AUTHOR: Diana L. Six
School of Forestry
University of Montana
Missoula, MT 59812-0576
Tel: (406) 243-5573
Fax: (406) 243-6656
Email: six@forestry.umt.edu

PINE ENGRAVER, *IPS PINI* (SAY), COLONIZATION OF LOGGING RESIDUES CREATED USING ALTERNATIVE SLASH MANAGEMENT SYSTEMS IN WESTERN MONTANA

In this study, we observed effects of various slash treatments on pine engraver colonization. Five slash treatments (slash-free, chipped, small piles, large piles, scattered) were replicated five times at each of two sites, one consisting mainly of ponderosa pine and the other predominantly lodgepole pine. No pine engravers were found in slash-free or chipped slash treatments at either site. At the ponderosa pine site, significantly more pine engraver attacks and galleries were found in the scattered slash treatment than in small and large pile treatments. A significantly greater number of invertebrate natural enemies were also found in the scattered slash treatment, where they were approximately 6 to 9 times as abundant as in the small pile and large pile treatments, respectively. No pine engravers were observed colonizing slash in the lodgepole pine treatments where slash was in an advanced stage of drying. At both sites, the use of a feller buncher-delimber during harvest increased the rate of drying of slash, reducing its suitability for pine engraver colonization.

INTRODUCTION

The use of appropriate means to manage logging slash is an important consideration when developing sustainable forestry practices. Sustainable forest practices require that the methods used be both economically and ecologically sound. Currently, the management of forest harvest residuals often involves piling and burning slash to reduce fire hazard and insect problems, and to expose soil for tree regeneration. While piling and burning is an effective and economical way to meet these management objectives, this method is not without drawbacks. Undesirable effects include: negative impacts on air quality (Cramer 1974), loss of woody debris and nutrients from the ecosystem (Little and Ohmann 1988; Jurgensen et al. 1997), sterilization and scarification of soils (Neal et al. 1965), disruption and loss of nutrient rich O and A soil horizons during piling (Atzet et al. 1989; Dyck et al. 1989), negative effects on mesofaunal populations (Fellin 1980), and disturbance of residual trees and the forest understory.

Harvest residuals, when left in the forest, provide significant sources of organic matter and nutrients that return to the soil through decomposition by microbes. Recycling of nutrients from woody debris is critical to ecosystem processes and productivity. Removal of this resource can lower site productivity resulting in long-term growth reductions (Weber et al. 1985; Powers 1997). To manage forests in a sustainable manner and maintain ecosystem processes, alternative slash management practices that enhance decomposition yet avoid negative impacts on soil, air quality, and of pest insect populations are desirable.

A major concern in leaving pine residues in the forest, in place and unburned, is the potential for increases in pine engraver (*Ips pini* (Say)) populations. The pine engraver is the most widespread insect associated with pine residues in the western United States and Canada (Livingston 1979). The pine engraver is typically considered a secondary bark beetle, attacking weak small-diameter trees, windthrow, or trees already killed by more aggressive primary bark beetle species. However, an abundance of slash, such as is generated during harvest operations and which provides ideal breeding material, can allow large numbers of these beetles to develop which then may attack surrounding living trees. The most frequent damage to live trees is the killing of young regeneration and top-killing of large older trees (Furniss and Carolin 1977). However, group killing of larger trees, especially ponderosa pine, may also occur (Sartwell et. al. 1971; Livingston 1979).

The pine engraver typically produces two generations a year. Pine engravers overwinter as adults under bark or in the duff layer (Livingston 1979). Overwintering beetles emerge in spring and typically attack windthrow, ice breakage, and logging slash. Fresh green slash over 5 cm in diameter is preferred (Furniss and Carolin 1977); as slash ages it becomes less suitable for colonization and successful brood production (Gara et al. 1999). The second generation typically emerges in mid-summer and is the generation most likely to move from slash to attack and kill living trees. Therefore, ideally, slash management should attempt to reduce production of beetles in the first generation (Livingston 1979).

As part of a study assessing the decomposition of logging residues under alternative slash management systems, we observed effects of various slash treatment methods on pine engraver colonization.

MATERIALS AND METHODS:

This research was conducted at the Lubrecht Experimental Forest of the University of Montana, Missoula County, Montana, in two units receiving thinning treatments. One unit consisted mainly of ponderosa pine (*Pinus ponderosa* Engelm.) with a lesser Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) component. The second unit consisted primarily of lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.) with a small component of Douglas-fir and western larch (*Larix occidentalis* Nutt.).

