Dendrochronologia 48 (2018) 10–19

Contents lists available at ScienceDirect

Dendrochronologia

journal homepage: www.elsevier.com/locate/dendro

Human influences superseded climate to disrupt the 20th century fire regime in Jasper National Park, Canada

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ARTICLE INFO

Keywords:
Fire-climate associations
Drought
ENSO
PNA
Tree-ring proxies
Fire suppression

ABSTRACT

To enhance understanding of how climate and humans influenced historical fire occurrence in the montane forests of Jasper National Park, we crossdated fire-scar and tree age samples from 172 plots. We tested effects of drought and climatic variation driven by the El Niño-Southern Oscillation (ENSO) and Pacific North American (PNA) pattern on fire occurrence. We also tested whether local droughts were associated with ENSO, PNA, Pacific Decadal Oscillation and Atlantic Multidecadal Oscillation. We used a combination of instrumental and proxy-climate records to test whether climatic variation explained the absence of fire scars in our study area during the 20th century. From 1646 to 1915, 18 fires burned mainly during drier than average years. Drought years, but not fire years, were associated with positive ENSO and PNA indices, corresponding to warmer conditions with reduced snowpacks. Fire frequency varied through time, although no fire scars have formed since 1915. Potential recording trees present at all plots and climate conducive to fire over multiple years provide evidence that human influences superseded climatic variation to explain the lack of fire scars during the 20th century. Fire suppression significantly altered the fire regime after the formation of Jasper National Park, justifying the ongoing mechanical fuel treatments, prescribed and managed wildfires to improve forest resilience to climate change.

1. Introduction

As global warming progresses, fire regimes in forests of western North America are anticipated to include wildfires of increasing number, size and severity, with measurable effects already observed (Flannigan et al., 2003; McKenzie et al., 2004; Westerling, 2016; Wotton et al., 2017). Apart from climate, fire regimes are influenced by land use and fire management (Bowman et al., 2009); however, their effects vary among forests (Schoennagel et al., 2004). Understanding the relative importance of climate and humans and their interacting effects on fire regimes is important for understanding the drivers of variable forest conditions over time at various spatial scales and for developing effective management plans in response to environmental change (Stephens et al., 2013).

Jasper National Park lies along the transition between Montane Cordillera and Boreal Plains ecozones in the Canadian Rocky Mountains (Ecological Stratification Working Group, 1995). In the Park, vegetation varies from grasslands to subalpine forests along steep environmental gradients over short distances. The historical fire regimes also vary with mixed-severity fires in the montane and lower subalpine forests, transitioning to infrequent high-severity fires in the upper subalpine forests. Recent fire history and forest demography reconstructions in montane forests of Jasper showed historical fires burned at a wide range of severities and frequencies (Chavardès and Daniels, 2016). Multiple fire scars on thick-barked interior Douglas-fir (*Pseudotsuga menziesii* var *glauca* (Beissn) Franco) as well as lodgepole pine (*Pinus contorta* Douglas ex Loudon) indicated repeated low-severity fires through time in many stands. Stand-level mean fire return intervals were 30–60 years, but intervals within stands varied from 11 to 165 years. Contemporary stand composition and age structures reflect moderate-to-high severity fires that initiated cohorts in the late 1800s, followed by no fires for most of the 1900s (Chavardès and Daniels, 2016). In absence of fire, documented changes in the 20th century include persistent understory trees that increase the density of montane

Abbreviations: AB, Alberta; AMO, Atlantic Multidecadal Oscillation; c., circa; dbh, diameter at breast height; ENSO, El Niño-Southern Oscillation; JNP, Jasper National Park; m.a.s.l., meters above sea level; PDO, Pacific Decadal Oscillation; PNA, Pacific North American pattern; SEA, superposed epoch analysis; USA, United States of America

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https://doi.org/10.1016/j.dendro.2018.01.002
Received 24 February 2017; Received in revised form 20 January 2018; Accepted 22 January 2018
1125-7865/

