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Development of the White Pine Blister Rust Outbreak in New Mexico

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Abstract

This report presents results to date from 14 monitoring plots installed between 1990 and 2002 in the outbreak area of southern New Mexico. The most recent measurements indicate that 39.7 % (238 of 600) of the sample trees in the Sacramento Mountains are infected. Stem cankers occur on 18.2% of the sample trees; these have resulted in topkill on 10.2% of the sample trees. Blister rust incidence (percent of trees infected) has increased considerably on most plots since installation, with an average increase of 2.6 % per year on the twelve oldest plots. By now, infected trees occur on all but one of these plots; three plots where no rust was detected initially are now lightly to moderately infected. Although not statistically representative of the white pine population in the outbreak area, these plots may provide a reasonable estimate of overall rust incidence and damage to white pines in the Sacramento Mountains. A strong correlation between rust incidence and elevation is demonstrated on the plots. Infection is relatively high in most stands above 8000 feet, and tapers off steadily at lower elevations.

Introduction

Since the discovery of white pine blister rust (*Cronartium ribicola*) on the Lincoln National Forest in southern New Mexico (Hawksworth 1990), we have been following the development of this invasive, non-native disease using a small set of permanent plots. This report presents results to date from these "rust behavior" plots and provides some additional observations about the outbreak.

The main outbreak area in the Sacramento and adjoining White Mountains (these will be referred to simply as the Sacramento Mountains in this report) probably contains the largest population of southwestern white pine (*Pinus strobiformis*) in the Region. White pines comprise a small, but significant proportion of trees throughout roughly one-half million acres of mixed conifer forests in this area. Upwards of 50,000 acres are at least 25% white pine, and several thousand acres are classified as white pine cover type.

Blister rust was first detected in Bradford Canyon, near of the village of Cloudcroft, where its effects became easily visible in early 1990. Informal surveys conducted that summer by Forest Health specialists and District personnel determined that the disease had already spread through much of the range of southwestern white pine in the Sacramento Mountains. That first year we detected blister throughout the higher elevations of the Cloudcroft and Mayhill Ranger Districts (later combined into the Sacramento District) and at several locations to the north on the Mescalero Apache Indian Reservation.

Rather than conduct more formal surveys that year, we decided to begin installing some permanent plots to assist with long-term monitoring of the outbreak and its effects. Three plots were set up in late 1990 – two on the Cloudcroft District and one at Mescalero – with initial rust observations conducted the following spring when blisters (aecia) were present. In 1994, we installed five additional plots on the Sacramento District and two on the Smokey Bear District (where we first detected the disease in 1991). Two more plots were installed at Mescalero in 1996.

Following our detection of blister rust on Gallinas Peak (Cibola National Forest, just west of Corona, NM, about 80 miles north of the main outbreak area) in 1999, we installed a similar plot there. Our most recent plot (#14) was set up in 2002 in the relatively dry southeastern part of the Sacramento District, where blister rust incidence is still very low. Although we detected blister rust in the Capitan Mountains (about 30 miles north of the main outbreak area) in 1994, we have not established any plots there because of poor access.

Summaries of rust incidence data from the 12 oldest plots were included in reports by Van Arsdel and others (1998) and Geils and others (1999). This report provides more current and in-depth results and analyses from this monitoring effort. Some comparisons are also made with other blister rust plots/surveys in New Mexico and adjacent Regions. Potential management strategies in response to this outbreak have been discussed in Conklin (1994) and Van Arsdel and others (1998).

Methods

Plots were set up in easily accessible, native stands having relatively high proportions (usually at least 20%) of white pine.[1] Suitable locations were chosen based on suggestions of District and Agency personnel, GIS queries, and intensive field reconnaissance. Inaccessible and/or difficult terrain, the fact that white pine most often occurs as a minor component in mixed stands, and other factors eliminated much of the outbreak area for potential plot location. As additional plots were added to the set, they were installed in widely spaced locations, sampling a wide range of site conditions (Figure 1).

Once a suitable location was selected, 40 to 50 white pines were tagged for periodic observation and remeasurement. Only trees that were relatively "free to grow" and had crowns that could be observed from several angles were selected. Suppressed and severely deformed trees were intentionally excluded because it can be difficult to accurately quantify rust infection on such trees, and because such trees are more likely to die from other causes. Presence or absence of rust was *not* a selection criterion for sample trees; in fact, most of these plots were initially set up and tagged in the late summer or fall, when infection status can be difficult to determine. A wide range of size classes – from young saplings (> 4.5' tall) to mature trees – were sampled on each plot.

When a surplus of suitable trees occurred on a particular site, some were intentionally "skipped" in order to expand the sampling area, thus reducing possible microsite factors and providing a more representative sample. Potential "edge effects" were minimized by locating plots within the interior of a stands, rather than along the edges of large meadows, drainages, etc. These plots (or perhaps more properly, "monitoring sites") vary in size and shape; most are one to two acres.

