

Final Report:

Brood Tree Removal and Verbenone Treatments, Smuggler Mountain 2009

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Summary: In 2009, forest land managers collaborated in an area-wide treatment to reduce tree mortality resulting from mountain pine beetle (MPB) attack over ca. 270 acres in the Roaring Fork Valley near Aspen, CO (Fig. 1) using a combination of pheromone applications and removal of infested brood trees. The three treatments were (1) application of verbenone pouches combined with brood tree removal; (2) application of verbenone flakes combined with brood tree removal; and (3) untreated reference stands. Efficacy was assessed by conducting post-season timber cruises to measure stand structure and pre- and post-treatment MPB attack rates. There were unavoidable differences between plots in the amounts of pheromone applied, pre-treatment MPB attack rates, and existing forest structure, which is known to influence bark beetle risk. This project was designed as an individual case study without replication of treatments. We used logistic regression techniques to assess differences in beetle attack rates and the influence of environmental conditions, including pheromone treatments, on the probability (risk) of MPB attack. We also used conventional general linear models where appropriate. Our key findings were:

- Failure to remove infested brood trees drastically increased the localized risk of MPB mass attack (by an average of nearly forty-fold) (Fig. 2-C). This finding cannot be extrapolated stand-wide, but suggests that brood tree removal is crucial for minimizing MPB damage.
- The risk of MPB attack increased with stand density, as we had predicted (Fig. 2-A and 2-B, Fig. 3); stand structure has previously been shown to play a key role in bark beetle outbreaks.
- The risk of MPB attack in verbenone-treated stands was significantly lower than in untreated stands; the risk of MPB attack was slightly less with flakes than with pouches, but the difference between them was not statistically significant (Fig. 4).

Introduction and Background.

Colorado, like many states in the Rocky Mountains, is experiencing record-breaking outbreaks of mountain pine beetle, *Dendroctonus ponderosae*, resulting in unprecedented mortality of lodgepole pine, *Pinus contorta*. It has been predicted that 80-90% of the mature lodgepole pines in Colorado will be killed by the end of this outbreak, and similar scenarios are playing out in British Columbia where forest stands that were once carbon sinks have become carbon sources. Although the scale of these outbreaks is challenging, there is evidence that MPB-caused tree mortality can be reduced at local scales through removal of infested trees and application of beetle anti-aggregation pheromones such as verbenone. For example, previous tests using verbenone-releasing flakes showed that we could reduce MPB attack rate by 55-78% compared to untreated stands. Other large-scale projects focusing on brood-tree removal suggest that rigorous brood tree removal can significantly reduce MPB outbreaks at local scales. Public land managers, however, desire consistent and repeated experimental proof of efficacy before committing to area-wide treatments, and they also require practical guidelines for implementation of such treatments. To that end, we initiated a nearly 300-acre demonstration project (the Smuggler Mountain Project) to test two verbenone formulations combined with removal of infested brood trees (sanitation) for protecting stands from attack by MPB. Conditions did not permit a randomized, replicated and controlled study, so we implemented an unreplicated project on public and private lands using an adjacent forest stand on the US Forest Service's White River National Forest as an untreated reference stand; a parcel of untreated privately owned land on the western boundary was also included in the reference stand.

Materials and Methods.

Site. The study site, referred to as Smuggler Mountain, is located east of the City of Aspen and consists of a patchwork of ownerships, including Smuggler Mountain Open Space (SMOS), managed jointly by the City of Aspen and Pitkin County; a privately held property north of SMOS; a portion of the Aspen Ranger District of the White River National Forest east of SMOS; a parcel owned by the Aspen Valley Land Trust north of SMOS; and privately held lands west of SMOS managed by Investlink Corp. west of SMOS (Fig. 1).

Brood tree removal. Infested trees (mass and strip-attacked trees) were identified and removed using snowmobile logging on the flakes site (January 2009) and helicopter logging on the pouch site (early July 2009). Nearly all infested trees were removed before beetle flight in July 2009, but a small number (less than 5% of all brood trees) were accidentally left in place in the verbenone plots. These remaining brood trees later proved to be valuable in assessing the effect of brood trees in subsequent risk of MPB attack.

