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Reducing Mountain Pine Beetle-Caused Mortality in Ponderosa Pine Plantations: A Risk-Rating System for Western Montana

Bruce Erickson, Silviculturist
USDA Forest Service
Superior Ranger District, Lolo National Forest

Jim Burwasser, TSI/Reforestation Technician
USDA Forest Service
Superior Ranger District, Lolo National Forest

Ken Gibson, Entomologist
USDA Forest Service, Forest Health Protection
Northern Region, Missoula, MT

Introduction

Mountain pine beetle, *Dendroctonus ponderosae* Hopkins, (MPB) most renowned for its devastating affects on lodgpole pine (*Pinus contorta*, ssp. *latifolia* Dougl.) stands, also poses serious threats to ponderosa pine (*Pinus ponderosa* Dougl. ex. Laws.) throughout its range. In fact, a MPB (then called Black Hills beetle) outbreak in ponderosa pine stands in the Black Hills of South Dakota, was one of the first major forest insect outbreaks with which we dealt in the western United States in the latter part of the nineteenth century (Hopkins 1902).

Current MPB outbreaks in the Northern Region are at levels not exceeded in more than 20 years (Meyer 2006); and in other parts of North America, are at unprecedented levels (Cleeveley 2005). While most outbreaks are found in lodgepole pine stands, many acres of ponderosa pine are severely affected at present. Of more than one million acres of pine type infested in the Northern Region in 2005, approximately 38,500 were in ponderosa pine—most are second-growth stands in Montana (Gibson 2005). In 1981, during the last major MPB outbreak in the Region, when nearly 2.5 million acres were infested, about 70,000 of those acres were in ponderosa pine stands (McGregor et al., 1985).

MPB Biology and Management

MPB epidemics in host stands can cause widespread depletion of mature trees. In pure stands of lodgepole pine, most trees greater than about 5 inches in diameter at breast-height (DBH) may be killed. Outbreaks in ponderosa pine are usually not as widespread, but may be devastating. MPB is a chronic pest in western

United States Department of Agriculture
Forest Service
Northern Region
200 East Broadway
P.O. Box 7669
Missoula, MT 59807

white pine stands, killing single trees or small groups each year. White bark and limber pine stands at mid- to higher-elevations are also being seriously affected at present.

MPB overwinter mostly as larvae within the inner bark of host trees. Occasionally, they may also pass the winter as pupae and callow adults. In most lodgepole and ponderosa pine stands, larvae pupate in late spring. Adults, small black beetles and strong fliers, emerge and attack new trees from about mid-July through August depending on elevation and temperature. Once mated, female beetles construct long, vertical egg galleries within the tree's inner bark. Egg galleries are mostly straight, vertical, and may be up to 30 inches long, with eggs being deposited along either side. Egg galleries are tightly packed with partially digested woody particles, or frass. Eggs hatch and larvae feed until freezing temperatures bring on dormancy. Completing their development the following year, larvae go through four instars before pupating. Typically, there is one generation each year (Amman et al. 1989).

Economic impacts of tree mortality are largely dependent on effects of epidemics on merchantable products, regeneration of affected areas, and increased fire protection costs. We should strive to avoid situations where MPB, not forest managers, set priorities and dictate management options. To assure such, management must focus on forests and not MPB populations, altering stand conditions that favor buildup of beetle populations.

There are two basic approaches to reducing MPB-caused mortality: (1) long-term (preventive) forest management, and (2) direct control.

The strategy of preventive management is to keep beetle populations below injurious levels by limiting beetles' food supply—best accomplished through forestry practices designed to maintain or increase tree or stand resistance. Preventive management addresses the basic cause of epidemics—stand susceptibility—and is considered the most satisfactory long-term solution. It includes a combination of hazard rating, priority setting, and silvicultural manipulations.

In contrast, suppression of MPB populations—killing beetles by various methods of direct control—treats only one symptom of the problem: too many beetles. Effects are usually temporary. When properly used, direct control may be effective in reducing rate of spread and intensification of infestations; but should be considered only a "holding action" until susceptible stands can be altered silviculturally (Anonymous 2005).

Current MPB Outbreak on Superior Ranger District (Lolo National Forest)

Current outbreaks on the Lolo National Forest (NF) began increasing noticeably in the mid-1990s. In 1995, approximately 12,500 total acres were infested on the Plains/Thompson Falls and Superior Ranger District (RD) (Gibson 1996). Infestations on the forest increased steadily during the next decade and by 2005 covered almost 210,000 acres—about 5,500 of those in ponderosa pine (Gibson 2005).

