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One and Two Year Follow-up Evaluation of TM BioControl-1 Treatments to Suppress Douglas-fir Tussock Moth in the Blue Mountains of Northeastern Oregon and Southeastern Washington

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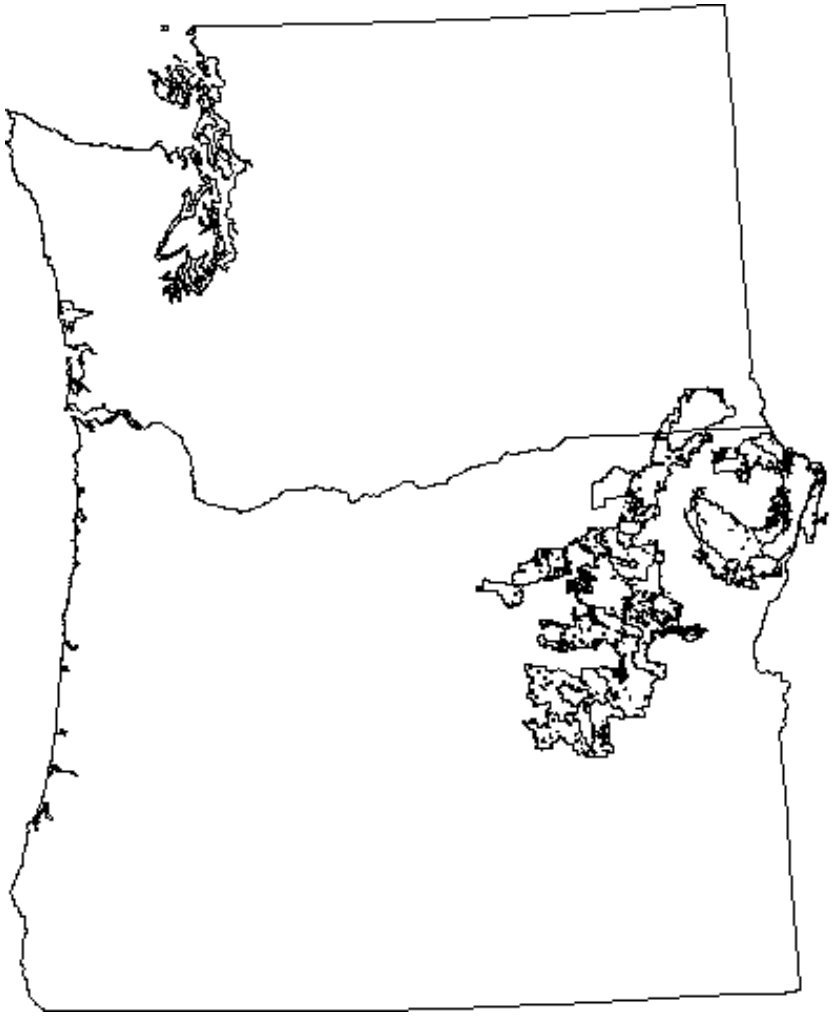

Executive Summary

Treatment of Douglas-fir tussock moth populations on 39,602 acres of the Pine, Walla Walla, and Pomeroy Ranger Districts in 2000 represented the first large-scale, operational use of the viral insecticide, TM BioControl-1, to suppress a tussock moth outbreak in the United States. This fact, and the widespread national and international interest in application of insect viruses to control forest defoliators, compelled the need to closely monitor treatment effects on populations, as well as subsequent damage to host trees. Accordingly, we re-sampled larval populations in 2001 and tree defoliation and mortality in 2001 and 2002 in treated and untreated areas. This provides information beyond the initial year of treatment on the effectiveness of the treatment in reducing defoliation, top-kill, and tree mortality resulting from defoliation or subsequent bark beetles.

Tussock moth populations were so low in 2001 that it was difficult to find larvae to sample. Midcrown densities in 2001 were less than 2 larvae per 1000 in^2 of foliated midcrown branch on all analysis units, with the exception of one untreated analysis unit on the Pomeroy Ranger District that had an average of 2.3 larvae per 1000 in^2. All densities represented a substantial decline in populations from the previous year. This decline is attributed to virus-caused mortality. The average virus infection rate of young larvae from all treated analysis units in 2001 was 34.1% compared to a rate of 29.9% on untreated control units. The low population and the similar virus infection rates indicate that applied virus did not influence larval infection rates any differently than natural virus levels one year after initial treatment.

The amount of defoliation that occurred in 2001 and 2002 was negligible due to the low numbers of larvae. Only the Duck analysis unit on the Pine Ranger District had measurable defoliation in 2001. This amounted to only 5 of 498 trees with defoliation that was 10% or greater by the end of the season in 2001. Only two trees had measurable defoliation in 2002.

While cumulative top-kill and tree mortality were similarly low on all units, there were significant differences between treated and untreated areas. All treated units on the Wallowa-Whitman had significantly less top-kill than untreated units ($p<0.025$). Differences on the Umatilla were not significant. Two of the three treated units on the Wallowa-Whitman had significantly more mortality than untreated units ($p<0.05$). All other differences in mortality were not significant.

These plot locations were chosen randomly to represent the overall conditions likely to be found in the defoliated areas. Due to the patchy nature of tussock moth defoliation and damage, it is very likely that more severe conditions can be found over the larger landscape of the entire defoliated area. Tussock moth damage tends to appear in the forest as spots of heavy defoliation grading out to no defoliation with every variation of defoliation intensity between these extremes. While approximately 220,000 acres were mapped with defoliation during the 2000 aerial survey, those acres exhibit the complete spectrum of defoliation. The results of this follow-up study indicate that less than 1% of

the trees in this 220,000 acres area are dead from the defoliation, with about 3% of trees suffering top-kill.