Initial tree measurements include diameter at breast height (dbh), total height, and the number of rust infections (cankers). All sample trees are examined thoroughly; binoculars are used to search for infections on the larger trees. All rust observations have been made in the spring at the time of peak aecial (blister) production, usually in early to mid-May.

Canker ages have been estimated (where feasible) by counting branch whorls from the canker center to the end of the branch (or to the top of the tree in the case of some stem infections on young trees). From these, it has been possible to construct a rough history of the outbreak. Notes have been kept on the location of some cankers (to facilitate re-location and to calibrate growth rates), rust damage (flagging, topkill), and the presence of other disease or insect damage.

[1]Since blister rust does not spread directly from pine to pine, the proportion of white pines in a stand should not affect rust incidence or severity. General observations appear to support this contention.

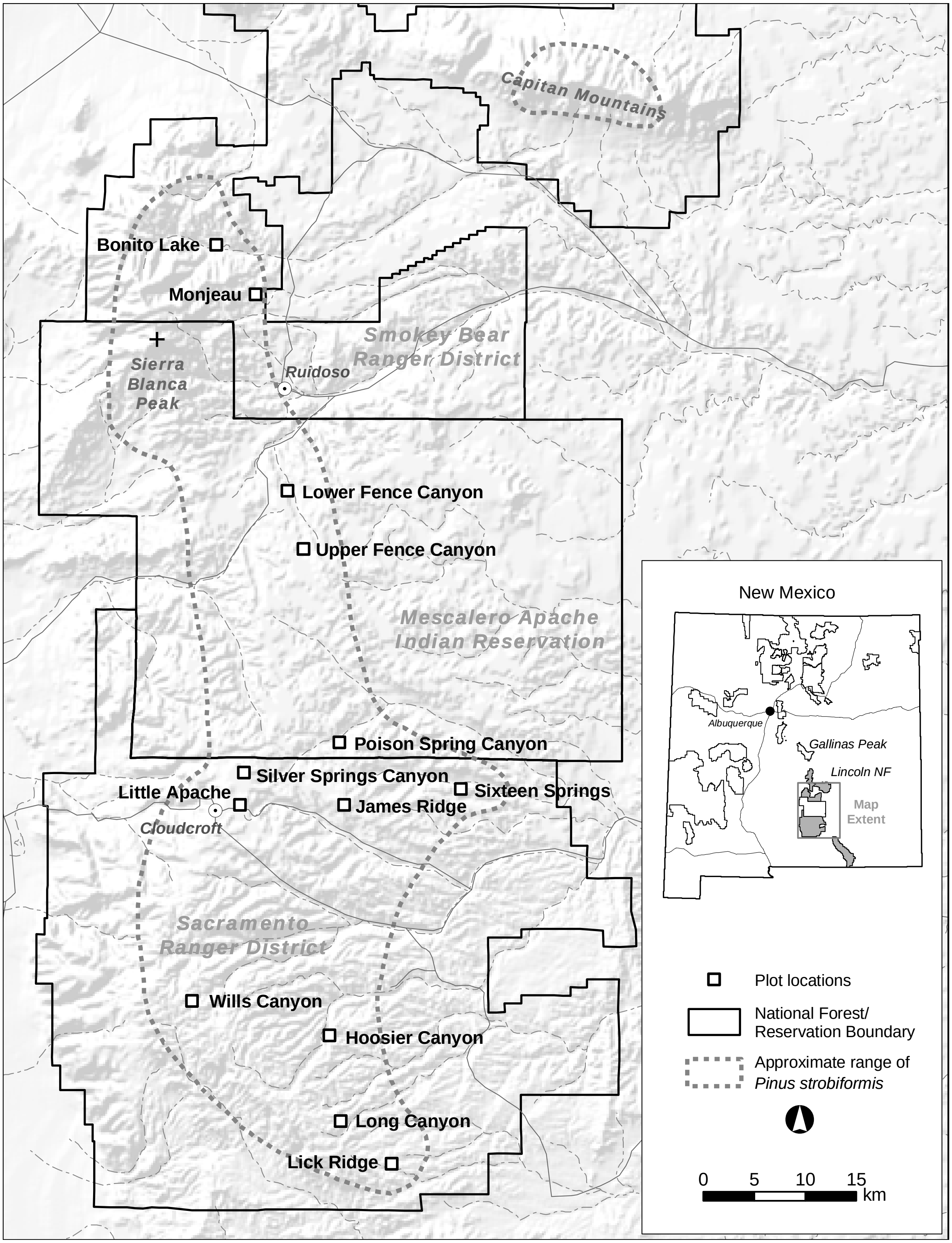

Figure 1. Location of white pine monitoring plots in the Sacramento Mountains of southern New Mexcio. The Gallinas Peak area is shown in insert.

