Establishing the Science Foundation to Sustain High-elevation, Five-needle Pine Forests Threatened by Novel Interacting Stresses in Four Western National Parks

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High-elevation, five-needle white pines are among the most picturesque trees in many national parks as well as other federal, state, and private lands in western North America. These trees often live to a great age; the trees' gnarled trunks give testimony to fierce winds that buffet them on exposed rocky sites. Ancient limber pines (*Pinus flexilis*) in Rocky Mountain National Park occupy the edge of Trail Ridge Road, and a remarkable old giant stands sentinel on the shore of Lake Haiyaha. Limber pines accompany Rocky Mountain bristlecone pines (*P. aristata*) on the exposed ridges around Mosca, Medano, and Music passes in Great Sand Dunes National Park and Preserve and Great Basin bristlecone pines (*P. longaeva*) top Wheeler Peak and Mount Washington in Great Basin National Park. Whitebark pines (*P. albicaulis*) grace the rim of Crater Lake and slopes of Mount Scott in Crater Lake National Park. Although the species may occur in only small areas within a park, they are ecologically invaluable to landscape dynamics and biodiversity and are vital for watershed protection (Tomback and Achuff 2010).

Whitebark and limber pine are declining across many parts of their range in the United States and Canada because of invasion by the non-native pathogen *Cronartium ribicola* that causes the lethal disease white pine blister rust (WPBR) and because of outbreaks of native mountain pine beetles (*Dendroctonus ponderosae*), which are further exacerbated by fire exclusion and a changing climate (Keane and Schoettle 2011). These conditions have resulted in inadequate population size to sustain recovery processes in some whitebark pine ecosystems and has led to whitebark pine's endangered species status ("warranted but precluded") under the Endangered Species Act (US Fish and Wildlife Service 2011). Foxtail pine (*P. balfouriana*), southwestern white pine (*P. strobiformis*), Great Basin bristlecone pine, and Rocky Mountain bristlecone pine have not yet experienced the major declines observed in northern distributions of limber and whitebark pines, but they too are in imminent dan-

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ger from WPBR and beetles. Restoring declining populations and sustaining the remaining healthy populations present unique challenges for land managers.

In the early to mid-1900s, several parks, including Crater Lake and Rocky Mountain, participated in efforts to eradicate *Ribes* species, the alternate host to WPBR, in attempt to slow the pathogen's spread. The practice was later deemed ineffective and abandoned in the West, and the rust continues to invade forest ecosystems. A full spectrum of infection intensities and impacts to the white pines are displayed within the national park system. The northern parks, such as Glacier, Mount Rainier and North Cascades, closest to the point of accidental introduction of the pathogen, have been infected for more than 60 years and have the heaviest impacts. Only 5–10% of the whitebark pine trees in Glacier National Park remain alive today due to WPBR and bark beetles. More moderate impacts can be found in Crater Lake National Park, the Greater Yellowstone Ecosystem, and other mid-latitude parks and monuments. Further south, WPBR was confirmed in Great Sand Dunes National Park and Preserve in 2003 (Blodgett and Sullivan 2004) and Rocky Mountain National Park in 2010 (Schoettle et al. 2011). Though impacts by WPBR are currently low in Rocky Mountain National Park, mountain pine beetle has caused high mortality among the pines and recovery of the limber pine forests may be significantly impacted in the presence of WPBR (Field et al 2012). New infection centers are being found yearly in the Southern Rockies; it is clear that the pathogen is still spreading and is now a permanent resident of our landscapes.

Intervention in wilderness: A management challenge

While not all national park lands are designated wilderness, there is agreement that the parks' backcountry is to be managed consistent with the wilderness philosophy. The Wilderness Act of 1964 provides guidance regarding intervention in wilderness areas. Central concepts in the act include the goals of restricting trammeling and preserving naturalness. Naturalness as a desired attribute of wilderness character implies both a lack of human impact (i.e., trammeling) and control (Cole and Yung 2010). Directional selective factors introduced by human activities, such as invasion by a lethal non-native disease such as WPBR, impacts the naturalness of a wilderness and challenges the concept of naturalness as a goal when it is likely that restricting trammeling (i.e., intervention) will not lead to recovery. In the face of impacts and threats such as WPBR and climate change, managers must decide between (1) increasing historical fidelity with intervention, (2) accepting change that will result from less intervention or control, and (3) transforming the ecosystem into a future state not true to the past but with greater resilience (Aplet and Cole 2010). Case-by-case analyses are needed to balance the maintenance of wilderness character with management for ecosystem health. As such, strategies to build the science foundation to provide site-based understanding of ecosystem conditions, processes, and trajectories under different intervention options (including the no action option) have been developed and are being implemented to assist managers in making informed decisions in a timely manner.