The suppression project had mixed success. The overarching goal was to protect foliage in high value areas such as sensitive species habitat and high value recreation areas. Post-treatment monitoring in 2000 clearly showed an increase in virus infection rates accompanied by a decrease in larval populations and defoliation in treated areas compared to larvae from untreated areas. However, the appearance of naturally occurring virus in all units obscures the overall results. By 2001 there was no difference in virus infection rates nor in measured defoliation in treated and untreated areas. The lower number of top-killed trees in treated areas indicates a lasting positive effect from spraying. The higher mortality in some treated areas needs further investigation.

The current Forest Service stocks of TM BioControl-1 are limited, and it would not be easy to produce additional quantities, nor could it be done quickly or inexpensively. Hence, application of the virus must be done with care to avoid wasting the biological insecticide by treating areas where treatment may not be required due to an abundance of naturally occurring virus in populations. Moreover, it would be helpful to know well in advance of treatment both if natural virus were present and the extent to which such occurrence might influence ultimate collapse of the population. Clearly, there is need for more research to provide information that would facilitate suppression project decisions that are timely, accurate, and cost effective.

Introduction

A Douglas-fir tussock moth, *Orgyia pseudotsugata* (McDunnough), suppression project was conducted in the Blue Mountains of northeastern Oregon and southeastern Washington in 2000 using the nucleopolyhedrovirus (NPV) product, TM BioControl-1. A total of 39,602 acres were treated. The Wallowa-Whitman National Forest treated 3 analysis units on the Pine Ranger District consisting of 33,427 acres, and the Umatilla National Forest treated 6,175 acres on two analysis units: 3,912 acres on the Pomeroy Ranger District and 2,263 acres on the Walla Walla Ranger District (Figure 1). This was the first large-scale operational use of TM BioControl-1 for tussock moth suppression in the United States.

Greear (2000) cites the project objectives for the 2000 Douglas-fir Tussock Moth Suppression Project for areas of the Umatilla and Wallowa-Whitman National Forests, as follows:

- **Protect riparian habitat where defoliation would cause unacceptable degradation of occupied habitat, especially critical spawning or rearing habitat for salmon, steelhead, and bull trout (loss of shade, increased sedimentation, etc.).**
- **Protect designated old growth and late/old structure ("OG/LOS") stands where defoliation would substantially degrade habitat values.**
- **Protect residential and administrative sites where defoliation and the presence of large numbers of larvae would adversely affect people living or working there. This would include work centers, special use permit summer home sites, resorts, or established camps.**
- **Protect high use recreation sites where defoliation and the presence of large numbers of larvae would adversely affect many forest visitors. This would include campgrounds, picnic areas, and interpretive sites.**
- **Protect municipal watersheds where an existing formal agreement is in place and where 100% defoliation would have unacceptable impacts on water quantity or quality.**
- **Protect designated foreground scenic Areas of Concern where defoliation would have a substantial adverse impact on scenery.**
- **Protect seed orchards and plantations of genetically superior trees where defoliation would result in a considerable loss of investment and a reduction of seed needed for future seedling demand.**
- **Protect areas where investments have already been made to protect Douglas-fir or other firs from bark beetles.**

During the spring and summer of 2001, we re-sampled Douglas-fir tussock moth larvae on treated and paired control analysis units in the project area. In both 2001 and 2002 we evaluated over 3000 trees for current year defoliation, top-kill and mortality. The purpose of this sampling was to track the course of virus one year after treatment, and evaluate the effect of treatment in reducing defoliation, top-kill, and tree mortality, especially in light of a current and widespread Douglas-fir beetle, *Dendroctonus pseudotsugae* Hopkins, outbreak in part of the project area.

Methods

To determine tussock moth population densities, we sampled larvae on treated and control areas during two sampling periods. We sampled early instar (L1-L3) larvae from

June 25 to July 10 and late instar (L4-L6) larvae from July 23 to August 7, 2001. This sampling was done using the lower crown beating method of Mason (1977b; 1979). The samples consisted of 5 haphazardly selected trees at 109 plot locations accessible within one mile of the road, selected from among the 461 plots established for the 2000 suppression project (see Greear 2000).

Larval counts determined by lower crown sampling were converted to mid-crown densities as is the custom in Douglas-fir tussock moth reporting (expressed as larvae per 1000 in^2 of foliage) (Wickman 1979). Larval counts were weighted to account for differential distribution of larvae within the crown (Scott and Mason 1992). These densities were compared to the densities found in 2000 to determine population trends following treatment.

To follow tree mortality, top-kill, and defoliation in 2001 and 2002 we revisited 3025 of the 3539 defoliation impact trees established during 2000. We recorded top-kill and mortality and used Wickman's defoliation estimation procedure to rate total current defoliation (Wickman 1979).