Throughout this monitoring effort, observations have been made on *Ribes* occurrence (species and relative abundance) on the plots and surrounding areas. A more formal attempt to quantify the alternate host on these plots is included in Van Arsdel and others (1998).

The three original plots were first remeasured in the spring of 1993, two years after the initial rust observations. Thereafter, observations have been conducted every three years on each plot. With the expanded set, three to five plots are remeasured annually, providing coverage of the entire set every three years.

Early work on these plots revealed that several types of damage could be confused with blister rust infection. In the results presented here, only fully developed, sporulating cankers (or those observed as such on previous occasions) are counted as rust infections. Subsequent counts are cumulative and include all previously recorded cankers plus any observed for the first time. All rust observations have been made by the author (occasionally assisted by others) to help insure consistency.

Results and Discussion

Rust incidence and damage

Changes in rust incidence (percent of trees infected) on the twelve oldest plots are displayed in Figure 2. Rust incidence has increased on all plots except Silver Springs Canyon, where the disease was already severe when the plot was established. The greatest increase – from 7% to 80% over an eleven year period – has occurred on the Wills Canyon plot, a result of a large increase in the amount of *Ribes pinetorum* on that site. Three plots where no rust was detected initially – Poison Springs Canyon, Monjeau, and Sixteen Springs – had incidences of 17%, 4%, and 11%, respectively, during the most recent remeasurements. By now, the only plot where blister rust has not been detected is Lick Ridge, which was installed recently and has not been remeasured. Rust incidence has increased at an average rate of 2.6 % per year on the twelve oldest plots.

Figure 2 also shows the average number of rust infections (cankers) per tree – an indication of disease intensity – at each measurement. This has often increased at a faster rate (on a relative basis) than the percent of trees infected. For example, on the Silver Springs Canyon plot, although rust incidence remained constant between 1991 and 2002, cankers/tree doubled. On the Wills Canyon plot, rust incidence increased from 71% to 80% between 1999 and 2002, while cankers/tree tripled.

