~~One type of disturbance interaction that has the potentially to alter carbon is short-interval disturbances: disturbances occurring within intervals of one another outside of the historic norms of intervals. The interval we use to define short-interval disturbances differs according to the system, since it is the historic norms of variability of a given system that denote what can be considered “outside” of the norms.~~

The mechanisms that drive post-fire aboveground and belowground carbon accumulation in Interior Alaska differ: fire severity is a key mechanism controlling belowground carbon accumulation, but even mediate or moderate fire severity can lead to full canopy mortality in boreal forests (Kasischke et al. 2008; Johnstone et al. 2010). Regeneration of aboveground carbon may be more controlled by the species composition and structure of seedlings via species dispersal traits (wind-dispersed vs aerial seedbanks).

An increase in fire size and frequency will expose more soil to burning. Cumulative severity of repeated fires may burn deeply into soil layers, altering the abundance and quality of soil carbon storage (Walker et al. 2019) or making carbon stored in deeper permafrost more available for decomposition.

Thus, the impact of shifts in cumulative severity, community composition and structure on landscape carbon remains unclear (Mann, Rupp, and Olson 2012) due to potentially different mechanisms driving the accumulation of above- and belowground carbon stocks. While research suggests that shifts in tree species composition from spruce to broadleaf dominance after single fire events may not directly alter the size of total carbon stocks (Mack et al. 2021), continued reburning may alter long-term carbon storage in boreal forests.

Short-interval disturbances can lead to shifts in stand composition and stand density in forested ecosystems and may occur with differing severity depending on the resiliency of the system, all with differing subsequent impacts on carbon. We define resilience here as traits that support the recovery of characteristics functionally equivalent to pre-disturbance conditions. In forest systems, resiliency often refers to recovery of structural (i.e., tree density) or compositional characteristics (i.e., species composition or community type).

Short-interval disturbances alter carbon directly (i.e., fire, which combusts carbon during the disturbance event) and indirectly. Shifts in regenerating forest characteristics occurring because of short-interval disturbances can alter carbon indirectly through three primary mechanisms: forest composition, forest structure and disturbance severity or resiliency. Short-interval fires that alter the species composition of regeneration may lead to different post-fire carbon accumulation in aboveground biomass based on the difference in species recruitment, dispersal, and growth rates. Similarly, changes in stand density via short-interval fires can shift how aboveground biomass accumulates in regenerating stands. In addition, shifts in stand composition and density can attract herbivores (pulled in by access and available resources), who in turn consume and remove biomass, potentially in meaningful amounts (ie, papers from kielland and others). Finally, disturbance severity can dictate post-disturbance regeneration …

[need a transition here]

Boreal forests are a global carbon (C) sink; aboveground biomass, forest floor materials and mineral soils in the boreal system represent as much as 30% of the world’s forest carbon stocks (IPCC 2007, Pan et al. 2011). Fire alters the distribution, accumulation, and stability of C in the boreal landscape across space and time (Kasischke and Stocks 2012) but changing fire regimes may weaken the strength of the boreal C sink at regional scales (Bradshaw and Warkentin 2015, Kurz et al. 2008). Small shifts in how and where C stocks accumulate in the boreal may have large impacts on the global C cycle (i.e., Alexander et al. 2012), thus understanding the status of the boreal ecosystem as either a net C sink or source requires investigating changes in carbon estimates after continued reburning.

Shortening fire intervals in Interior Alaska drive ecological transitions from conifer to deciduous-dominated forests (Hayes and Buma2021*).* Black spruce (*Picea mariana*) forests provide the greatest overall storage of C (both above- and belowground) relative to other Alaskan boreal species (Johnson and Kern 2003). However, empirical estimates of emerging post-fire deciduous stands indicate that faster-growing deciduous individuals may produce greater overall stand biomass initially (Alexander et al. 2012). Furthermore, laboratory incubations suggest deciduous species enable greater longer-term stability of soil C stocks under warming conditions compared to black spruce (Laganiere et al. 2013). Thus, the impact of fire-driven shifts in community composition on overall landscape C remains uncertain (Mann et al. 2012) due to potentially different mechanisms driving the accumulation of above- and belowground C stocks.

Continuing short interval fires facilitate ecological transitions from conifer to deciduous species even in historically resilient lowlands, but specific community composition in regenerating reburned stands may differ between upland and lowland topographies (Hayes and Buma 2021). Upland reburned stands were dominated by birch (*Betula neoalaskana*) and willow (*Salix* spp.), while wetter lowland reburned stands were predominantly composed of willow and aspen (*Populus tremuloides*). Given the potential interacting effects present in ecologically transitioning stands, an increase in short interval fires should theoretically lead to shifts in C stocks in regenerating reburned stands. Without quantifying those stocks or investigating the role of differing species composition in regenerating stands, we remain limited in our ability to predict or model how ecological transformations in the boreal may alter future C cycling dynamics.