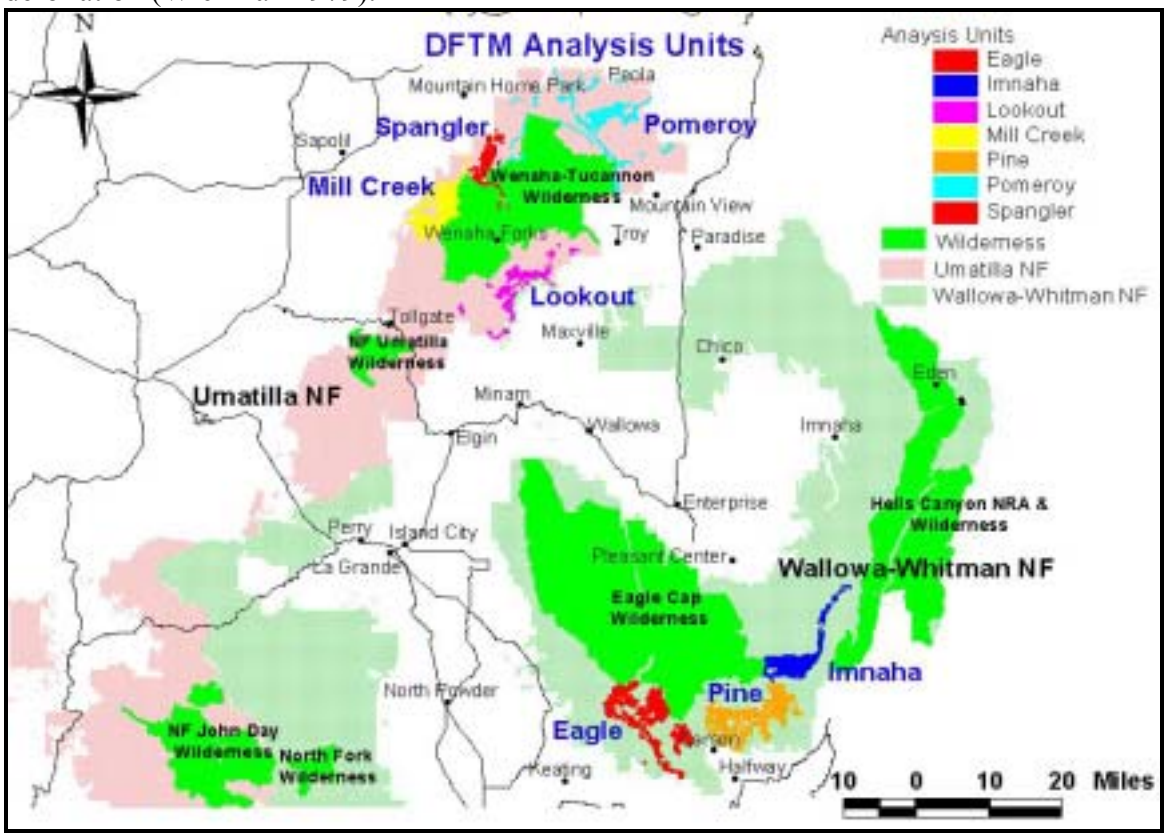

Figure 1. 2000 Douglas-fir tussock moth analysis unit map (Note: only Eagle, Imnaha, Mill Creek, Pine, and Spangler Analysis Units were treated during the 2000 project).

We collected up to 15 larvae from each plot, during each sampling period, for laboratory rearing to determine causes of mortality including nucleopolyhedrosis (NP) disease. Larvae were collected and placed individually into small disposable plastic petri dishes (50 x 9 mm) with a small piece of artificial tussock moth diet (Thompson and Peterson 1978), approximately 1in. x 1in. x ¼in. Larvae were re-supplied with fresh diet

approximately once per week, depending on the condition of the diet. Larvae were reared until pupation or death. Upon death, larvae were microscopically examined by phase contrast microscopy to determine cause of death. Since we were sampling discrete variables from a population of individuals having one of two mortality attributes (virus presence or absence), the relative frequency of occurrence of individuals in these populations were binomially distributed. Our estimates of proportion of tussock moth larvae with nucleopolyhedrovirus were made based on formulas for calculating the statistic in a binomial distribution.

Results and Discussion

Population Densities

Early larval (L1-L3) mid-crown densities on all units in 2001, which corresponds in sample timing to the pre-treatment sample of 2000, were substantially lower than pre-treatment densities in 2000 (Fig. 2, and see Greear 2000). Early larval mid-crown densities from treated and untreated analysis units on both the Wallowa-Whitman and Umatilla National Forests were less than 2 larvae per 1000 in^2 of branch foliage in nearly all cases (Table 1), and were classified as "low" or "very low" populations. Only one analysis unit, the early sample, untreated Pomeroy control unit on the Umatilla NF, exceeded the threshold level for "sub-outbreaks" ($\geq$ 2 larvae per 1000 in^2, but less than 21; Mason 1977a). With a mid-crown density of 2.34 larvae per 1000 in^2, this unit was only slightly higher than those early larval populations on other analysis units with densities that classified as "low."

Analysis Unit	Total No. Early-Stage Larvae Sampled	Early-Season Larval Density (Larvae per 1000 in^2)	Total No. Late-Stage Larvae Sampled	Late-Season Larval Density (Larvae per 1000 in^2)	Seasonal Change in Larval Density (Percent)
Imnaha	10	0.58	0	0	-100.0
Pine	10	0.28	4	0.06	-78.6
Duck Control	48	0.26	11	0.03	-88.5
Eagle	3	0.08	2	0.03	-62.5
Gold Control	37	1.34	27	0.57	-57.5
Spangler	17	0.30	9	0.10	-66.7
Mill Creek	3	0.14	3	0.08	-42.8
Pomeroy Control	57	2.27	31	0.78	-65.6

Table 1. 2001 Seasonal change in Douglas-fir tussock moth larval density from early- to late-instar samples, by analysis unit.

The tussock moth populations continued to decline through the 2001 season. All analysis units showed decline in mid-crown population density from the early instar to the late

