Cutting strategies can reduce probabilities of mountain pine beetle epidemics in lodgepole pine

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ABSTRACT—Mountain pine beetle attacks in lodgepole pine stands are generally concentrated on trees of large diameter and thick phloem, and brood production is greatest within such trees. Three lodgepole stands infested at various epidemic levels were sampled in 1971 and pre-epidemic diameter and phloem thickness distributions were estimated. Estimates of residual food supplies for beetles when partial cutting levels were applied to the data show that managing the stands so that trees did not reach 10 inches dbh would have substantially lowered the probabilities that epidemics would develop.

Mountain pine beetle (*Dendroctonus ponderosae* Hopkins) epidemics in lodgepole pine (*Pinus contorta* Douglas) stands throughout the Intermountain and Rocky Mountain areas usually last 5 to 7 years. During this period, tree mortality increases from about 0.5 tree per acre to a peak of over 25 trees per acre in 3 or 4 years, then declines to less than 0.5 tree per acre during the next 2 or 3 years. The cumulative effect on the stand is drastic. Tree losses range from 60 percent of the 12-inch dbh class to about 90 percent of the trees 18 inches dbh and larger. Total stand mortality may average 33 percent.

Efforts to control populations of the mountain pine beetle in lodgepole pine by chemical spraying, salvage logging, or combinations of both treatments have been evaluated (Amman and Baker 1972). Where infestation was complete, all beetle populations declined in about the same number of years, whether or not control was attempted. Lodgepole pine survival was comparable in both treated and untreated stands, but suppression measures slowed the rate of tree mortality in stands still under attack. Results were the same whether stands consisted of pure lodgepole or lodgepole mixed with other species.

The question that follows is, "Do control measures exist?" One possibility is short-rotation management that would prevent trees from reaching large diameters, thus eliminating or greatly reducing the potential for beetle epidemics. Amman (1973) has shown that epidemics are definitely correlated with the presence of large-diameter, thick-phloemed trees, and that the decline of epidemics is definitely correlated with the loss of these trees.

Beetle brood production is correlated positively with phloem thickness (food supply), and phloem thickness is correlated positively with tree diameter (Amman 1969, 1972). The distribution of phloem thickness over diameter classes thus is an effective measurement for evaluating infestation potential in a stand. Cole and Amman (1969) verified the importance of this measurement by estimating brood production (emerging new adults) from attacked trees of one documented epidemic.

This paper describes three lodgepole pine stands in various stages of epidemic development within the Rocky Mountain region and discusses cutting pre-

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Figure 1. Relationship between diameter distribution within stands and phloem thickness distribution among diameter classes for green trees.

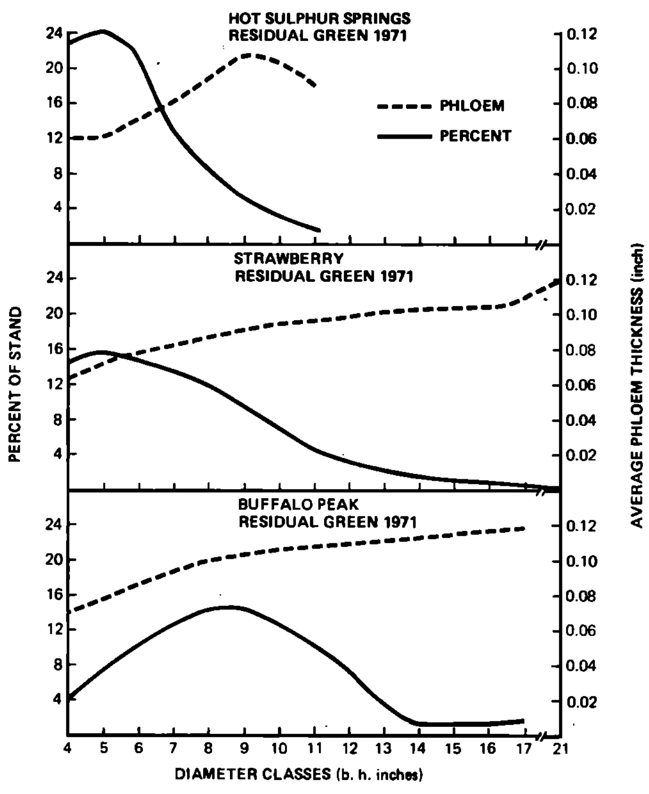

Table 1. Phloem class by tree diameter class for green trees remaining in the three areas, fall 1971.

