Holocene Fire History of Terra Nova National Park

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Introduction

Fire is one of the largest natural disturbance factors in the boreal forest and plays a critical role in shaping the composition and trajectory of a forest; however, on the island of Newfoundland, with its unique climate, the fire dynamics are poorly understood. Arnold's Pond (Fig. 1), located in Terra Nova National Park, Newfoundland and Labrador, was selected to investigate (1) What was the mean fire return interval since the establishment of the current vegetation in the park and (2) Has the fire frequency during the Holocene varied with changes in vegetation?

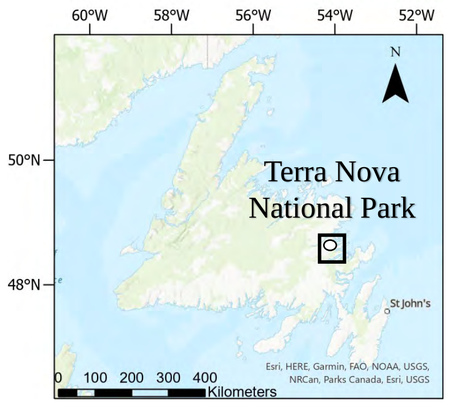

Figure 1. Location of Arnold's Pond (circle) in Terra Nova National Park, Newfoundland and Labrador.

Methods

Pond sediment was used to answer my questions as it is an excellent archive of the past landscape (Fig. 2). The sediment was sampled for charcoal, pollen grains, terrestrial plant macrofossils and sand grains, which were used to reconstruct the landscape, create a chronology, identify changes in fire activity and determine when vegetation changed. Pollen data were subjected to statistical treatment using CONISS to determine the number of pollen zones. Charcoal data were subjected to peak detection in the program CharAnalysis to determine the fire frequency.

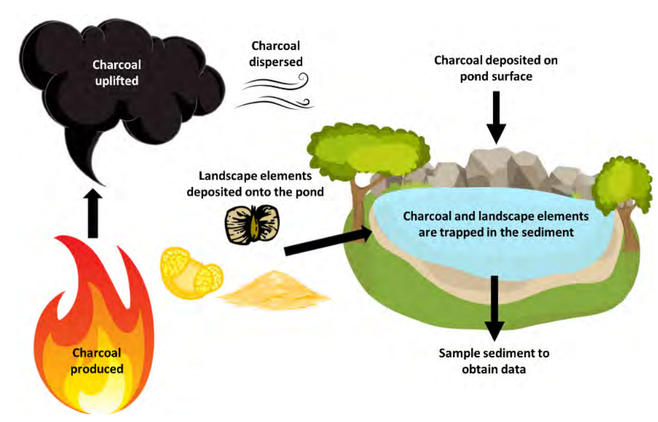

Figure 2. An overview of how charcoal and landscape elements were deposited in the sediment.

