



# Historical conditions in mixed-conifer forests on the eastern slopes of the northern Oregon Cascade Range, USA



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## ABSTRACT

Historical forest conditions in frequent-fire forests may be increasingly useful in guiding contemporary forest management given (1) projections for increased drought stress associated with climate change and (2) increases in vertical and horizontal fuel connectivity related to changes in land use over the past 150 years. Records from a 1922–25 timber inventory reveal historical variability at the landscape-level on mixed-conifer habitats on the eastern slopes of the Cascade Range in northern Oregon. Live conifers >15 cm dbh (diameter at breast height) were tallied by species and diameter class in a 20% sample of over 50,000 hectares (ha). Forests were predominantly low density (66 tph, standard deviation = 32, range = 0–289) relative to current conditions (312 ± 245, 0–1643 tph). Historical basal area averaged 14 ± 7 (0–70) m<sup>2</sup> ha<sup>-1</sup>. Total stand density, large tree (>53 cm dbh) density, and ponderosa pine density were relatively stable across a wide moisture gradient (42–187 cm annual precipitation). Large trees dominated total basal area (73 ± 16%) and comprised 42 ± 17% of total trees per hectare (tph). Ponderosa pine contributed 62 ± 27% of basal area. Together, ponderosa pine and Douglas-fir constituted 91 ± 15% of basal area. Large ponderosa pine and Douglas-fir were nearly ubiquitous across the landscape in this historical data set, occurring on 94% and 83% of transects respectively. Large grand fir occurred on 20% of transects but contributed only 2 ± 6% to large tree basal area. Higher-density values (>120 tph), although rare, were distributed throughout the mixed-conifer habitat while large (>1.6 ha) treeless (no conifers >15 cm dbh) areas were almost entirely restricted to higher elevation, colder, wetter habitat types. Currently ponderosa pine no longer dominates large tree basal area, large trees no longer dominate total basal area, and Douglas-fir is now the dominant species across the landscape. Current mean tree densities are more than four times greater than values recorded in the historical cruise, and current basal area is approximately two times greater. Currently, large trees dominate basal area on only 29% of area inventoried compared to 91% in 1922–25. This systematic sample of a large landscape provides information about variability in species composition, densities, and structures at multiple spatial scales, which are highly relevant to management activities to restore and conserve desired ecosystem functions. Forest conditions comparable to those in this historical record have demonstrated resilience and resistance to fire and drought-related stressors in other frequent-fire forests.

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## 1. Introduction

Proposals for restoring mixed-conifer habitats in dry, frequent-fire forest landscapes in the interior Pacific Northwest (PNW) seek outcomes that balance multiple objectives, including reduction of risk of stand-replacement disturbances and increases in future management options for these ecosystems (Gaines et al., 2010; Franklin and Johnson, 2012; North, 2012; USFS, 2012; Franklin

et al., 2013). Contemporary mixed-conifer forests in dry forest landscapes are highly vulnerable to drought-induced competitive stresses, severe wildfires, and insect outbreaks as a consequence of both past management and changes in climate (see reviews in Perry et al., 2011; Spies et al., 2011; US FWS, 2011; Stine et al., In press). Today, federal managers and stakeholders seek to restore characteristic processes, functions, and structures – especially older trees of fire- and drought-tolerant species – so as to increase the capacity of these ecosystems to adapt to expected increases in temperature and drought stress while maintaining desired ecosystem functions (Stephens et al., 2010; USFS, 2010; Franklin et al., 2013).

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Ecological restoration incorporates relevant information from diverse sources, including historical records. Historical conditions may be useful guides to management designed to conserve or restore desired functions and processes in frequent-fire ecosystems given projections of warmer climate. Increases in insect activity correlate positively with warmer, drier climate over the past several centuries (Pohl et al., 2006; Bentz et al., 2010; Flower et al., 2014). Increases in fire frequency, area burned, and biomass consumed correspond with warmer, drier climate in historical and contemporary records (Heyerdahl et al., 2008; Lutz et al., 2011; Miller et al., 2012; Abatzoglou and Kolden, 2013; Cansler and McKenzie, 2013; Riley et al., 2013; Zhang et al., 2014). Forest conditions comparable to those in other historical records have demonstrated resilience and resistance to fire and other drought-related stressors (Stephens and Fulé, 2005; Stephens and Gill, 2005; Collins and Stephens, 2010). Consistent with these expectations, methods that merge historical conditions with other sources of information are being developed and implemented at both tree and patch scales (Larson and Churchill, 2012; Larson et al., 2012; Churchill et al., 2013) as well as landscape levels (North et al., 2009; USFS, 2010; Hessburg et al., 2013; Moritz et al., 2013).

Structure and composition of mixed-conifer forests vary substantially across the interior PNW as well as along the Cascade Range (which forms the western boundary of the region) for multiple reasons including variation in climate, topography, species distributions, and disturbance history (Perry et al., 2011; Stine et al., *In press*). On the east slopes of the Cascade Range in northern Oregon, mixed-conifer forests are characterized by *Pseudotsuga menziesii* (Douglas-fir) and *Abies grandis* (grand fir) (Franklin and Dyrness, 1988). Dry and moist mixed-conifer habitat types may be differentiated by the abundance of species indicative of mesic site conditions, such as grand fir and associated shrubs and herbs (Marsh et al., 1987; Simpson, 2007; Stine et al., *In press*); however, presence and abundance of these species may vary with disturbance. These mixed-conifer forests are bounded at lower elevations by drier habitat characterized by *Pinus ponderosa* (ponderosa pine) and at upper elevations by wetter and colder habitat types characterized by species such as *Tsuga mertensiana* (mountain hemlock), *Tsuga heterophylla* (western hemlock), *Abies amabilis* (Pacific silver fir), *Abies procera* (noble fir), and *Pinus contorta* (lodgepole pine).

