CHAPTER 8.

Status and Trends of Whitebark Pine Distribution and Health in California, Oregon, and Washington

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INTRODUCTION

Whitebark pine (*Pinus albicaulis* Engelm.) is a keystone species that provides a variety of ecosystem services, such as soil stabilization and protracted snowmelts. Found in many upper subalpine forests in Western North America (Arno and Hoff 1989), whitebark pine is an important high-elevation food source for grizzly bears (Bjoernlie and others 2014) and numerous other wildlife species (Tomback and others 2001, 2014). A rapid, widespread decline in whitebark pine throughout its range has been observed and reported for about 30 years (e.g., Arno 1986, Arno and Hoff 1989, Shanahan and others 2016, Tomback and others 2001). The decline in whitebark pine populations is attributed to white pine blister rust (*Cronartium ribicola*), which damages and kills five-needle white pines (Geils and others 2010); mountain pine beetle outbreaks (Tomback and Achuff 2010); altered fire regimes (Keane 2001, Keane and others 1994, Murray and others 2000); and drought (Shanahan and others 2016).

Most of the current information about whitebark pine health status and trends is based on case studies conducted in selected stands and geographic locations, predominantly in the species range in the Rocky Mountains (e.g., Fiedler and McKinney 2014, Larson and others 2009). Few studies provide information about whitebark pine populations in the Pacific Coast States (California, Oregon, and Washington) (e.g., Goheen and others 2002, Rochefort 2008, Smith and others 2011), and none of them is region-wide. The objectives of this study are (1) to compile the available whitebark pine inventory data in the Pacific Coast States, and (2) use this rangewide inventory dataset to provide statistically based estimates of distribution and health status and trends of whitebark pine populations in California, Oregon, and Washington.

METHODS

We compiled a complete database of the available regional inventory plots in California, Oregon, and Washington that tallied whitebark pine as a seedling or live or dead tree (table 8.1). This included annual U.S. Department of Agriculture, Forest Service, Forest Inventory and Analysis (FIA) plots (Phase 2 grid) and the various National Forest System (NFS) intensifications and special studies, measured between 2001 and 2013. We also compiled data from the older Current Vegetation Survey (CVS) plots measured on Pacific Northwest Region (Region 6) NFS land (different plot design,

Table 8.1—Summary of the available data, including FIA annual data (2001–2013) and spatial and temporal intensification on Pacific Southwest and Pacific Northwest Region (Regions 5 and 6, respectively) National Forest System lands

	Number of plots		Number of trees		
	Plots	Plots, including remeasurements	Live	Dead	Seedlings
California	108	161	2,077	214	241
Oregon	139	177	775	299	342
Washington	173	203	686	624	303
Total	**420**	**541**	**3,538**	**1,137**	**886**

superseded by the FIA inventory). The FIA design consists of a probability sample of one plot every 6,000 acres (Bechtold and Patterson 2005) and up to three times that density on NFS lands outside of a wilderness area. The core sample is divided into 10 interpenetrating panels, measured annually. Thus, the data in this report include a 30 percent remeasurement of the total sample for California and Oregon (2011–2013) and 20 percent for Washington (2012–2013). For each tallied live tree, the FIA inventory collects information about tree damage agents and their location and severity. Because of their severity, both pine blister rust and bark beetles are emphasized in the data collection. For dead trees, the crews assign the cause of death, if possible. Because the main sources of insect and disease mortality are likely to be bark beetles and blister rust, we assumed that whitebark pine trees recorded as killed by insects were killed by bark beetle, and those killed by disease were killed by blister rust. This may result in a slight overestimation of the incidence of those agents if some of the mortality attributed to insects or disease was caused by a different agent. In this report, we present descriptive statistics of the species distribution, the blister rust infections, and bark beetle impact across the three Pacific Coast States.

RESULTS AND DISCUSSION

We identified 420 plots that contained whitebark pine and, as of 2013, 121 were visited more than once (table 8.1). We found that, in the Pacific Coast States, 98 percent of the whitebark pine range is on public land, of which the Forest Service manages approximately 87 percent. Approximately 62 percent of the range is in reserved land such as congressionally designated wilderness areas and National Parks.

