Incidence of White Pine Blister Rust in Maine After 70 Years of a *Ribes* Eradication Program

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ABSTRACT

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Effectiveness of a *Ribes* eradication program for control of white pine blister rust was evaluated by comparing the incidence of the disease in areas never treated for *Ribes* with areas from which *Ribes* were regularly eradicated over the past 70 years. White pine stands were sampled to determine the effect of treatment (whether or not *Ribes* were controlled), tree size class, and hazard rating on disease incidence. Disease incidence, as measured by the number of infected trees, is lower (3.8%) in areas treated for *Ribes* compared with areas with no treatment (9.1%). Rust incidence is lowest in reproduction stands, and highest in pole stands. Hazard zone ratings did not reflect disease levels. Survey results indicate that a significant reduction in the incidence of white pine blister rust on a statewide level has been achieved through the *Ribes* control effort.

Additional keywords: *Cronartium ribicola*, disease survey, eastern white pine

Cronartium ribicola J. C. Fisch. ex Rabenh., the causal agent of white pine blister rust, has had a well-documented history in eastern North America since its discovery there in 1906 (13). The disease has been known in Maine since 1916. A control program based on the removal of *Ribes* host plants was begun in 1917 (11). By 1927, the disease was widespread throughout the state, and was causing considerable mortality.

The present control program involves delineation of white pine (*Pinus strobus* L.) stands to be protected, scouting the stands to map large *Ribes* populations, and killing individual plants, with later stand revisitation to destroy the large concentrations previously mapped. Herbicides are the predominant means of *Ribes* destruction.

To be considered for treatment, stands must be at least 2 hectares (5 acres) in size. A minimum white pine stocking of 865 trees/ha at least 1.2 m (4 ft) in height, or 370 white pine/ha at least 10.0 cm (4 in.) in diameter at 1.37 m aboveground (dbh) is required. Approximately 1.86 million acres are currently within the treatment area. Stands in the treatment area have been surveyed approximately every 10–12 yr.

Although the *Ribes* eradication program in Maine has undergone numerous administrative changes over the past 70 years, the basic approach and the area treated have remained relatively constant. Despite numerous case history studies demonstrating the potential impact of the disease (3,8,12), the effectiveness of *Ribes* eradication for the control of white pine blister rust in the eastern United States is still not well quantified (1). A more recent USDA Forest Service survey concluded that the destruction of *Ribes* was ineffective in controlling the disease on a regional level (9).

To update control program management in Maine, information was required regarding disease impact and program effectiveness on a statewide level. No statistically precise statewide surveys for white pine blister rust have ever been made in Maine. The objectives of the present survey, conducted in 1987, are 1) to determine current levels of white pine blister rust infection in Maine, and 2) to compare levels of the disease in areas with and without *Ribes* control.

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MATERIALS AND METHODS

Study design and stand selection. Incidence of white pine trees infected with blister rust was evaluated by surveying five stands representing each of two treatments (*Ribes* control and no *Ribes* control), three disease hazard zones (low, moderate, and high), and three tree size classes (reproduction, sapling, and pole). A total of 90 stands were examined, representing 18 cross-classified categories (5).

In areas where *Ribes* treatment has been conducted continuously, unpruned stands were randomly selected using the "block" numbers currently used by the control program. Unpruned stands in areas that have never been included in the *Ribes* eradication program were randomly selected from lists generated from old blister rust records, aerial photos, type maps of major landowners, and other existing knowledge of white pine stand locations. These stands were selected from towns within the established quarantine boundary for white pine blister rust that were known to contain the white pine cover type (4).

Hazard zones were those described by Charlton (2). Tree size classes were as follows: reproduction = trees 0.3–1.8 m (1–5.9 ft) in height; sapling = trees 1.8 m (6 ft) in height to 15 cm (5.9 in.) dbh; and pole = trees 15.2–25.4 cm (6–10 in.) dbh.

Field survey. Within each stand, 100 trees of the appropriate, specified size class were examined for rust cankers. A plot center was randomly chosen, and 25 trees were checked for infection along each of the four cardinal directions from this centerpoint. At 3 m (10 ft) intervals, the nearest white pine of the size class for the stand was evaluated. If one or more transect lines reached the edge of the stand before 25 trees were evaluated, additional centerpoints were chosen until the sampling was completed. Field personnel were trained in survey procedures and disease recognition, but specifically were not informed as to the hazard zone or the *Ribes* treatment class of the stands they examined.

