

Monitoring direct and indirect climate effects on whitebark pine ecosystems at Crater Lake National Park

By Sean B. Smith, Dennis C. Odion, Daniel A. Sarr, and Kathryn M. Irvine

WHITEBARK PINE (*PINUS ALBICAULIS*) GROWS IN tree line habitats throughout the American West, where freezing temperatures, snow, and strong winds can occur any day. Such harsh conditions exclude most other tree species. Tight groups of wind-sculpted and gnarled whitebark pine can form in these extreme sites. These distinct krummholz formations disperse wind and aid in snowpack retention. Subalpine areas occupied by whitebark pine provide inspiring views for national park visitors.

Whitebark pine is threatened by an invasive, nonnative pathogen, white pine blister rust (*Cronartium ribicola*) (MacDonald and Hoff 2001), a fungus that forms lesions, or cankers, of necrotic tissue that girdle tree boles or stems (fig. 1). To complete its life cycle, the fungus must disperse from the pines to an alternative host, a shrub in the genus *Ribes* (currant and gooseberry) or the herbs *Castilleja* (Indian paintbrush) and *Pedicularis* (lousewort) (Geils et al. 2010).

Plump, fleshy, and nutritious whitebark pine seeds are eaten and dispersed by many animals. In particular, Clark's nutcracker (*Nucifraga columbiana*) has developed a mutualistic relationship with the pine (Tomback 2001). This boisterous, robin-sized bird with flashy black-and-white wings and tail has a specialized pouch under its tongue for storing seeds, which it caches widely in the soil. Seeds that are not eaten by the nutcracker maintain populations of the pine. McKinney et al. (2009) found that nutcrackers decrease in whitebark stands as tree mortality increases.

In a study of historical data from sites in and around Crater Lake National Park, Daly et al. (2009) noted significant increases in average and winter temperatures, but no change in precipitation over the last 100 years. The implications of recent climate change for the whitebark pine ecosystem are complex and likely to operate through direct and indirect mechanisms. The most significant, observable effect of climate change is indirect: warmer temperatures in recent years have allowed mountain pine beetles (*Dendroctonus ponderosae*) to shift upward and persist in higher-elevation forests (Logan et al. 2010). Murray (2010) reported that mountain pine beetle is now the primary cause of whitebark pine mortality at Crater Lake, presently at a rate of 1% annually from all causes. Other indirect, pathogen-related effects could occur

Abstract

Whitebark pine (*Pinus albicaulis*) is the distinctive, often stunted, and picturesque tree line species in the American West. As a result of climate change, mountain pine beetles (*Dendroctonus ponderosae*) have moved up in elevation, adding to nonnative blister rust (*Cronartium ribicola*) disease as a major cause of mortality in whitebark pine. At Crater Lake National Park, Oregon, whitebark pine is declining at the rate of 1% per year. The Klamath Network, National Park Service, has elected to monitor whitebark pine and associated high-elevation vegetation. This program is designed to sample whitebark pine throughout the park to look for geographic patterns in its exposure to and mortality from disease and beetles. First-year monitoring has uncovered interesting patterns in blister rust distribution. Incidence of rust disease was higher on the west side of the park, where conditions are wetter and more humid than on the east side. However, correlating climate alone with rust disease is not straightforward. On the east side of the park, the odds of blister rust infection were much greater in plots having *Ribes* spp., shrubs that act as the alternate host for a portion of the rust's life cycle. However, on the park's west side, there was not a statistically significant increase in blister rust in plots with *Ribes*. This suggests that different species of *Ribes* associated with whitebark pine can increase pine exposure to blister rust disease. There is also convincing evidence of an association between total tree density and the incidence of blister rust. Warmer temperatures and possibly increased precipitation will affect both whitebark pine and *Ribes* physiology as well as tree density and mountain pine beetle numbers, all of which may interact with blister rust to cause future changes in tree line communities at Crater Lake. The Klamath Network monitoring program plans to document and study these ongoing changes.

