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

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Key words

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**ABSTRACT**

The health of fragile tree species is a concern in forests around the world. In the Northeastern United States, the absence of natural fire is thought to have a negative impact on the globally rare species pitch pine (*Pinus rigida* Miller) because it is considered essential for pitch pine reproduction and niche preservation. In the northeastern extreme of the species range, a stand-replacing conflagration enveloped a portion of Acadia National Park (ME, USA) in 1947 but there is no recurrence since then. Within populations on the eastern side of Mt. Desert island in the Park we examined the enigma of pitch pine proclivities amidst 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. We found photosynthetic intrinsic water use efficiency, a key metric of physiological performance, was significantly higher (*P*=0.004) at a previously burned upper elevation, South Cadillac trail. Individuals strung along this path were also shorter (*P*=0.031), had a narrower canopy (*P*=0.035), and a smaller dbh (*P*=0.001) than those at several sea level aggregations. 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 significantly more plentiful foliar minerals Ca, P, K, Al and Zn (on average *P*=<0.01). In summary, we found trees with a one hundred year fire absence history allocated more energy to growth than stress resistance amidst forecasts for worsening biotic and abiotic pressures. Our analysis has the capacity to explain at least some of the reasons for the survival enigma as well as provide data to inform forest management decisions about soil and foliar mechanics which differ between burned and unburned populations.

**INTRODUCTION**

Fire is a disturbance that can sometimes drastically alter the landscape of a forest ecosystem and so can its absence. In the Northeastern US, and in Maine (USA) particularly (Miller et al 2017), many species in fire-prone regions rely on natural fire to stimulate reproduction and preserve niche populations (Patterson Saunders and Horton 1983). Several species in fire ecosystems, like pitch pine (*Pinus rigida* Miller), expend energy on fire avoidance and tolerance based on previous history of fire frequency. A previous study (Jordan et al 2003) suggested that wildfire is required every ten years to perpetuate and rejuvenate pitch pine populations. Yet, recently, in the Northeast that rate of frequency is nowhere near reality. As a result fire adaptations such as cone serotiny (Givnish 1981) are disappearing in pitch pine colonies due to a change in fire regimes. From that perspective, adaptations (Little 1953) may be wasted investments, potentially causing fire-adapted pitch pine to be outcompeted from an ecosystem perspective (Buma et al 2013).

For some time, fire suppression, due to concerns for nearby human populations, is offset by selective prescriptive fire intervention as an anthropogenic device to reduce fuel, evergreen competition and open canopies (Neill et al 2007). At Acadia National Park, prescriptive fire is rarely used and as a result, ongoing fire suppression creates an enigmatic situation where both burned and unburned communities are sorely tested in a harsh island environment. Uppermost in our minds is the need to unravel a conundrum as to whether long term benefits found in burned preserves outshine those in populations untouched by fire. Given the uniqueness of the island investigators are rewarded with an ideal testbed to understand pitch pine-fire dynamics and address important conservation questions.

Pitch pine fragility is of course much more complex than simply community response to a lack of fire. Day et al (2005) assert pitch pines 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 like fire. These concerns are shared by other Maine scientists (Copenheaver White and Patterson 2000) confirmed elsewhere where the species is removed from wildfire and other pertubations (Howard and Stelacio 2011). The fragile nature of pitch pine endurance is underscored by experience in a severe environment of abiotic and biotic pressures (Harris et al 2012). Ironically, glaciated edaphics on Mt. Desert island (e.g., Ellsworth schist) enable a more competitive edge for pitch pines in mixed barren ecosystem; upon entering their juvenile phase, that species does the unexpected, shading and nurturing evergreen competitors for up to a decade. As time passes, the picture of fragility morphs into a more complex and unexpected image of near vitality under the glare of intense sunlight coupled with limited nutrient and moisture root sorption. These factors provide a backdrop for competition with red spruce (*Picea rubens*), hemlock (*Tsuga canadensis*) and balsam fir (*Abies balsamea*). Further, where bare soil beckons (Lee et al 2019), pioneering efforts enable accelerated establishment in stressful locations less suited to these other, broader competitors.

At burned sites, such as those along Cadillac South Ridge trail, pyrogenic carbon deposits (Laing 1993), embroidered by thermal exfoliation (Shakesby and Doerr 2006), act as a magnet for moisture retention despite what is, reportedly, initially hydrophobic repulsion by lignocellulosic charcoal (Licht and Smith 2020). Those investigators find in a controlled study of matching slope and aspect, charcoal pyrogenic carbon from anthropogenic forest pyrolysis spurs subsurface water retention and nutrient supply, further impacting photosynthetic intrinsic water use efficiency (iWUE). For example, as a result of natural, or prescriptive fire, charcoal yields carbonate addition (Licht and Smith 2020) resulting from negligible consumption of Ca, K and Mg(Aber et al 1998; Kahl et al 2007) following forest fire. An increase in alkali cations (Kolden *et al* 2017) in a glaciated ‘O’ soil layer (DeBano 1981) is reported to increase availability of solubilized minerals (Caldwell and Richards 1989) and moisture retention—this phenomenon has been suggested as an artifact of soils at Wonderland trail (Butak 2014). Natural and anthropogenic fire pyrolysis has been shown to impact the structure and function of pitch pine colonies (Carlo et al 2016) through the influence of sufficient moisture to enable trees to defeat punishing drought, winds and runoff.

Used in concert with data on plant growth, knowledge of foliar traits provides substantial information about plant carbon and nutrient economies (Wright et al., 2004) and life history strategy (Reich 2014). For instance, foliar traits can reveal mechanisms underlying tradeoffs between growth and abiotic stress resistance (Gururani Mohanta and Bae 2015) underscored by growth data. There are little data on plant traits, especially allometrics, at Mt. Desert island with which to better understand and interpret influence of fire absence on ecophysiology. However, at Wonderland trail at least (Butak 2014), iWUE is studied as a framework for long-term seasonal growth; there was no burned population for comparison. Previous findings suggest that iWUE increases with elevation (Wang et al., 2017) and is greater in fire-involved as opposed to fire absent trees (Chen Wang and Jia 2017). Nonetheless, it is unclear how this increased efficiency may influence growth nor to what extent elevation gradients may play a role.

We employ metrics of photosynthesis, foliar and soil nutrient, elevation and topography to examine mechanisms underlying the impact of fire at four sites serving as a proxy for more than eighteen niches at Mt. Desert. Specifically, we hypothesize growth characteristics of the individuals experiencing fire would be greater, correlated to greater iWUE and leaf nutrition, as well as enhanced soil nutrition. The use of multiple elevations allowed us to examine the generality of the response.

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