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The Enigma Of Pitch Pine Survival Proclivity In Fire Absent Populations At Acadia National Park

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**ABSTRACT**

Forest health, particularly in regard to fragile tree species, is an overarching concern in the Northeastern US as elsewhere. In particular, the absence of fire and its impact on globally rare pitch pine (*Pinus rigida* Miller), in the region, stands in dramatic contrast to stand-replacing conflagrations like the one which occurred at the northeastern extreme of the species range limit in Acadia National Park (ME, USA) in 1947. As an essential stimulus for pitch pine reproduction and niche preservation, fire is even more noticeable by its absence. We examined species level response to the demise of natural fire using data from forty stations in and outside of the 1947 fire footprint along an altitudinal (12 to 404 m) gradient to consider this; our study revealed basic data to inform about niche status. Photosynthetic intrinsic water use efficiency, a key metric of eco physiology performance, was significantly higher (*P*=0.004) at a previously burned upper elevation, South Cadillac trail, with correspondingly shorter (*P*=0.031), narrower canopy (*P*=0.035) and smaller dbh (*P*=0.001) trees than those closer to sea level. This result seems reasonable based on a conjecture pitch pine at lower elevation have less need to compensate for moisture loss, wind and cooler temperature effects and instead push photosynthetic growth supported by available foliar minerals Ca, P, K, Al and Zn, significantly more plentiful (on average *P*=<0.01). In summary, we found trees with a 100 year fire absence history exhibited self-preservation tendencies even amidst worsening biotic and abiotic pressures. Our analysis quantified tree and soil performance with specificity as to fire, geographic and topographic gradients to inform forest management decisions especially where prescribed fire is contemplated.

**INTRODUCTION**

The fragility of globally rare pitch pine (*Pinus rigida* Miller) is nowhere more in evidence than Northeast U.S. and particularly the northeastern extreme of the species range limit (Patterson Saunders and Horton 1983) in Acadia National Park (ME, USA). A dramatic conflagration disturbed the eastern half of Mt. Desert island in the Park in 1947; since then wildfire is suppressed (Pyne 2019). To obtain a better purchase on the impact of fire—either natural occurring or anthropogenic-based—on forest health of pitch pines (Charpentier 2020) requires resolving an enigma of resilience in fire absence. Investigators appreciate a unique opportunity to explore factors on the isolated pristine island—photosynthesis, foliar and soil nutrient, elevation and topography—with which to gauge globally rare pitch pine niche performance (Harris et al 2012).

A few investigators (Jordan et al 2003) suggest wildfire is required every ten years to perpetuate and rejuvenate pitch pine populations. Thus, a sustained fire absence causes concern about pitch pine decline (Copenheaver White and Patterson 2000) on Mt. Desert as it does for trees removed elsewhere from wildfire and other pertubations (Howard and Stelacio 2011). Besides the lack of pyrolysis (save for occasional prescribed fires lit by the US Forest Service, Acadia National Park 2020, at scenic vistas on the road to Cadillac summit) other pressures exist. Maine researchers (Day et al 2005) assert pitch pine are poised to decline at a more rapid pace, due as much to higher summer and winter temperatures and moister autumns as stand-replacing disturbances (Fernandez *et al* 2015). A significant delay in further pyrolysis does not necessarily signal an end to island wildfire (Pyne 2019), since fuel buildup continues unabated (Charpentier 2020).

Certainly, the historical importance of fire ecology and the 1947 stand-replacing inferno (Fig. 1) is well documented (Patterson Saunders and Horton 1983; Harris et al 2012). Clearly, natural and anthropogenic fire pyrolysis play a significant role in the status of eco physiological and biological processes common to fire-prone pitch pine (Carlo et al 2016). In a previous paper about pitch pine in the upper Northeast US (Licht and Smith 2020) researchers seek to understand the influence of charcoal pyrogenic carbon on pitch pine intrinsic water use efficiency, subsurface water retention and nutrient supply changes in a non-glaciated ecosystem. That effort falls short of a key discussion, namely whether fire absence (Lee et al 2019) is a decisive factor in soil and tree biological and chemical outcomes as much in pitch pines promoted by fire prone sites as those *not* subjected to it. The authors compare and evaluate two populations within just a few kilometers from each other, alternately exposed to wildfire pyrolysis or not (Fig. 2).