Groups of MPB-caused mortality in stands of second-growth ponderosa pine were first observed in early 2000 on Superior RD, Lolo NF in Western Montana. We had experienced nearly a decade of epidemic-level MPB-caused mortality in lodgepole pine stands and scattered individual mature ponderosa pine, but this was the first outbreak found in relatively uniform stand conditions resulting from even-aged regeneration harvests of 30-40 years ago.

By 2002, MPB outbreaks in ponderosa pine regeneration on the district had expanded remarkably. Some stands, in which MPB outbreaks were first observed only two years earlier, had experienced over 50 percent beetle-caused mortality. In 2002, groups of beetle-killed trees were found in 30- to 40-year-old regenerated ponderosa pine stands scattered throughout the district.

These stands were predominantly planted and naturally regenerated ponderosa pine with varying amounts of natural Douglas-fir regeneration. Some plantations had a significant lodgepole pine component that was also experiencing mortality from MPB. Naturally regenerated stands typically had between 200 and 600 total trees per acre with average DBH of 5 to 10 inches. Plantations, on the other hand, had between 100 and 300 trees per acre that were over 5 inches DBH and had average DBH between 7 and 10 inches.

MPB outbreaks in young, even-aged ponderosa pine stands are uncommon, but not unprecedented. Similar events occurred on the Kootenai NF in the late 1980s (Gibson and Oakes 1990).

Research conducted on the Lolo NF in the early 1970s showed MPB-caused mortality could be substantially reduced by thinning young, overstocked ponderosa pine stands (Griffin 1975). Loveless (1981) showed MPB-caused mortality in ponderosa pine was associated with site index, stocking level, age, and diameter. Other studies in eastern Oregon and the Black Hills have confirmed that MPB-caused mortality in second-growth ponderosa pine can be reduced by thinning (Sartwell and Dolph 1976; Stevens et al. 1980).

Because of the number of young, even-aged ponderosa pine stands and limited funding available, we looked for a hazard-rating system that would help prioritize stands for treatment. Such a system must allow us to use readily obtainable stand-condition data. In addition, to be truly successful, a hazard-rating system must be capable of functioning reasonably well using either standardized formal stand inventories or relatively simple walk-through examination notes.

Methods

After looking at several hazard-rating systems, we determined a combination of two systems in a three-tiered hazard rating process would satisfy our needs:

1. Determine the probability of initial infestation for each stand (Schmid et al. 1994).
2. Determine risk of beetle-caused mortality (Munson and Anhold 1995).
3. For lower priority stands, estimate MPB hazard 10 years into the future.

Chojnacky and others (2000), in *Mountain Pine Beetle Attack in Ponderosa Pine: Comparing Methods for Rating Susceptibility*, found the risk-rating method developed by Munson and Anhold (1995) using basal area of trees over 5 inches DBH, average ponderosa pine diameter, proportion of ponderosa pine in the canopy, and number of trees currently infested by MPB, seemed to best predict mortality in even-aged ponderosa pine stands on the Colorado Plateau.

Because many competing trees in our district's stands were less than 5 inches DBH, we determined the basal area part of the model would not be sensitive enough to differences in total stand stocking between stands. However, this model does incorporate factors for proportion of ponderosa pine and amount of currently infested trees in the stand. Both would be useful for prioritizing treatments. Using basal area as a predictor, our stands were found to be somewhere in the 6-9 ("Moderate") rating unless MPB were already heavily infesting the stand. Basal area did not provide a meaningful ranking for prioritizing treatments.

To increase the sensitivity of the Munson and Anhold (1995) model to smaller-diameter trees, we investigated the system developed by Schmid et al. (1994). Their system predicts probability of infestation based on growing stock levels of ponderosa pine in the Black Hills. While growing stock level is not easy to quantify in the field, Schmid et al. (1994) developed equations to identify breaks between low, moderate, and high probability of infestation based on tree size and spacing, which are more easily quantified. We used their equations—admittedly beyond the range of data on which they were based—to replace basal area and average size inputs of the Munson and Anhold (1995) model and to increase sensitivity to effects of small trees.

Stand characteristics needed for this combined approach include:

- Stand average diameter (Quadratic Mean Diameter [QMD])
- Trees per acre
- Proportion of ponderosa pine
- Level of current infestation.