Five replicated plots were established for each of the following treatments at each of the two harvest units: 1) slash, large pile (one slash pile per plot approximately 4 m in diameter and 2-2.5 m in height, 2) slash, small pile (five slash piles per plot approximately 1.5 m in diameter and 1.5 m in height), 3) slash, scattered (even distribution of slash in plot), 4) chipped slash, piled, (4 circular piles of chips per plot approximately 2 m in diameter) and 5) slash-free (all slash removed). Slash in the plots consisted of varying proportions of pine and Douglas-fir representative of tree species composition in the plots when thinned. Each circular plot had a radius of 11.28 m for a total area of 400 m^2. Due to variation in topography, plots were established in roughly square (lodgepole pine) or rectangular (ponderosa pine) grids. Within grids, all plot centers were 25 m apart. Treatments were assigned to the plots using a complete randomized design. Additional treatments incorporating burning approximately 1 year after harvest were also established but not included in this study.

The units were harvested and slash treatment plots established in October of 1998. Sampling for pine engraver was conducted in summer 1999 between June 22 and July 8 after spring emergence of over-wintering pine engraver was complete.

Sampling was conducted as follows: Each plot was divided into a grid of nine cells. A $2m^2$ square sampling frame was placed in the center of each grid cell. Within the frame, all pine slash falling within the sampling frame, 5 cm in diameter and greater, was assessed for pine engraver colonization. First, the number of entrance holes (attacks) in the outer bark was counted. Then the slash was debarked and the number of individual successful galleries (with brood production) was determined. In all plots except large pile plots, slash was sampled to ground level. In large pile plots, sampling extended a minimum of 1 meter into the pile (no pine engravers were ever found deeper than 60 cm).

Any evidence of woodpecker excavation and invertebrate natural enemies of bark beetles was also recorded. Sampling was conducted several weeks after attack by pine engravers, therefore, adult invertebrate natural enemies such as clerid beetles, that arrive coincident with pine engraver adults during attack, were no longer commonly seen searching the external surface of the bark. Therefore, our estimates of natural enemies were made by counting the number of developing clerid larvae and other within-gallery invertebrate natural enemies.

Because clerids may have substantial impacts on their host populations, we estimated potential impact of these predators on potential production of pine engraver in the three slash treatments. Kegley et al. (1997) estimated 30-60 eggs are produced per pine engraver gallery. To calculate our estimates, we used the midpoint estimate of 45 eggs per gallery times the mean number of galleries observed per m^2 in each treatment. A single larva of *E. lecontei* may consume up to seven larval prey during its development and up to 158 adult beetles during its life as an adult (Berryman 1966). To calculate our estimates of predation we used conservative values of 5 larval and 100 adult pine engravers for a total of 105 prey per clerid beetle. We multiplied this figure with the mean number of clerids observed per m^2 in each treatment to estimate potential reduction of pine engraver in each treatment due to predation.

This sampling scheme allowed an estimation of treatment effects on pine engraver colonization and natural enemy abundance.

Data analyses: Kruskal-Wallis one way analysis of variance on ranks (ANOVA) was used to test for significant effects of slash treatments on the number of pine engraver attacks (entrance holes), galleries, and the abundance of natural enemies. The Mann-Whitney rank sum test was used to do pair-wise comparisons of medians. All analyses were conducted using SigmaStat version 2.0 statistical software (SPSS Inc. 1997).

RESULTS

Ponderosa pine.

Pine engravers were found in three of five slash treatments in the ponderosa pine unit. As expected, no pine engravers were found in the slash-free or chipped slash treatments and these treatments were dropped from subsequent analyses. One plot was dropped per small pile, large pile, and scattered slash treatment because each contained only Douglas-fir slash.

The greatest number of entrance holes (holes with boring dust) was found in bark in the scattered slash treatment, followed by the large pile and small pile treatments, respectively (Table 1). A significant difference in the number of pine engraver entrance holes in ponderosa pine bark was found among the treatments ($H = 12.169$, $df = 2$, $P<0.002$) (Table 2). Bark of scattered slash had approximately two times the number of entrance holes than did bark of slash in small pile or large pile treatments (Table 1).

A significant difference was also found among treatments in number of successful galleries ($H = 11.123$, $df = 2$, $P = 0.004$) (Table 2). The greatest number of successful galleries was found in the scattered slash treatment, where slash contained approximately 2.5 times more galleries than slash in the large pile treatments and 3 times more galleries than in the small pile treatments (Table 1).

