EXOTIC PATHOGENS, RESISTANT SEED AND RESTORATION OF FOREST TREE SPECIES IN WESTERN NORTH AMERICA

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Abstract

Non-native invasive pathogens such as white pine blister rust (*Cronartium ribicola*) and Port-Orford-cedar root disease (*Phytophthora lateralis*) are killing trees and disrupting forest ecosystems in western North America. Populations of western white pine (*Pinus monticola*), sugar pine (*P. lambertiana*), whitebark pine (*P. albicaulis*), and limber pine (*P. flexilis*) are declining precipitously from

damage by blister rust. Foxtail pine (*Pinus balfouriana*) and southwestern white pine (*P. strobiformis*) populations are also infected by blister rust in parts of their range. *Phytophthora lateralis* continues to spread and kill Port-Orford-cedar (*Chamaecyparis lawsoniana*) in Oregon and California. Because resistant individuals in all these species are rare, genetic variation may be reduced to the point where future populations may not be viable without active management. Seeds from resistant parents are now available for western white pine, sugar pine, and Port-Orford-cedar restoration for some areas. Selection and breeding programs for resistance, coupled with active ecological management, will be needed to create opportunities to restore and retain these species in forest ecosystems on federal or crown lands. Restoration strategies for maintaining these species on the landscape must include planting resistant stock and increasing any opportunities for natural regeneration until resistance characterizes populations, and they are able to continue to evolve in the continued presence of the pathogens. Scientists and the public will have difficult decisions to face regarding actions to take in wilderness areas and national parks.

Problem

Non-native invasive pathogens are having large impacts on natural ecosystems in western North America (Tomback et al. 1995; Campbell and Schlarbaum 2002). Two prominent examples include Cronartium ribicola, which causes white pine blister rust, and Phytophthora lateralis, which causes Port-Orford-cedar root disease (Hunt 1997; Hansen 1997; Jules et al. 2002). Blister rust is rapidly killing five-needled white pines, and disrupting the associated ecosystems (Kendall and Keane 2001; McDonald and Hoff 2001). Port-Orford-cedar root disease is killing Port-Orford-cedars, particularly in riparian areas (Jules et al. 2002). Both pathogens continue to spread geographically and to intensify infection levels in many locations (Kendall and Keane 2001; USDI-BLM and USDA-FS 2004). As a consequence we are losing major forest habitat types, and the biodiversity and ecosystem services they provide (Hunt 1997; Fins et al. 2001; Tomback et al. 2001; Jules et al. 2002; 2003USDI-BLM and USDA-FS 2004).

Trees resistant to these pathogens are present in the forests, but in many cases they are too rare and may be too widely scattered to provide adequate regeneration as well as broad genetic diversity to maintain these species (Fins et al. 2001; Hoff et al. 2001; Kinloch et al. 2003; Kegley and Sniezko 2004). Active management will be essential if white pines and Port-Orford-cedar are to continue as vital ecosystem components (Hoff et al. 2001; USDI-BLM and USDA-FS 2004).

White Pine Blister Rust

Inadvertently introduced to the West in 1910, white pine blister rust has spread across the range of five-needled white pines (McDonald and Hoff 2001). All eight of the western North American species of white pines are susceptible to this pathogen (Childs and Bedwell 1948, Hoff et al. 1980). These pines occur in ecosystems from near sea level to tree line. Six of these eight species have already been impacted—several severely (McDonald and Hoff 2001). Prior to 2003 there were no known cases of bristlecone pine with blister rust infection in natural stands, but blister rust was known to occur dangerously near both the ancient Great Basin bristlecone pines (*Pinus longaeva*) in California and the Rocky Mountain bristlecones (*Pinus aristata*) in Colorado. In 2003, infection was discovered on a Rocky Mountain bristlecone in southern Colorado (Blodgett and Sullivan 2004). As these white pines are killed, the associated ecosystems also decline, altering western forest landscapes. In addition, these white pines are all fire dependent, and have declined due to past fire exclusion policies and resulting successional replacement (Tomback 2003; Tomback and Achuff, in preparation).

Three pines, southwestern white (*Pinus strobiformis*), western white, and sugar pine, are important to local logging economies (Kinloch 1984; Lowery 1984; Fins et al. 2001). The sugar pine and western white pine industries have already suffered major collapse (Graham 1990; Kinloch and Scheuner 1990). Whitebark pine, limber pine, both bristlecone pines, and foxtail pine are important high elevation species that stabilize soils and regulate snowmelt (Farnes 1990; Tomback et al. 2001).

