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Radial growth rates of two co-occurring coniferous trees in the Northern Rockies during the past century

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ABSTRACT

We examined radial growth rates of locally co-occurring Douglas-fir (PSME – *Pseudotsuga menziesii* var. *glauca*) and ponderosa pine (PIPO – *Pinus ponderosa* var. *ponderosa*) trees growing within the Northern Rockies to determine if there are differential growth and climatic responses between these species and whether these responses are consistent among topographically and climatologically diverse sites. We developed standardized tree-ring chronologies from seven sites, with each site a matched pair of PSME and PIPO. For each chronology we examined the climate response of radial growth by comparing the standardized ring widths to a suite of climatic variables. We examined temporal changes by comparing 1905–1950 and post-1950 growth rates and climatic conditions. Both conifers experience increased radial growth post-1950. A combination of spring/summer moisture conditions related positively to radial growth and the primary climatic drivers were consistent both between species and within the region. The primary climatic drivers of radial growth remain unchanged during the last century or have trended toward drier conditions unfavorable for growth. We conclude that increases in standardized radial growth rates are unlikely climatically-driven. Other potential vectors of radial growth change, such as atmospheric CO_2 enrichment, have affected these co-occurring species on a largely equal basis and positively.

1. Introduction

Global circulation models for the Northern Rockies – an area that encompasses the natural range of some of the most commercially viable U.S. tree species and includes extensive tracts of semiarid woodlands – predict warmer and drier conditions the next several decades (Christensen et al., 2007; Littell et al., 2011). In North America west of the Mississippi river, summer temperatures are predicted to rise by as much as 4 °C coupled with precipitation declines up to 20% below current normals by late century (Christensen et al., 2007). Similar predictions for warmer, drier summers occur for other areas containing arid and semiarid lands, including the Mediterranean region and central Asia (Christensen et al., 2007).

The predicted climatic conditions create an impetus to examine the historical responses of trees to changing climate and atmospheric composition to improve our understanding of how the dominant conifers in the region have responded during and after warmer and drier periods throughout the past century. If climatic change in the Northern Rockies occurs as predicted (Christensen et al., 2007; Hamlet et al., 2007; Littell et al., 2011; Westerling et al., 2006), forests in this region will experience more frequent drought conditions that should impact forest productivity. But to what degree and which species will be most affected? Complicating this understanding is that the limiting impacts of drought may be offset by one possible cause of the climatic change – increasing atmospheric CO_2.

Water stress may enhance the *relative* effects of elevated CO_2 on woody plant growth (Huang et al., 2007; Idso and Idso, 1994; Wullschleger et al., 2002), thus the impacts of increasing CO_2 can be ameliorative for drought stress in semiarid environments (Knapp and Soulé, 2011; Soulé and Knapp, 2006, 2011) and older trees (i.e., >250 years) may benefit the most (Knapp and Soulé, 2011). Under higher atmospheric CO_2 concentrations, stomatal openings for tree leaves contract during photosynthesis (e.g., Tognetti et al., 1998), reducing transpiration rates and resulting in increased water-use efficiency (WUE). Soulé and Knapp (2011) examined changing rates of intrinsic water-use efficiency (iWUE – a measure of the relationship between the rate of CO_2 assimilation and transpiration through stomatal openings) for Ponderosa pine trees

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(*Pinus ponderosa* var. *ponderosa* – hereafter PIPO) throughout semiarid sites in the western United Sates and found significant upward trends at all locations, including three of the sites examined in this study. With increasing iWUE, radial growth may continue later through the summer in environments where soil moisture becomes limiting by July or August such as the Pacific Northwest and Northern Rockies, or may continue at higher rates during a drought period.

In this paper we examine relationships between climatic conditions and radial growth rates of locally co-occurring Douglas-fir (*Pseudotsuga menziesii* var. *glauca* – hereafter PSME) and PIPO trees within USFS Region 1 of the Northern Rockies and determine if differential responses to changing environmental conditions exist between these two conifers. By working in natural settings where gradual increases in atmospheric CO_2 have occurred during the last 100+ years, by sampling from sites with minimal historic human agency where the trees locally co-occur, and by carefully selecting trees so as to minimize potentially confounding factors for radial growth, we gain insight into how these two species are responding to climate and changing atmospheric conditions. Specifically, we hypothesize that: 1) radial growth rates of PSME and PIPO have changed significantly during the past century; 2) changes in observed radial growth rates are climatically driven; 3) radial growth responses of PSME and PIPO during and after drought have temporally changed; and 4) differential responses between the two co-occurring tree species exist and are spatially consistent. Herein we follow methodologies developed from earlier studies (Knapp and Soulé, 2011; Soulé and Knapp, 2011) in the same region that focused on PIPO, and use similar evaluative metrics (Knapp et al., 2001a, 2001b) to compare PSME and PIPO responses to changing environmental conditions.