Signs of woodpecker foraging, including scaling and drilling, were seen in samples in two scattered slash plots but were not common throughout the unit. Invertebrate natural enemies found in the scattered slash, small pile, and large pile treatments included clerid beetles (the black-bellied clerid, *Enoclerus lecontei* (Wolcott)), histerid beetles, staphylinid beetles, dolichopodid flies (*Medetera* sp.), and a torymid wasp (*Roptrocerus* sp.) (Table 3). The number of invertebrate natural enemies observed in the three treatments was significantly different ($H = 11.529$, $df = 2$, $P = 0.003$) (Table 2). The greatest number of natural enemies were found in the scattered slash treatment, where they were approximately 6 to 9 times as abundant as in the small pile and large pile treatments, respectively (Table 1). Estimated reduction of pine engravers due to clerids was highest in the scattered slash (36% versus 13% and 3% in large and small piles, respectively); however, despite this reduction, potential production of pine engraver remained highest in the scattered slash treatment (Table 4).

At the time of sampling, much of the pine slash in the piled and scattered treatments was very dry and no longer constituted suitable habitat for pine engraver brood development. Drying often occurs rapidly in small diameter slash, while larger diameter slash typically retains moisture for a relatively longer period of time. Timing of harvest may have had an impact on slash moisture levels at the two study sites. Gara et al. (1999) reported that slash created in October on the Northern Cheyenne Reservation in southeastern Montana was too dry the following spring for pine engraver brood development. Premature drying in the larger diameter slash in this study also appeared to have been accelerated by the use of a feller buncher-delimber (FBD) which produced numerous regularly spaced punctures in the bark during harvest.

Lodgepole pine:

No pine engravers were found colonizing slash in any treatments in the lodgepole pine harvest unit. Slash in this unit was in very poor condition in terms of suitability for pine engraver attack and brood development due to the combination of thin bark, timing of harvest, and the use of the FBD. At the time of sampling, bark was already peeling on many pieces of slash, and phloem and sapwood were very dry presenting a highly unsuitable resource. Lack of colonization of the slash by pine engravers due to a low baseline population of pine engraver in the surrounding area was discounted when a recently (within 1 mo) windthrown lodgepole pine in the unit was examined and found to be heavily colonized by the beetle.

DISCUSSION:

The striking difference in utilization of ponderosa and lodgepole pine slash by pine engravers in this study resulted from a combination of factors that rendered the lodgepole pine slash unsuitable to *Ips*. Moisture content and phloem thickness and condition are the major limiting factors for bark beetle development in slash (Anderson 1948; Haack et al. 1984; 1987). The greater the diameter of the slash and the greater the thickness of the bark and phloem, the slower the rate of drying of the slash and the longer the slash remains suitable for colonization. Lodgepole pine has thin outer bark relative to ponderosa pine which may have allowed a more rapid degradation of the phloem and a more rapid drying of the sapwood. Further, the method and timing of harvest used in this study allowed more rapid drying of the slash than might have occurred had the slash been produced without the use of a FBD and at a different time of year. In the ponderosa pine unit, despite the thicker bark of ponderosa pine slash, the timing of harvest and the use of the FBD during harvest reduced the amount of slash as breeding material; however, it did not totally eliminate it.

In this study at the ponderosa pine site, a greater number of pine engraver attacks and galleries was observed in the scattered slash than in slash in the piled treatments. This may be explained by two factors. With scattered slash, more preferred substrate may have been available for colonization by pine engravers than in piles where much of the slash was contained in the interior of the pile where it apparently was not attractive to the engravers. Further, the scattered slash was in direct contact with the ground, and because of its contact with the soil may have retained moisture longer, maintaining its suitability. This pattern of colonization is not always observed. Slash piles may sometimes be colonized while scattered slash remains relatively un-utilized (PFK, personal observation). Site and weather factors can be very important determinants of slash quality. Therefore, preference for slash type may be site or seasonally dependant.

Scattering logging slash in open, sunny areas to promote rapid drying is recommended to reduce pine engraver production (Livingston 1979). However, in thinned stands such as those used in this study where the residual overstory provides shading for both soil and slash, drying rate may be reduced rather than accelerated. Little information exists on the effect of overstory shading on slash condition and pine engraver colonization over time. Villa-Castillo and Wagner (1996) found that moisture content in ponderosa pine logs placed on the ground in thinned stands did not differ over a 60 day period when exposed to differing light conditions. However, they did find that logs exposed to low and moderate light intensities were attacked at a greater rate than those exposed to high light intensities. Shading, slope, and aspect greatly affect temperature which may also play an important role influencing colonization of slash. Future studies should address the interactions of timing of harvest, shading, soil contact, moisture, temperature, and site characteristics on slash colonization.