Pollen Zones

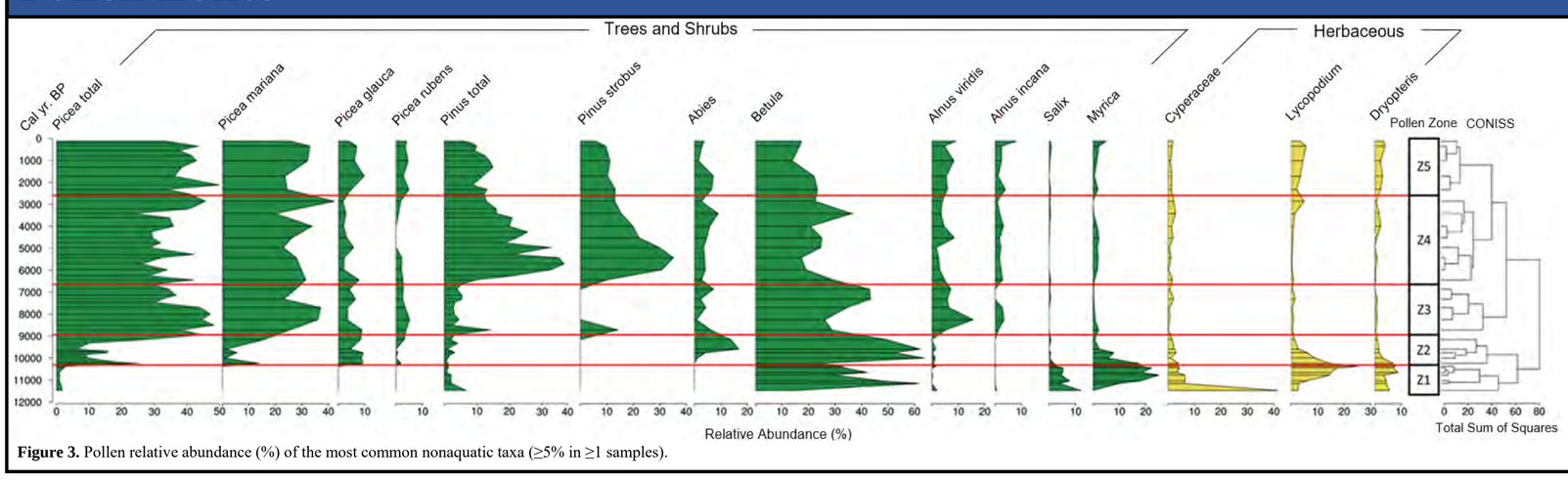

Figure 3. Pollen relative abundance (%) of the most common nonaquatic taxa (≥5% in ≥1 samples).

Pollen zone 1 (Fig. 3) represents a shrub tundra landscape largely dominated by *Betula*. Zone 2 marked a transition to an open forest and the arrival of *Picea* and *Abies*. From zone 3 onwards, the canopy closed with *Picea* being the dominate taxa along with *Betula*. Zone 4 featured a distinctive spike in *Pinus strobus.* Zone 5 showed that the current vegetation in the park has been on the landscape since ~2600 cal. yr BP.