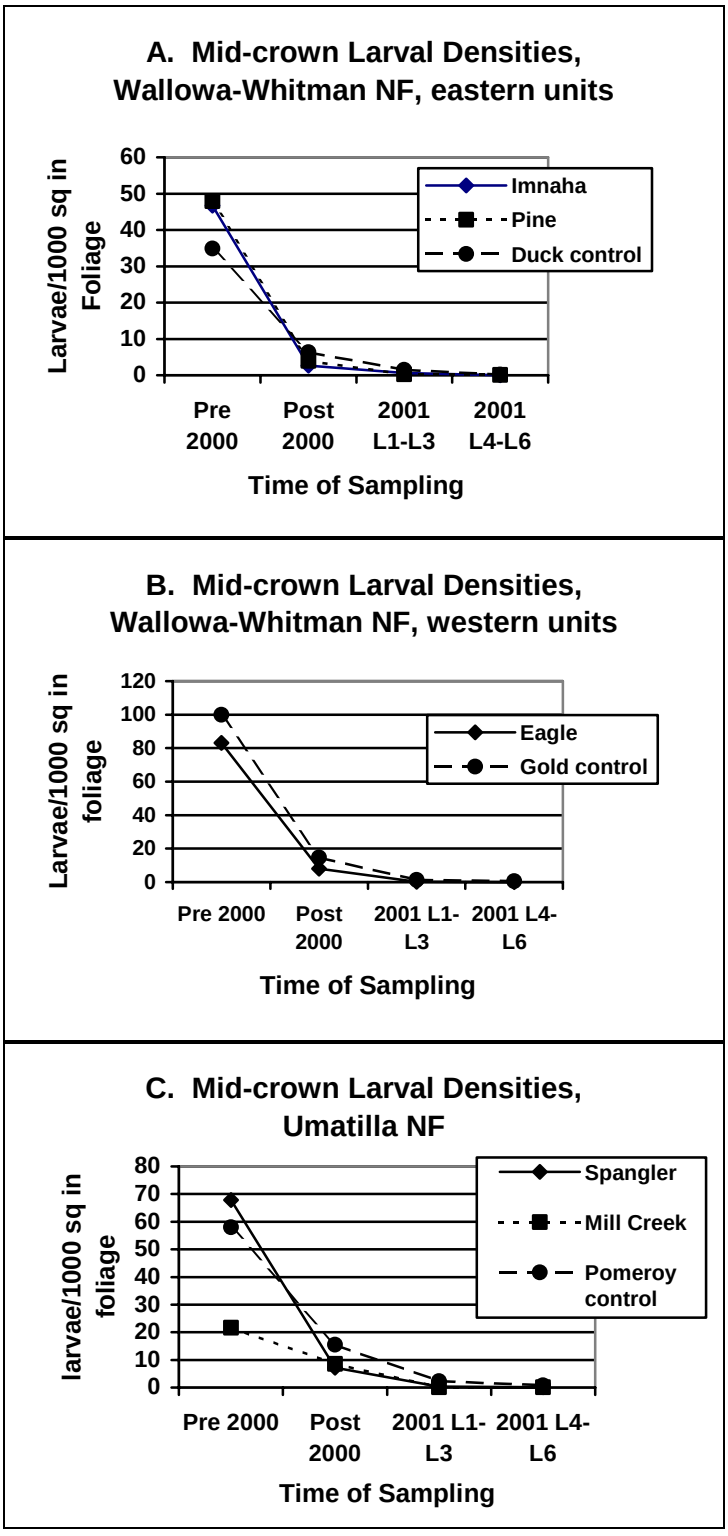

Figure 2: Mid-crown Douglas-fir tussock moth larval densities, treated and control areas 2000 & 2001.

instar sample periods (Fig. 2 and Table 1). However, given that the larval populations were already so low at the beginning of the 2001 season, the percentage reduction over

the course of the season—though it appears large on a percentage basis—is biologically insignificant.

Larval Mortality

Tussock moth populations in 2001 continued collapsing with very high levels of mortality particularly in the early sample (Fig. 3). Extraordinarily low larval populations made it difficult to find adequate numbers to collect for rearing to monitor causes of mortality. We collected only 219 larvae (of a possible 2400, given sampling protocol) for rearing on all 8 treated and untreated analysis units over both sampling periods in 2001.

Analysis by X^2 tests revealed no differences in virus infection rate between treated and control units in either the early or late sampling periods. The percent virus infection rate in early larval collections ranged from 25% to 43% from treated analysis units, and from 22% to 38% on the untreated controls. The percent virus infection rate for older larvae ranged from 0% to 33% in the treated analysis units, and from 22% to 42% in the untreated control units (Table 2).

The low numbers of larvae available for collection make conclusions on the effect of treatment after one year difficult. A larger proportion of larvae survived in the late-stage sample than in the early-stage sample (Table 2). The Pine Analysis Unit had larval survival as high as 75% in the late-stage sample, and the Eagle Analysis Unit had 100% larval survival; whereas, no larvae survived in the earlier larval collections (Table 2). However, the 75% survival represents 3 larvae. So in this case very few larvae remained at the end of the 2001 season when we made the late-larval stage census, but the survival rate to adult of those that did survive was rather high.

Analysis Unit	**Larval Mortality Rate From Early Sampling Period**					**Larval Mortality Rate From Late Sampling Period**				
	NPV	Para	Unk	Total	N	NPV	Para	Unk	Total	N
Imnaha	0.43a	0	0.57	1.00	7	0a	0	0	0.00	0
Pine	0.25a	0	0.62	1.00	8	0.25a	0	0	0.25	4
Duck Control	0.22a	0	0.74	1.00	23	0.42a	0.08	0.08	0.58	12
Eagle	0.25b	0	0.75	1.00	4	0b	0	0	0	2
Gold Control	0.38b	0	0.56	0.96	24	0.22b	0.09	0.39	0.70	23
Spangler	0.41c	0	0.47	0.88	17	0.11c	0.22	0.33	0.67	9
Mill Creek	0.33c	0.33	0.33	1.00	3	0.33c	0	0.33	0.67	3
Pomeroy Control	0.31c	0.02	0.60	0.96	48	0.25c	0.11	0.21	0.57	28

Table 2. Comparison by analysis unit of causes of mortality of Douglas-fir tussock moth larvae collected during the 2001 early and late sampling periods (Para=parasitism, Unk=unknown, N=number of larvae in sample). Same letters for treated and paired control units indicate no difference, p>0.05.

The higher virus incidence in sprayed versus unsprayed units observed in 2000 no longer held in 2001 (Figure 4). The similar virus infection rates indicate that applied virus did not influence larval infection rates any differently than natural virus levels one year after initial treatment. We believe many larvae become infected during egg eclosion. Hatching larvae are believed to pick up virus from eggs that become contaminated as winter rains and melting snow leaches virus from larvae and cocoons containing pupae that had been killed by virus the previous summer (Shepherd et al. 1988; Stelzer 1979; Thompson 1978). The spread of the virus to new egg masses and over foliage is believed to greatly enhance the incidence of virus in the new generation of larvae. Virus spread by rainfall and snowmelt may help initiate the collapse of an outbreak by widely contaminating the environment of the insect with virus.