Evidence suggests that natural enemies have strong influences on populations of bark beetles (Turchin et al. 1991; Turchin et al. 1999). Clerids and other predators can be important regulators of pine engraver populations (Gara et al. 1999). They are often the most abundant predators associated with bark beetles (DeLeon 1934; Dahlsten 1970; Moore 1972). This was true in the present study where clerids comprised 53% of all invertebrate natural enemies (Table 2). Gara et al. (1999) also observed that of the three major predators of pine engraver, the black-bellied clerid was most prevalent.

Although we observed a greater number of pine engraver attacks and galleries in the scattered slash treatment, the greater number of natural enemies colonizing scattered slash, most notably clerid beetles, may at least partially offset any increased production of pine engravers. Further, at least under the conditions of this study, scattered slash may provide an important reservoir of natural enemies to aid in the regulation of future generations of pine engraver.

Additional possible impacts by other natural enemies observed in this study are difficult to estimate. Staphylinid beetles were also abundant relative to other groups of natural enemies (Table 2); however, their impact on bark beetle populations remains unknown. Only one parasitoid, *Roptrocerus* sp., was collected in the samples. This parasitoid has been reared previously from Montana pine engravers (Six and Dahlsten 1999) and its abundance in a given population can be quite variable (Six, unpubl. data). Its rarity in samples in this study may reflect a low baseline population of these parasitoids, or more likely, an effect of the timing of sampling. Most bark beetle parasitoids, *Roptrocerus* included, attack late instar larvae or pupae. Sampling in this study coincided with early instars, and therefore, prior to the arrival of most parasitoids to the slash.

In this study, the proportion of pine to Douglas-fir slash was not consistent across plots and treatments, but rather reflected the composition of trees harvested in each plot. This uneven distribution of slash from the two tree species, one of which is a host of the pine engraver and the other which is not, probably contributed to the variation in samples among plots and treatments. While the slash in treatments in this study reflected a more natural harvest situation for mixed species stands, the use of slash with known proportions of host and non-host slash or only host slash in future studies may be useful in reducing variation. Also, what we termed "large slash piles" were in reality rather small compared to those used in many harvest operations. In the future, the use of larger piles would be helpful in assessing pine engraver and natural enemy preference.

As alternatives to slash management systems that deplete nutrients from forest soils are gaining acceptance and increasing in use, it is important that we understand the impacts these alternatives can have on other aspects of forest management. In order to reduce losses due to pine engraver in residual stands after harvest, it will be important to better understand the dynamics of this beetle and its natural enemies in slash. Our estimates of potential pine engraver production and clerid impact on production in this study are extremely coarse. Specific detailed studies assessing pine engraver production and natural enemy impact, including parasitoids, under differing site and seasonal conditions, are needed to accurately estimate impact.

LITERATURE CITED:

Anderson, R. F. 1948. Host selection by the pine engraver. J. Econ. Entomol. 41: 596-602.

Berryman, A. A. 1966. Studies on the behavior and development of *Enoclerus lecontei* (Wolcott), a predator of the western pine beetle. Can. Entomol. 98: 519-526.

Cramer, O. P. 1974. Air quality influences. P. F1 – F46 *in* Environmental effects of forest residues management in the Pacific Northwest. USDA For. Serv. Gen. Tech. Rep. PNW-24.

Dahlsten, D. L. 1970. Parasites, predators, and associated organisms reared from western pine beetle infested bark samples. P. 75-79 *in* Studies on the population dynamics of the western pine beetle, *Dendroctonus brevicomis* Le Conte (Coleoptera: Scolytidae). R.W. Stark and D.L. Dahlsten (eds.). Univ. of Calif. Div. of Agri. Sci.

DeLeon, D. 1934. An annotated list of the parasites, predators, and other associated fauna of the mountain pine beetle in western white pine and lodgepole pine. Can. Entomol. 66: 51-61.

Fellin, D. G. 1980. A review of some interactions between harvesting, residue management, fire, and forest insects and diseases. USDA For. Serv. Gen. Tech. Rep. INT-90.

Furniss, R. L. and V. M. Carolin. 1977. Western Forest Insects. USDA For. Serv. Misc. Publ. 1339.