Both PSME and PIPO are ecologically important tree species throughout the American West, have similar and extensive geographical ranges, and often grow at the same locations (Earle, 2007). PSME and PIPO are also major species for US forestry, representing the first- and third-most harvested trees by volume, respectively (WWPA, 2012). Changing atmospheric and climatic conditions may create a scenario where growth rates of PSME or PIPO are differentially affected, either positively or negatively, thus potentially affecting the structure and composition of these forests/woodlands. Globally, climate change can impact semiarid forests directly through water use and net primary productivity changes, and via “cascading” disturbances whereby a change in one climatic vector such as drought can cause subsequent changes in fire regimes and the frequency and intensity of insect and pathogen outbreaks (Dale et al., 2001). These cascading perturbations can result in radical changes in forest dynamics (Dale et al., 2001; Paine et al., 1998), and this has a direct bearing on current and future management decisions and practices (Peterson et al., 2011).

2. Methods

2.1. Tree-ring data collection and processing

We collected samples and developed fourteen standardized tree-ring chronologies from seven matched-paired sites (PSME and PIPO) in Idaho and Montana (Fig. 1, Table 1). Each chronology is identified using a three letter alphabetic code common in tree-ring science (Table 1). We selected all sites based on criteria designed to limit the number of potential confounding influences that could affect radial growth. Specifically, our selected sites: 1) were open stands of co-occurring PSME and PIPO trees available in both older (establishing prior to AD 1800) and younger (interior dates post-1875) age classes; 2) had a history of minimal anthropogenic disturbance; 3) are located in interior Idaho and western Montana to negate or minimize potential impacts on radial growth by ozone (Lee and Hogsett, 2001) or nitrogen deposition (Fenn et al., 2003); 4) have no known histories of pandora moth (*Coloradia Pandora*)

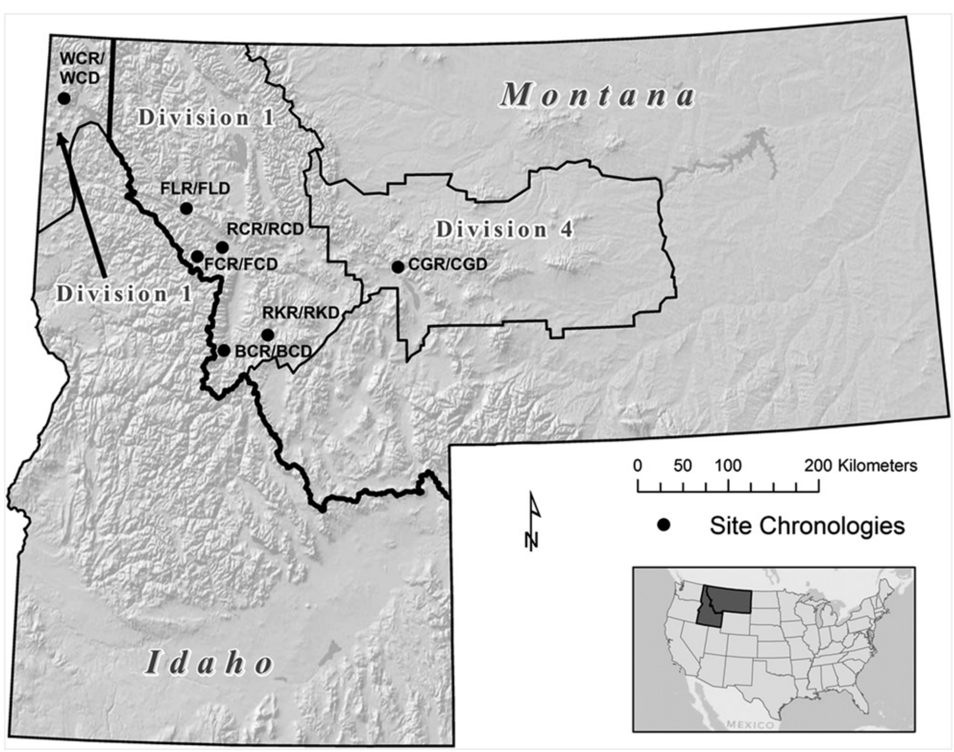

Fig. 1. Location of the seven matched pair study sites in Montana and Idaho, USA and boundaries of the climatic divisions from which climatic data were used. Study site names for the three letter site codes are found in Table 1.