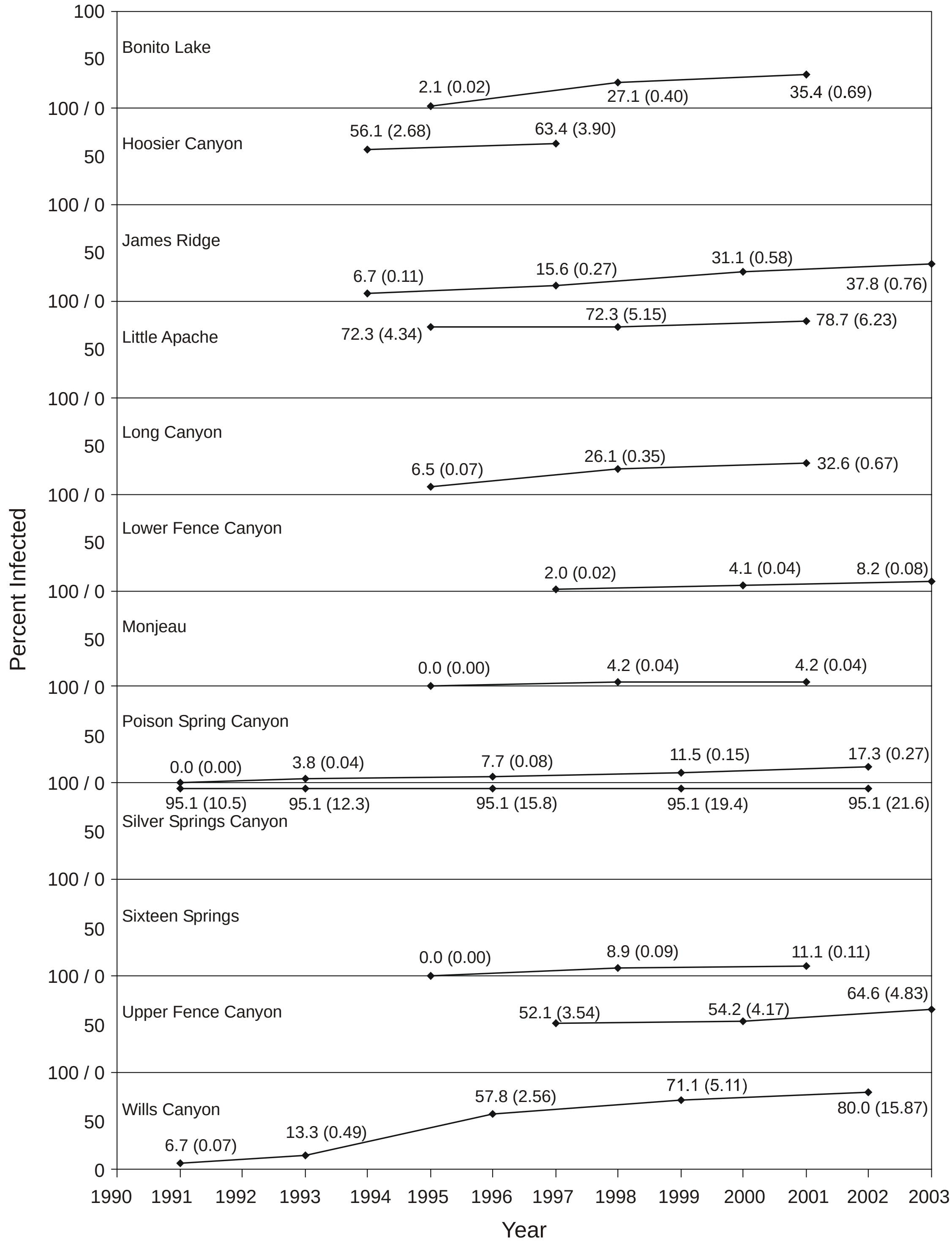

Figure 2. Proportion of trees infected with white pine blister rust on plots in the Sacramento Mountains. The average number of infections per tree is shown in ( ).

The most recent measurements indicate that 39.7% (238 of 600) of the sample trees in the Sacramento Mountains are infected. Stem cankers occur on 18.2% (109) of the sample trees; these have resulted in topkill on 10.2% (61) of the sample trees. Most of the stem cankers and topkill have occurred on three of the 13 plots in the Sacramento Mountains. Figure 3 illustrates the progression of stem cankers and topkill on these three heavily-impacted plots. The majority of topkill to date has been a result of older (mostly 1985) infections. By contrast, the Wills Canyon plot, which now has a very high rust incidence (Figure 2) has so far suffered relatively little damage since most infections there have occurred more recently.

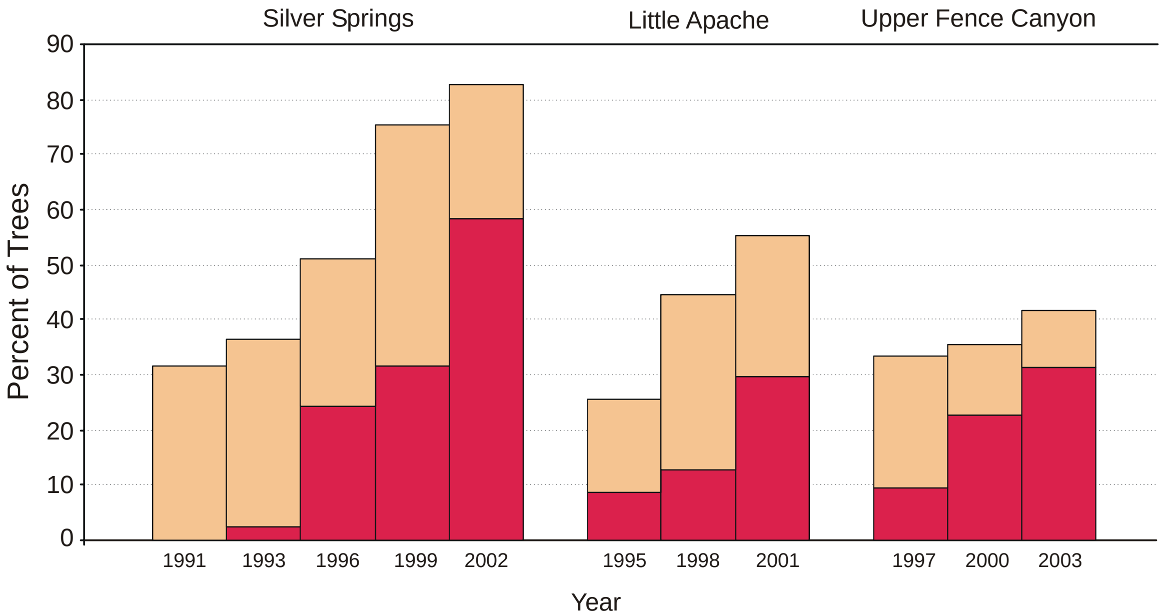

Figure 3. Proportion of trees with stem cankers, and proportion with resultant topkill (bottom portion of bars), on the three most severely affected plots.

Twelve (2.0%) of the sample trees in the Sacramento Mountains have died from blister rust (and related factors) since the plots were established.[2] All of these rust-killed trees were less than 6” dbh. Five trees have died from other causes, including animal damage and mechanical damage. The entire sample (41 trees) on the Hoosier Canyon plot – which had heavy rust and where topkill was starting to occur – was killed by a wildfire in May 2000.