Gara, R.I., D.R. Millegan, and K.E. Gibson. 1999. Integrated pest management of *Ips pini* (Coleoptera: Scolytidae) populations in southeastern Montana. J. Appl. Entomol. 123: 529-534.

Haack, R. A., J. L. Foltz, and R. C. Wilkinson. 1984. Longevity and fecundity of *Ips calligraphus* (Coleoptera: Scolytidae) in relation to slash pine phloem thickness. Ann. Entomol. Soc. Am. 77: 657-662.

Haack, R. A., R. C. Wilkinson, J. L. Folz, and J. A. Cornell. 1987. Spatial attack pattern, reproduction and brood development of *Ips calligraphus* (Coleoptera: Scolytidae) in relation to slash pine phloem thickness: a field study. Environ. Entomol. 16: 428-436.

Jurgensen, M. F., A. E. Harvey, R. T. Graham, D. S. Page-Dumroese, J. R. Tonn, M. J. Larsen, and T. B. Jain. 1997. Impacts of timber harvesting on soil organic matter, nitrogen, productivity, and health of inland northwest forests. Forest Science 43: 234-251.

Kegley, S. J., R. L. Livingston, and K. E. Gibson. 1997. Pine engraver, *Ips pini* (Say), in the United States. USDA For. Serv. FIDL Leaflet 122.

Livingston, R. L. 1979. The pine engraver, *Ips pini* (Say), in Idaho: Life history, habits and management recommendations. Idaho Dept. of Lands, Rep. 79-3. pp. 1-7.

Neal, J. L., Jr., E. Wright, and W. B. Bollen. 1965. Burning Douglas-fir slash. Physical, chemical, and microbial effects in soil. Oregon State Univ. For. Res. Lab Res. Paper 1, 32 p. Corvallis.

Powers, R. F. 1997. Are we maintaining the productivity of forest lands? Establishing guidelines through a network of long-term studies. P. 70-81 *in* Management and productivity of western-montane forest soils. USDA For. Serv. Gen. Tech. Rep. INT-280.

Sartwell, C., R.F. Schmitz, and W.J. Buckhorn. 1971. Pine engraver, *Ips pini*, in the western states. USDA Forest Service. For. Pest Leaflet. No. 122. 5p.

Six, D. L. and D. L. Dahlsten. 2000. Interactions of bark beetle natural enemies and beetle-associated fungi. P. 41-43 *in* Proc. Joint Mtg. Western International Forest Disease Work Conference and Western Forest Insect Work Conference. Breckenridge, CO. Sept. 1999.

SPSS, Inc. 1997. SigmaStat Statistical Software version 2.0, Chicago, IL.

Thatcher, R. C. and L. S. Pickard. 1966. The clerid beetle, *Thanasimus dubious*, as a predator of the southern pine beetle. J. Econ. Entomol. 59: 955-957.

Turchin, P., P. Lorio Jr., A.D. Taylor, and R.F. Billings. 1991. Why do populations of southern pine beetles (Coleoptera: Scolytidae) fluctuate? Environ. Entomol. 20: 401-409.

Turchin, P., A.D. Taylor and J.D. Reeve. 1999. Dynamical role of predators in population cycles of a forest insect: an experimental test. Science 285: 1068-1071.

Villa-Castillo, J. and M. R. Wagner. 1996. Effect of overstory density on *Ips pini* (Coleoptera: Scolytidae) performance in ponderosa pine slash. J. Econ. Entomol. 89: 1537-1545.

Weber, M. G., I. R. Methven and C.E. Van Wagner. 1985. The effect of forest floor manipulation on nitrogen status and tree growth in an eastern Ontario jack pine stand. Can. J. For. Res. 15: 313-315.

PINE ENGRAVER, *IPS PINI* (SAY), COLONIZATION OF LOGGING RESIDUES CREATED USING ALTERNATIVE SLASH MANAGEMENT SYSTEMS IN WESTERN MONTANA

Diana L. Six, Mark Vander Meer, and **Thomas H. DeLuca**, School of Forestry, University of Montana, Missoula, MT 59812, and **Peter Kolb**, Extension Forestry Specialist, Montana State University, Missoula, MT 59812
Acknowledgements: This study was funded through McIntire-Stennis and the Montana Forest and Conservation Experiment Station. We thank Kenneth E. Gibson (USDA Forest Service, Missoula, MT), R. Ladd Livingston (Idaho Department of Lands, Coeur d''lene, ID), and an anonymous reviewer for their helpful comments.