Pheromone applications.

- 1. Biodegradable Verbenone Flakes.** Applications of biodegradable verbenone-releasing flakes (Hercon Disrupt® BioFlake Verbenone, Hercon Environmental, Emigsville, PA), were made on 64 acres of private and Aspen Valley Land Trust properties from ground level using broadcast spreaders at the rate of 300 grams verbenone/acre on June 29 and 30, 2009. Beetle flight began later than expected and gas chromatographic residue analyses conducted to determine the rate of loss of verbenone from these flakes under field conditions indicated that all of the

verbenone had dissipated before beetle flight in mid-late July, so a second application was made on August 2 and 3 at the same rate.

- 2. Verbenone Pouches.** Verbenone pouches were provided by Synergy Semiochemicals, a subsidiary of ChemTica, located in Burnaby British Columbia. Each pouch contained 7.5 grams of verbenone, and they were applied over 95 acres of SMOS stands at the rate of 30 pouches/acre (225 grams verbenone/acre) by stapling them at a height of six feet to individual host trees in a grid throughout the plot. Applications were made during the week of July 6, 2009.

Reference Stands. Untreated reference stands comprising a total of 103 acres were demarcated on White River National Forest lands adjacent to the pouch-treated and flakes-treated plots (east and south of the treated stands), and on Investlink properties adjacent to the SMOS plots (immediately to the west). These stands received no treatment, but beetle attacks in previous years resulted in some natural thinning of the stands.

Efficacy Assessment and Statistical Analysis. A preliminary survey was conducted to locate every tree attacked in 2008 or 2009 in all plots; these were GPS-ed and a variable plot cruise was conducted adjacent to each in order to characterize stand structure and 2008 and 2009 MPB attack rates. To develop a database for unattacked trees, we cruised three variable-radius plots per acre over the entire project area. The response variable for the analysis was the rate of beetle attack in 2009 (categorized by type of attack: mass, strip, or pitch-out); explanatory variables were rate of beetle attack in 2008, stand basal area, lodgepole pine basal area, total trees/acre, lodgepole pines/acre, mean lodgepole DBH, UTM coordinates (to define treatments), wind speed, and wind direction. Responses were analyzed using ANOVA models to estimate and compare stand conditions, and logistic regression (applied to the Case-Control sampling design) to relate the risk of MPB attack in 2009 to the following covariates: spatial location, rate of beetle attack in 2008, stand basal area, lodgepole pine basal area, total trees/acre, lodgepole pines/acre, and mean lodgepole pine diameter (DBH). We have shown the MPB attack rates as the ratio of 2009 to 2008 attack rates (Fig. 4) because that response variable removes the effect of differing stand structures for the three types of plots.

Key findings:

- Failure to remove infested brood trees drastically increased the localized risk (i.e. within the variable-radius plots) of MPB mass attack (by an average of nearly forty-fold) (Fig. 2-C).
- Measures of stand density, including lodgepole pine DBH, total basal area, lodgepole pine basal area, total stems per acre, and lodgepole pine stems/acre were all significant factors in the risk of attack by MPB.
- Most measures of stand structure and density, including stems/acre and basal area/acre, were significantly different in the three types of plots, with all measures of stand density decreasing in the same order as risk of attack, i. e. reference stands > pouch treatment > flakes treatment (Fig. 3).
- The risk of MPB attack increased with stand density, as predicted; stand structure has previously been shown to play a key role in bark beetle outbreaks. The probability of attack by MPB in 2009 decreased in the following order: reference

stands > pouch treatment > flakes treatment, and the difference between the two treated stands and the reference stand was highly significant (experiment-wise error rate $\alpha < 0.01$). In 2009, stands treated with pouches had roughly half the risk of attack of the untreated stands, and stands treated with flakes had less than one fifth the risk of attack, but the difference between the two verbenone treatments was not significant.