Building the science foundation to sustain and restore healthy ecosystems

In this paper, we review the progress of Rocky Mountain, Great Basin, Great Sand Dunes, and Crater Lake national parks in building a science foundation to aid in the development of conservation strategies for high-elevation, five-needle pine ecosystems (Table 1). Due to the current impacts or threat of impacts, each of these parks considers their five-needle pine species of conservation concern. The science provides an assessment of the ecosystems and reduces the uncertainty related to possible outcomes of interventions and consequences of inaction. Depending on the intensity of impact, efforts are focused on developing (1) restoration activities in declining landscapes ("restoration strategy") and/or (2) proactive interventions in threatened ecosystems to mitigate future impacts ("proactive strategy") (Keane and Schoettle 2011). Rocky Mountain, Great Basin, and Great Sand Dunes national parks are currently following the proactive strategy approach and Crater Lake National Park the restoration strategy approach. Restoration treatments can slow impacts and rebuild impacted populations and proactive interventions can help prepare the landscape for invasion to mitigate the severity of future impacts. These programs may also provide conservation areas or refugia for the pines. The goal of both approaches is to conserve the species and promote self-sustaining five-needle pine ecosystems in the presence of WPBR using available tools and methods that are compatible with land use designations. Interagency collaboration between the national park service and US Forest Service has facilitated the progress of these programs in each park.

Sustaining population resilience requires maintenance of recovery capacity after disturbance and genetic diversity to support adaptive capacity over time. Therefore, conservation approaches must consider a long-term and evolutionary perspective and adaptation to climate change (Schoettle et al. 2012). Tree longevity is not enough for multigenerational sustainability; sustainability depends on an intact regeneration cycle and, in the presence of WPBR, increased disease resistance to support recovery capacity. These conservation programs include in situ and ex situ genetic conservation, evaluating parent trees for genetic resistance to WPBR, pine regeneration dynamics, planting trials, and monitoring forest health stressors. These programs provide a science foundation from which conservation plans are currently being drafted for Crater Lake National Park (Beck and Holm 2013) and Rocky

Table 1. Status of white pine blister rust in the four western National Parks discussed in this paper. "RM bristlecone pine" refers to Rocky Mountain bristlecone pine; "GB bristlecone pine" to Great Basin bristlecone pine.

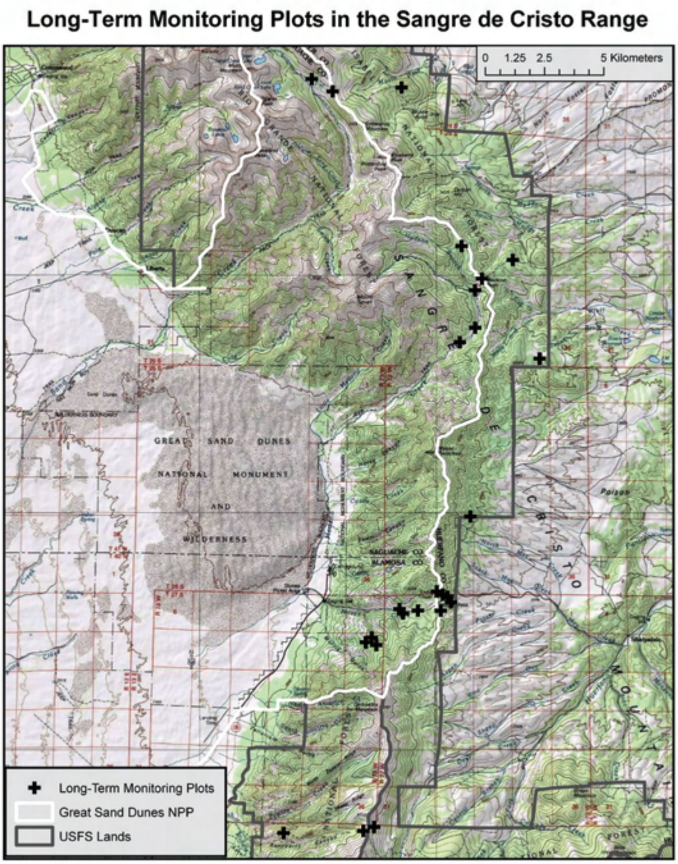
National Park	Species	WPBR first confirmed	Current WPBR incidence	Active program initiated
Great Sand Dunes	Limber pine RM bristlecone pine	2003 2003	13% localized	2004
Rocky Mountain	Limber pine	2010	0% (eradicated?)	2008
Great Basin	GB bristlecone pine Limber pine	— —	0% 0%	2011
Crater Lake	Whitebark pine	1941	25% widespread	2003

