Modeling Climate Changes and Wildfire Interactions: Effects on Whitebark Pine (*Pinus albicaulis*) and Implications for Restoration, Glacier National Park, Montana, USA

Paper

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Abstract—Climate changes are projected to profoundly influence vegetation patterns and community compositions, either directly through increased species mortality and shifts in species distributions, or indirectly through disturbance dynamics such as increased wildfire activity and extent, shifting fire regimes, and pathogenesis. High-elevation landscapes have been shown to be particularly sensitive to climatic change and are likely to experience significant impacts under predicted future climate change conditions. Whitebark pine (*Pinus albicaulis*), a keystone and foundation five-needle pine species, is vulnerable to multiple and interacting disturbances that have already caused major changes in species distribution and abundance. We used the mechanistic simulation model FireBGCv2 to assess potential interacting effects of future climate changes and wildfire patterns on the presence and persistence of whitebark pine in a high-elevation watershed in Glacier National Park, Montana, USA. We did not include white pine blister rust and mountain pine beetles as disturbance factors in our simulation so that we could isolate climate-fire impacts, and because these disturbance factors have already so severely reduced whitebark pine populations in the area that few live trees remain. Hence, our results presume the establishment of initial populations of live, rust-resistant trees on the MD-GNP landscape through successful restoration efforts. Our results indicate that climate changes may significantly impact whitebark pines in this region through indirect mechanisms including altered distributions of competing tree species and increased fire frequency and fire size. The sensitivity of the species to a complex suite of interacting disturbance agents suggests that conservation efforts must address and mitigate these multiple threats through a suite of restoration treatments including planting of rust-resistant stock, fuels treatments, and prescribed burning to restore whitebark pine to its current range. In addition, additional simulation modeling experiments should be developed to identify areas suitable for restoration under potential future climate regimes and test efficacy of restoration strategies under these new climate conditions.

Introduction

Climate changes are projected to profoundly influence landscape patterns and biotic community compositions either directly through increased species mortality and shifts in species distributions, or indirectly from factors such as increased wildfire activity and extent, shifting fire regimes, and pathogenesis (Bentz and others 2010; Dale and others 2001; Flannigan and others 2000; Lenihan and others 2003; McKenzie and others 2004). High-elevation landscapes have been shown to be particularly sensitive to climatic change and are likely to experience significant impacts under predicted future climate change conditions (Fagre and Peterson 2000). Whitebark pine (*Pinus albicaulis*), an important high-elevation five-needle pine that is both a keystone and foundation species (Logan and others 2010), is particularly sensitive to a complex set of interacting disturbances—climatic change, anthropogenic fire exclusion, white pine blister rust (*Cronartium ribicola*), and mountain pine beetles (*Dendroctonus ponderosae*)—that have already caused major changes in species distribution and density (Keane and Parsons 2010). Further changes in abiotic and biotic conditions will likely pose additional threats to the success of this treeline species, with likely negative consequences for snowpack accumulation and retention, timing and amount of surface water runoff, wildlife habitat and food availability, and forest succession and structure in subalpine environments in the northern Rocky Mountains (Keane and Parsons 2010; Klasner and Fagre 2002; Tomback and others 2001).

We developed a simulation modeling experiment using the mechanistic ecosystem process model FireBGCv2 (Keane and others 2011) to assess the effects of predicted future climate changes and wildfire patterns on whitebark pines in the Northern Rocky Mountains. Our objective was to test whether different trajectories of climate change would result in markedly different wildfire patterns and abundance and persistence of whitebark pine-dominated stands within the study landscape. We incorporated two climate change scenarios designed to span a range of potential regional climate futures from warmer and wetter to hotter, drier conditions. Differences in these climate projections result from alternate trajectories of global anthropogenic drivers and associated greenhouse gas emissions (IPCC 2007). We hypothesized that warming temperatures would negatively affect whitebark pine stands at lower elevations within their current range as the result of species thermal limits and competitive replacement by lower-elevation conifers; but

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