Since our plot locations were not randomly selected (and since other nonconventional sampling methods have been used), averages from these plots are not statistically representative of the white pines population in the outbreak area. Similarly, the plots provide no *direct* information on stems per acre or volume affected. On the other hand, the data provide documentation of rust incidence at various sites and provide insight into the development of the outbreak over time. Familiarity with the outbreak area suggests that these plots probably do provide a reasonable

[2]By 1990, the year blister rust was discovered in New Mexico and we began establishing these plots, some topkill and mortality – perhaps approaching five percent – had already occurred among seedlings and small saplings on some heavily infected sites.

(albeit crude) estimate of overall rust incidence and damage to white pines (on a percentage basis) in the Sacramento Mountains.

General observations (and some data, see Appendix A) suggest that these plots are representative of much larger areas in the surrounding landscape, in terms of rust incidence (% of white pines infected) and damage (% topkill and mortality). This is because of what might be called the "diffuse" nature of blister rust infection (in contrast to the "patchy" nature of a pathogen like dwarf mistletoe). This diffuse nature is a result of windblown spores (three types), widespread distribution of alternate hosts, and climate patterns over relatively broad areas. The damage displayed in Figure 3 is well representative of that occurring over many thousands of acres of mesic, high-elevation mixed conifer forest in the Sacramento Mountains.

Over the next ten to 20 years, we can expect rust topkill – which from a forest health standpoint may be as significant as outright mortality – to continue at a fairly steady rate in the higher elevation forests of the Sacramento Mountains. Topkill will become more widespread, especially in areas where the disease has increased to moderate or heavy levels more recently. Over time, increasingly larger trees will experience topkill and mortality from blister rust.

Based on these plots, overall rust incidence and damage appear to be higher in the Sacramento Mountains of southern New Mexico than in areas recently surveyed in the Intermountain Region (Smith and Hoffman 2000). Our incidence and damage data are not directly comparable to those from permanent plots in the Sierra Nevada (Byler and Parmeter 1979; Kliejunas 2001), since only areas known to have moderate to heavy infection were sampled on those plots. However, a comparison of these data suggests that blister rust incidence may have increased more rapidly in the Sacramento Mountains than in the Sierra Nevada (on sugar pine, *Pinus lambertiana*). The severity and potential impact of the New Mexico blister rust outbreak are amply described by Kinloch (1994).

Infection and tree size

Overall, the percentage of white pines with rust infection increases with increasing tree size (Figure 4). This relationship was clearly observed on several of the individual plots, although on some plots results were obscured by a small sample of larger (> 12") trees. Probably the main reason that larger trees have higher infection rates is simply that their crowns present larger targets for the windblown rust spores than the smaller trees.

However, smaller trees were more likely to have stem cankers (Figure 4), because the rust has less distance to travel – from the needles (where infection is initiated) to the main stem. Among infected trees only, about two-thirds those < 4" dbh had stem cankers, while less than 5% of those > 12" dbh did (Figure 5). Our observations about tree size and blister rust are generally consistent with those reported by Smith and Hoffman (2000) for the Intermountain Region, and Kliejunas (2001) for the Pacific Southwest Region.

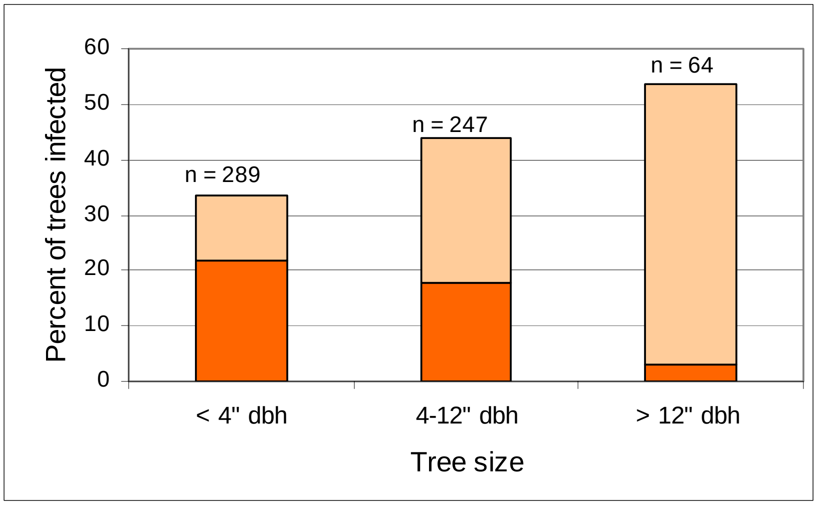

Figure 4. Proportion of trees infected, and proportion with stem cankers (bottom portion of bars), by size class.

Canker locations and growth rates

Blister rust cankers have been well distributed throughout the crowns of affected trees. As in the Intermountain Region (Smith and Hoffman 2000), infections often occur high in the crowns, where they are more likely to be damaging. Growth rates on the more vigorous cankers have averaged about two inches (along a branch toward the main stem) per year, similar to what has been reported elsewhere (Harvey 1967).