Mountain National Park. They provide knowledge pertinent to the greater geographic areas and contribute to knowledge on the pines, WPBR, and disturbance dynamics in these mountain ecosystems.

Sampling framework

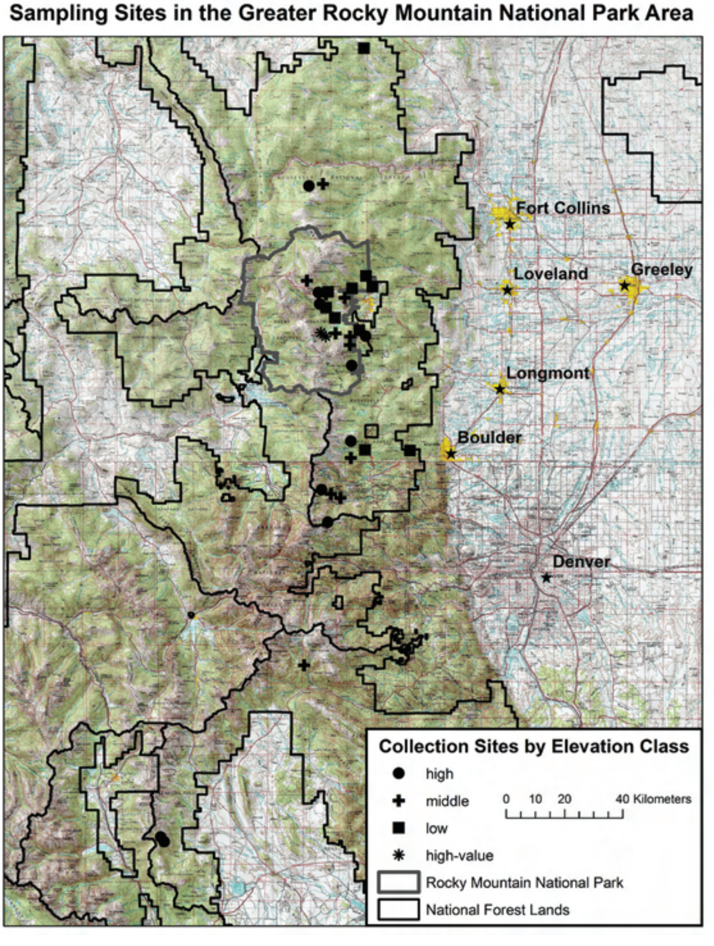
Each of the four parks discussed here has established a different sampling design for their high-elevation pine programs. Crater Lake National Park initiated WPBR incidence assessments in 2000 and 2002 by establishing 24 transects in whitebark pine stands (Murray and Rasmussen 2003); additional transects and plots have been added to the network recently (Smith et al. 2011; McKinney et al. 2012). At Great Sand Dunes National Park and Preserve, 28 long-term monitoring plots were installed in 2004 radiating out from the initial WPBR infection center (Figure 1; Burns 2006). In 2008, Rocky Mountain National Park and the US

Figure 1. Location of long-term monitoring plots in and around Great Sand Dunes National Park and Preserve (adapted from Burns 2006). The plots were first installed in 2004 and remeasured in 2012 and 2013. Plots include Rocky Mountain bristlecone and limber pine trees; seed collections of both species have been made in the Mosca Pass area.



Forest Service established 17 limber pine sites in the park and 10 sites outside the park to serve as the sampling framework for the limber pine conservation project (Figure 2; Schoettle et al. 2011). This cross-boundary network of sites (populations) was stratified by elevation to capture the full breadth of limber pine habitats in the greater geographic area. In addition, long-term monitoring plots were installed in 10 of the 17 sites within the park in 2013. Great Basin National Park established three areas of concentration in 2011 and further sampling is planned.