Infestation area	Percentage of green trees by diameter class in inches			Percentage of green trees containing ≥0.11 inch phloem by diameter class in inches		
	≥8	≥10	≥12	≥8	≥10	≥12
Hot Sulphur Springs	18	3	0	29	50	....
Strawberry Creek	41	20	8	19	23	27
Buffalo Peak	66	40	17	45	51	72

Table 2. Percentage distribution of green trees and beetle-killed trees by diameter class and phloem thickness class for Hot Sulphur Springs stand.

Dbh class	Green trees before epidemic, by phloem thickness class of:			Trees killed during epidemic, by phloem thickness class of:		
	<0.11 inch	>0.11 inch	Total	<0.11 inch	>0.11 inch	Total
≤7	47	3	50	17	1	18
8-9	20	3	23	19	4	23
10-11	11	4	15	16	9	25
≤12	5	7	12	14	20	34
Total	83	17	100	66	34	100

scriptions applicable to two. Results suggest that management for small tree-size classes would eliminate or at least greatly reduce the epidemic potential.

History of the Outbreaks

Hot Sulphur Springs Outbreak.—This outbreak originated during 1967 near Hot Sulphur Springs, Colorado. It developed in mature lodgepole pine next to a sagebrush opening at elevations below 9,500 feet, and had run its course by fall 1971. By that time, beetles had killed most trees of 10 inches and greater diameter.

Strawberry Creek Outbreak.—This infestation started in 1970 with a few localized attacks on lodgepole pine below 9,500 feet in elevation near sagebrush pasturelands east of Granby, Colorado. The epidemic had partially developed at the time of our measurements in 1971.

Buffalo Peak Outbreak.—This infestation, first reported in the summer of 1970, was in a mature stand of lodgepole pine near pasture and sagebrush openings at the lower elevational range (9,500 feet) of lodgepole pine in North Park, Colorado. By 1971, an epidemic was developing rapidly.

No trees were removed from the three stands by logging before our phloem thickness and diameter size measurements were made in fall 1971.

Data Gathering and Results

Twenty plots (each one-tenth acre) were established on a grid basis within each infestation area. We measured diameters of all trees on all plots.

On each plot, phloem thickness samples were taken from each of two green, noninfested trees selected at random from each 1-inch diameter class down to 4 inches dbh. Phloem thickness was estimated (D. M. Cole 1973) for all infested and beetle-killed trees on all plots. Beetle population data were gathered by counting entrance and emergence holes for two bark samples (each 1 square foot) from all infested trees in the stands. The number of emerging, new adults was estimated (Amman 1969).