The proportion of mature trees that are dead is lowest in California (9 percent), intermediate in Oregon (28 percent), and highest in Washington (48 percent) (table 8.1). Lower whitebark pine mortality in California compared to other regions of Western North America has been previously reported (Millar and others 2012) and is most likely due to the lower observed disease and insect incidents in California compared to the rates in Oregon and Washington (figs. 8.1B and 8.1C). Surprisingly, white pine blister rust was not detected in any of the California inventory plots (fig. 8.1A). Blister rust has been recorded in northern California, and less so in the Southern Sierras. Maloney and others (2012) found high blister rust incidences on eight selected populations in the Lake Tahoe Basin, but Millar and others (2012) sampled the six patches of highest whitebark pine mortality in the Eastern Sierra and did not observe any evidence of blister rust. The low number of dead trees in California supports our finding that, if blister rust is present, it has not drastically increased tree mortality. In contrast, blister rust was detected in 17 percent and 49 percent of the inventory plots in Oregon and Washington, respectively, and the proportion of dead trees reflects those greater detection rates (fig. 8.1B).

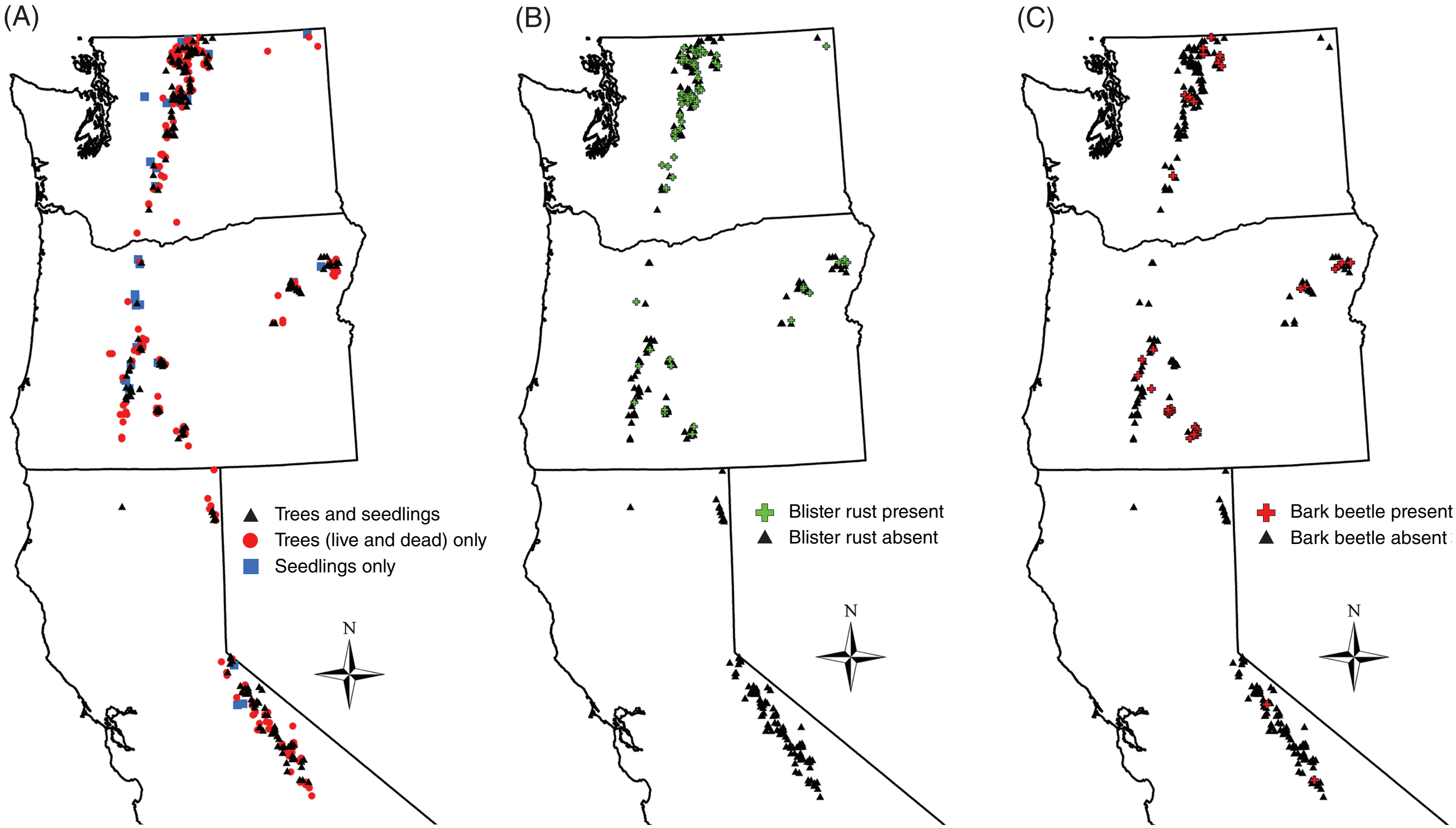

Figure 8.1—Distribution of sample plots with whitebark pine (FIA plot locations are approximate). (A) Total number of plots. (B) Plots with live trees where blister rust was detected. (C) Plots with live trees where bark beetle was detected.

Figures 8.2A and 8.2B show the number of plots measured per year in Washington and Oregon, respectively, along with the number of plots infected by blister rust. In Washington, plots measured in 2012 and 2013 were previously measured in 2002 and 2003, respectively. In Oregon, plots measured in 2011 to 2013 were previously measured in 2001 to 2003. An increase in blister rust incidences in these sets of plots occurred in the 10-year period between remeasurements in both States (figs. 8.2A and 8.2B). Because the number of plots measured per year differs, and different plots were measured each year for the first 10 years of the presented data, we also present the proportion of plots that had blister rust incidents, which increased over time (fig. 8.3A). Smith and others (2008) found increases in blister rust infection levels between 1996 and 2003/2004 in the 170 plots that they established in British Columbia and Alberta, Canada, with highest infection levels close to the U.S. border. Our results show an increase in blister rust incidences from 2001 to 2013 with incidents being most pronounced close to the Canadian border. Our study looks at a fairly short time period (12 years) and tree mortality can vary over time due to a large number of stressors other than insect and disease (e.g., precipitation, temperature). Yet, our reported regional increases in blister rust incidences in Oregon and Washington confirm what other case studies have previously reported at smaller scales.