- Overall attack rates declined significantly between 2008 and 2009 (Fig. 4), probably because of weather, but the areas treated with verbenone and brood tree removal had a significantly greater decline in attack than untreated reference stands.

Discussion and Conclusions. Brood tree removal combined with the application of either one of two verbenone formulations (pouches or flakes) significantly reduced the probability of lodgepole pine trees being attacked by mountain pine beetle, compared to untreated reference stands. We measured this effect only over extremely localized areas (the radius of the variable plots was ca. 32 feet), so this result can only be interpreted within that context). Stand structure varied significantly among the three types of plots, with increases in stand density positively correlated with higher rates of attack. Previous research has clearly demonstrated that pheromone applications without brood tree removal or stand structure modifications can protect lodgepole pines from bark beetle attack in small (< 50 acre) plots, and our results provide evidence that such protection can be achieved over large (ca. 100 acre) areas. Similarly, there is existing evidence that increasing stand density heightens the risk of bark beetle attack, and the Smuggler Mountain Project provides further support for the role of stand structure in bark beetle risk. Brood tree removal has not been experimentally demonstrated to mitigate bark beetle damage, but operational treatments suggest that it effectively lowers attack rates. In this project, brood tree removal combined with pheromone application resulted in a significantly lower probability of bark beetle attack, and the presence of brood trees resulted in a drastically increased risk, at the local scale, in subsequent MPB attack. Future research should emphasize replicated, controlled studies to more rigorously test the relative contributions of stand structure treatments, brood tree removal, and pheromone applications to bark beetle mitigation.

Considerations for future treatments.

- Removal of infested trees is key for the integrated pest management of MPB. This treatment is expensive and can be difficult to implement because attacked trees may not show discolored foliage until the following year, but it is clearly worthwhile in high-value areas. Future research will test the possibility that beetle trap-out may be substituted for brood tree removal, but this technique remains to be demonstrated operationally. We are also investigating new technologies for more precisely identifying brood trees for removal.
- Rigorous inspection of treatments and follow-up assessments is crucial. We recommend that care be taken to deploy flakes and pouches evenly so as to improve coverage, even where rough terrain presents obstacles. Helicopter application of flakes may help overcome these obstacles because evenness of application is easier to achieve with aerial application than from the ground. Contracts for ground applications, in the meantime, must be carefully written and enforced to ensure even application.

- The success of this project was possible because of the rigorously applied treatments and follow-up assessments based on geo-referenced collection of response data; future measurements should maintain the spatial analysis in order to preserve the value of the dataset for analytical purposes.
- Future assessments of the Smuggler Mountain Project will be much less expensive because the stand structure there has been fully characterized; future treatments can be assessed simply by locating and describing current-year MPB attacks.
- Long range management should incorporate risk mapping and stand modeling techniques, using the baseline spatial data collected in this study, for long-term forest management to mitigate MPB risk at Smuggler Mountain.