Data were collected on canker incidence, canker location (branch or stem), height to lowest and highest canker, tree dbh, and total tree height (if infected). Both live and dead white pines were evaluated. Dead trees were included to determine disease incidence resulting over the maximum time period during which the trees may have become infected. Dead trees were included if they were standing with the bark and major branch structure intact. *Ribes* abundance in the stands was rated as not present, scattered, or common.

Data analysis. An analysis of cross-classified categorical data was used to interpret study results because all the variables, including the dependent variable, were class variables (5). Since the response was dichotomous (0, uninfected or 1, infected), the log-linear model was selected. In this model, a parameter is estimated for all n-1 levels of the main effects and interactions. The signs and significance of these estimates were used for model analysis.

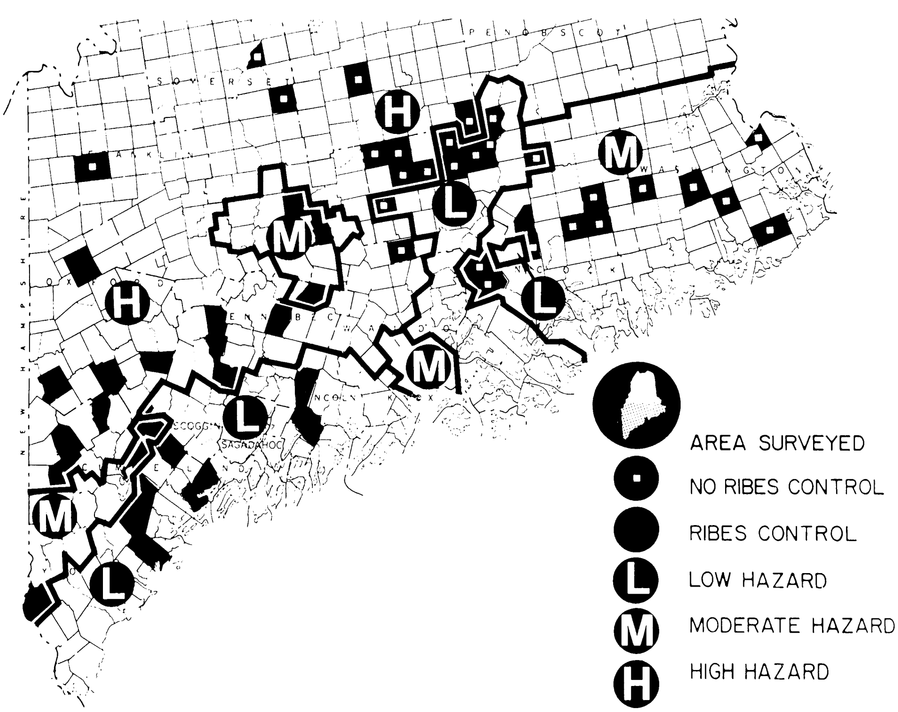

Fig. 1. Map of southern Maine (43° 05′ to 45° 30′ N, 61° 00′ to 71° 00′ W) showing location of townships surveyed for white pine blister rust incidence, *Ribes* treatment status of townships, and white pine blister rust hazard zones. Hazard zones are those of Charlton (2).

Table 1. Percent infection of white pine by *Cronartium ribicola* by tree size class, hazard zone, and *Ribes* treatment[a]

Tree size	Hazard zone	Treated	SE[b]	Untreated	SE
Reproduction	Low	2.0	0.7	6.0	2.0
	Moderate	3.6	2.2	7.4	2.5
	High	1.6	0.9	10.2	5.1
Sapling	Low	9.2	3.1	13.4	7.3
	Moderate	2.4	1.0	5.6	1.8
	High	4.0	1.6	5.8	1.8
Pole	Low	4.4	1.3	15.2	6.2
	Moderate	5.4	1.2	8.4	1.7
	High	1.8	0.7	9.6	3.3
Mean (SE)		3.8	(0.59)	9.1	(1.32)

[a] Values represent the mean percent of all trees with cankers out of 500 trees (100 trees in each of five stands).

[b] SE = standard error.

