Preparing the Landscape for Invasion – Early Intervention Approaches for Threatened High Elevation White Pine Ecosystems

Schoettle Anna W.[1]; Sniezko, Richard A.[2]; Burns, Kelly S.[3]; and Freeman, Floyd [4]

[1] USDA Forest Service, Rocky Mountain Research Station, Fort Collins, CO
[2] USDA Forest Service, Dorena Genetic Resources Center, Cottage Grove, OR
[3] USDA Forest Service, Forest Health Management, Lakewood, CO
[4] USDA Forest Service, San Isabel National Forest, Salida District, Salida, CO

White pine blister rust is now a permanent resident of North America. The disease continued to cause tree mortality and impact ecosystems in many areas. However, not all high elevation white pine ecosystems have been invaded; the pathogen is still spreading within the distributions of the whitebark, limber, foxtail, Rocky Mountain bristlecone pine and has yet to infect Great Basin bristlecone pines. While the heavily impacted areas are in need of immediate management to restore ecosystem function, management of the threatened areas to position them to avoid development of severe impacts upon invasion is also an immediate need – as the disease intensifies, time is running out (Schoettle 2004b).

Increasing the frequencies of durable resistance or tolerance traits within tree populations is accepted as a promising avenue for the co-existence of native tree species and non-native pathogens. Two of the five strategies for proactive management of high elevation 5-needle pine ecosystems (Schoettle and Sniezko, *in press*) will contribute to evolutionary change toward greater resistance in the pine species:

(a) Increasing the frequency of resistance through introduction of resistant stock, via artificial regeneration, to sustain forest cover (Option 4 in Schoettle and Sniezko, *in press*) and

(b) Accelerating natural selection for resistance through age class diversification to sustain populations (Option 5 in Schoettle and Sniezko, *in press*).

Artificial regeneration with resistant pine stock is a well accepted strategy for management of many pathosystems including the white pine blister rust system (Samman et al. 2003). A proactive application of this strategy requires that resistant stock be planted before or soon after pathogen invasion, thereby lowering the risk of ecosystem collapse by reducing the window between overstory mortality and reproductive maturity of the resistant outplantings (Option 4 in Schoettle and Sniezko, *in press*). The resistant genotypes can be identified from areas that have experienced extensive pathogen-caused mortality and transferred to the target management area or identified from screening of on-site genotypes using standard techniques (i.e. Danchok et al. 2003). Both approaches require considerable resources: the first requires a thorough understanding of geographic variation in physiological traits, focused family rust-resistance screening and validated seed transfer guidelines while the second requires extensive genotype rust-resistance screening.

Early intervention to accelerate the selection for rust resistant individuals while sustaining ecosystem function may be an effective, affordable alternative for high elevation 5-needle pine forests (Option 5 in Schoettle and Sniezko, *in press*). Generation of a mosaic of diverse age classes will provide trees at a highly susceptible life stage (young) to promote rust-resistance selection within that cohort while the older trees hold site occupancy and provide ecosystem services during pathogen invasion (Schoettle, 2004b; Schoettle and Sniezko, *in press*). Accelerating the generation time and natural selection process through silvicultural treatments will reduce the ecological consequences of mortality in any one cohort and increases the potential for development of durable resistance within the population while maintaining broad genetic diversity.

Both of these strategies, applied singly or together, will increase the frequency of resistance on the management unit as well as benefit near-by populations through gene flow. Increasing resistance on accessible portions of the landscape will, over time, improve resistance in the next cohort of pines on neighboring harsh, inaccessible yet highly valuable areas. In heavily impacted areas or high hazard areas, populations may need to be supplemented with resistant stock. However, if sufficient resistance is in the native population, and the hazard or infection level is low, stimulating natural regeneration may be sufficient to increase the proportion of resistance to sustain ecosystem function in the presence of the pathogen.

A program to support the application of these strategies in the threatened Rocky Mountain bristlecone pine and limber pine forests of the Southern Rockies is ongoing. White pine blister rust is in the early stages of invasion in these susceptible high elevation ecosystems (Schoettle 2004a). To aid in the development and testing of silvicultural prescriptions for this objective, spatial and temporal dynamics of regeneration of limber and bristlecone pine are being defined. To improve decision making ability and prioritization of intervention, the frequency of rust resistance is being estimated for bristlecone and limber pine populations of the Southern Rockies. The geographic distribution of adaptive traits is also being studied. This information can be combined with climate change estimates to improve seed transfer guidelines and outplanting procedures. Guidelines for selecting putatively resistant seed trees are being developed for low rust incidence areas. Silvicultural prescriptions to stimulate regeneration are being developed, implemented and tested for limber pine and Rocky Mountain bristlecone pine forests on the San Isabel National Forest (Colorado). Seed collections have been initiated to archive genetic diversity and prepare for artificial regeneration projects to restore impacted areas of the Medicine Bow National Forest (Wyoming).

Both the artificial regeneration and the stimulation of natural regeneration strategies have been recommended for application in whitebark pine ecosystems (Schwandt 2006). Likewise, maximizing population size through natural regeneration is among the recommendations for management of small Port-Orford-cedar stands threatened by *Phytophthora lateralis* in northwest California and southwest Oregon (Frank Betlejewski, personal communication (Interregional Port-Orford-Cedar Program Manager, SW Oregon Forest Insect and Disease Service Center, Central Point OR)).

As with any intervention strategy and especially for those in the high elevation wildlands that support 5-needle pines, involvement and acceptance by diversity constituents is essential if these threatened ecosystems are to be sustained into the future. An educational website to increase the awareness of the high elevation white pine species, their ecosystems and the threats that face them is now available on-line (Schoettle et al. 2006).

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