asexual reproduction is achieved through sprouting (Greene et al. 1999). Both traits involve adaptations to infrequent fire. Conifers like black spruce typically regenerate sexually via semi-serotinous seedbanks (Viereck 1973). This strategy allows for a large input of relatively heavy seeds, shortly after fire, allowing black spruce to maintain dominance after low or moderate severity fires (Johnstone et al. 2006). Deciduous species may regeneration either sexually via either wind-borne seed establishment or asexually via sprouting (Chapin et al. 2006). Species like birch and aspen have lightweight seeds that can be carried by wind over great distances (Van Cleve et al. 1983). Greater dispersal distance capability means that many broadleaf boreal species are not as meaningfully constrained by local seed availability post-fire as black spruce (Johnstone and Chapin 2006, Gill et al. 2017, Whitman et al. 2019). Finally, species like aspen, poplar and birch often regenerate by resprouting (often vigorously) after fire (Greene et al. 1999). Aspen can reproduce from seed, sprout in genetically identical clumps of stems, or sprout individually (Howard 1996). Patterns of sexual vs asexual reproduction across the boreal landscape influence ecosystem process like the distribution of aboveground carbon storage, genetic diversity and the connectivity of fuel loads.

~~Fire severity in most systems is often measured as a metric of canopy or overstory mortality; however, even moderate severity fires in the boreal can cause full canopy mortality (Kasischke et al. 2006). Substrate consumption, or the amount of soil consumed during fire, is often used as a more sensitive alternative (i.e., Turetsky et al. 2011). Not only does organic layer consumption as a metric of burn severity encompass higher severity events, it also captures potential resilience within topographic contexts that may mediate or negate the effects of fire. Specifically, poor drainage and generally higher soil moisture characteristic of lowland topographies indicates two fires in different topographic positions may produce different levels of organic soil consumption, culminating in ultimately different fire severity in terms of effects. Here, we use the term “cumulative severity” to indicate not the severity of individual events, but the difference in severity observed more generally between topographic position due to underlying drainage conditions.~~

~~Burn severity is primarily measured through organic layer consumption in Alaska (Keeley 2009), and poorly drained soils in lowland topographies may mediate initial severity by preventing full combustion.~~

Here, we use soil organic layer depth as a proxy for severity and infer accordingly that the lowland site experienced milder burn severity since less soil was consumed during each fire (Hayes and Buma 2021).

Methods

Regeneration strategy was distinguished based on rooting style: we categorized individual stems as sexual reproduction and treated clumps of stems as an initial single sexual reproduction event, while each stem thereafter we recorded as asexual reproduction. We determined the relative abundance of each strategy by dividing the abundance of a given trait by the total number of stems on a plot.

One current challenge in the modeling approach is the possible collinearity between the independent variables of number of fires and organic layer depth. A solution to this problem would be to collect additional species-level data in the lowland site. Lowland plots have an identical number of fires, but their organic layer depths are known to be different (I.e., Fig. 7B in Chapter 1). Including species-level data from the lowland site would introduce variability, potentially resolving any issues of collinearity. Furthermore, including the lowland site in the analysis would help resolve any potential problems related to small sampling size.

Furthermore, if additional species-level data is collected from the lowland site, comparisons can be made between upland and lowland plots.

~~To investigate the prevalence of different regeneration strategies in post-fire communities across the reburn sequence, we intend to use a permutation test to create a null distribution in which the relative abundance of asexual reproducers is distributed randomly across reburn history and topographic position. This approach will allow us to quantify the difference between the null distribution of randomly distributed asexual reproducers and the observed distribution of asexual reproducers across reburn history, essentially comparing between the mean across all samples, and the means of each reburn history (0, 1, 2 and 3). A p-value of mean difference between the pooled sampled mean and means of each reburn category will be calculating using a two-tailed t-test.~~ [Not doing anymore, need to revise]

#### Regeneration strategies

Presence of asexual reproducers appears to increase across increasing reburns (Fig. 2).

Chart, scatter chart

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**Fig. 2. Relative abundance of regeneration strategies across reburn history.**

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.

## Proposed Timeline

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Summer 2018-19** | | **Fall 2018-19** | | | | | **Spring 2020** | | | | |
| June | July | Aug | Sept | Oct | Nov | Dec | Jan | Feb | March | April | May |
| Field Sampling | | Literature Review | | | | | Literature Review / Exploratory Data Analysis | | | | |
| Data entry / processing | | | | |

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Summer 2020** | | **Fall 2020** | | | | | **Spring 2021** | | | | |
| June | July | Aug | Sept | Oct | Nov | Dec | Jan | Feb | March | April | May |
| Comps | Data Analysis: conduct for Upland site | | | | | | Writing: draft introduction, methods, upland results | | | | |