Rust incidence and elevation

The strong correlation between rust incidence and elevation in the Sacramento Mountains is displayed in Figure 5. Data from intensive sampling of five study areas in 1998 and 1999 also demonstrate this relationship (Geils 2000). Figure 5 indicates that blister rust became established on most high elevation sites relatively early in the outbreak (especially in 1985), and more recently on many low elevation sites.[3]

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[3]Informal (off plot) surveys conducted in 1990 and 1991 actually detected very low levels (often < 1% incidence) of blister rust (from 1985 infections) on many low elevation sites. The disease has become more common at lower elevations as a result of more recent "waves" of infection.

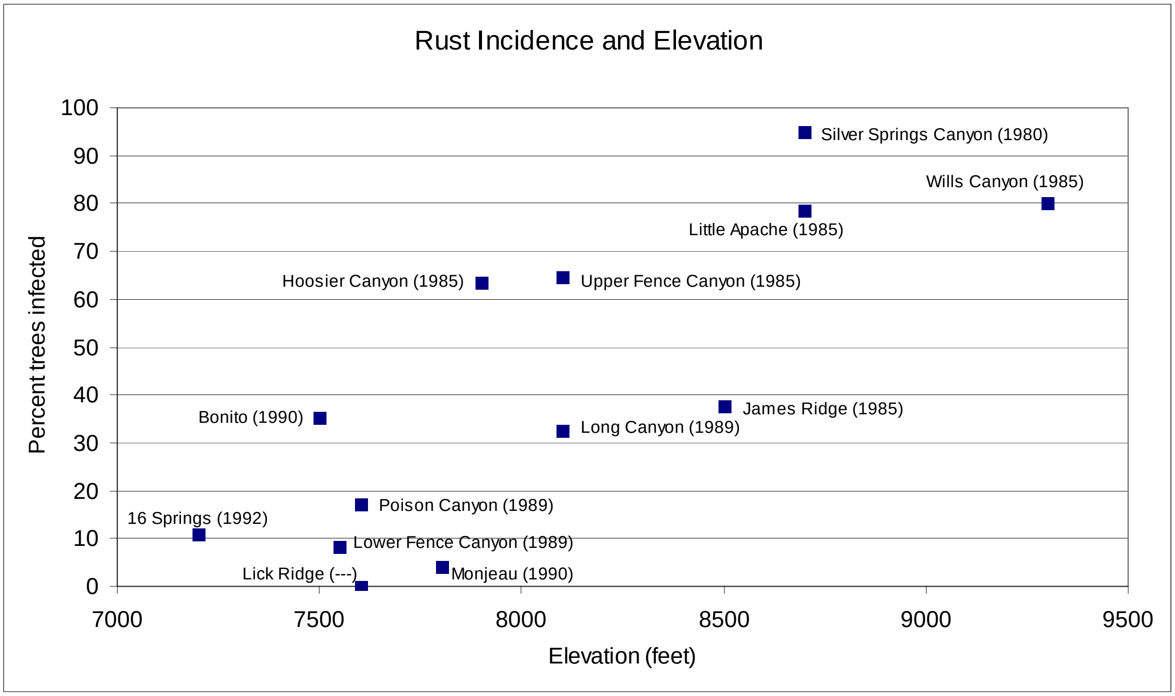

Figure 5. Proportion of trees infected, by plot, vs. elevation. The approximate date of the first infection on each plot is shown in ( ).

Blister rust "hazard"

As would be expected, microsite factors, including variations in *Ribes* density and local air currents, result in some variation in rust incidence and severity (Van Arsdel and others 1998; Geils and others 1999; Geils 2000). Overall, however, much broader patterns of infection appear to predominate in the Sacramento Mountains. Where rust is severe, it tends to occur at high levels throughout the surrounding landscape; where rust is light, it tends to be light over fairly extensive areas. In the Sacramento Mountains, infection is relatively high in most stands above 8000 feet, and tapers off steadily at lower elevations. Van Arsdel and others (1998) discuss how topographic factors may influence rust severity, at least at intermediate elevations (roughly 7500 to 8500 feet), with rust tending to be more abundant near canyon bottoms.

High "rust hazard" at higher elevations is a result of 1) relatively cool, moist conditions favorable for rust establishment, and 2) the widespread distribution of the orange gooseberry, *Ribes pinetorum*, a very susceptible alternate host. The importance of *R. pinetorum* in this outbreak has long been recognized (Hawksworth and Conklin 1990; Conklin 1994). *R. pinetorum* is common and widespread at the higher elevations (8000 to 9500 feet) in the Sacramento Mountains, sometimes extending to lower elevations in canyon bottoms.