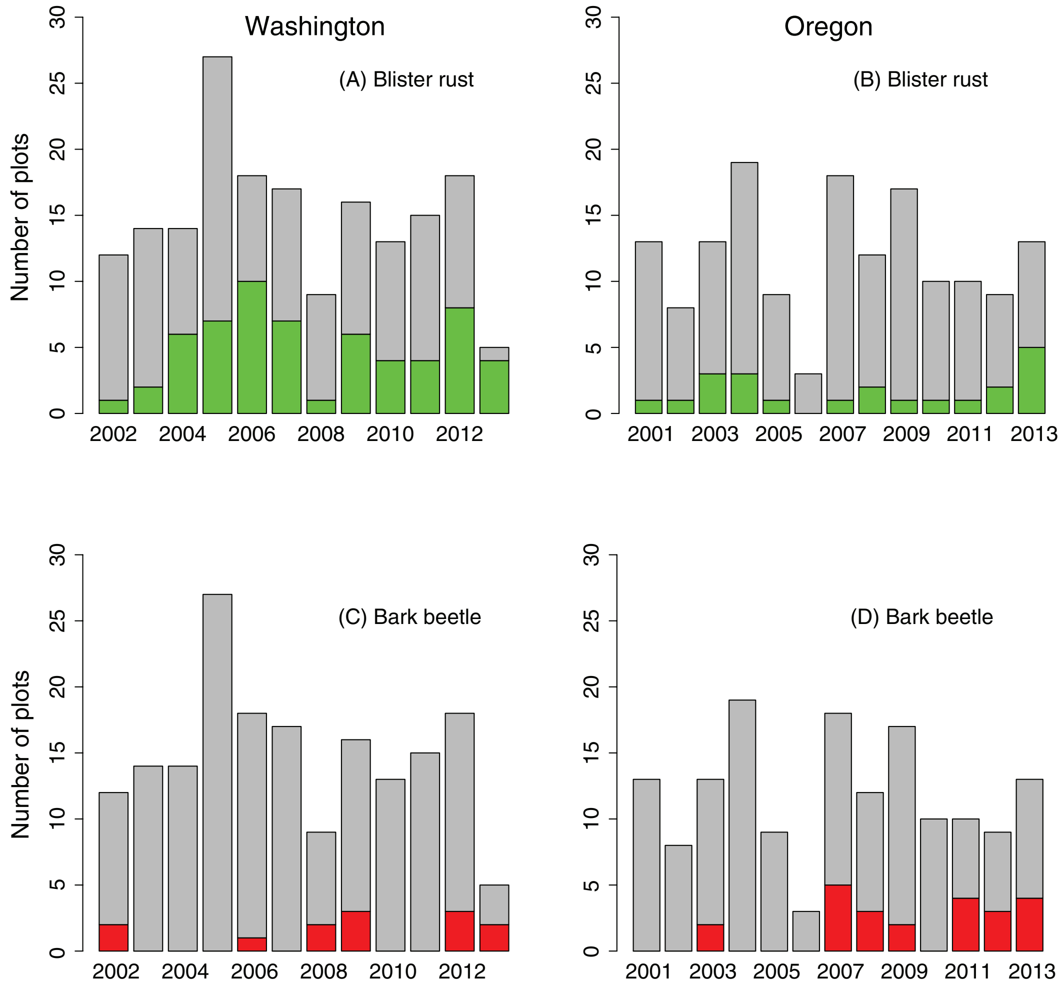

Figure 8.2—Plots where (A, B) blister rust was detected (green) and (C, D) bark beetle was detected (red), with total number of plots measured per year in Washington (left) and Oregon (right).

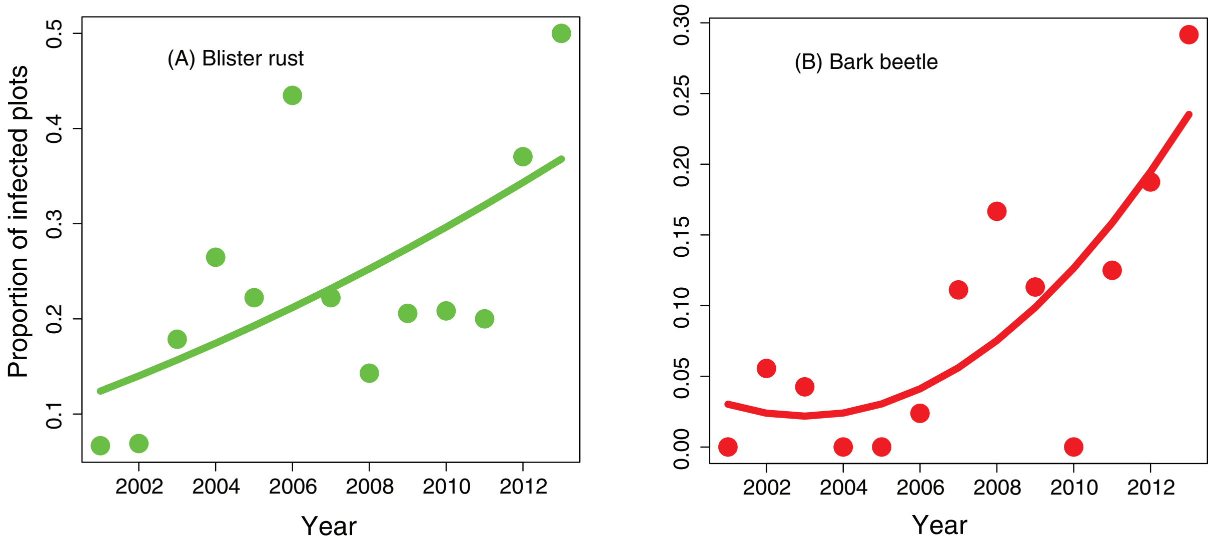

Figure 8.3—Proportions of plots (A) infected by blister rust and (B) attacked by bark beetles in Oregon and Washington combined.