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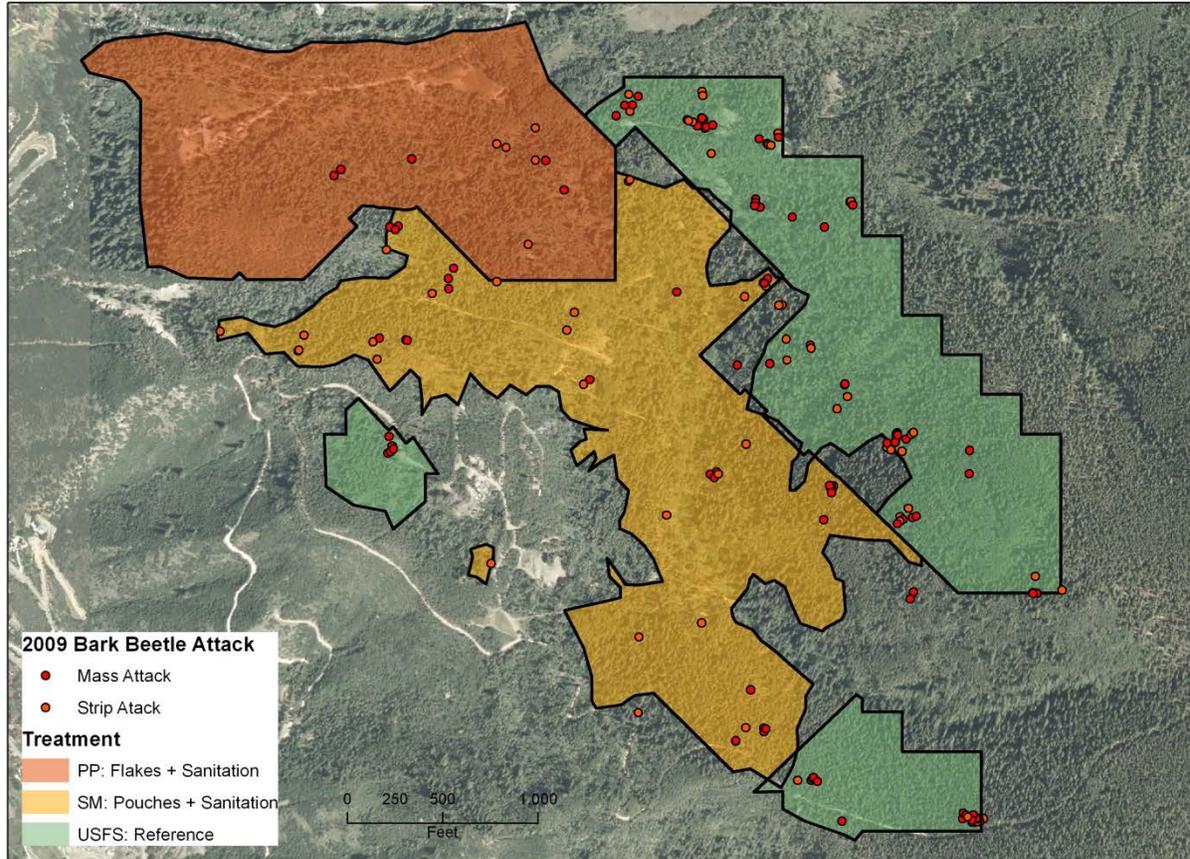


Fig. 1. Smuggler Mountain Project Map, 2009. Circles indicate trees mass-attacked or strip-attacked in 2009. PP = private property, SM = Smuggler Mountain Open Space, and USFS = Reference stands on USDA Forest Service, White River NF and InvestLink lands. Sanitation consisted solely of brood tree removal, not removal of uninfested, susceptible trees.

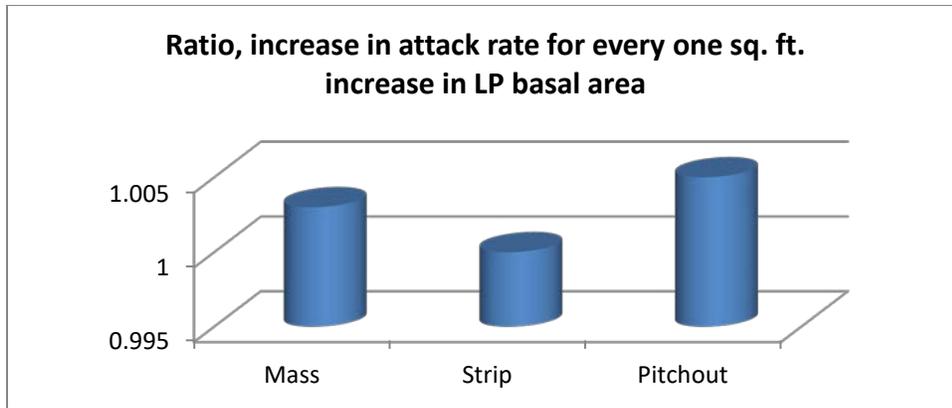


Fig. 2A. Effect of lodgepole pine basal area on risk of MPB attack.