This study quantifies C stocks stored in biomass and soil of stands burned in continuing short interval fires and tests hypotheses regarding the potential mechanisms driving carbon accumulation within reburned stands. We propose the following three mechanisms: 1) stand density, 2) stand composition, 3) stand resiliency (as measured by soil organic layer depth). We test the following hypotheses about C recovery in reburned boreal stands: 1) that faster growing deciduous trees result in higher overall carbon after a regime shift vs a resilient system because the loss of older carbon from soil is outweighed by the increase in carbon from more dense or more deciduous regeneration or 2) that more resilient systems will have greater overall carbon due to the carbon stored within soils, overcoming the effects of carbon accumulating as deciduous tree biomass. We also investigate the role of browsing by herbivores attracted to a greater presence of deciduous species in removing carbon in regenerating stands.

~~Specifically, understanding the fate of the Alaskan boreal as either a net sink or net source of carbon requires thorough investigation of post-fire and post-reburn carbon pool distribution at a stand scale~~.

and 3) to determine whether regenerating species composition, topographic conditions or burn history are the primary driver of aboveground and soil C in emerging deciduous stands.

Furthermore, the boreal is generally a nitrogen-limited system (Van Cleve and Alexander 1981). Increased fire activity may volatilize N in significant amounts since N is primarily stored in organic soils often consumed partially or entirely by fire (Kasichke et al. 1995). A reduction in available N may limit both forest regeneration and productivity post-fire, two factors important for C accumulation and storage in aboveground stocks (Harden et al. 2000, Alexander and Mack 2016).

Type of herbivory was evaluated both by the characteristics of browse marks and the height of browsing: hare herbivory is typically limited to 200 cm high, while the browse limit for moose is typically 3 meters (Seaton et al. 2011). Furthermore, hare bite marks are typically sharp browse scars that occur at a 45-degree angle, making them easily distinguishable from moose which tend to bite perpendicularly or strip branches of leaves and shoots entirely (Olnes et al. 2019, Wam and Hjeljord 2010). Although sampling in this way is inherently a snapshot in time, bite marks were measured regardless of age, and so evaluations of browsing behavior and herbivore presence may capture more than one season of activity.

#### Browsing preference [ should likely take this out]

Few species were browsed in complete proportion to their availability (Fig. 6). Both moose and hare grazed deciduous species in greater proportions than conifer species relative to the abundance available.

**A screenshot of a cell phone

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**Fig. 6. Species browsing preference of moose and hare. Preference based on number of individuals of a species browsed on a plot divided by total number of individuals available.**

To evaluate foliar C:N ratios across reburned stands, we harvested foliage from each tree species present at a plot in replicates of 3-5, sampling intentionally for that year's growth. To estimate foliage moisture and ensure safe transport, each foliage replicate was dried in paper bags in a 60°C oven at the University of Alaska Fairbanks during the summer field season, before being shipped and stored in plastic bags in a freezer. Each foliage sample was ground and homogenized using a roller mill, before being combusted in an Elemental Analyzer to produce estimates of %C and %N.

### Hypotheses

* I hypothesize that short interval reburning will lead to greater aboveground C and N stocks, via the increased abundance of deciduous species which produce, accumulate and store both C and N faster than black spruce.
* I hypothesize that soil C stocks will be greatest in once-burned and twice-burned plots and will begin to decline in thrice-burned plots via continued combustion of substrate.

To assess how continued reburning altered carbon stocks directly, we modeled logged total live aboveground biomass and soil carbon (grams / meter 2) individually to account for the possibility of both pools being altered via different mechanisms. We modeled both as a function of fire using the following model:

Where is the mean carbon (either live aboveground biomass or soil) for plot i and site j, is the intercept modified by site, is the slope coefficient of fire, also modified by site, and is a normally distributed error term. We allowed both the intercept and slope coefficient to vary by site to examine whether either coefficient appeared meaningfully different between our upland and lowland site.

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**Fig 5. Posterior density distributions for fire-site interaction models. Line in center of distribution represents the median value, 95% credible interval marked with lines on left and right. A) Posterior estimates for soil carbon intercept and slope coefficients, split by the categorical variable of site. B) Posterior estimates for live aboveground biomass intercept and slope coefficients, split by the categorical variable of site.**

Both soil carbon and aboveground biomass displayed intercepts that were distinctly different when allowed to vary by site: the intercept of upland carbon was consistently higher than lowland (Fig. 5). The slope coefficient of the effect of fire on soil and aboveground carbon had median values close to zero in uplands, but closer to -0.5 in lowlands, indicating a larger relative effect size.