Key words

blister rust, climate change, Crater Lake National Park, disease susceptibility monitoring, mountain pine beetle, whitebark pine

if climate increasingly favors blister rust. For example, the rust favors moister conditions, and increased precipitation in winter is an expected trend under climate change in the Pacific Northwest. Conversely, summers may be drier and inhibit the formation and spread of rust spores and fruiting body development. Daly et al. (2009) noted an increasing tendency for the summer dry season to extend into early fall at Crater Lake and elsewhere in the Oregon Cascades over the last few decades. Direct effects of longer, high-elevation growing seasons because of climate change could



Figure 1. Whitebark pine with an active blister rust infection (canker).

favor the pines, as many high-elevation trees are growing more rapidly today (Bunn et al. 2005). However, direct effects of longer growing seasons could increase competition among pines and other trees that can grow faster than the notoriously slow-growing whitebark pines. This could act as an indirect effect that places the pine at a competitive disadvantage, especially if whitebark pine populations cannot migrate quickly enough to competition-free environments like those in which they presently live.

Whitebark pine and its associated community of species are among the vegetation resources identified for long-term, focused monitoring by the Klamath Inventory and Monitoring Network of the National Park Service. This monitoring is designed to complement park monitoring of whitebark pines at Crater Lake National Park (Murray 2010). The network's monitoring is also specifically designed to help identify factors related to whitebark pine infection and mortality from disease and beetles, and to track changes in all high-elevation vegetation structure, function, and composition related to climate and other factors. By tracking disease progression and beetle impacts, as well as vegetation change, we can link observed changes to direct and indirect climate-mediated mechanisms and determine the effects of climate change and other factors on whitebark pine. The network has completed its first year of monitoring, sampling 20 plots at Crater Lake National Park. We briefly highlight our initial findings here.

Whitebark pines are more exposed to rust spores if they are associated with Ribes that are more susceptible to blister rust. . . . The roles of tree density, alternative hosts, and geography will need to be sorted out through focused research and continued monitoring.

Key findings

The leading cause of whitebark pine mortality was indirectly related to climate change: mountain pine beetle. Beetles caused 21% of tree deaths, followed by mortality from blister rust (20%), a pattern consistent with findings of Murray (2010). However, 54% of trees had an indeterminable cause of death. We also found that active infections were more common on the west (11%) than on the east side of the park (4%) ($P = 0.04$). There was convincing evidence of a positive association between tree density and the probability of a tree having evidence of a blister rust infection (logistic regression, $P < 0.01$; fig. 2, next page). One hypothesis explaining this finding is that increased competition for resources where tree density is highest may make whitebark pines more susceptible to blister rust. This would suggest that if longer growing seasons under future climate continue to cause increased tree growth and density at higher elevations, blister rust may be favored.

There was also evidence suggesting that the east-to-west geographic pattern is mediated, in part, by the alternative hosts, *Ribes* species. Plots with *Ribes* on the east side of the park had a higher incidence of blister rust than those without *Ribes*, but this was not the case on the west side (fig. 2). We can only speculate on explanations for this finding. For example, species of *Ribes* differ in their susceptibility to blister rust infection (Maloy 1997). Whitebark pines are more exposed to rust spores if they are associated

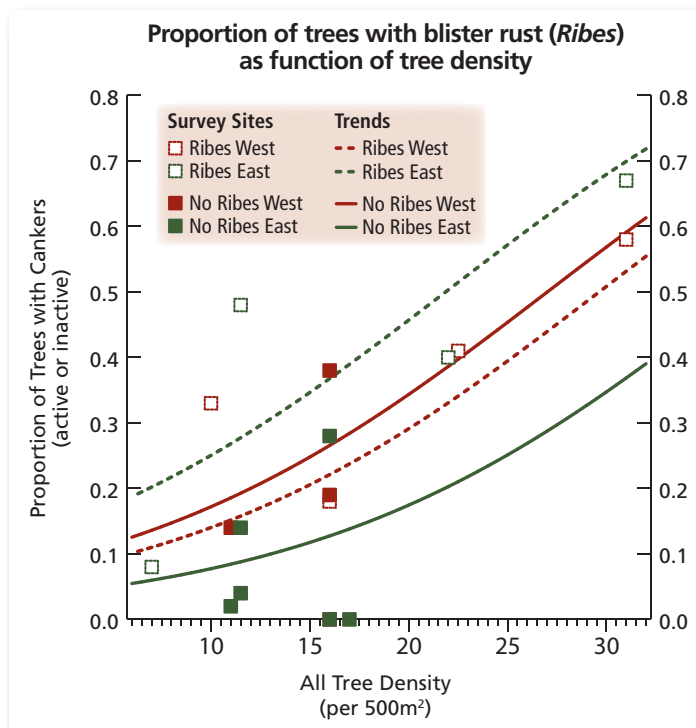


Figure 2. As tree density increases by one tree per 500 m² (598 yd²), the odds of blister rust infection increase by a factor of 1.09 (95% confidence interval: 1.02–1.17). Although the rate of change is the same for plots with or without *Ribes* located on the west or east side of Crater Lake National Park, sites with *Ribes* on the east side tend to have the highest proportion of infected trees.