Fire History and Paleoclimate Proxies

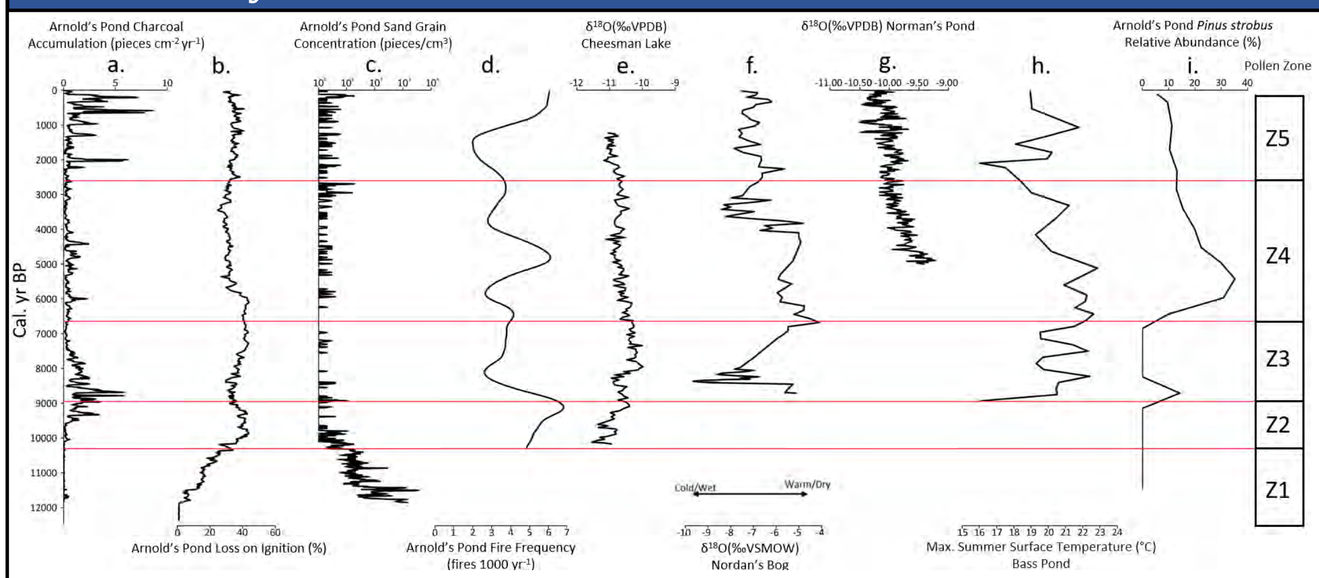

Figure 4. Cumulative figure comparing Arnold's Pond data to other paleoclimate proxies present on the island of Newfoundland, classified by pollen zone. (a.) Arnold's Pond charcoal accumulation (pieces cm^{-2} yr^{-1}). (b.) Arnold's Pond Loss on Ignition (%). (c.) Arnold's Pond Log_{10} transformed sand count (grains). (d.) Arnold's Pond fire frequency (fires 1000 yr^{-1}). (e.) Cheeseman Lake carbonate $\delta^{18}O$(‰VPDB) (Finkenbinder et al. 2016). (f.) Nordan's Pond Bog $\delta^{18}O$(‰VSMOW) (Daley et al. 2009). (g.) Norman's Pond carbonate $\delta^{18}O$(‰VPDB) (Finkenbinder et al. 2022) (h.) Bass Pond chironomid inferred summer surface temperature (°C) (Rosenburg et al. 2005). (i.) Arnold's Pond *Pinus strobus* Relative Abundance (%).

Fire estimates were not calculated for the first zone due to charcoal counts being too low for analysis. It can be inferred that fire activity was low and that the landscape was unstable during this time due to the abundance of sand grains (Fig. 4c). Fire frequency and charcoal accumulation increased in Zone 2, especially towards the zone boundary (Fig. 4a,d). Fire frequency was elevated at the zone 3 transition and continued to decline. Temperatures rose following this dip (Fig. 4e,f,h), but charcoal accumulation continued to decline while the fire frequency stabilized. Fire activity was low for much of zone 4 but did increase following peak *Pinus strobus* abundance. The Holocene Thermal Maximum likely occurred in this zone, as indicated by peak *Pinus strobus* and my LOI values. The Nordan's Bog, Norman's Pond and Bass Pond $\delta^{18}O$ records also indicate the Holocene Thermal Maximum in this zone (Fig. 4f,g,h). Zone 5 briefly had the lowest fire frequency of the entire record, but fire frequency and peak magnitudes dramatically increased in the final ~1300 yr of the record. This zone had a mean fire return interval of 271 yr.

Answering the Questions

- The current mix of *Picea-Pinus-Betula* has been on the landscape since ~2600 cal. yr BP, as represented by pollen zone 5. Within this pollen zone, the mean fire return interval is 271 yr with confidence estimates of 145-456 yr. This fire return interval is within the the estimates for the eastern boreal forest and is similar to the North Shore region of southern Québec. Previous studies found the fire interval to be 226 yr and a regional mean fire return interval of 270 and >500 yr (Bouchard et al. 2008, Cyr et al. 2012).
- Two examples of the fire frequency shifting as the vegetation on the landscape changed were identified. The transition from a shrub tundra landscape to an open forest provided additional fuel for fire events and resulted in the highest fire frequency of the record. The transition from an open forest to a closed canopy forest corresponded with a shift towards a lower fire frequency while charcoal accumulation values increased due to the fire-facilitated *Picea* becoming more dominant on the landscape.
- I found that the frequency of local fire events was not strictly controlled by changes in vegetation, but it is likely that a combination of factors resulted in the changes to the fire frequency. This was observed in zone 5 as the frequency of fire events increased midway through the zone, despite the absence of a major shift in vegetation.

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