Another *Ribes* species, *R. mescalarium*, a black currant, is common throughout the Sacramento Mountains, including lower elevation stands, but is much less susceptible to blister rust. Infections occurring on pines in low elevation stands could be a result of spread from more distant, higher elevation *R. pinetorum* rather than from closer *R. mescalarium*. This situation may have occurred on some or perhaps even all of the six infected plots below 8000 feet.

Most of the high elevation plots have *R. pinetorum* in the immediate vicinity (Van Arsdel and others 1998). Based on elevation, the James Ridge plot has less blister rust than expected (Figure 5), due its location near the top of a relatively dry ridge and the scarcity of *R. pinetorum* in the area. Similarly, the Bonito Lake plot may have *more* rust than expected because of the abundance of *R. pinetorum* further up Bonito Canyon (South Fork), a mile or more distant from the plot. As mentioned previously, a dramatic increase in rust incidence has occurred on the Wills Canyon plot because of a large increase in the amount of *R. pinetorum* on that site, following a logging operation.[4]

Waves of infection

Blister rust outbreaks in North America have often been characterized by “wave years”, i.e., years when conditions especially favorable for new infections result in significant intensification and spread (Mielke 1943). Although it appears that blister rust arrived in New Mexico by the early to mid-1970’s (Hawksworth 1990), and perhaps somewhat earlier, it remained at very low levels and had limited distribution for several years. Around 1985, a very pronounced wave year resulted in a major expansion of the outbreak. The rather striking “flagging” that first appeared in 1990 – the year the outbreak was detected – was a result of these 1985 infections.

The disease arrived at five of the 13 Sacramento Mountain plot locations in 1985 (Figure 5). The Silver Springs Canyon plot was infected earlier – three or four infections date to about 1980 – but around 400 infections occurred in 1985. The oldest infection detected in the Capitan Mountains – an isolated range about 30 miles north of the Sacramentos – also dates to 1985.

After 1985, very few infections occurred until about 1989 – perhaps the first year an abundance of spores were released from 1985 cankers. Three of the plots were first infected about 1989, and two others around 1990. Blister rust spread to our lowest elevation plot about 1992, probably the same year it arrived on Gallinas Peak. Since 1989, new infections have occurred almost every year in the Sacramento Mountains, with considerable variation from site to site. Several of the plots had distinct waves of infection around 1993 and/or 1996. Another distinct wave occurred on some plots in 1998; over 300 new infections occurred that year on the Wills Canyon plot. The most recent infections detected so far occurred in year 2000.

To date, the overall magnitude of the 1985 wave year has not been surpassed, although infections have become more widespread since then, especially at lower elevations. Even after several years of additional infection, roughly half of all infections on the Silver Springs Canyon, Little Apache, and Upper Fence Canyon plots are from 1985; the Hoosier Canyon plot displayed a similar pattern until it was destroyed.

In describing the development of blister rust, it is important to note that most infections take a minimum of three or four years to fully develop, i.e., produce blisters. Many infections develop more slowly, or at least remain so inconspicuous as to be undetectable for many years. Thus, the “new” cankers recorded on these permanent plots during remeasurements have included both young (3 to 5-year old) infections *and* older ones that were inconspicuous or not fully developed

[4]*Ribes* abundance can also increase dramatically following stand-replacing wildfire.

at the time of the previous measurement. (Although there has been considerable variation from plot to plot and at different times, overall these have occurred in roughly equal proportions.) Branch flagging, which can be a helpful clue for recognizing blister rust infections (especially on larger trees), usually does not occur for at least five years, and often much longer, after infection.

Gallinas Peak Outbreak

Blister rust was first detected on this isolated peak, located about 80 miles north of the Sacramento Mountains, in 1999. A significant population of southwestern white pine occurs here, intermixed with Douglas-fir and ponderosa pine, from near the summit (8637') to below 8000 feet. So far, infected trees have been found only on the north slope, just below the summit, although by now rust may occur elsewhere at low levels. Our plot, located on this relatively mesic north slope, had an incidence (percent of trees infected) of 44% in 2002.[5] The oldest infections occurred around 1992 (5 cankers) with additional infections in 1995 (21 cankers) and 1998 (39 cankers). The whitestem gooseberry, *Ribes inerme*, the primary alternate host on Gallinas Peak, appears to be at least moderately susceptible to blister rust.

Additional comments on sampling methods

Some of the difficulties in sampling white pines for blister rust in mixed-species stands, over variable terrain, etc. are mentioned in Byler and Parmeter (1979) and Smith and Hoffman (2000). Difficult terrain, the irregular distribution of white pines, and other factors discussed earlier led to our unconventional sampling methods. The disease itself can be difficult to identify, resulting in irregularities in blister rust data (Jackson and Lockman 2003). This can pose problems, especially when interpreting data from permanent plots. A blister rust survey conducted by contract on a portion of the Lincoln National Forest in 1995 and 1996 greatly underestimated disease incidence (Appendix B). Proficiency in surveying for blister rust may require months, if not years, of relevant field experience (depending on the accuracy and precision desired) because of the inconspicuous nature of many infections and other damages that can be confused the disease (Appendix C).