Table 1 summarizes diameter and phloem thickness

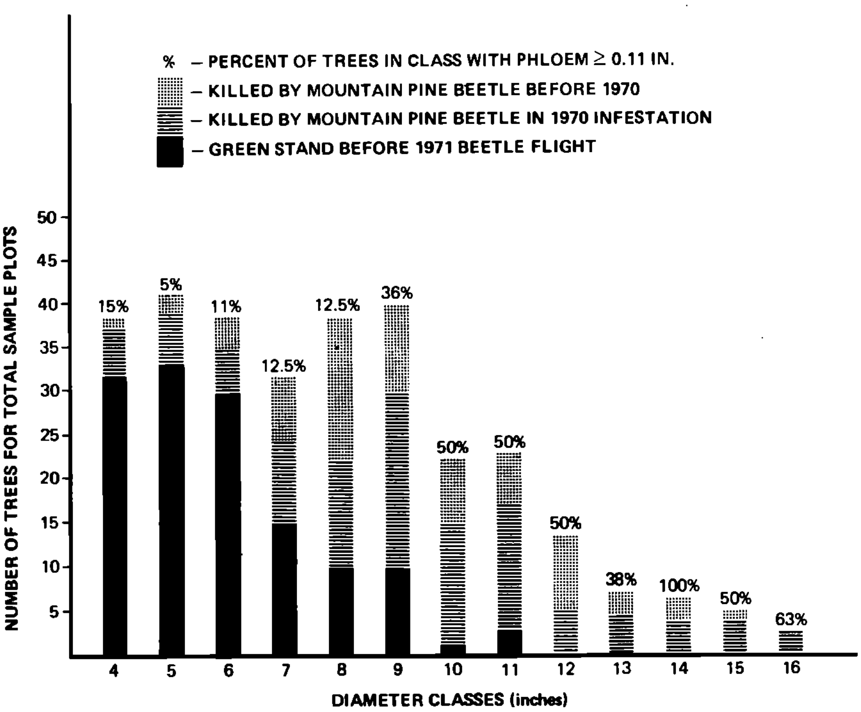

Figure 2. Hot Sulphur Springs stand after 5 years of mountain pine beetle activity.

Table 3. **Percentage distribution of beetle population by diameter class and phloem thickness class for trees killed during the 5-year epidemic within the Hot Sulphur Springs stand.**

Dbh class	Attacking adults in phloem thickness class of:			Emerging new adults in phloem thickness class of:		
	<0.11 inch	>0.11 inch	Total	<0.11 inch	>0.11 inch	Total
≤7	7	1	8	1	1	2
8-9	15	3	18	5	4	9
10-11	18	7	25	10	10	20
≤12	20	29	49	15	54	69
Total	60	40	100	31	69	100

data representing all green trees that were above 8 inches dbh. Trees in these diameter classes would provide food for beetles and thus are the keys to epidemic development.

In the Hot Sulphur Springs area, among green trees greater than 4 inches dbh, average dbh was 5.9 inches and phloem thickness was 0.074, the lowest averages of the three stands studied. Of all phloem samples taken within this stand, only 16 percent were greater than 0.11 inch thick. The brood-producing capacity of the residual stand was estimated to be low.

In the Strawberry Creek area, average dbh was 7.4 inches and phloem thickness was 0.081 inch for green trees greater than 4 inches dbh. Only 14 percent of all phloem samples within this stand were greater than 0.11 inch thick, but the phloem distribution in larger trees (*table 1*) indicates that epidemic brood-producing potential still exists.

Among green trees at Buffalo Peak with diameters greater than 4 inches, average dbh was 8.9 inches and phloem thickness was 0.095. One-third of all phloem samples taken within this stand were thicker than 0.11 inch. The stand was estimated to have a high-brood producing capacity.

Figure 1 shows the phloem-diameter relation for each stand, reflecting the established relationship of thick phloem to large-diameter lodgepole pines.

The Hot Sulphur Springs stand suffered the full effects of an epidemic. Our 1971 data, including dead and surviving trees, enabled us to describe the condition of the stand before beetle populations reached epidemic levels (*table 2*). It is clear that trees 10 inches dbh and larger were attacked at disproportionately high rates.

Table 3 focuses on adult beetle production. An estimated 69 percent of emerging adults came from trees with 12 inches or greater dbh. An additional 20 percent came from trees 10 to 12 inches dbh. Maintaining this stand so that trees grew no larger than 10 inches in diameter thus would have eliminated about 90 percent of emerging adult beetles by severely restricting brood production.

Harvesting Strategies

The basic problem facing the manager is lowering the probability of beetle epidemics developing within particular stands of lodgepole pine. Clearcutting is not always desirable. To determine whether partial cutting