Integration of these two models is as follows:

STEP 1: Determine Probability for Initial Infestation of a Stand by MPB (Schmid, Mata, and Obedzinsky [1994] as developed for Black Hills, even-aged ponderosa pine). Determine following stand conditions for live trees:

- Stand average diameter (QMD)
- Spacing (trees per acre)

Low Hazard – Growing Stock Level (GSL) less than 80. GSL 80 represented the highest number of trees per acre, or tightest spacing, for a given QMD where no MPB-caused mortality was observed in the study. This is represented by the formula:
Smallest spacing (feet) = 1.75 x QMD + 1.61.
Example: 10-inch QMD = 19.1 feet (119 trees per acre).

Stands with greater spacing (fewer trees per acre) at that QMD are considered “low hazard.”

Moderate Hazard – GSL 80-120. This range of GSL represented the continuum between finding no MPB-caused mortality (<80) and finding consistent annual mortality (>120).

For the sample stand shown above, spacing between 16 and 19.1 feet (119 to 170 trees per acre) may or may not experience MPB-cause mortality.

High Hazard – GSL over 120. GSL 120 represented the lowest number of trees per acre, or the greatest spacing, for a given QMD where consistent annual MPB-caused mortality was

Table 1. Quick-Reference to Determine Hazard at Varying QMD[1] and Spacing

	Low Hazard		Moderate Hazard	High Hazard	
QMD[1]	Spacing (feet)	Trees/ Acre	Trees/ Acre	Trees/ Acre	Spacing (feet)
1	3.4	< 3768	3768-6969	> 6969	2.5
2	5.1	< 1675	1675-2723	> 2723	4.0
3	6.9	< 915	915-1440	> 1440	5.5
4	8.6	< 589	589-889	> 889	7.0
5	10.3	< 411	411-603	> 603	8.5
6	12.1	< 298	298-436	> 436	10.0
7	13.8	< 229	229-329	> 329	11.5
8	15.6	< 179	179-258	> 258	13.0
9	17.3	< 146	146-207	> 207	14.5
10	19.1	< 119	119-170	> 170	16.0
11	20.8	< 101	101-142	> 142	17.5
12	22.6	< 85	85-121	> 121	19.0

[1] Round fractional QMD up to account for short-term growth.

observed in the study. This is represented by the formula: Greatest spacing (ft) = 1.5 x QMD + 1.0. Example: 10-inch QMD = 16.0 feet (170 trees per acre).

Stands with less spacing (more trees per acre) at that QMD are considered "high hazard." Table 1 provides a breakdown of hazard levels for stands with QMD up to 12 inches.

Stands with low hazard were given a rating of "2," moderate-hazard stands a "4," and high-hazard stands given a rating of "6." Table 3 (Appendix) shows risk rating distribution for stands analyzed on the District resulting from this step.

STEP 2: <u>Factor in Risk of Loss of Ponderosa Pine</u> (Munson and Anhold [1995] as developed for Colorado Plateau [Modified]). Based on following stand conditions for live trees, 5.0 inches DBH and larger:

- Basal area
- Average DBH for ponderosa pine
- Proportion of ponderosa pine in canopy
- Currently infested trees per acre

As described previously, this method is not very sensitive to small-diameter plantations with which we are working. However, it does incorporate factors for proportion of ponderosa pine and amount of currently infested trees in the stand. Both would be useful for prioritizing treatments.

A. Assign a stand rating based on percent ponderosa pine:

- Less than 50 percent ponderosa pine = 1 Low
- 50 to 65 percent ponderosa pine = 2 Moderate
- More than 65 percent ponderosa pine = 3 High

B. Assign a stand rating based on infested trees per acre:

- Less than 3 infested trees per acre = 1 Low
- 3 to 10 infested trees per acre = 2 Moderate
- More than 10 infested trees per acre = 3 High

Table 3 (Appendix) shows risk rating distributions for stands analyzed on the District resulting from this step.

STEP 3: <u>Combine the Two Hazard Ratings.</u> We combined hazard rating from Schmid et al. (probability of initial infestation) with species-at-risk and current infestation factor from Munson and Anhold (risk of loss if infestation occurs). Table 2 was used for each stand to determine rating for each factor. Factors were summed to determine overall stand hazard rating.

Table 2. Risk Rating for Each Contributing Factor

GSL Hazard Step 1			**PP Proportion Step 2A**			**Infested Trees Step 2B**	
Hazard	**Rating**		**Percent**	**Rating**		**Trees/Acre**	**Rating**
low	2		<50	1		<3	1
moderate	4		50-65	2		3-10	2
high	6		>65	3		>10	3

Summed ratings provided us a priority ranking with "4" being lowest priority and "12" being highest priority stands. Thus we determined treatment priority based on current stand conditions for stands analyzed on the District. (Table 3, Appendix)

At this point, the combined hazard rating system stretched our three-rank priority from Step 1 to a five-rank priority rating (Table 3, Appendix). This made it easier to tailor our treatment budget to the stands that would benefit most.