The methodology used for this set of plots was designed to be practical and efficient, providing quality information at relatively low cost. All rust observations have been made by experienced pathologists, helping insure reliability and consistency. Field work on these plots usually involves only three to five days per year, and travel is often combined with other evaluations, monitoring, and information transfer activities. The modest commitment needed for these "rust behavior" plots has allowed time for scouting for the disease in other white pine populations, exploring genetic options, and related work.

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[5]Clearly this plot is not representative of overall rust incidence on Gallinas Peak. The primary objective of this plot is to compare rust development here with that in the Sacramento Mountains.

Acknowledgements

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Appendix A

Do these plots approximate rust incidence over larger areas?

Data supporting the idea that these plots represent larger areas in terms of rust incidence and damage are available from a more intensive survey conducted in 1998 and 1999 in the Hoosier Canyon area. This survey involved 36 smaller plots (either 0.05 or 0.1 acre, depending on white pine density) more or less randomly located throughout a 900+ acre area surrounding the original Hoosier Canyon plot. Infected white pines were found on all 36 of these plots. Fifty-five percent of the sample trees were infected, compared to 63% (1997 data) on the original plot. The proportion of trees with stem cankers (20% in the intensive survey vs. 29% on the original plot) and the average number of infections per tree (2.9 vs. 3.9) were also quite similar. The somewhat lower rust levels detected in the intensive survey could easily be because less experienced workers collected the data on several of the plots.

Data from four other areas intensively surveyed in 1998 and 1999 as part of a "Special Technology Development Project" (Geils and others 1999; Geils 2000), also demonstrate that rust infection tends to be relatively uniform over extensive areas in the Sacramento Mountains.

Appendix B

Reliability of a contracted blister rust survey on the Lincoln National Forest

A blister rust survey involving approximately 1000 one tenth-acre circular plots was conducted on a 14,000 acre portion of the Sacramento Ranger District of Lincoln National Forest in 1995 and 1996. I spent about three days in the spring of 1996 field checking the results.

The District provided me with data from 16 relatively accessible stands where white pines had been sampled. Within these stands, I relocated the 26 plots that had white pines. I found rust infection on 16 of the 26 plots, and on 25 of 102 sample trees. By comparison, the survey detected rust on only five of these plots, and on a total on seven trees. The survey data also indicated infection on one plot where I found no evidence of blister rust.

Clearly this survey greatly underestimated the amount of blister rust in most areas. Some probable reasons for this were 1) about half the plots were done in the fall, when rust infection is more difficult to detect than in the spring, 2) several of the infections were relatively inconspicuous, and 3) most members of the survey crew had relatively little experience working with blister rust (although they did receive a limited amount of training in blister rust identification prior to the survey).

Appendix C

Other disease and insect damage on southwestern white pine

Work on these plots has provided opportunities to observe the effects of several other damaging agents over time. The most common are described briefly:

Atropellis canker, a native fungal disease, occurs on at least nine of the 14 plots. On three plots, nearly all the sample trees were infected. *Atropellis* causes elongated cankers on branches and stems, and can easily be confused with blister rust. Although less damaging than blister rust, *Atropellis* causes some branch flagging and occasional topkill of smaller trees.

Very pitchy, elongated cankers (not unlike some blister rust cankers) of undetermined cause have been observed on the main stem of saplings, and occasionally near the top of pole-size trees, on several plots. A possible cause of this injury, which I have been calling "resin canker," is sunscald. These have occasionally caused topkill; a few have been observed to largely heal over after several years.

Smooth tapered to globular swellings of undetermined origin have occurred sporadically on young growth on several of the plots. In the early stages of this monitoring effort, these were sometimes confused with young (latent, pre-sporulating) blister rust cankers. Dissection of these swellings has indicated hypertrophy (enlargement) of the zylem (Brian Geils, personal communication). (Note that blister rust causes swelling of the phloem). The swellings consistently display a small elliptical scar on the bark, perhaps sign of an insect "sting." These swellings gradually disappear within three to six years with the normal growth (thickening) of the branch.

Flagging of branch tips, caused by twig beetles or similar tunneling insects, has been observed on several plots on several occasions. These "flags" are typically smaller (affecting only two or three years of growth) than those caused by blister rust. Affected trees usually recover within a few years, although heavy infestation has occasionally resulted in thin crowns. This damage appears to be drought related.

Each of these damages (and others) can be confused with blister rust infection. Blister rust cankers themselves are commonly infested by *Dioryctria* larvae, whose tunneling appears to hasten girdling of infected branches and stems. Similarly, rodents often gnaw on rust -infected bark, hastening branch mortality and topkill.