RESULTS

The 90 stands were located in 56 townships: 28 towns in areas receiving *Ribes* treatment, and 28 towns in areas with no treatment (Fig. 1). Average infection levels for the 18 cross-classified categories are shown in Table 1. A relatively consistent difference in disease incidence is apparent between *Ribes* treated areas and untreated areas. The mean level of infection was always found to be lower in the *Ribes* treated areas, regardless of hazard zone or tree size class.

Incidence of infected trees ranged from 0 to 18% in treated stands, with incidence in three stands over 10%. In untreated stands, incidence ranged from 0 to 42%. Ten untreated stands had over 10% of the trees infected; four of those stands had over 20% infected.

A total of 580 infected trees (6.4% of all trees examined) was found. Stem cankers accounted for 83.3% and branch cankers for 16.7% of all infected trees. Branch infections that had reached the main stem were recorded as stem cankers, and only stem cankers were recorded for trees with both stem and branch cankers. Numbers of infected trees with stem or branch cankers for each of the cross classifications are shown in Table 2.

A total of 379 trees (4.2% of all trees examined) was dead. Of these, 116 (30.6%) were infected and 263 (69.4%) were uninfected. More dead trees had been killed by white pine blister rust in the untreated areas than in the treated areas (Table 3).

The log-linear model that best fits the data contained all the main effects (*Ribes* treatment, hazard zone, and tree size class), plus all the two- and three-way interactions. The model is of the form: ln (no. uninfected/no. infected) = 2.87194 + (B_1 treatment) + (B_2 hazard) + (B_3 size) + (B_4 treatment × hazard) + (B_5 treatment × size) + (B_6 hazard × size) + (B_7 treatment × hazard × size). Although the model becomes difficult to interpret when significant interactions confound the main effects, a few observations regarding the main effects can be made.

Plots of the natural logs of the ratio of uninfected to infected white pine (Fig. 2), and the significance of the estimated parameters in the model, indicate the following trends. The effect of stands treated for *Ribes* versus those not treated is evident both in the plots (Fig. 2) and in parameter significance. The parameter for treatment is highly significant (P = 0.0001, chi-square = 93.58); treatment for *Ribes* decreases the proportion of infected trees, compared with untreated stands. In addition, reproduction stands were found to have a significantly lower level of infection compared with pole stands (P = 0.0013, chi-square = 10.35). Low hazard zones were found to have a significantly higher number of infected trees than the high hazard zones (P = 0.0001, chi-square = 14.89).

The interactions can confound these main effects to some extent. For example, the interaction "treatment × size class" indicates that untreated sapling stands tend to have a lower incidence of infected trees than treated pole stands (P = 0.002, chi-square = 9.92), and the "treatment × hazard zone" interaction shows less infection on untreated moderate hazard zones compared with treated high hazard zones. However, the log ratio of treated stands is always higher than those of untreated stands, despite the significant interactions.

DISCUSSION

This survey depicts the level of white pine blister rust control achieved through a program conducted over 70 years. Overall, 5.3% fewer trees are infected, representing over a 50% reduction in incidence of blister rust infected trees in *Ribes* treated areas. Effectiveness of the control program appears to be significant. These results support the conclusions of Martin (8), but not those of O'Brien and Miller (9), who examined infection rates over a relatively short (6 yr) period of time in treated areas only.

All cankers, particularly branch cankers, will not result in tree mortality. Phelps and Weber (10) estimated that in 25- to 35-yr-old trees (approximating the pole classification used in the present study), 45–70% of the branches with cankers died before stem infection occurred. For 9- to 13-yr-old trees (saplings), 9% of the branches with cankers died. Thus, those infections would fail to cause tree mortality. If trees with only branch cankers are discounted entirely in the pole and sapling classes of the present survey, the control effort was still successful in maintaining 45% fewer stem-cankered trees in the treated than in the untreated areas. This is a substantial number, especially in marginally or moderately stocked pole stands.

The analysis of dead trees (Table 3) indicates that 50% of the mortality in untreated areas is a result of the disease, compared with only 14% in treated areas. Therefore, inclusion of dead trees in the survey was important in assessing overall disease impact. Although length of time a tree had been dead was not critically evaluated, the selection criteria included trees dead for approximately 10 years or less. The length of time surveyed trees were exposed to the disease was judged to be a maximum of 20 years. Surveying over an extended exposure period assures the inclusion of infection "wave" years, thus minimizing errors associated with surveys over shorter periods.