STEP 4: Estimate MPB Hazard 10 Years from Present. The affected stands are rapidly growing, young ponderosa pine stands. Beyond identifying today's hazard, we needed to determine which stands would grow into a high-hazard condition in the near future. We used past growth to conservatively estimate future growth, and that to estimate average tree size 10 years from now. That procedure was as follows:

> **To estimate mean stand diameter 10 years from now, divide QMD by stand age (minus five years for growth to 4.5 feet) to get average annual growth, and multiply by 10 to get expected growth over the next 10 years. Add estimated growth to existing QMD to estimate stand diameter in 10 years.**
>
> **[(QMD / (age – 5)) X 10] + QMD = QMD in 10 years**

We then ran estimated future stand QMD through Step 1, used the existing proportion of ponderosa pine, and equalized the level of infestation to get future hazard rating. That was done because of our interest in the effect of growth on changes in stand risk ratings. We expected stands with higher levels of current infestation to change composition, average DBH, and GSL more dramatically than we could accurately predict. In addition, many of those stands would be silviculturally treated during the ten-year prediction period, depending on available means, and would be then taken off the priority treatment list.

Table 4 (Appendix) illustrates predicted increase in overall future stand risk ratings with expected tree growth. These ratings, alone, do not establish priorities for treatment, but they do point out the long-term nature of the epidemic and the need for more long-term solutions.

STEP 5: Combine Current and Future Hazard. We then combined current and future hazard to get a comprehensive hazard rating and priority ranking. This helped determine treatment priority for stands currently of moderate risk by identifying those stands expected to become higher risk in the near future--adding considerably to sensitivity of the Munson and Anhold (1995) model. While not obvious from the first year's surveys done on stands we anticipated would be highest priority for treatment, this step did help prioritize stands surveyed later because of their lower current hazard ratings. Comprehensive hazard ratings ranged from lowest rating of "8" to highest rating of "24." Table 5 (Appendix) shows the combined risk ratings and resulting priorities to help establish treatment schedules.

Results and Conclusion

We gathered inventory data on young ponderosa pine stands in summer 2002, then determined hazard ratings and priority ranking during the following winter. Having identified the highest priority stands, we started preparing them for pre-commercial thinning during summer 2003, but we found most of the highest priority stands had more than 50 percent mortality from the latest MPB flight. The rating system obviously worked well for determining highest risk stands! We have continued to prioritize other stands and found existing beetle-caused mortality is approximately what we would expect.

One operational advantage of this new system has been as an aid in determining pre-commercial thinning prescriptions. For example, in a 35 year-old stand with crop trees averaging 7 inches DBH, we might have thinned to a 14-foot spacing, leaving the stand at low risk for imminent MPB attack. However, in 10 years those trees would average more than 9 inches DBH, which is high hazard for that spacing. Thinning to a spacing of 20-feet or greater now keeps the stand in a low- to moderate-hazard for nearly two decades. At that time trees will have attained both height and diameter to warrant commercial thinning.

Bark beetles and people both prefer large-diameter trees. In these stands MPB appeared to preferentially, but not always, attack and kill the larger ponderosa pine, Subsequent generations of beetles then killed smaller-diameter trees in the same vicinity. Others have observed MPB killing moderate sized trees initially, then moving into larger trees as the infestation persisted (Schmid, pers. comm.).

Our pre-commercial thinning focused on removing the smaller trees and favoring larger-diameter ones. Stands now have larger average diameters than prior to thinning, so they will more quickly become fire-tolerant stands of large, healthy, ponderosa pine trees. Because of the beetles' typical preference for trees of larger diameters, it might seem that thinning from below would increase a stand's susceptibility. Thinning studies (McGregor and others, 1987) and operational observations, however, have confirmed the findings of Bartos and Amman (1989). They demonstrated immediate benefits to thinning are realized as the microclimate around individual tree boles is altered to one (warmer and brighter) that beetles tend to avoid. Later, increased tree vigor in thinned stands maintains lower overall susceptibility to bark beetles.

Monitoring plots established in some of the first plantations to be pre-commercially thinned in 2003 using this priority ranking system and tree spacing guidelines have not had new MPB-caused mortality through the end of 2006. Observations in other stands also show very little or no new MPB attacks after thinning since implementing this process. Unthinned high priority ponderosa pine plantations have shown continued expansion of MPB-caused mortality.