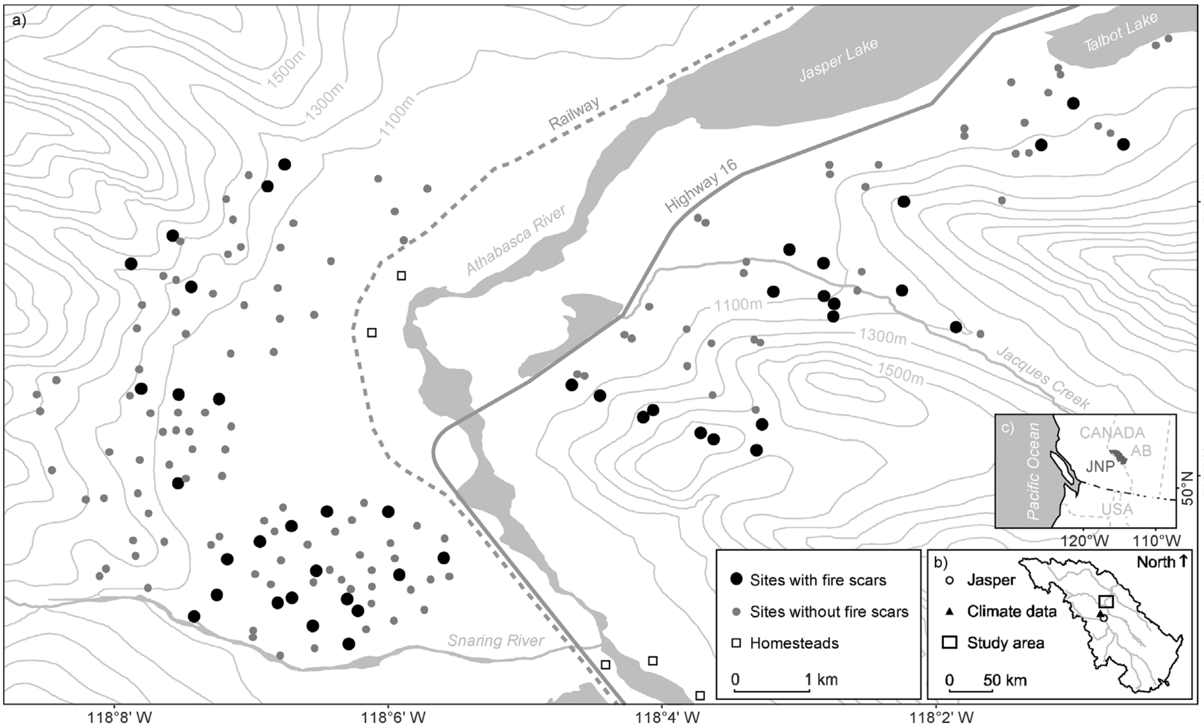

Fig. 1. a) Fire history plots (n = 172) in the Athabasca River valley of Jasper National Park (JNP). b) The study area is 12 km north of the town of Jasper and c) located in Alberta (AB), Canada. Climate data are for the midpoint between Pyramid and Patricia Lakes located 2.5 km northwest of the town of Jasper.

forests (Chavardès and Daniels, 2016) and increased closed-canopy forest cover at landscape scales (Rhemtulla et al., 2002). Whether changes in the fire regime and forest structures were caused by climate, human impacts, or both, remains undetermined.

In many forests of western North America, interannual to multi-decadal climatic variation driven by atmospheric and oceanic circulation has been associated with dry conditions conducive to fire (Kitzberger et al., 2007; Trouet et al., 2006, 2010). The effects of these climatic drivers vary geographically, for example, the El Niño-Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO) have contrasting effects in the southern and northern Rocky Mountains (Schoennagel et al., 2005) and across the continental divide in Canada (Macias Fauria and Johnson, 2006). The effects of the Pacific North American pattern (PNA) extend across western North America (Trouet et al., 2006) and manifest at both interannual and multidecadal scales (Liu et al., 2017), with large fires associated with its positive mode during the 20th century across western North America (Trouet et al., 2006) and in the Canadian Rocky Mountains (Johnson and Wowchuck, 1993). Using Tande's (1979) record of historical fires in Jasper, derived from ring counts on fire-scarred trees, Schoennagel et al. (2005) showed large fires from 1700 to 1975 tended to burn during El Niño conditions coinciding with warm departures of the PDO. Although weak, this pattern is consistent with fire-climate relations in the northern Rockies and Pacific Northwest of the United States (Hessl et al., 2004; Gedalof et al., 2005; Heyerdahl et al., 2008a,b). At multidecadal scales, warm phases of the Atlantic Multidecadal Oscillation (AMO) interact with ENSO and PDO to synchronize historical fires across much of western North America (Kitzberger et al., 2007). To our knowledge, fire-climate relations have not been assessed using a crossdated fire record for Jasper National Park, nor has research on AMO effects extended this far north in the Rocky Mountains.

In some Canadian subalpine and boreal forests, reduced fire frequency has been explained by cooler and wetter climate starting in the mid-1700s and persisting through much of the 20th century (e.g., Johnson et al., 1990; Johnson and Larsen, 1991). In these forests, infrequent crown fires are ignited by lightning and burn large areas, with climate and weather affecting fuel combustibility and controlling fire occurrence, area burned, and severity (Macias Fauria and Johnson, 2008). Underlying this interpretation, historical and contemporary human impacts on the fire regime are assumed to be negligible (Johnson et al., 2001). However, recent research provides compelling evidence that fire suppression has significantly impacted even the crown-fire regimes at landscape scales in some subalpine and boreal forests (Kipfmueller and Baker, 2000; Cumming, 2005; Podur and Martell, 2009), including the Canadian Rocky Mountains (Wierzchowski et al., 2002; Van Wagner et al., 2006; Rogeau et al., 2016). The debate over human impacts on fire regimes, interactions with climate change, and their consequences for effective ecosystem management and restoration (Stephens et al., 2013; Moritz et al., 2014), highlights the need for ecosystem-specific understanding of historical fire regimes and their drivers.

In this study, we examined the role of climatic variation as a driver of historical fire occurrence in the montane forests of Jasper National Park. We present a fire-climate analysis using the first crossdated fire-scar record from a Canadian National Park in the Rocky Mountains. To compare with other research on fire-climate relations in western North America (Hessl et al., 2004; Schoennagel et al., 2005; Kitzberger et al., 2007; Heyerdahl et al., 2008a,b), we tested for associations between historical fire occurrence and tree-ring proxies of drought and interannual to multidecadal drivers of climatic variability. Secondly, we conducted tests to understand how local, historical drought was influenced by these climatic drivers. Ultimately, using both instrumental and proxy-climate records, we assessed whether climatic variation explained the absence of fire in our study area during the 20th century. We combined our results with the well-documented land-use history of Jasper to disentangle the relative importance of climate and humans to explain this observed disruption to the fire regime.