Late instar virus infection rates did not appear to be different from early instar infection rates. Overall population abundance had declined last year such that horizontal spread of the virus by contagion in 2001 was quite restricted. Disease transmission by contagion may be less important in the disease cycle at this phase of the outbreak when the virus is so widespread in the environment of the insect that it may be difficult to avoid.

Parasitism rates were quite low overall during both collection periods based on parasite incidence in reared larvae (Table 2). The late-larval collection period was timed to correspond with the last 2 or 3 instars of the tussock moth to capture some of the mortality related to late-season parasitism. However, we still missed parasitism that occurred during the egg and pupal stages, as we did not collect eggs nor pupae for rearing. One tachinid fly, *Carcelia yalensis*, is a known important parasite during the pupal stage of tussock moth (Mason 1976; Dahlsten et al. 1977; and Torgersen 1981) that was unaccounted for during this monitoring. Pupal parasitism can affect a significant component of mortality in a residual tussock moth population at the end of the season (Mason 1981), and sometimes hastens the decline of an outbreak (Furniss and Carolin 1977).

Defoliation, Top kill and Tree Mortality

The Mill Creek analysis unit was dropped from this analysis due to a very low sample size. In 2001 only 15 trees were sampled, and in 2002 that number shrank to 5 trees. There was no recorded top-kill or mortality in either year in this unit.

Defoliation was very low in both years in all units. In 2001 the Duck control unit was the only area to exhibit defoliation. One percent of the trees in the Duck unit were 10% defoliated, the lowest recordable level. In 2002 only 2 trees, one in a control unit and one in a sprayed unit showed current year defoliation of barely 10%.

Heavy defoliation in 2000 was expected to lead to top-kill and tree mortality. The Duck and Gold control areas were the only units with more than 10% of sample trees that had defoliation levels high enough in 2000 to expect some levels of top-kill or mortality (i.e. >25%, Wickman 1978). The Duck control area had 12.4% and the Gold control area had

66.8% of sample trees with defoliation >25%. Still, only 5% of these trees had more than 50% of the crown defoliated in 2000 (Greear 2000). Less than 1% of the trees on each of the other units had more than 50% of the crown defoliated in 2000 (Greear 2000).

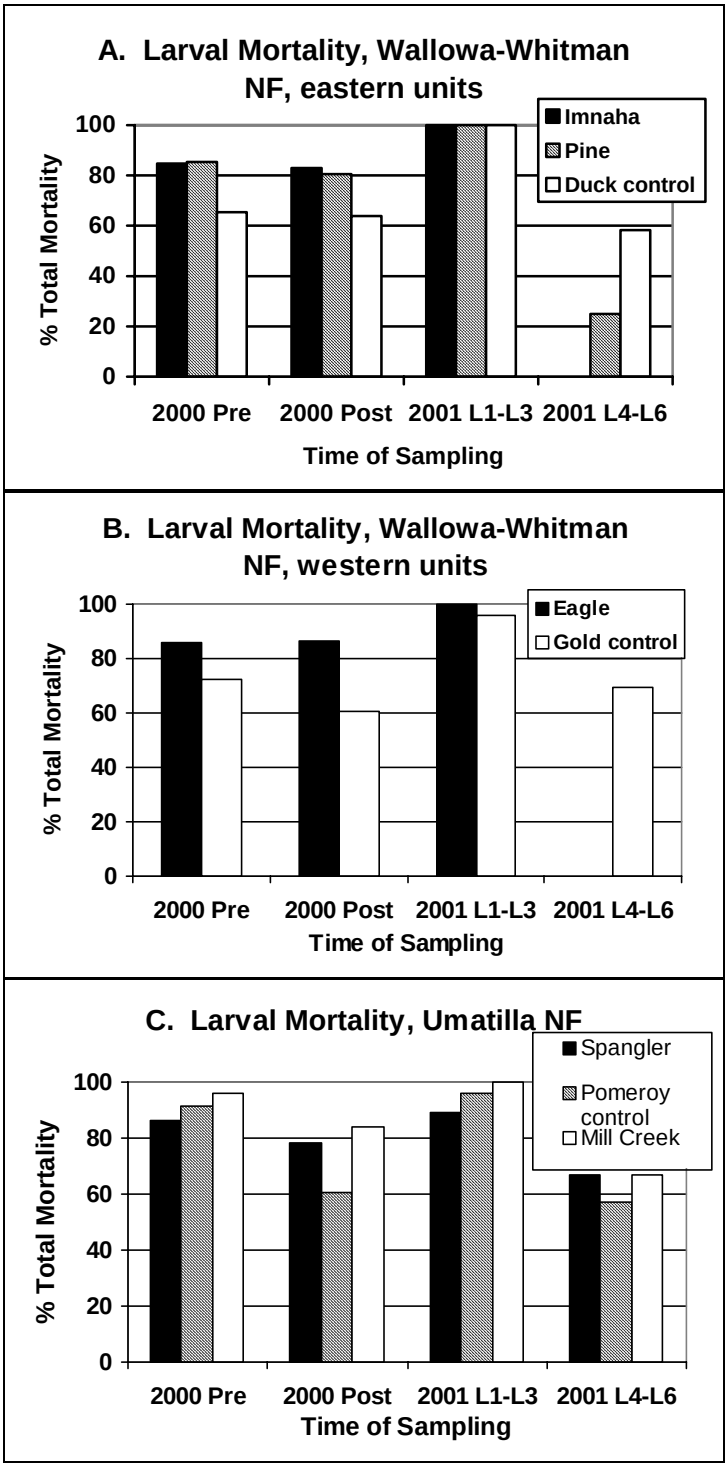

Figure 3: Mortality of Douglas-fir tussock moth larvae from all causes and all areas during 2000 and 2001.

