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A Preliminary Hazard Model of White Pine Blister Rust for the Sacramento Ranger District, Lincoln National Forest

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Abstract—Blister rust, caused by the introduced fungus *Cronartium ribicola,* is a serious disease of white pines in North America. Since about 1970, an outbreak has been increasing in the Sacramento Mountains of southern New Mexico and threatens southwestern white pine. To help determine the expected extent and impact of blister rust, we propose a preliminary hazard model for the Sacramento Ranger District. The model is based on field observations and experience. We assume blister rust incidence and severity on white pine varies with microclimate and proximity to telial hosts (certain species of *Ribes*). We identify the sites at risk and rank them into three relative hazard classes based on elevation, plant association, and topographic position. Information is currently available to provisionally identify hazard for blister rust on 35% of the district area at risk. Of the area rated, 12% is low hazard, 43% is moderate hazard, and 45% is high hazard. Average rust incidence level for plots rated as low, moderate, or high hazard was 6%, 45%, and 47%, respectively; average severity was 0.1, 2.5, and 4.5 cankers per tree. Studies are underway to test and refine the model.

Keywords: *Cronartium ribicola*, southwestern white pine, *Pinus strobiformis*

Introduction

White pine blister rust, *Cronartium ribicola* J. C. Fisch., is an introduced pathogen to North America where it causes serious economic and ecological damage to white pines (Ziller 1974). The fungus has a complex life cycle of alternating spore stages between white pines (section *Strobus*, aecial hosts), where it causes perennial cankers, and currents or gooseberries (*Ribes*, telial hosts), where it causes a foliage disease.

Since the initial report of the disease in the Sacramento Mountains of southern New Mexico (Hawksworth 1990), the rust has been found throughout most of the range of southwestern white pine (*Pinus strobiformis* Engelm.) in the Sacramento and adjoining White Mountains. This area includes the Sacramento Ranger District (RD), much of the Smokey Bear RD, and the Mescalero Apache Indian Reservation. Based on the apparent age of cankers, the rust first became established around 1970 on the west side of the Sacramento Mountains. After remaining at relatively low levels for several years, a major expansion occurred around 1985 (Hawksworth and Conklin 1990, Conklin 1994, Van Arsdel and others 1998). Since then, there have been several years in which significant numbers of new infections have occurred on pine. In 1994, infected pines were found in the Capitan Mountains (Smokey Bear RD), an isolated range about 30 miles north of the main outbreak area (Conklin and Schultz, 1999, personal communication). In 1999, two infected white pines were found on Gallinas Peak (Cibola National Forest), about 50 miles north of the Capitan Mountains (Van Arsdel and Conklin, 1999, personal communication). Other nearby populations of white pine at risk are on the San Mateo and Magdalena Mountains.

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Peterson and Jewell (1968) suggested that conditions in the Southwest were suitable for an "explosion" of blister rust. Especially in the Sacramento Mountains, the abundance of susceptible hosts and favorable climate permits development of a serious epidemic. Southwestern white pine is present throughout much of the forest, and *Ribes pinetorum* Greene (a telial host that supports abundant rust production) is common in many locations (Conklin 1994, Van Arsdel and others 1998). July and August rains favor rust dispersal and development (Kimmey and Wagener 1961). If a severe outbreak of blister rust reduced or eliminated southwestern white pine, this would have negative impacts on biodiversity, forest health, and wildlife habitat (Conklin 1994, Dahms and Geils 1997).

Although the blister rust outbreak in the Southwest is recent, several efforts have described its status and planned appropriate research and management (Geils 1993, Conklin 1994, Van Arsdel and others 1998). In 1997, the Special Technology Development Program (USDA Forest Service, Forest Health Protection and Vegetation Management and Protection Research) funded a project to determine the expected effects of white pine blister rust on the distribution and abundance of white pine in the Southwest. The description and work plan are available on line (*The Peridium* 1999). A major task of that project is to develop, test, and revise a model that can be used to map hazard for blister rust across the Sacramento RD using data already available in the Rocky Mountain Resource Information System (RMRIS) and geographic information system (GIS). This task is preliminary to construction of a more detailed hazard model requiring site-specific data on *Ribes* distribution and microclimatic patterns (McDonald and others 1990). Hazard maps provide a tool for management planning at forest and project scales, a basis to stratifying landscapes for damage and impact surveys, and a foundation for additional epidemiological and ecological studies.

