Modeling the potential distribution of white pine blister rust in the central Rocky Mountains

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Introduction

Cronartium ribicola (J. C. Fischer ex Rabh.), the causal agent of white pine blister rust (WPBR), was introduced to western North America via infected nursery stock imported from France to Point Grey near Vancouver, British Columbia (Mielke 1943). Primary infection of white pines occurs on the needles where fungal spores land, enter through stomata, grow within the vascular tissue, and then enter branches and stems. The fungus grows in the intercellular spaces within the bark of white pines where the production of spores breaks apart the bark causing the girdling of branches and stems; the ultimate result of which is tree death (Tainter and Baker 1996). White pine blister rust through its disruption of vascular tissues and bark affects white pines by reducing their growth and reproductive potential, eventually killing the pine host and, in turn, affecting community structure and composition by removing the host from the community (Kendall and Arno 1990).

White pine blister rust has been present in northwestern Wyoming since the 1940s and in central Wyoming since the 1970s (Brown 1978), but has only recently been observed in Colorado. The disease was first reported in Colorado in 1998 with the area of highest infection located within approximately 18 km of the Wyoming border (Johnson and Jacobi 2000). In 2003, isolated WPBR infestations were discovered in the Wet and Sangre de Cristo Mountains of southern Colorado, more than 300 miles away from other known infections. Limber pines (*Pinus flexilis*) are infected in these new areas, but the first natural infections on Rocky Mountain bristlecone pine (*P. aristata*) were also discovered (Blodgett and Sullivan 2004), heightening concern about rust spreading throughout populations of limber, southwestern white (*P. strobiformis*), and bristlecone pines in the southern and central Rocky Mountains.

Research Objectives

The objectives of this project were to examine the current status of WPBR and to develop models that predict the likelihood of disease occurrence in and damage to native white pine populations in the central Rocky Mountains. White pine blister rust epidemiology is strongly affected by genetics, profusion of inoculum, nearness and distribution of hosts, and microclimate (Geils et al. 1999). In order to develop these predictive models, we attempted to characterize interactions between white pine and *Ribes* hosts, the pathogen, and environmental conditions, and how these interactions change through time.

Methods

To achieve these objectives we performed a survey of limber pine throughout central and southeastern Wyoming and northern Colorado. At each of 504 established survey plots, a series of transects in which the condition of limber pine and the occurrence and density of *Ribes* by species were recorded. In addition, an extensive *Ribes* survey consisting of 758 plots was conducted to determine

[1] In: Guyon, J.C. comp. 2006. Proceedings of the 53rd t Western International Forest Disease Work Conference; 2005 September 26-30; Jackson, WY. U.S. Department of Agriculture, Forest Service, Intermountain Region, Ogden UT

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This research was funded by the USDA Forest Service Special Technologies Development Program, USDA Forest Service Rocky Mountain Research Station, and the Colorado State Agricultural Experiment Station.

the distributions, densities, and associated site factors of *Ribes* by species growing in the vicinity of white pines. Live cankers were collected and analyzed using dendrochronological techniques to examine the relationship between total canker length and time (i.e. canker growth rate).

Results & Discussion

WPBR was present on 55% of the 504 survey plots. Incidence, the proportion of infected trees, ranged from 0 to 100% and averaged 15.5% over all plots and 28.0% on infested plots. Diameter class and crown class were significantly related to likelihood of infection by WPBR. Incidence varied significantly by elevation and slope position and did not vary by aspect, limber pine density, slope configuration, or degree of canopy closure. Incidence of WPBR is currently low along the southern boundary of its distribution in southeastern Wyoming and northern Colorado. The current level of infestation has been attained within the past two to four decades, and with time the pathogen may spread to currently uninfested white pine populations and intensify throughout its current distribution. Monitoring of permanent plots and large-scale resurveys will be necessary to evaluate spread of the pathogen to currently uninfested areas and to determine the impacts of the disease over time.

Species of *Ribes* were found growing in the vicinity of white pines in all study areas surveyed, but the species present and the density of each species varied between the study sites. The most commonly encountered species were *R. cereum*, *R. inerme*, *R. lacustre*, and *R. montigenum*. Densities and probabilities of occurrence were related to site variables and varied by *Ribes* species. *Ribes cereum* had higher densities in dry, open areas than in moist, densely forested areas. *Ribes inerme* had highest densities on lower elevation, riparian and wetlands areas with components of aspen and willow. *Ribes lacustre* was associated with riparian areas and closed canopy forests with components of Engelmann spruce, subalpine fir, and alder. *Ribes montigenum* had highest densities in high elevation, open stands of Engelmann spruce.

An analysis of canker growth rates was performed on 134 WPBR cankers harvested from limber pine. There was a strong relationship between total canker length and time. Total canker length was related to number of years dead at canker center and proximal branch/stem diameter. Longitudinal canker growth rate varied by branch diameter, branch height, and condition of the branch distal to the canker, but did not vary by study area.

The data collected in the field surveys was used to develop a series of regression and categorical and regression tree analysis models that predict risk and hazard of WPBR in Colorado's native white pine populations. Risk models predicting the presence of WPBR employed meteorological, *Ribes*, and tree size data and resulted in good agreement between predicted and actual presence. Forest land managers can utilize the developed risk maps in concert with the models to prioritize monitoring, management, and, if necessary, control efforts. By monitoring areas with the greatest likelihood of pathogen establishment, control measures can be applied where impacts of WPBR create conditions outside the desired range. When the pathogen becomes established in an area, the infestations can be followed through time, which should allow for better calibration of disease pressure and hazard models to specific conditions found in Colorado.

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