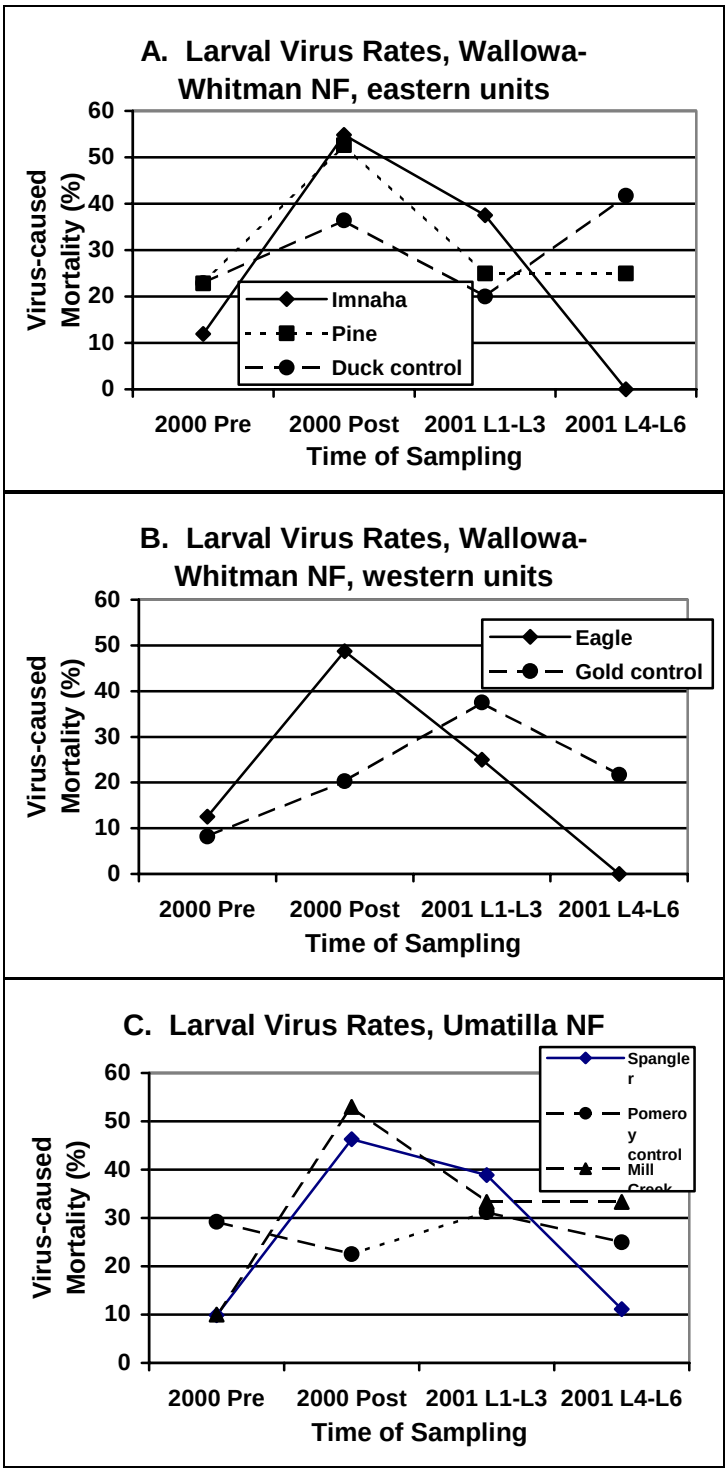

Figure 4: Virus-caused Douglas-fir tussock moth larval mortality in all sampling areas during 2000 and 2001.

A total of 88 trees were recorded with top-kill or 2.9% of sampled trees. Of the trees with top-kill, 47 occurred on the Duck control unit. In this unit, top-kill was not randomly distributed but was higher than expected in trees with greater than 25% defoliation and no defoliation, and less than expected in trees with measurable defoliation

up to 25% (Figure 5). There was less top-kill on treated areas on the Wallowa-Whitman National Forest than on untreated areas ($p<0.05$) (Figure 6). Treated and untreated units were not different on the Umatilla National Forest. The Gold unit was not revisited in 2002 due to road construction and so the data for the Gold and Eagle units is limited to 2001 information.

Number of Trees top-killed, 2002	Duck analysis unit Defoliation rating, 2000 post-spray					
	0	>0-10%	>10-25%	>25-50%	>50%	**Total Trees**
Actual top-kill	3	11	21	10	2	**47**
Expected top-kill	1.7	13.6	25.5	5.8	0.5	**47.1**
Top-kill ratio	0.176	0.083	0.084	0.175	0.4	**0.102**

Figure 5: Duck analysis unit: Comparison of 2000 defoliation rating and subsequent top-kill. The most defoliated trees, >50%, contribute the most to the cumulative top-kill ratio.