In times of ever-declining budgets, it is imperative that we work as effectively and efficiently as possible to "protect the land and serve the people." This hazard- and risk-rating system has afforded us that opportunity.

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Appendix

The following three tables illustrate the progressive hazard- and risk-rating development for the series of stands described in the text.

Table 3: Current Stand Condition, Individual and Combined Risk Ratings, and Priority

Stand ID	Step 1 All Live Trees	Step 2 Trees Over 5" DBH		Step 3	Priority
	Growing Stock Level Hazard	Proportion of Ponderosa Pine Hazard	Current Infestation Hazard	Combined Risk	
70601001	6	3	3	12	1
70602003	6	3	3	12	1
70802110	6	3	3	12	1
73501001	6	3	3	12	1
73501004	6	3	3	12	1
74501148	6	3	1	10	2
75802001	2	3	1	6	5
75903035	4	3	1	8	4
76002001	4	3	1	8	4
76401002	6	3	1	10	2
76401005	6	3	1	10	2
76401019	6	3	3	12	1
76401020	4	3	1	8	4
76401021	4	3	1	8	4
76401025	6	3	1	10	2
76401036	6	3	1	10	2
76401047	4	3	3	10	2
76401048	4	3	3	10	2
76401057	4	3	1	8	4
76401083	4	3	3	10	2
76401130	4	3	3	10	2
76402017	6	3	1	10	2
76403010	6	3	3	12	1
76403113	4	3	3	10	2
76404014	4	3	1	8	4
76404042	4	3	1	8	4
76501016	4	1	1	6	5
76501064	4	3	1	8	4
76502003	4	3	1	8	4
76502006	6	2	1	9	3
76502010	2	3	1	6	5
76502011	6	3	1	10	2
76602009	6	3	3	12	1
76802114	4	3	3	10	2

Table 4: Future Stand Condition, Individual and Combined Risk Ratings, and Priority

Stand ID	Step 1	Step 2		Step 3	Priority
	All Live Trees	Trees Over 5" DBH			
	Growing Stock Level Hazard	Proportion of Ponderosa Pine Hazard	Current Infestation Hazard	Combined Risk	
70601001	6	3	1	10	1
70602003	6	3	1	10	1
70802110	6	3	1	10	1
73501001	6	3	1	10	1
73501004	6	3	1	10	1
74501148	6	3	1	10	1
75802001	6	3	1	10	1
75903035	6	3	1	10	1
76002001	6	3	1	10	1
76401002	6	3	1	10	1
76401005	6	3	1	10	1
76401019	6	3	1	10	1
76401020	6	3	1	10	1
76401021	6	3	1	10	1
76401025	6	3	1	10	1
76401036	6	3	1	10	1
76401047	6	3	1	10	1
76401048	6	3	1	10	1
76401057	6	3	1	10	1
76401083	6	3	1	10	1
76401130	6	3	1	10	1
76402017	6	3	1	10	1
76403010	6	3	1	10	1
76403113	6	3	1	10	1
76404014	6	3	1	10	1
76404042	6	3	1	10	1
76501016	6	1	1	8	3
76501064	6	3	1	10	1
76502003	6	3	1	10	1
76502006	6	2	1	9	2
76502010	6	3	1	10	1
76502011	6	3	1	10	1
76602009	6	3	1	10	1
76802114	6	3	1	10	1

Table 5: Combined Current and Long-Term Risk Ratings and Priority

Stand ID	Current Combined Risk	Future Combined Risk	Total Risk Rating	Priority
70601001	12	10	22	1
70602003	12	10	22	1
70802110	12	10	22	1
73501001	12	10	22	1
73501004	12	10	22	1
74501148	10	10	20	2
75802001	6	10	16	4
75903035	8	10	18	3
76002001	8	10	18	3
76401002	10	10	20	2
76401005	10	10	20	2
76401019	12	10	22	1
76401020	8	10	18	3
76401021	8	10	18	3
76401025	10	10	20	2
76401036	10	10	20	2
76401047	10	10	20	2
76401048	10	10	20	2
76401057	8	10	18	3
76401083	10	10	20	2
76401130	10	10	20	2
76402017	10	10	20	2
76403010	12	10	22	1
76403113	10	10	20	2
76404014	8	10	18	3
76404042	8	10	18	3
76501016	6	8	14	5
76501064	8	10	18	3
76502003	8	10	18	3
76502006	9	9	18	3
76502010	6	10	16	4
76502011	10	10	20	2
76602009	12	10	22	1
76802114	10	10	20	2