White pine forests comprise large tracts of land in western National Forests and Wilderness Areas and National Parks in the United States, and Crown Lands in western Canada. Disruption of these ecosystems threatens local economies, alters fire regimes and ecosystem function, and degrades the aesthetic beauty of these lands (e.g., Fins et al. 2001; Tomback and Achuff, in preparation). In the Kootenays of British Columbia, extensive stands of western white pine have been replaced by less valuable western hemlock (Hunt et al. 1985). Less than 10% of the historic five million acres of western white pine cover type remains in today's Inland Northwest forests (Fins et al. 2001). On a smaller scale, white pine blister rust has killed all western white pine in the Champion Mine area on the Umpqua National Forest (Sniezko, personal communication). Similarly, dead whitebark pine is prevalent throughout the higher elevations of Glacier National Park and the surrounding National Forests and Bob Marshall Wilderness Complex (Kendall and Keane 2001). White pine blister rust will make recovery of these species difficult, if not, impossible without human intervention.

Whitebark Pine: a Case History

Whitebark pine is the most widely distributed white pine in the western United States and Canada, inhabiting upper subalpine and treeline elevations (Arno and Hoff 1990; Tomback and Achuff, in preparation), Because of inaccessibility, slow growth rates, and its shrubby growth form, the species has not been commercially valuable. Whitebark pine, however, provides keystone services as a wildlife food source and as a pioneering species in community development after fire (Tomback et al. 2001; Tomback and Kendall 2001). In the Greater Yellowstone

Area, whitebark pine ecosystems are designated critical habitat for grizzly bear (*Ursus arctos*). Only recently, has the widespread damage and mortality from blister rust in whitebark pine communities gained serious attention (e.g., Tomback et al. 2001; Tomback 2003).

Surveys since the 1990's show moderate to heavy blister rust infection and mortality in many parts of the range of whitebark pine in both the U.S. and Canada (reviewed in: Kendall and Keane 2001; Tomback 2003). For example, since the 1930's approximately 26% of the whitebark pine has died from blister rust in Crater Lake National Park in the southern Cascades of Oregon. By 2050, it is estimated that the decline in mature whitebark in the western portions of the Park will be 46% (Murray and Rasmussen 2003). In a recent survey along the Pacific Crest National Scenic Trail on the Umpqua National Forest, over half the trees present had been infected with blister rust (Goheen et al. 2002). In the Northern Rockies, the average infection rate in 337 plots was 84% (Kendall and Keane 2001; Tomback 2003). For many whitebark pine populations in areas of moderate to high infection, rust-resistant seedlings will be needed to restore the species.

Restoration Options: White pines

Several experimental projects in recent years have explored techniques for restoring white pines. A pioneering series of demonstration projects for whitebark pine restoration were initiated by Keane and Arno (2001) in west-central Montana. These projects are being monitored for successful tree recruitment over time. The techniques used by Keane and Arno (2001) comprise the basic restoration strategy for all declining white pines. They include (1) silvicultural thinning and in some cases use of prescribed fire to provide regeneration opportunities for these pines; allowing wildfire to burn where possible; (2) planting seeds and seedlings with high probabilities of rust resistance; and (3) using silvicultural tools (e.g. pruning [Hunt 1998], risk hazard rating [Hunt 1983]) to help minimize the impact of the disease in high priority forest stands.

Prescribed fire and silvicultural thinning are more likely to be successful and more cost efficient in areas of lower disease hazard or in stands with low infection levels of blister rust. However, these techniques alone are not sufficient to increase the frequency of rust-resistant individuals on the landscape. It is inevitable that rust-resistant stock will need to be planted in order to establish white pine populations that will continue to co-exist with blister rust (Fins et al. 2001). More experimental work is needed to develop specialized and effective techniques for each five-needled white pine species. The necessity for planting resistant populations and implementing restoration techniques for white pine species is now well recognized (USDA Forest Service 2003).

Over the last 40 years, genetically rust-resistant stock has been developed for some western white pine and sugar pine populations by evaluating thousands of trees to find the rare, naturally occurring resistant trees (Fins et al. 2001; Sniezko and Kegley 2003; Kegley and Sniezko 2004; McDonald et al. 2004; Hunt, in press). The resistant trees are placed in seed orchards to produce seedling populations that are genetically diverse and rust resistant. Another strategy used for western white pine in British Columbia is seed collection from seed production areas, which have been developed by culling cankered trees and retaining the putative resistant ones (Meagher et al. 1987). Screening programs for disease resistance have recently begun for whitebark pine and should be feasible for the remaining susceptible pines as well (Mahalovich and Dickerson 2004; Sniezko, personal communication). In addition, information is required on seed transferability of the high elevation white pines — that is, how far seeds can be moved within a species' range and still maintain good survival and adaptability. Common garden studies have been used to establish seed movement guidelines for western white pine and sugar pine (Campbell and Sugano 1987; Campbell and Sugano 1989).

Techniques now utilized in evaluating western white pine and sugar pine for resistance can likely be applied to other white pine species as well. In addition, tools from molecular genetics may make it simpler and less expensive to identify parent trees with natural resistance (Ekramoddoullah and Hunt 2002).