Hazard Rating

Forest disease outbreaks are described in the epidemiological terms of rates of spread and intensification, incidence, severity, damage, and ecological impacts. Hazard rating provides a means for combining these attributes into a relative index or classification for comparing disease potential among sites. Rust epidemiology is strongly influenced by genetics, abundance, and proximity of hosts and by microclimate. Because these factors vary in time and space, rust behavior and effects are difficult to characterize. Direct measurement of spread and intensification requires either years of observation or a reliable dating method. Incidence and damage surveys that only describe present conditions have limited predictive value when the outbreak is still increasing. But a knowledge of rust epidemiology combined with information on forest conditions can be used to produce a hazard model for mapping disease potential. Hazard models may project percent of trees infected, number of cankers per tree, volume lost and killed, or changes in various ecological indicators. In the preliminary hazard model presented here, we rank forest sites with regard to existing and / or expected rust infection on white pine. In combination with a damage or impact model, this information can be used to project resource losses or ecological effects.

A Preliminary Model

Our observations in the Sacramento Mountains and experience with older rust outbreaks (Van Arsdel and others 1961, Van Arsdel and Krebill 1995) identify two primary factors that affect infection rate: microclimate and proximity to a telial host. These factors, however, are not easily determined; and their relationship to infection rate is complex. Elevation, plant association (i.e., potential vegetation), and topographic position are standard elements used to describe forest sites (note: a *site* or land unit is the smallest area mapped in the GIS and described in the RMRIS). These features serve in our preliminary model as surrogates for microclimate and proximity. We are focusing on the Sacramento RD for initial model development since it includes the greater proportion of the outbreak area and the largest concentration of white pines in the Southwest. However, the model may be applicable in other portions of the outbreak area as well. We are also attempting to determine relative hazard in other ranges in New Mexico and Arizona that contain white pines.

The landform of the Sacramento Mountains is a tilted, block uplift with a steep west escarpment and gentle east slope dissected by broad canyons (Alexander and others 1984). The general landform determines regional precipitation and vegetation; local topography modifies these at the site level.

Annual precipitation is greatest along the escarpment ridge (over 25 inches above 8,000 feet); amounts decrease sharply to the west and gradually to the east (under 20 inches below 7,500 feet). Plant associations are broadly zonal with elevation; but cooler, wetter aspects and positions allow associations to occur at lower elevations. Southwestern white pine and *Ribes* species have broad ecological requirements. They are more common on cool, mesic sites; they generally occur above 7,500 feet on the western escarpment and above 7,000 feet on the eastern slope. The habitat types (Alexander and others 1984) that comprise the mesic mixed conifer plant associations (and rare spruce-fir types) occur on the coolest, wettest sites where white fir (*Abies concolor* (Gord. & Glend.) Hilde.) is the dominant climax tree species. On warmer and drier sites of the xeric mixed conifer plant associations, Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) is the dominant climax tree species. On the warmest and driest forested sites, ponderosa pine (*Pinus ponderosa* Doug. ex Laws. & Laws.) is the dominant climax species. Southwestern white pine and *Ribes* are rare or absent in other plant associations. Topographic position not only affects a site's annual climate and vegetation, it also influences diurnal temperature-moisture patterns. Cool, moist air descending from upper slopes and settling into valley bottoms during the critical stage of rust dispersal to pine creates favorable conditions for infection (Van Arsdel and others 1961).

We define 27 strata from three levels of the three factors (elevation, plant association, and topographic position). These strata are used to rank sites for hazard and to allocate sampling effort for testing the model. Sites are ranked for increasing hazard as follows:

- elevation—sites below 7,500 feet, 7,500-8,000 feet, and above 8,000 feet;
- plant association—pine, xeric mixed conifer, and mesic mixed conifer; and
- topographic position—sites on ridges and upper slopes, mid-slopes, and lower slopes.

Although these factors may be confounded and could be weighted and combined various ways, we use a simple, additive model for reducing 27 strata to three hazard levels. Each stratum is assigned a score of 0, 1, or 2 for increasing hazard from each factor, scores are summed, and levels are assigned. Sites with a composite score of 0, 1, or 2 are low hazard; sites with a score of 3 or 4 are moderate hazard; and sites with a score of 5 or 6 are high hazard. Sites at risk of blister rust infestation lay between the 7,500-foot contour on the west and the 7,000-foot contour on the east (the approximate range of southwestern white pine). The preliminary hazard map (see page 5) is compiled by scoring sites with data from the RMRIS database (USDA Forest Service 1998); sites are mapped with location data from the GIS. The hazard class area is obtained by summation (table 1). The model is tested in six study areas that are distributed across the district and include the sample strata (map on page 5 and see Future Model Development).

