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Characteristics of Red Spruce (*Picea rubens* Sarg.) Encroachment at Two Central Appalachian Heathland Study Areas

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ABSTRACT

*During the late 19th and early 20th centuries, intensive land use nearly eliminated red spruce (*Picea rubens *Sarg.) throughout portions of West Virginia (WV). Red spruce has been slow to regenerate on mountaintop heathland barrens surrounding Canaan Valley, West Virginia (WV), and little is known about the nature of encroachment. Using field surveys, geospatial data, and statistical modelling, the objectives were to 1) characterize and compare red spruce encroachment at two upland heath study areas in West Virginia (Bear Rocks and Cabin Mountain), 2) characterize percent cover of major ground cover types associated with red spruce regeneration sites in order to elucidate biotic interactions, and 3) model the biophysical correlates of red spruce encroachment using geospatial data and statistical modelling. Red spruce count was similar at both study areas, but there were substantially more seedlings and saplings at Cabin Mountain. Modelling revealed a positive relationship between red spruce count and rock cover and a negative relationship between red spruce and stand distance.*

KEYWORDS

Canaan Valley, Geospatial, Heath, Landscape Change, Picea Rubens, Red Spruce, Vegetation Expansion

INTRODUCTION AND BACKGROUND

Historical events may have profound and lingering effects on ecosystems (Foster, 2003). Canaan Valley, WV, and the surrounding Allegheny Highlands have a dramatic history of human land use that has left a lasting landscape legacy on its formerly extensive old growth red spruce (*Picea rubens* Sarg.) forests. Beginning with the establishment of pulp and paper mills in Davis, WV, and the arrival of the railroad in 1884, hundreds of thousands of acres of red spruce were eliminated through logging (Allard & Leonard, 1952). Removal of the extensive old-growth spruce forests altered the cool, moist microclimate and soil conditions necessary for red spruce growth and reproduction (Adams & Stephenson, 1989). Deep layers of moist humus dried out and eroded to bedrock in the wake of logging-associated fires (Allard & Leonard, 1952). When logging ceased by 1924, the formerly extensive red spruce forests had been nearly eliminated leaving a substantially altered ecosystem with an uncertain future (Allard & Leonard, 1952; Fortney & Rentch, 2003; Schimpf & Miller, 2016).

Subsequent to this intense anthropogenic disturbance, the former red spruce forests have been replaced by heath, grassland, and deciduous forest communities (Fortney & Rentch, 2003). Heath

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barrens and grassy balds present today in the southern and central Appalachian Mountains may have either anthropogenic or non-anthropogenic origins (Gimingham, 1972; Strausbaugh & Core, 1978; Specht, 1979). Some were purportedly maintained during the Pleistocene by mammalian herbivores (Weigl & Knowles, 1995). Others are the result of prehistoric and historic anthropogenic disturbances in the form of burning, agriculture, and timbering (DeViro, 1991; Rentch & Fortney, 1997; Wells, 1956). Although the present range of red spruce is expanding due to encroachment into these altered habitats (Allard & Leonard, 1952), modern spruce extent is still more restricted than historical distributions (Adams & Stephenson, 1989).

Myriad factors regulate tree encroachment in abiotically stressful, transitional ecosystems (e.g., alpine treelines, heathlands, bogs). Aspect and slope, for example, determine potential for a surface to receive solar radiation and regulate landscape interactions with regional climate and weather patterns (Barry, 2008). Aspect can thus influence the timing and spatial pattern of snowmelt, and in effect, exposure of seedlings to desiccating forces and frost damage (e.g., Frey, 1983; Miller & Halpern, 1998). Microtopography is also important in improving local site conditions that may increase seedling establishment and survival in exposed locations (Resler, 2006); fine-scale geomorphic features, such as boulders, hummock and hollow topography, and periglacial patterned-ground can provide leeward wind sheltering, shading, increase soil moisture retention, elevate roots from water inundation, and allow sediment to accumulate (e.g., Stine et al. 2011; Resler et al. 2005). These fine scale features exist within meso and macro topographic contexts that have further relevance to community growth and regeneration. Additionally, biotic characteristics such as groundcover and species associations can facilitate or impede regeneration. Research suggests that the vegetation stratum into which tree encroachment occurs can profoundly and differentially impact tree seedling germination and survival (e.g., George & Bazzazz, 2014) thereby affecting spatial pattern of regeneration, and ultimately recruitment.

Factors contributing to red spruce encroachment into heathlands are important to consider given the local extinction vulnerability of both red spruce ecosystems (given land use history) and heathland ecosystems (given spruce encroachment). The distribution of spruce is discontinuous throughout the central and southern Appalachians, restricted to areas characterized by the cool, moist environment conducive to red spruce growth and regeneration (Adams et al., 2010). Red spruce is restricted to the highest elevations, typically above ~ 900 m (3000 ft) in Allegheny Mountain region of the Appalachian Plateau (Adams et al., 2010), rendering red spruce stands ecological 'sky islands' under present environmental conditions, with limited migration capacity in light of climatic warming and current land uses. Globally, heathlands are characterized by ericoid shrubs and acidic, nutrient-poor soils (Gimingham, 1972; Fagúndez, 2013). Because these communities are represented by complex interspecific interactions and narrow specialist species, many are at risk from intensive land use, pollution, climate change, and tree encroachment (De Graaf et al., 2009; Fagúndez, 2013).

Here, the authors use geospatial technologies and primary data collected from field surveys to examine abiotic (i.e., terrain features and ground surface cover) and biotic (i.e., associated species and species cover) factors associated with red spruce regeneration and encroachment. The study focuses on two heathlands of the Central Appalachian highlands surrounding Canaan Valley, West Virginia. Our objectives were to: 1) characterize and compare red spruce encroachment at two upland heath study areas in West Virginia, 2) characterize percent cover of major ground cover types associated with red spruce regeneration sites in order to elucidate biotic interactions, and 3) model the biophysical correlates of red spruce encroachment using geospatial data and statistical modelling.

STUDY AREAS

The study focuses on red spruce encroachment into upland heathlands in the Allegheny Mountains of West Virginia (WV). Here, conditions are favorable to species that are less tolerant of the wider regional climatic regime (Dobroski, 2011). Although technically found at elevations below climatic