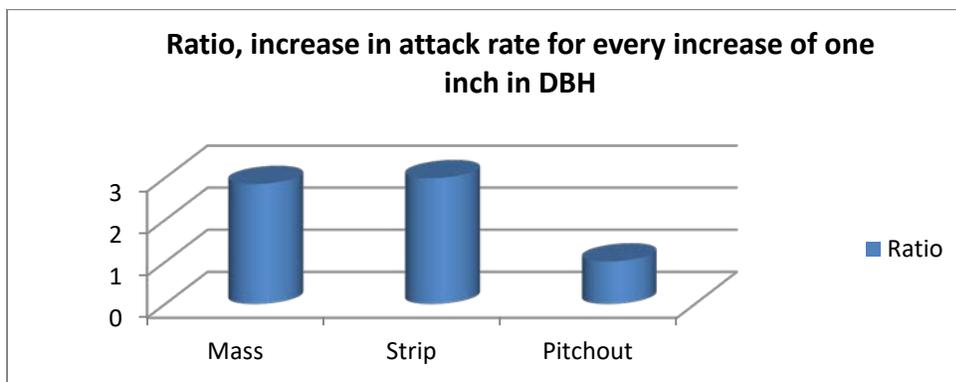


Fig. 2B. Effect of lodgepole pine DBH on risk of MPB attack.

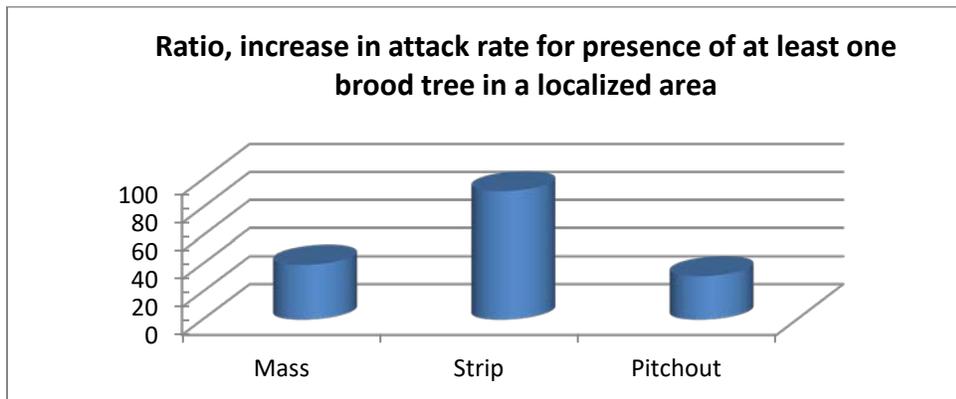


Fig. 2C. Effect of failure to remove brood trees on risk of MPB attack.

Fig. 2A-C. Effects of covariates affecting risk of MPB attack; A = Lodgepole pine basal area; B = Lodgepole pine DBH; C= Presence of infested brood trees in plots. Mass and strip attacks are likely to kill trees; pitchouts are usually not lethal.