For that portion of the Sacramento RD (federal lands) considered at risk, the preliminary model classifies 35% of the area into three rust hazard levels (map on page 5 and table 1). Of the 97,234 acres that were classified, 12% was identified as low hazard, 43% as moderate, and 45% as high. Sixty-five percent of the area at risk was not classified because information for either ownership, elevation, plant association, or slope position was not available in the RMRIS database. Information may be missing because data have not been updated since the last fire or silvicultural treatment. Considering the landform and distribution of vegetation, we suspect much of the unclassified area would be ranked as moderate to high hazard. Classifying these additional areas could increase the extent of moderate and high hazard by 50 to 100%.

Because data are still being collected on rust distribution and history, the statistical significance of the model rankings have not been tested and alternative formulations of the model have not been assessed. However, available data (Van Arsdel

Table 1. White pine blister rust hazard on the Sacramento District, Lincoln National Forest. Hazard area is determined for federal lands at risk by application of a preliminary hazard model to site data extracted from the RMRIS database, compiled 5/3/1999. The area of missing information includes areas for which data on ownership, elevation, plant association, or topographic position were not available.

Hazard zone	Area, acres
Low hazard	11,214
Moderate hazard	42,066
High hazard	43,954
Missing information	183,682

and others 1998) can be used to characterize rust incidence and severity by hazard class. The plots established by Conklin (average 46 white pine trees per plot) are classified by the preliminary model into three plots of low hazard, four plots of moderate hazard, and five plots of high hazard. The average incidence of blister rust infected white pine trees is 6%, 45%, and 47%, respectively. The average number of cankers per tree is 0.1, 2.5, and 4.5, respectively (table 2). *Ribes pinetorum* is found to be common at the Hoosier and Little Apache plots but not found at the Monjeau and Carisa Lookout plots. The preliminary model appears reasonable but discrimination may be improved by including information on proximity to *Ribes pinetorum*.

Future Model Development

Our observations suggest that white pine blister rust is spreading across the district in the early phase of exponential expansion (Van Arsdel and others 1998). We have visited numerous mesic sites close to susceptible *Ribes* bushes where the white pine trees bear only a few young cankers. In time, rust incidence and severity on these sites is expected to increase. Our projections of the extent of rust hazard (map and table 1) are therefore provisional. The model is being tested and refined with data from studies described by Van Arsdel and others (1998). Plots on six study areas provide detailed information on microclimate, rust severity and history, and *Ribes* by strata for elevation, plant association, and topographic position (see *The Peridium*).

A hazard model based on the fundamental land management units (sites) and standard inventory elements (elevation, plant association, and topographic position) is readily integrated into various planning and monitoring activities. The model could be used at the forest planning level to assess where significant change in forest species composition is expected. Information sources in addition to the RMRIS database may be used to extend the map hazard over a greater area. Although the preliminary model is constructed using physical site characteristics, future refinements could include factors such as current vegetation, stocking, or crown density, which are affected by silvicultural treatment. This second generation hazard model could be used to assess how vegetation management projects might reduce the impacts of the blister rust outbreak.

Table 2. Incidence and severity of blister rust for selected plots sorted by a preliminary hazard model. Adapted from Van Arsdel and others (1998).

Plot location	Hazard rating	Percent infected	Cankers per tree
Lower Fence	Low	2	0.02
Poison Spring	Low	8	0.1
Sixteen Springs	Low	9	0.1
James Ridge	Moderate	16	0.4
Bonito Lake	Moderate	27	0.4
Hoosier	Moderate	63	3.9
Little Apache	Moderate	72	5.2
Monjeau	High	4	0.04
Carisa Lookout	High	26	0.4
Wills Canyon	High	58	2.6
Upper Fence	High	52	3.5
Silver Springs	High	95	15.9