Soil dynamics on the island are well proscribed within the pitch pine enclaves; glaciated edaphics are the rule (e.g., Ellsworth schist) as opposed to sandy or gravelly loam (Entisols and Ultisols) in most other pitch pine refugia in the Northeast US. Well-drained and infertile soils at Mt. Desert provide competitive advantages to pitch pine in competition with red spruce (*Picea rubens*), hemlock (*Tsuga canadensis*) and balsam fir (*Abies balsamea*). Spread proceeds more quickly where bare soil beckons (Lee et al 2019), allowing pitch pines to migrate to stressful locations less suited to other, bigger competitors. Once situated by themselves, they may be better enabled to balance the scales of growth and stress resistance.

Foliar mechanics reveal a well understood photosynthesis model reflecting growth (measured by height, canopy and dbh) or deference to abiotic stress resistance signaled by closing of stomata (Gururani Mohanta and Bae 2015). Understanding forest allometrics and their variability according to fire event proximity, elevation or topography enables a more comprehensive view of factors which affect colony advancement. There are few data which identify pitch pine ecophysiology and foliar nutrient storage at Mt. Desert island with the exception of a single study at Wonderland trail (Butak 2014). In that precinct, photosynthetic intrinsic water use efficiency (iWUE) measurement, calculated from carbon uptake**.** water lost-1 during C3 photosynthesis, is conducted to frame long-term seasonal growth. Previous findings suggest elevated iWUE is prevalent at higher as opposed to lower elevations (Lambers Chapin Pons 2006) and found more frequently in fire-involved as opposed to fire absent trees (Chen Wang and Jia 2017). To confirm these outcomes across multiple gradients, we consider differences which arise between pitch pines according to known fire history.

Competition begins early across a transect of elevation and topographic gradients, with juvenile pitch pine nursing evergreen competitors. As time passes, this counterintuitive irony untangles as intense sunlight coupled with soils infertile from root sorption thrusts pitch pine into a more enviable position. In both burned and unburned locales, growth or retreat to achieve escape from others is dependent on how much advantage is enjoyed in sorption of available organic and mineral deposits. Immediately after wildfire or prescribed fire events carbonate availability is noted (Licht and Smith 2020) as there is negligible pyrolytic consumption of Ca, K and Mg(Aber et al 1998; Kahl et al 2007).

Biogeographical gradients may play some role in greater or lesser accumulations; recently, there is a report identifying a relation between low elevation, absence of fire and an increase in alkali cations (Kolden *et al* 2017), specifically in an ‘O’ soil layer (DeBano 1981). Perhaps, as has been suggested earlier (Butak 2014), there is a connection between an absence of fire and greater availability of solubilized minerals (Caldwell and Richards 1989) at Wonderland. Alternately, what is worth noting at burned sites is the impression that pyrogenic carbon deposits act as a magnet for moisture retention despite what are, reportedly, initially hydrophobic repulsion by lignocellulosic-based charcoals (Licht and Smith 2020). Soil moisture retention, boosted by carbonates is critical to pitch pine well-being (Licht and Smith 2020); the contrast between retention and soil history (burned or unburned), including thermal exfoliation effects (Shakesby and Doerr 2006), provides potential to further distinguish those intra-system effects.

In fire absence, investigators seek to determine communalities and differences between populations to tease out data which support the premise that long-term benefits arise from recalcitrant charcoal still available in pitch pine stations as well as other factors consistent with supporting an hypothesis which claims superior benefits for pitch pine arising from the 1947 fire compared to those which did not.

The objective of this study was to consider that hypothesis and evaluate multiple indices of pitch pine and soil performance at four stations representative of variations in exposure to the 1947 fire pertubation, and accompanying elevation and topographic gradients.