Contrary to expectations, the hazard zone ratings did not reflect incidence of diseased trees. A significantly higher incidence was found in low hazard zones than in high hazard zones. A high incidence of infected trees in low hazard areas was also found in a survey conducted from 1940 to 1945 (Maine Forest Service, *unpublished data*). This would suggest that more refined criteria are needed to define zones, or that zones are drawn too broadly to reflect statewide conditions. Accordingly, hazard zones in Maine may not be useful as a basis for manipulating *Ribes* control intensity in the future, as suggested by Hodges (6).

Although most untreated areas are north and east of the treated areas as a result of control program boundaries, this is unlikely a significant cause of the difference in incidence of infected trees. The high potential for trees to become infected in the treated areas in Maine has been demonstrated by Posey and Ford (11), and by other surveys since that time (Maine Forest Service, *unpublished data*). Similarly, the high levels of damage that this disease is capable of causing have been known to occur over a wide geographic range, from North Carolina (12) to Quebec (7). The abrupt change in incidence of infected trees shown by the present survey occurs over a relatively small geographic range, and coincides

Table 2. Numbers of trees with stem or branch cankers of white pine blister rust found in the *Ribes* treated and untreated stands, by tree size class and hazard zone

		Branch cankers		Stem cankers	
Tree size	**Hazard zone**	**Total**[a]	**SE**[b]	**Total**	**SE**
Untreated stands					
Reproduction	Low	8		22	
	Moderate	15		22	
	High	6		45	
Total		29	2.7	89	7.7
Sapling	Low	26		41	
	Moderate	4		24	
	High	10		19	
Total		40	6.6	84	6.7
Pole	Low	6		70	
	Moderate	0		42	
	High	4		44	
Total		10	1.8	156	9.0
Treated stands					
Reproduction	Low	2		8	
	Moderate	0		18	
	High	2		6	
Total		4	0.7	32	3.7
Sapling	Low	9		37	
	Moderate	3		9	
	High	1		19	
Total		13	2.4	65	8.2
Pole	Low	0		22	
	Moderate	1		26	
	High	0		9	
Total		1	0.3	57	5.1

[a]Values represent the number of trees, out of 500, with cankers (100 trees in each of five stands). Trees with both stem and branch cankers are included as stem-cankered trees.
[b]Values represent standard errors of the means.

Table 3. Total number[a] and percentage of dead trees infected or uninfected with *Cronartium ribicola* in stands treated and untreated for *Ribes*

Trees	Treated	Untreated	Total
Infected	28 (13.9%)	88 (49.4%)	116
Uninfected	173 (86.1%)	90 (50.6%)	263
Total	201	178	379

[a]From a sample of 9,000 trees.

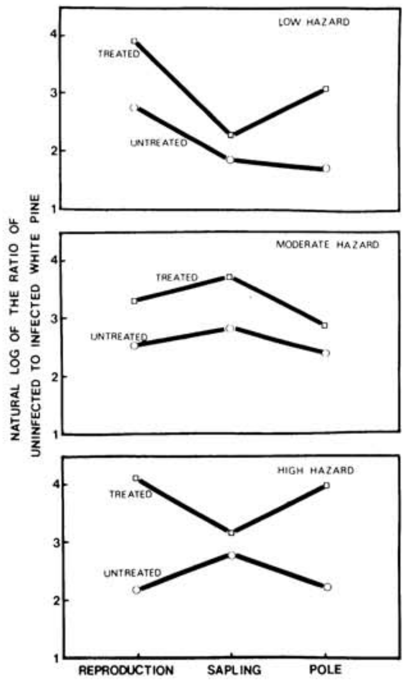

Fig. 2. Natural logs of the ratios of uninfected to infected white pine for each tree size class, by the three hazard zones.

with the control program boundary.

Adequate data comparing *Ribes* population levels in treated and untreated areas is not available. *Ribes* was noted in only two stands, one in each treatment, during this survey.

Although this study supports the effectiveness of the *Ribes* eradication program, additional control alternatives, particularly those that can be used on a more local level such as early pruning, are often required and should be considered by individual landowners. The survey now provides the information necessary to determine the economic effectiveness of the *Ribes* control program.

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