Figure 2. Network of limber pine sites in (17 sites and 2 high-value tree sites) and around (10 sites) Rocky Mountain National Park that serve as the sampling framework for the limber pine conservation program (adapted from Schoettle et al. 2011). The sites were selected to represent the diversity of limber pine habitats in the park. The sites are stratified by elevation; the mean elevation of low, moderate, and high elevation sites is 2740 m, 3080 m, and 3320 m, respectively (full elevation range of the sites is 2450–3430 m). Seed collections, forest health and regeneration assessments, and verbenone deployment have been the focus in these limber pine populations. In 2013, long-term monitoring plots were installed in 10 of the sites within the park.



Ex situ genetic conservation

Across these four parks, extensive seed collections are now archived and comprise some of the first gene conservation collections for the parks (Table 2). These collections provide insurance against impacts of climate change, seed material for testing progeny of parent trees for resistance to WPBR, and baseline materials for genetic studies to detect changes in diversity in the future. Initial whitebark pine seed collections in Crater Lake National Park were obtained from healthy trees in stands heavily impacted by WPBR for resistance testing, an approach utilized in tree improvement programs for the commercial white pine species, and more recently has expanded throughout the park's whitebark pine distribution (Figure 3). Similarly, Rocky Mountain bristlecone and limber pine individual-tree seed collections in Great Sand Dunes National Park and Preserve are concentrated near the WPBR infection areas and not directly associated with the plot networks. A sampling approach more typical for conservation programs has been adopted by Rocky Mountain and Great Basin national parks, where WPBR is thought to be currently absent. Individual-tree seed collections and a bulked seed collection have been collected from each of the 27 limber pine populations in and around Rocky Mountain National Park (Figure 2). Seed collections of Great Basin bristlecone pine began in 2011 in Great Basin National Park and more extensive collections are planned park-wide for both Great Basin bristlecone and limber pine.

In situ protection and conservation

Active protection of seed trees from mountain pine beetle and fire, when feasible, is ongoing.

Table 2. The number of individual-tree and bulked seed collections made to date from five-needle pine species in each of the four parks, the number of seed lots currently in WPBR resistance testing at the USFS Dorena Genetic Resource Center (Cottage Grove, OR) and, for those tests that are completed, the number of individual-tree seed lots that demonstrated signs of WPBR resistance is reported in parentheses (number with resistance/number tested). The seed collections are also archived for ex situ conservation. Rocky Mountain bristlecone pine from other locations in Colorado have shown evidence for genetic resistance to WPBR, yet no lots from within Great Sand Dunes National Park and Preserve have been tested. This table does not differentiate among the types of resistance found yet it is accepted that populations with greater diversity of resistance mechanisms will be the most resilient. In most cases, additional testing is needed to comprehensively quantify the diversity of WPBR resistance types present in each species and park. "RM bristlecone pine" refers to Rocky Mountain bristlecone pine; "GB bristlecone pine" to Great Basin bristlecone pine.

National Park	Species	Individual-tree seed collections	Seed lots in WPBR resistance testing	Resistance found?
Great Sand Dunes	Limber pine RM bristlecone pine	39 13	23 (0 from park)	Yes (6/23) (Yes)
Rocky Mountain	Limber pine	213 + 44 bulk	124 + 16 bulk	Yes (18/87)
Great Basin	GB bristlecone pine Limber pine	9 + 1 bulk Planned	9 + 1 bulk Planned	In process Planned
Crater Lake	Whitebark pine	101	70	Yes (16/35)