Port-Orford-cedar Root Rot

Phytophthora lateralis was introduced to the native range of Port-Orford-cedar around 1952. This root pathogen is killing all size classes of Port-Orford-cedar, particularly in riparian areas of northwest California and southwestern Oregon (USDI-BLM and USDA-FS 2004). Port-Orford-cedar is an important component of these forest ecosystems, in addition to being a valuable species for timber and specialty products (Hansen et al. 2000). In areas of high disease incidence, we are unlikely to see many old growth trees again unless action is taken. Private landowners are unlikely to replant Port-Orford-cedar without the availability of resistant seedlings, thus decreasing species diversity over the landscape.

Restoration Options: Port-Orford-cedar

The major management strategies for Port-Orford-cedar are: management to slow the spread of the disease (e.g. road closures), and use of seeds or seedlings from the resistance program to restore areas of high mortality where large Port-Orford-cedar is desired. Activities to slow or prevent the spread of Port-Orford-cedar root disease have received major emphasis in the past, and will continue to be the primary focus (USDI-BLM and USDA-FS 2004). Other management activities such as planting resistant Port-Orford-cedar will potentially have an important role where disease is already present or where new infestations occur (USDI-BLM and USDA-FS 2004).

The frequency of natural resistance to *Phytophthora lateralis* may be too low and scattered in native Port-Orford-cedar ecosystems for successful natural regeneration in areas of highest disease incidence (USDI-BLM and USDA-FS 2004). Since 1997, the operational resistance program has made significant progress in finding trees with natural resistance, establishing seed orchards and producing seed for some areas (Sniezko et al. 2000; Sniezko and Hansen 2003; Sniezko et al. 2003; USDI-BLM and USDA-FS 2004; Sniezko et al. this proceedings). Traditional methods of selection and breeding allow us to bring together rare resistant Port-Orford-cedar trees for cross-pollination. Seeds from these pollinations can generate populations of genetically diverse, adapted, and resistant trees for restoration. However, the resistance program is relatively new and more work is needed to provide resistant populations for all areas (USDI-BLM and USDA-FS 2004). Guidelines are being developed to aid managers in determining where resistant seedlings could be used and where to limit their use (USDI-BLM and USDA-FS 2004). Field trials have been established to monitor the effectiveness of resistance on an array of sites.

A Dilemma

The fact that National Parks and designated wilderness areas are also severely impacted by these pathogens raises pressing management issues (See Tempel et al. [2003] for discussion on research needs for managing non-native species in wilderness areas). Traditionally, these lands are considered reasonably intact ecosystems without need for active management (e.g., McCool and Freimund 2001). We face the quandary of doing nothing and watching the destruction of white pine and cedar ecosystems, or, with public and government support, we evaluate on a case-by-case basis the need to restore white pines and Port-Orford-cedar in wilderness areas against other wilderness values. Similar considerations will be needed in National Parks. We recognize that both of these pathogens and fire exclusion are *anthropogenic* in origin, which could support some level of management action.

Conclusion

Ecologists, pathologists, geneticists, silviculturists, land managers, and the public will have to work together to reverse population declines and restore ecosystems damaged by these introduced pathogens. The development of resistant tree populations offers an opportunity to counter some of the effects of these pathogens. It will be a long-term process, but with concerted efforts, responsible land stewardship can be accomplished. Intervention to restore more natural conditions in wilderness may be evaluated case-by-case, and weighed against other wilderness values. Organizational and implementation strategies that are developed for managing white pine blister rust and Port-Orford-cedar root disease can provide a starting point for work involving other introduced pathogens. Restoration work with these species should provide insights that will be useful in dealing with other non-native invasive insects and pathogens.

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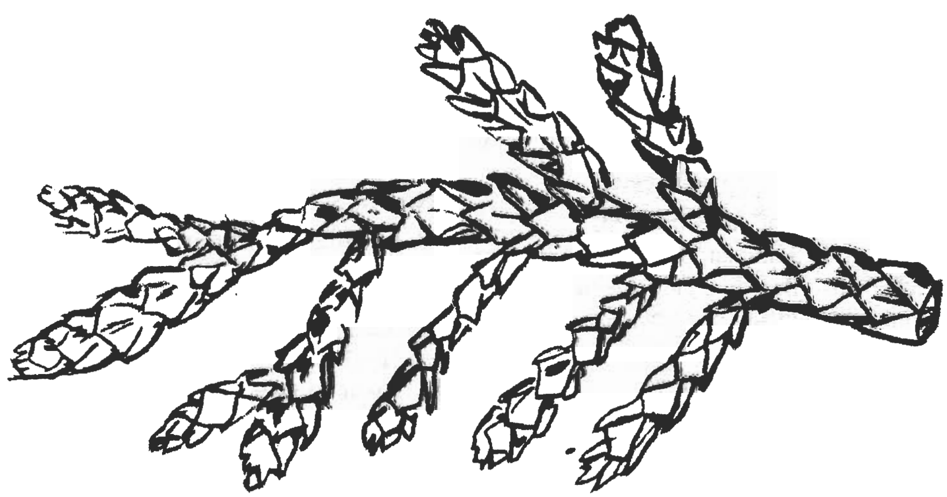

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