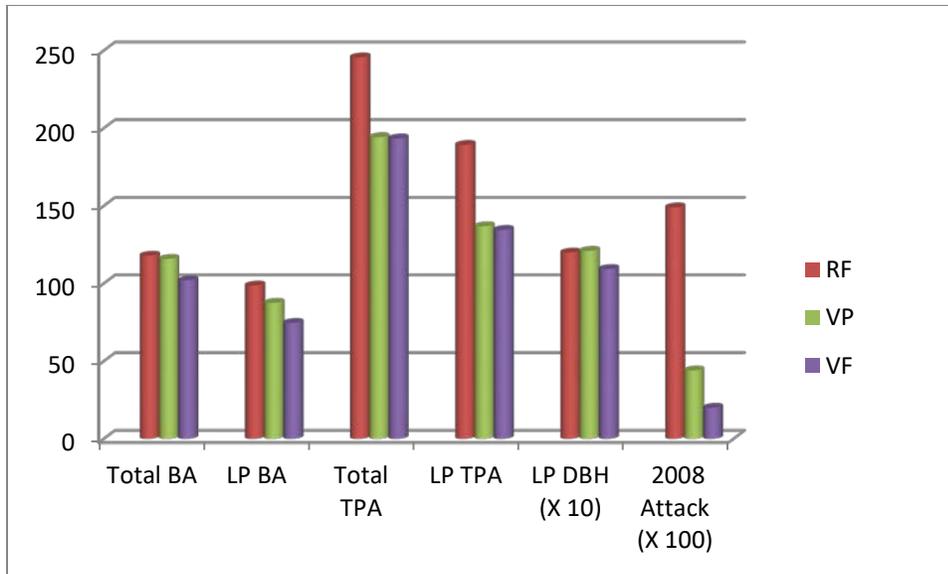


Fig. 3. Stand structure and previous-year MPB attack rate at Smuggler Mountain, 2009 (RF = Untreated reference stands; VP = Verbenone pouch treatment; VF = biodegradable verbenone flakes treatment; LP = lodgepole pine; BA = basal area in square feet/acre; TPA = trees/acre; DBH = diameter at breast height, in inches X 10 to make columns visible; 2008 MPB attack rate in percentage multiplied by 100 to make columns visible).

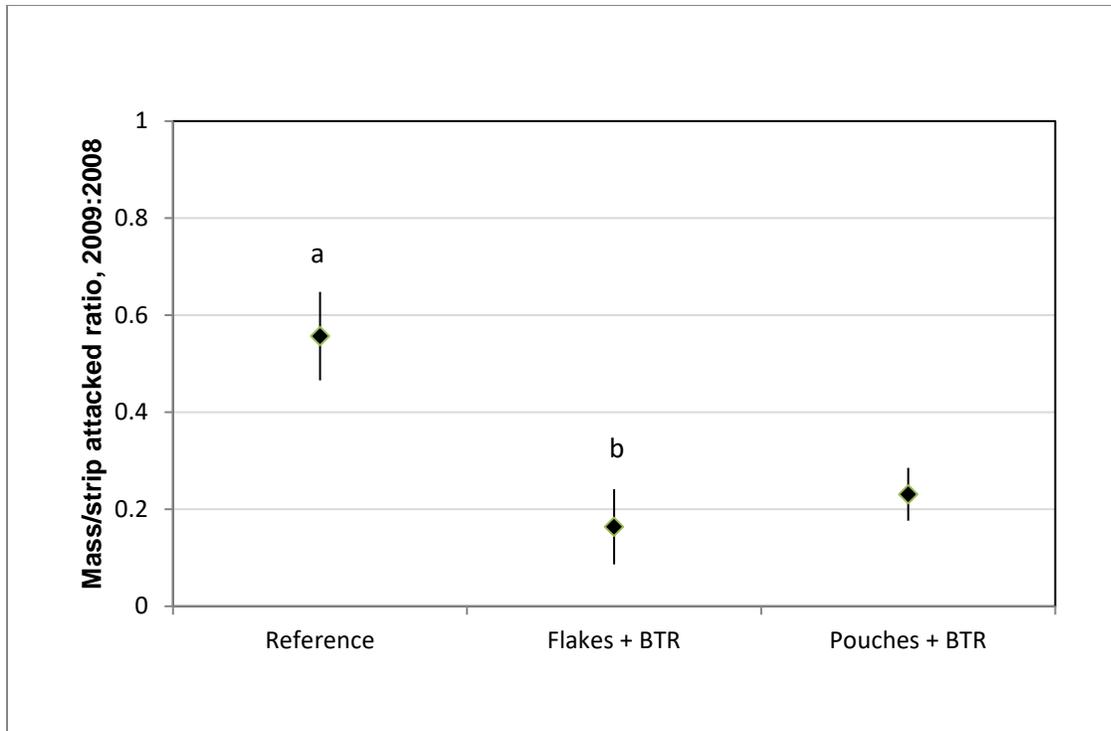


Fig. 4. Ratio of attack rates in 2009 to 2008 (a measure of the relative decline in MPB attack rates with and without verbenone applications and brood tree removal). BTR = brood tree removal. Mass and strip attacks are summed because they are the two types of attacks most likely to kill trees.