with *Ribes* that are more susceptible to blister rust, as *Ribes* with high susceptibility are more likely to become infected and transmit spores. Additional research may provide insight into the roles of individual *Ribes* species and possible interactions with climate.

These initial findings suggest that climate change sets in play a complex array of direct, indirect, and potentially confounding changes in whitebark pine ecosystems. The roles of tree density, alternative hosts, and geography will need to be sorted out through focused research and continued monitoring, but it is already clear that increased mountain pine beetle activity associated with warming temperatures is adding to the loss of an estimated one-third of whitebark pine since the arrival of blister rust in the 1930s. Multifaceted monitoring by the Klamath Network and by Crater Lake National Park will allow the National Park Service to track future change in the pines, pathogens, and composition of the associated vegetation community. It will also help the Service to identify genetically resistant trees for use in propagation programs, to aid the park's future whitebark pine restoration efforts (Murray 2010). In addition, we plan to implement whitebark pine monitoring at Lassen Volcanic National Park in California.

Literature cited

- Bunn A. G., L. J. Graumlich, and D. L. Urban. 2005. Trends in twentieth-century tree growth at high elevations in the Sierra Nevada and White Mountains, USA. *Holocene* 15:481–488.
- Daly, C., J. Smith, and M. Doggett. 2009. An assessment of temporal and spatial trends in historical climate data for the Klamath network parks. Unpublished report on file. National Park Service, Klamath Network Inventory and Monitoring Program, Ashland, Oregon, USA.
- Geils, B. W., K. E. Hummer, and R. S. Hunt. 2010. White pine, *Ribes*, and blister rust: A review and synthesis. *Forest Pathology* 40:147–185.
- Logan, J. A., W. W. Macfarlane, and L. Wilcox. 2010. Whitebark pine vulnerability to climate-driven mountain pine beetle disturbance in the Greater Yellowstone Ecosystem. *Ecological Applications* 20:895–902.
- MacDonald, G. I., and R. J. Hoff. 2001. Blister rust: An introduced plague. Pages 193–220 in D. F. Tomback, S. F. Arno, and R. E. Keane, editors. *Whitebark pine communities: Ecology and restoration*. Island Press, Washington, D.C., USA.
- Maloy, O. 1997. White pine blister rust control in North America: A case history. *Annual Review of Phytopathology* 35:87–109.
- McKinney S., C. E. Fiedler, and D. F. Tomback. 2009. Invasive pathogen threatens bird-pine mutualism: Implications for sustaining a high-elevation ecosystem. *Ecological Applications* 19(3):597–607.
- Murray, M. 2010. Will whitebark pine not fade away? *Park Science* 27(2):64–67. Online (<http://www.nature.nps.gov/parkscience/index.cfm?ArticleID=417>). Accessed 4 March 2011.
- Tomback, D. F. 2001. Clark's nutcracker: Agent of regeneration. Pages 89–104 in D. F. Tomback, S. F. Arno, and R. E. Keane, editors. *Whitebark pine communities: Ecology and restoration*. Island Press, Washington, D.C., USA.

About the authors

Sean B. Smith and **Daniel A. Sarr** are with the Klamath Inventory and Monitoring Network, National Park Service, Southern Oregon University, Ashland, Oregon. They can be reached by e-mail at sean_b_smith@nps.gov and dan_sarr@nps.gov, respectively.

Dennis C. Odion is with the Department of Environmental Studies, Southern Oregon University, Ashland, Oregon. His e-mail address is dennis@odion.name. **Kathryn M. Irvine** is a research statistician with the U.S. Geological Survey, Northern Rocky Mountain Science Center, in Bozeman, Montana. Her e-mail address is kirvine@usgs.gov.