A recently rediscovered 90-year-old timber inventory provides historical landscape-level characterizations of forest structure and composition on mixed-conifer habitats on the eastern slope of the Cascade Range in northern Oregon, USA. In this timber inventory of the Warm Springs Indian Reservation conducted roughly 90 years ago by the Bureau of Indian Affairs (BIA) more than 20% of the area in more than 50,000 ha of mixed-conifer forests was sampled using a systematic strip cruise anchored on documented survey points. Cruisers recorded live conifers at least 15 cm dbh by species and diameter class in 1.6 ha sample units. As a spatially extensive, systematic inventory this data set provides a unique record of historical forest conditions at the landscape level and complements existing historical records and reconstructions for similar forest types. All methods and studies have limitations. The use of multiple sources of information and diverse methods to examine the same or similar systems strengthens our confidence in the inferences drawn from any single study or method.

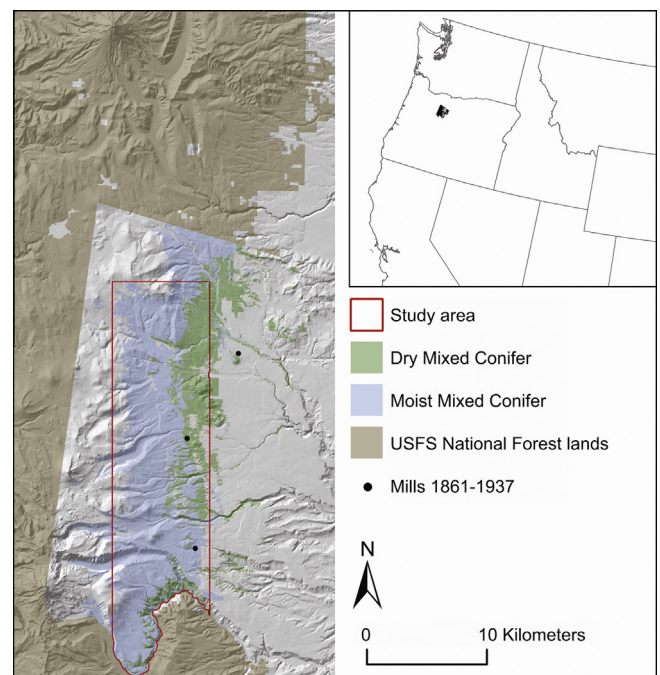
In this paper we summarize these historical data and interpret them in relation to the following questions: (1) what was the structure and composition of forests (conifers >15 cm dbh) on these mixed-conifer sites in the early 20th century; (2) did forest conditions on dry mixed-conifer sites differ from those on moist mixed-conifer sites; and, (3) how do current conditions on these sites differ from this historical record? Our interest in current

conditions on tribal lands is motivated by what this comparison with unique historical data might suggest about conditions and change over time in similar forest types on federal lands. Our purpose is to provide previously scarce data on historical stand- and landscape-level conditions that can be used in developing management goals for ecological restoration of comparable mixed-conifer forests on public lands.

## 2. Methods

### 2.1. Study area and site history

Mixed-conifer habitat on the Warm Springs Indian Reservation (hereafter “Reservation”) extends for roughly 62 km of latitude north along the eastern slopes of the Cascade Range from Mt Jefferson to the southern slopes of Mt Hood (Fig. 1). Located in the rain shadow of the Cascade Range, the Reservation experiences a continental climate. Summers are typically hot and dry with cold nights while winters are cold and snowy. Within the study area, annual precipitation increases with elevation and ranges from 42 cm at the lowest elevations in the study area to 187 cm at the highest (Fig. 2). Minimum January temperatures range from  $-7.0$  to  $-3.4$  °C, and maximum July temperatures range from 19 to 29 °C across the study area. Precipitation and temperature were derived from spatially gridded estimates modeled from point measurements taken at national and local weather stations and averaged over a 30-year period from 1981 to 2010 (PRISM, 2012). Much of the precipitation on these sites falls as snow during the late fall



**Fig. 1.** The Warm Springs Indian Reservation lies south of Mt Hood and encompasses the east slopes of Mt Jefferson east of the crest of the Cascade Range and shares boundaries with National Forest lands. Our study area (red outline) on the Warm Springs Indian Reservation encompasses forests on mixed-conifer habitat types. Habitat classification is represented by the ILAP potential vegetation type map. (See Appendix B for a comparison study results using different vegetation classification models.) Three mills operated intermittently in or near the study area from 1861 to 1937 to provide timber for use on the Reservation. Cruisers noted evidence of logging on tally sheets for transects within a 1.5 km radius of the two mills in the study area. These transects were excluded from the study. Commercial harvests began on the Reservation in the 1940s. An inset map shows the location of the Reservation in the state of Oregon. For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.

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