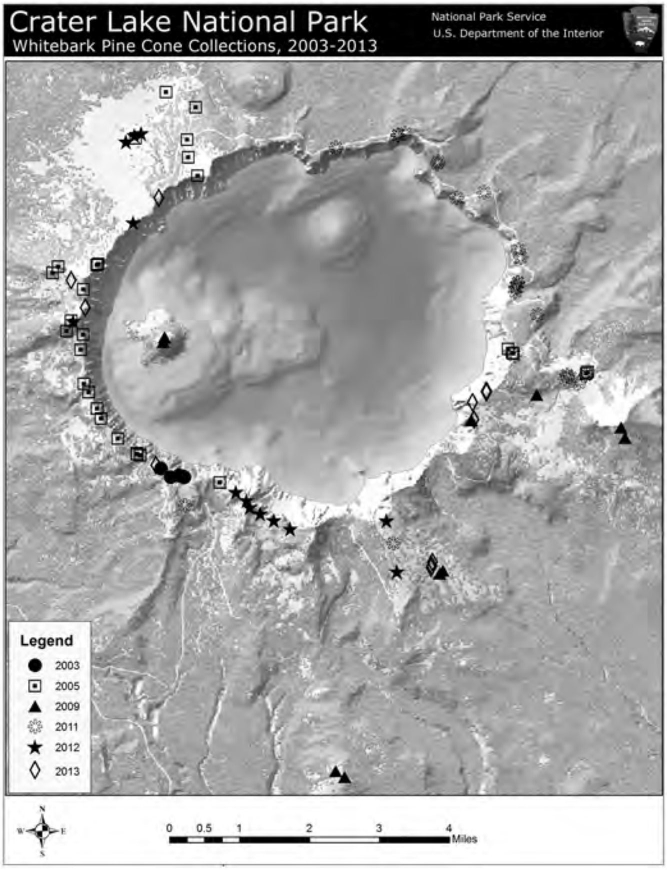


Figure 3. Whitebark pine seed tree locations in Crater Lake National Park by seed collection year.

These trees are an important component of the long-term conservation strategy. When progeny tests from these trees indicate that the seed tree has heritable resistance to WPBR, additional seed collections are made to build seed stocks for planting or seeding. In Crater Lake National Park in recent years, mountain pine beetle has surpassed WPBR as the primary mortality agent of whitebark pine and has killed several seed trees with genetic resistance to WPBR; mountain pine beetle has likewise caused extensive mortality of limber pine in Rocky Mountain National Park. In these parks and Great Basin National Park, an anti-aggregation pheromone (verbenone) is used to repel mountain pine beetle and provide in situ protection of the seed trees from which seed collections have been and continue to be made. Additional mature limber pine trees are also protected from mountain pine beetle in Rocky Mountain National Park to help support natural regeneration as well as several limber pine trees that are of high value to park visitors. The seed trees in both Rocky Mountain and Crater Lake national parks are listed as resources at risk for potential protection from wildfire. Mountain pine beetle activity is low in Great Sand Dunes National Park and Preserve, so *in situ* protection of the seed trees has not been necessary thus far.

WPBR resistance trials

Reducing the effect of disease on survival and fecundity by increasing heritable disease resistance is essential to sustaining impacted pine populations. WPBR resistance testing is a progeny test requiring artificial inoculation of pine seedlings with *C. ribicola* in a nursery setting followed by disease assessments. The testing process can take two to seven years, depending on the resistance mechanism being investigated. Several testing centers administered by the US Forest Service operate in the western United States (Sniezko et al. 2011); the testing of the plant material from these parks is being conducted at Dorena Genetic Resource Center (Cottage Grove, Oregon). Past studies revealed disease resistance in each North American five-needle pine species and the current studies demonstrate an encouraging frequency of genetic resistance within the national parks (Table 2).

Because the seed sources from Rocky Mountain National Park and Great Basin National Park were sampled without bias toward disease-free trees in the field (in areas with no WPBR present), these resistance trials provide estimates of the baseline frequencies of resistance in the native pine populations. These frequencies and their geographic distributions provide valuable information for designing, prioritizing, and evaluating management options (Schoettle et al. 2013). Healthy populations in which resistance is present at moderate frequency can be (1) seed sources for outplanting in similar habitats with less resistance and (2) managed to facilitate rust resistance selection and therefore accelerate the evolution of resistance throughout the population once WPBR invades (Schoettle and Sniezko 2007). A common garden study for limber pine was also conducted for Rocky Mountain National Park seed sources to identify genetic differentiation among populations and guide seed transfer decisions should outplanting or assisted migration be recommended.

Planting trials and natural regeneration dynamics

In populations with few or no WPBR-resistant parent trees, planting or direct-seeding resistant stock may be needed to sustain the community. In addition, planting may be recommended to increase the population size, if natural regeneration is sparse. Planting studies help define the techniques for high seedling survival and can verify field expression of rust resistance identified in the WPBR resistance trials. Crater Lake National Park has installed four whitebark pine restoration plantings since 2009 (total of 939 seedlings). Survival has been over 77% so far and as high as 90% for one trial four years after planting. Limber pine plantings at Great Sand Dunes National Park and Preserve have also demonstrated over 70% survival four years after planting (Casper et al., in preparation). These and other trials suggest that planting can be successful and feasible in these high-elevation habitats. Thus far, planting in Crater Lake and Great Sand Dunes national parks has been outside of designated or proposed wilderness. Planting WPBR-resistant seedlings may be acceptable within some wildernesses after following the proper National Environmental Policy Act (NEPA) process, as it has been practiced with whitebark pine in Glacier National Park for the past 10 years and is being considered on national forest wilderness lands in the Pacific Northwest. Rocky Mountain National Park is 95% wilderness and a strategic plan being developed will help in deciding appropriate actions for both inside and outside wilderness.