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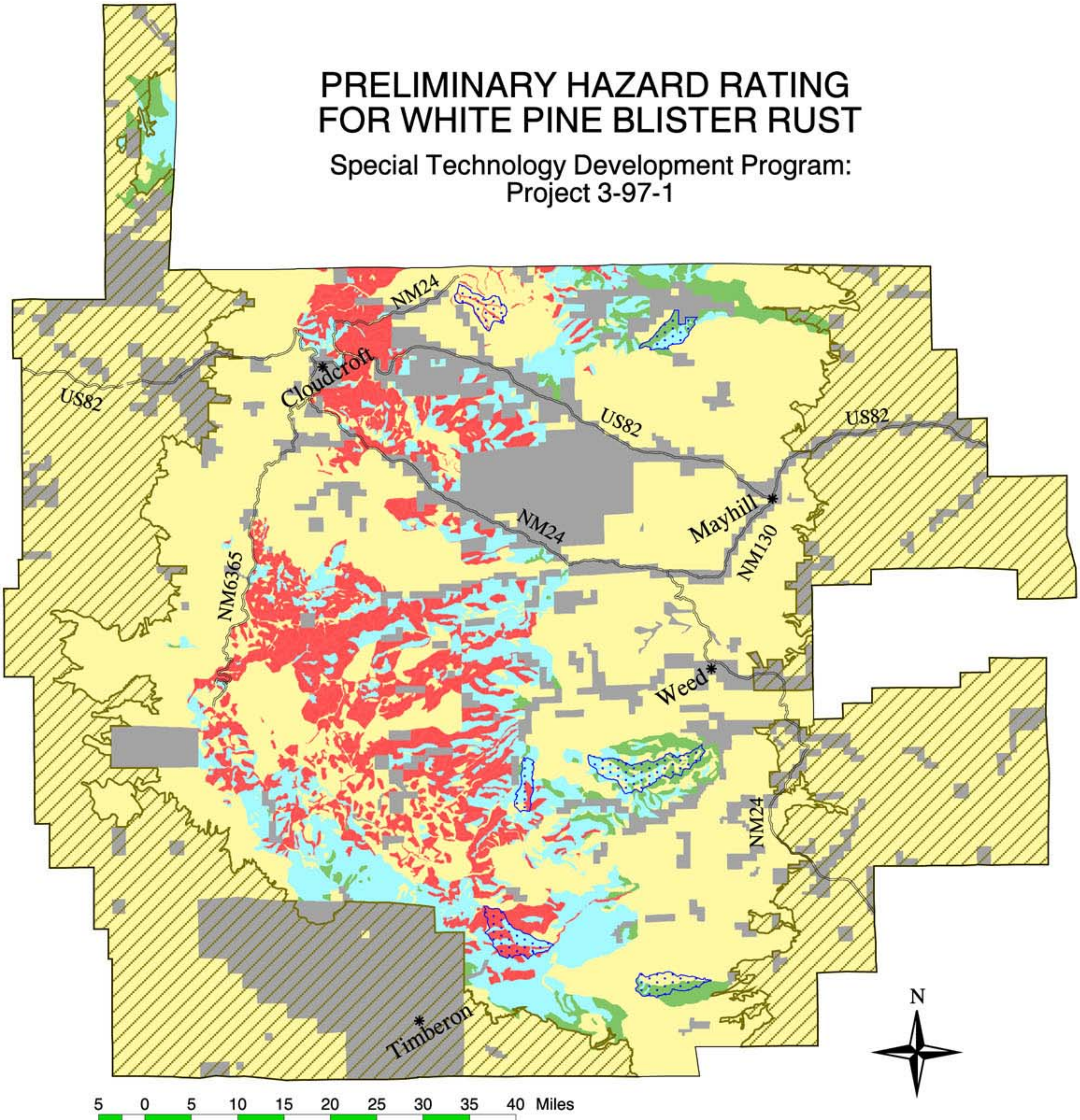
PRELIMINARY HAZARD RATING FOR WHITE PINE BLISTER RUST

Special Technology Development Program:
Project 3-97-1



Low Hazard
Moderate Hazard
High Hazard
non-FS lands
Missing info
Not at Risk
Study Areas

SOUTHWESTERN REGION
and
ROCKY MOUNTAIN
RESEARCH STATION

-Map compiled by B.Nelson, RMRS, for STDP Project 3-97-1 on 5/3/99.
-GIS polygon stand data and RMRIS databases are from the the Lincoln National Forest, Sacramento Ranger District.
(Source maps: 1:24000 resolution, State Plane, NAD27)

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