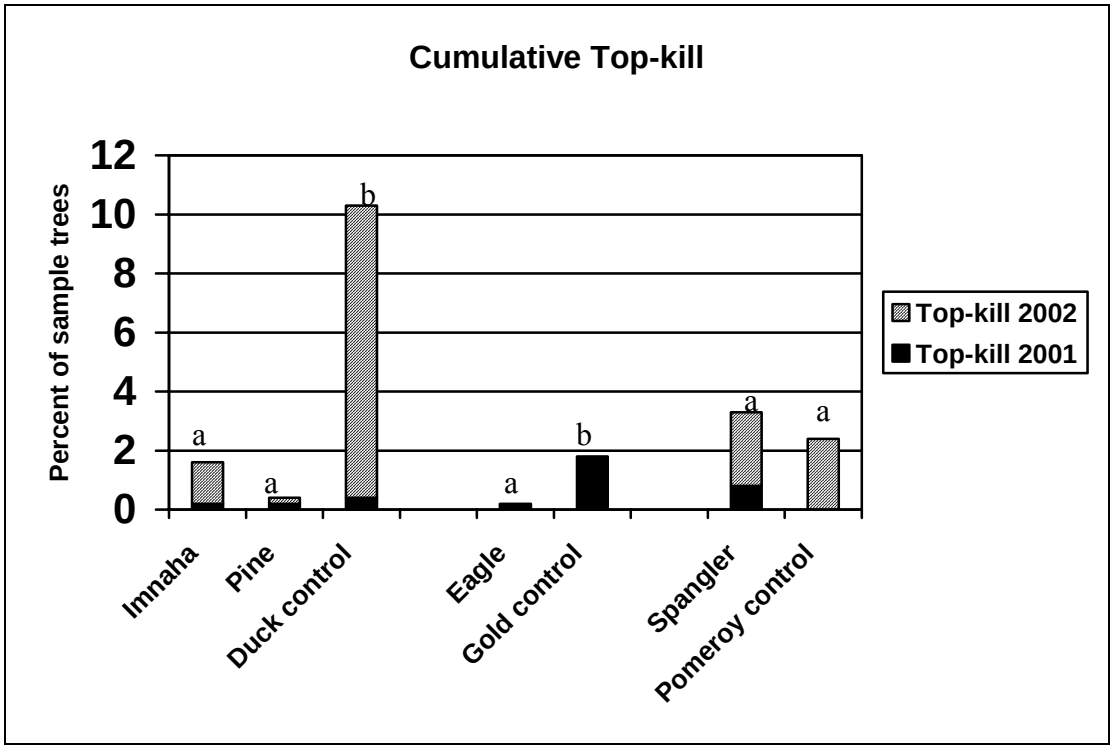

Figure 5: Top-killed trees: no current year foliage on upper 10% of crown, older dead tops ignored, Eagle and Gold have no data for 2002, Pomeroy had no top-kill in 2001. Different letters indicate significant differences between units, $p<0.025$.

A total of 20 trees died on all analysis units, 0.7% of sampled trees. There was no recorded mortality on two of the three untreated analysis units. The third, Duck, had significantly less mortality than it's corresponding treated units (Figure 6). The reasons for this are not immediately apparent. Perhaps further analysis of all the data will reveal some possible reasons. The overall mortality rate is so low it is possible the mortality we saw was not directly related to the tussock moth defoliation but instead represents some more general forest-wide mortality during these years. Populations of fir engraver beetle, *Scolytus ventralis*, and Douglas-fir beetle were elevated in some areas, possibly close to the monitored trees, during these years. All tree mortality recorded on defoliation plots was caused by a combination of defoliation and Douglas-fir beetle or fir engraver beetle.

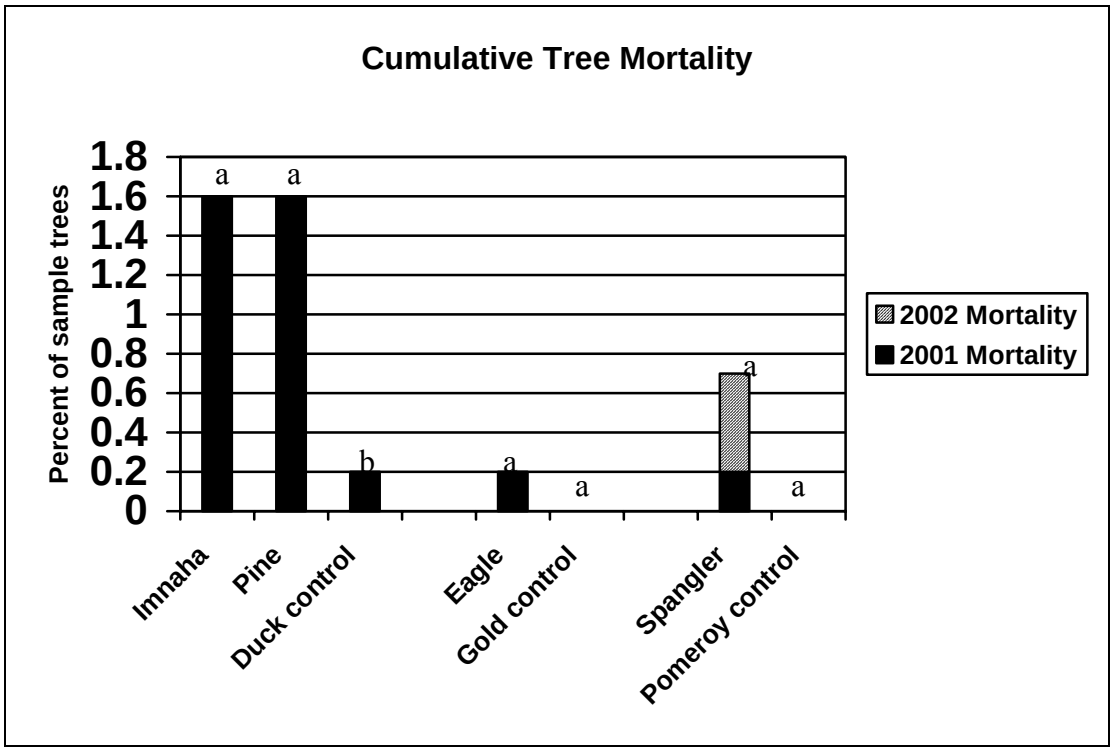

Figure 3: Total tree mortality detected in 2001 and 2002, needles fading, boring frass present.

These figures for overall tree mortality and top-kill probably approximate the overall mortality in the respective locales of the defoliation plots. However, because of the patchy nature of Douglas-fir tussock moth epidemics, tree mortality generally occurs in concentrated patches scattered on the landscape (Mason and Wickman 1988), similar to fire-caused mortality. There are patches of 100% mortality where defoliation was 100%, ringed by patches of top-kill and lower mortality rates where defoliation was less uniform and less severe. A more informative way to monitor Douglas-fir tussock moth impact would be to link larval density counts at very specific, delimited sites with subsequent defoliation, top-kill, and tree mortality. We are not aware of any attempts at making this linkage for specific sites, although Mason et al. (1998) have demonstrated that acres of current defoliation can be estimated over large areas from the means and variances of larval density estimates obtained from a series of sample plots.