For the high-elevation, five-needle pines, generation time is very long and seedling establishment after disturbance is protracted. These species are tolerant of stresses under which they have evolved, but are not well equipped, without additional regeneration opportunities, for rapid adaptation to novel stresses such as WPBR in a changing climate (Field et al. 2012). A study three decades after the stand-replacing Ouzel Fire of 1978 revealed high regeneration capacity of limber pine in Rocky Mountain National Park (Coop and Schoettle 2009); geographic variation in regeneration among the limber pine study sites in and around Rocky Mountain National Park will add further information. At Great Sand Dunes National Park and Preserve, seedling densities of limber pine and Rocky Mountain bristlecone pine are being assessed through repeat measurement of the established plot network.

Integration and application

Building a timely, solid science foundation assists in the careful consideration of the consistency of interventions, and consequences of no interventions, with park and wilderness policies and values as the ecosystems are challenged by non-native diseases or other factors. This knowledge reduces the uncertainty in projecting outcomes of interventions or inactivity to improve trade-off analyses as managers assess their options; it can also feed into economic analyses as well (Bond et al. 2011). Under wilderness conditions where the impacts of inadvertent human trammeling through WPBR introduction and climate change may be grave, the concept of maintaining naturalness may not provide sufficient guidance for wilderness management. A shift toward another concept may be needed; perhaps one that focuses on maintaining diversity to support natural processes of continued evolution. Through productive interagency collaborations and partnerships, each of these parks is using science to responsibly and creatively conserve and manage their resource for increased resilience to these novel interacting stresses.

References

Aplet, G.H., and D.N. Cole. 2010. The trouble with naturalness: Rethinking park and wilderness goals. In *Beyond Naturalness: Rethinking Park and Wilderness Stewardship in an Era of Rapid Change*. D.N. Cole and L. Yung, eds. Washington, DC: Island Press,12–29.

Beck, J., and G. Holm. 2013. *Draft Crater Lake National Park Whitebark Pine Conservation Plan*. Crater Lake, OR: Crater Lake National Park.

Blodgett, J.T., and K.F. Sullivan. 2004. First report of white pine blister rust on Rocky Mountain bristlecone pine. *Plant Disease* 88: 311.

Bond, C.A., P. Champ, J. Meldrum, and A.W. Schoettle. 2011. Investigating the optimality of proactive management of an invasive forest pest. In *The Future of High-Elevation, Five-Needle White Pines in Western North America: Proceedings of the High Five Symposium*. R.E. Keane, D.F. Tomback, M.P. Murray, and C.M. Smith, eds. RMRS-P-63. Fort Collins, CO: US Department of Agriculture–Forest Service, Rocky Mountain Research Station, 295–302.

Burns, K.S. 2006. *White Pine Blister Rust in the Sangre de Cristo and Wet Mountains of Southern Colorado*. U.S. Department of Agriculture–Forest Service, Rocky Mountain Region, Renewable Resources. Biological Evaluation R2-06-05. Online at www.fs.fed.us/r2/fhm/.

Cole, D.N., and L. Yung. 2010. Park and wilderness stewardship: The dilemma of management intervention. In *Beyond Naturalness: Rethinking Park and Wilderness Stewardship in an Era of Rapid Change*. D.N. Cole and L. Yung, eds. Washington, DC: Island Press,12–29.

Coop, J.C., and A.W. Schoettle. 2009. Regeneration of Rocky Mountain bristlecone pine (*Pinus aristata*) and limber pine (*Pinus flexilis*) three decades after stand-replacing fires. *Forest Ecology and Management* 257: 893–903.

Field, S.G., A.W. Schoettle, J.G. Klutsch, S.J. Tavener, and M.F. Antolin. 2012. Demographic projection of high-elevation white pines infected with white pine blister rust: a nonlinear disease model. *Ecological Applications* 22: 166–183.