Bark beetle attacks were detected in only 2 percent of the California inventory plots, while 21 percent and 10 percent of the Oregon and Washington inventory plots were attacked by bark beetles, respectively (fig. 8.1C). Millar and others (2012) report extensive bark beetle infestations, which seems to contradict the low observed bark beetle incidents in this study. However, Millar and others (2012) focused their analysis on the 'largest patches of tree mortality in the study region,' which suggests that they selected their study sites based on bark beetle presence. The plots that were remeasured in Washington and Oregon show no or a smaller number of plots with bark beetle attack at the initial measurement and higher numbers of bark beetle plots at the remeasurements (figs. 8.2C and 8.2D). Over time, the proportion of plots attacked by bark beetle increased even more drastically than the proportion of plots with blister rust incidents (fig. 8.3B). Increases in acres with mountain pine beetle-killed whitebark pine have been reported by Gibson and others (2008) based on aerial detection surveys. They reported very low levels of bark beetle-killed areas in California from 1998–2005 and observed slight increases in 2006 and 2007. For Oregon, they observed moderate levels up to 2005 with large increases in 2006 and 2007. In Washington, the amount of acres with beetle-killed whitebark pine has been at high levels since 2001.

The number of tallied seedlings and live or dead mature trees (table 8.1, fig. 8.1A) shows that the proportion of seedlings is higher in the northern portion of the whitebark pine species range in the Pacific Coast States. Shanahan and others (2016) found that bark beetles preferentially attacked larger whitebark pine trees and that smaller trees with white pine blister rust exhibited higher mortality than larger trees. Their findings suggest a shift from large to smaller-sized trees as large, mature trees are attacked and killed by bark beetle. The current distribution of seedlings and mature trees may be used as a surrogate for range shift. However, the difference between the mean temperature of the range of seedlings and that of mature trees was not statistically significant (Monleon and Lintz 2015), which suggests that the population shift may be due to causes other than warming climate. This coincides with findings in British Columbia, Canada, where local climate variables showed weak or no relationship with whitebark pine mortality (Campbell and Antos 2000).

Inventory plots sample the entire range of whitebark pine and, therefore, are well suited to provide region-wide estimates of the conditions and status of its population. However, as the inventory plots in the compiled regional whitebark pine database were measured with various sampling intensities, with varying remeasurements and measurement periods, standard design-based approaches cannot easily be applied. Therefore, we are working on developing spatio-temporal models that account for these varying spatial and temporal dependencies in the dataset. Specifically, we are developing spatial copula models (e.g., Madsen 2009) that allow the incorporation of spatial and temporal dependence structures as well as non-normally distributed response variables. The application of these new models allows us to make use of all available inventory data instead of the base grid FIA plots without temporal intensification. Therefore, we will be able to provide information on the status and trend of whitebark pine health at a finer spatial and temporal scale than would be possible with the base grid FIA plots.

CONCLUSIONS

There is a clear north-south trend in blister rust incidence, with most incidences observed in Washington and none in the southern whitebark pine range in California. The least amount of bark beetle attacks was observed in California. The higher incident rate of bark beetle attacks in Oregon and Washington may be due to already weakened whitebark pine trees due to blister rust infections. The proportion of plots infected by blister rust as well as the proportion of plots attacked by bark beetles increased over time. Washington showed the largest proportion of dead trees. Because there is considerable variability in spatial and temporal sampling intensity, it is impossible to use design-based sampling estimation. Spatio-temporal models have to be employed to account for the complexity of the sampling design, the different number of measurements, and variable time between measurements when temporal trends and regional variation in mortality, recruitment, and incidence of insect and disease are estimated.

CONTACT INFORMATION

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