Declining beetle populations in 2002 may reduce occurrence of delayed tree mortality from bark beetles. Peak Douglas-fir mortality generally occurs in the year immediately following cessation of defoliation, while true fir mortality peaks in the second year after defoliation ceases (Berryman and Wright 1978). Within a few years, we would expect trees to be nearly fully recovered, and many of the trees that were not top-killed will probably show little sign of the defoliation that occurred mostly in 1999 and 2000.

Decision Protocol and Criteria For Suppression of Tussock Moth Populations with TM BioControl-1

Having monitored the populations on both treated and untreated areas for two years after the suppression project, it seems appropriate to revisit the biological decision protocol and criteria for arriving at a treatment decision. There are several factors to consider in deciding when or where to apply TM BioControl-1. The first is the presence and magnitude of natural virus in the target population. Another factor is the density of the target tussock moth population and potential for increase to levels causing unacceptable damage to the resource in whatever way that may be defined. These factors are interwoven and difficult to monitor.

Two techniques have been developed to detect the natural level of NPV in the field. A soil-borne virus bioassay procedure described by Thompson and Scott (1979) can detect very low levels of virus persisting for 40 years or longer (Thompson et al. 1981). An egg mass virus detection technique developed by Stelzer (1979) can determine levels of virus in newly hatched larvae. Use of the former technique is valuable in areas where the historical occurrence of NPV is unknown. The latter technique can be used to estimate virus prevalence in current populations. In September 1998 60 egg masses were collected from a part of the proposed spray area. We found 6.7% of egg masses contaminated with virus and 0.9% of 1,508 hatched larvae died from virus infection (personal communication from Dr. Imre Otvos, Canadian Forest Service, April 2000). Stelzer (1979) found that if 25% of larvae reared from egg masses were contaminated with virus at egg hatch, the population would collapse before unacceptable tree damage occurred. He noted that if initial (first instar) infection rates are low (below 15 percent) spread of virus disease during the first four or five instars is slow, but then dramatically increases as the larvae reach maturity and begin to pupate. Our low virus levels measured from egg mass collections in 1998 were not expected to control this population prior to the occurrence of unacceptable levels of tree damage (Stelzer 1979).

The density of tussock moth larvae also affects the decision to suppress a population. We decided Douglas-fir tussock moth larval densities must be above 10 larvae per 1000 in^2 of foliage in the midcrown to proceed with suppression treatment (see Greear 2000). Mason et al. (1993) report that populations lower than 2 larvae per 1000 in^2 of foliage are considered low density and not expected to outbreak. Populations >2 but <21 are considered suboutbreak and result in little visible defoliation. Populations higher than 40 larvae per 1000 in^2 foliage indicate a severe outbreak and it is expected some trees will be completely defoliated (Mason et al. 1993). Our 1999 cocoon sampling indicated that early 2000 larval densities would average over 35 larvae per 1000 in^2 foliage (Scott

2000). At this density the population would be in outbreak and cause visible defoliation and other damage (Mason et al. 1993).

Our decision to proceed with suppression treatment in 2000 was based on the predicted high larval densities on the Pine Ranger District (Wallowa-Whitman NF) and the low natural virus levels in egg masses collected in fall 1998. These low virus levels were not expected to control the outbreak. Given these data, we anticipated tussock moth would cause unacceptable damage. We believed that natural virus would build slowly in this population, and natural virus prevalence rates would not prevent unacceptable tree damage. However, we did not make another collection of egg masses in 1999 to determine if natural egg mass virus levels had changed from the previous year. In retrospect, this was a mistake because tussock moth populations had increased to levels high enough during 1999 to cause more than 20,000 acres of light to moderate defoliation in this area (Campbell et al. 2001). Larval populations high enough to cause this amount of defoliation would probably be accompanied by an increase in overwintering egg mass virus levels in 1999-2000. Therefore, we believe the unknown levels of 1999 naturally occurring egg mass virus were higher than anticipated. This inoculum source caused the natural virus to develop rapidly in the populations. This resulted in higher virus levels in 2000 in all analysis areas than were expected from the egg masses collected in 1998.

Conclusions

The 2000 suppression project demonstrated that on an operational basis, it is possible to induce an NP epizootic in an outbreak population of tussock moth. The purpose of treatment with TM BioControl-1 was to protect foliage of trees in areas of special concern such as riparian areas, late/old structure stands, and high use recreation sites. To determine effectiveness of treatment, larval mortality and tree defoliation and mortality were monitored. While there is no question that treated areas exhibited a widespread NP disease epizootic immediately after treatment, the degree to which treatment protected foliage and reduced tree mortality is less clear.

Post-treatment larval collections beginning about 10 days after treatment clearly showed a treatment-related response in virus prevalence rates compared to untreated areas. But a year later, by the end of the 2001 season, larval densities had declined to such low levels that there were no longer any real differences between treated and untreated areas. The overall low numbers of insects in 2001 makes interpretation of these data difficult. Our virus monitoring results suggest that there was enough naturally-occurring virus present in all areas for the virus to build up in 2000 and initiate the collapse of tussock moth populations in 2001. Evidence from many sides suggests that when virus is present and increasing in a tussock moth outbreak, buildup of virus in the population may be rapid and strongly contribute to the collapse of the population (see Dahlsten and Thomas 1969, Evenden and Jost 1947, Harris et al. 1985; Hughes and Addison 1970; Mason and Thompson 1971; Morris 1963; Shepherd et al. 1988; Wickman et al. 1973).

Still, there remains the question of whether or not this project would have gone forward had we known the potential for natural virus in overwintering egg masses in 1999-2000 to initiate an NP epizootic in this population. These results point out the important fact

that having this virus information in a timely manner is paramount to making the critical decision of whether or not to suppress tussock moth populations. Some bioassay tools are available to assist in generating information needed to make this decision in advance of a project. However, greater refinement and standard protocol is needed to interpret and apply this information in a timely and efficient manner to determine if population suppression is justified or needed.

Acknowledgments

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