Keane, R.E., and A.W. Schoettle. 2011. Plenary paper: Strategies, tools, and challenges for sustaining and restoring high elevation five-needle white pine forests in Western North America. In *The Future of High-Elevation, Five-Needle White Pines in Western North America: Proceedings of the High Five Symposium*. R.E. Keane, D.F. Tomback, M.P. Murray, and C.M. Smith, eds. RMRS-P-63. Fort Collins, CO: US Department of Agriculture–Forest Service, Rocky Mountain Research Station, 276-294.

McKinney, S.T., T. Rodhouse, L. Chow, A. Chung-MacCoubrey, G. Dicus, L. Garrett, K. Irvine, S. Mohren, D. Odion, D. Sarr, and L.A. Starcevich. 2012. *Monitoring White Pine (Pinus albicaulis, P. balfouriana, P. flexilis) Community Dynamics in the Pacific West RegionóKlamath, Sierra Nevada, and Upper Columbia Basin Networks: Narrative Version 1.0*. Natural Resource Report NPS/PWR/NRRó2012/532. Fort Collins, CO: National Park Service.

Murray, M.P., and M.C. Rasmussen. 2003. Non-native blister rust disease on whitebark pine at Crater Lake National Park. *Northwest Science* 77: 87–90.

Schoettle, A.W., B.A. Goodrich, J.G. Klutsch, K.S. Burns, S. Costello, R.A. Sniezko, and J. Connor. 2011. The proactive strategy for sustaining five-needle pine populations: An example of its implementation in the Southern Rocky Mountains. In *The Future of High-Elevation, Five-Needle White Pines in Western North America: Proceedings of the High Five Symposium*. R.E. Keane, D.F. Tomback, M.P. Murray, and C.M. Smith, eds. RMRS-P-63. Fort Collins, CO: US Department of Agriculture–Forest Service, Rocky Mountain Research Station, 323–334.

Schoettle, A.W., J.G. Klutsch, and R.A. Sniezko. 2012. Integrating regeneration, genetic resistance, and timing of intervention for the long-term sustainability of ecosystems challenged by non-native pests: A novel proactive approach. In *Proceedings of the Fourth International Workshop on the Genetics of Host-Parasite Interactions in Forestry: Disease and Insect Resistance in Forest Trees*. R.A. Sniezko, A.D. Yanchuk, J.T. Kliejunas, K.M. Palmieri, J.M. Alexander, and S.J. Frankel, tech. coords. General Technical Report PSW-GTR-240. Albany, CA: US Department of Agriculture–Forest Service, Pacific Southwest Research Station, 112–123.

Schoettle, A.W., and R.A. Sniezko. 2007. Proactive intervention to sustain high-elevation pine ecosystems threatened by white pine blister rust. *Journal of Forest Research* 12: 327–336.

Schoettle, A.W., R.A. Sniezko, A. Kegley, and K.S. Burns. 2013. White pine blister rust resistance in limber pine: Evidence for a major gene. *Phytopathology* (in press). Online at http://dx.doi.org/10.1094/PHYTO-04-13-0092-R .

Smith, S.B., D.A. Sarr, D.C. Odion, and K.M. Irvine. 2011. Research report: monitoring direct and indirect climate effects on whitebark pine ecosystems at Crater Lake National Park. *Park Science* 28(2): 92–94.

Sniezko, R.A., M.F. Mahalovich, A.W. Schoettle, and D.R. Vogler. 2011. Plenary paper: Past and current investigations of the genetic resistance to *Cronartium ribicola* in high-elevation five-needle pines. In *The Future of High-Elevation, Five-Needle White Pines in Western North America: Proceedings of the High Five Symposium*. R.E. Keane, D.F. Tomback, M.P. Murray, and C.M. Smith, eds. RMRS-P-63. Fort Collins, CO: US Department of Agriculture–Forest Service, Rocky Mountain Research Station, 246–264.

Tomback, D.F., and P. Achuff. 2010. Blister rust and western forest biodiversity: Ecology, values, and outlook for white pines. *Forest Pathology* 40(3–4): 186–225.

US Fish and Wildlife Service. 2011. Endangered and threatened wildlife and plants; 12-month finding on a petition to list *Pinus albicaulis* as endangered or threatened with critical habitat. *Federal Register* 76(138): 42631–42654.

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