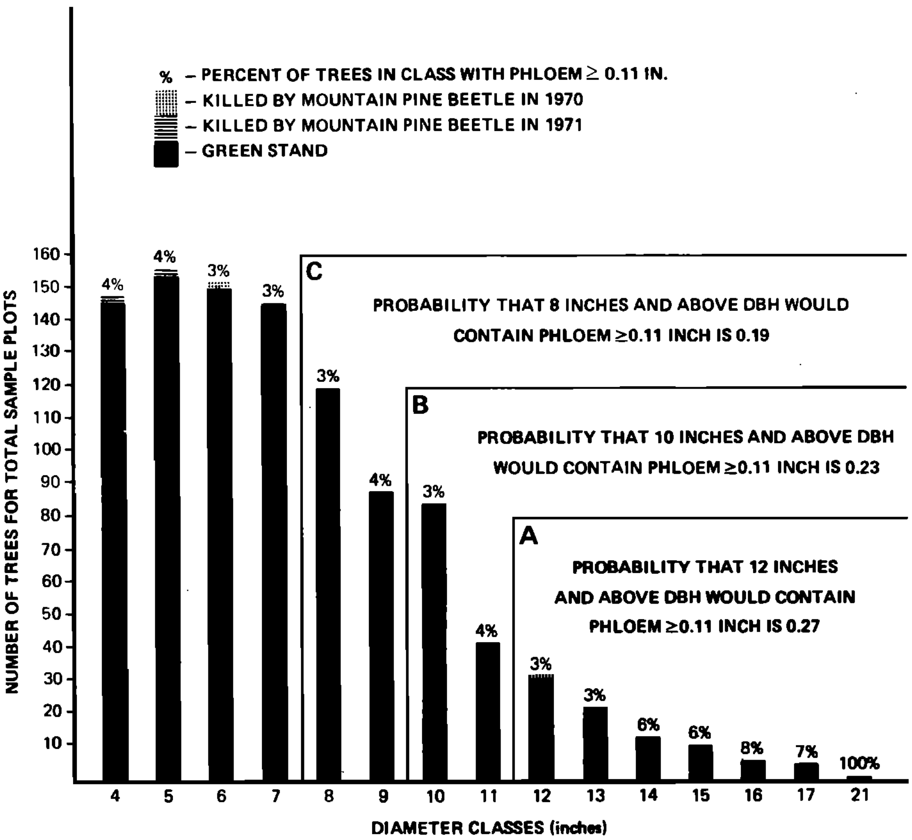

Figure 3. Strawberry stand. Land manager's alternatives to control mountain pine beetle outbreak by timber harvest: A, *remove all host trees 12 inches dbh and larger with 0.11-inch or thicker phloem;* B, *remove host trees 10 inches dbh and larger with 0.11-inch or thicker phloem;* C, *remove all trees 8 inches dbh and larger with 0.11-inch or thicker phloem.*

would be useful, the manager needs to determine tree diameter distribution in a stand and phloem thickness distribution within the diameter classes, and decide how much he wants to lower epidemic probability.

Sample data show that the Hot Sulphur Springs epidemic killed all trees of 12 inches or greater dbh and that only 3 percent of the trees of 10 inches or greater dbh survived (*fig. 2*). Of trees in the latter class, half had phloem thickness of 0.11 inch or greater. The probability of intense beetle activity continuing in this stand is small because suitable host trees are absent. Consequently, cutting is now considered unnecessary. But if 10-inch and larger trees containing phloem 0.11 inch or thicker had been cut before 1967, the beetles' food supply probably would have been removed.

The Strawberry Creek area had only light infestation effects. The pre-infestation stand is not reconstructed here. In 1971 in this stand, there was a 27 percent chance that any given tree over 12 inches dbh would contain phloem at least 0.11 inch thick (*fig. 3*). If all these trees were removed, the chance that any given smaller tree would contain thick phloem would be reduced to 23 percent. A partial cut of all trees above 10 inches dbh would reduce the chance to 19 percent, a low beetle food supply level unlikely to allow further epidemic development.

In the Buffalo Peak stand, 17 percent of the trees were 12 inches dbh or larger, with a 72 percent chance that any one tree in this class would contain phloem 0.11 inch thick (*fig. 4*). If this stand were partially cut to remove all trees 12 inches dbh and larger, the chance of smaller trees containing thick phloem would be reduced to 51 percent. Further partial cutting to remove all trees above 10 inches dbh and larger would reduce the chance to 45 percent. That is still a high beetle food supply level, and the manager of a stand with such a potential for epidemic development may want to consider clearcutting.

Conclusions

Cutting based upon lodgepole pine stand structure and phloem distribution among diameter classes can reduce the food supply of the mountain pine beetle before it becomes excessively active. In the stands studied, partial cutting to prevent trees from reaching 10 inches dbh would have restricted brood production and substantially lowered the probabilities of epidemics developing or running their full course. The Buffalo Peak stand, however, illustrates that partial cutting may not always lower epidemic development potential to levels that can be considered "safe." ■

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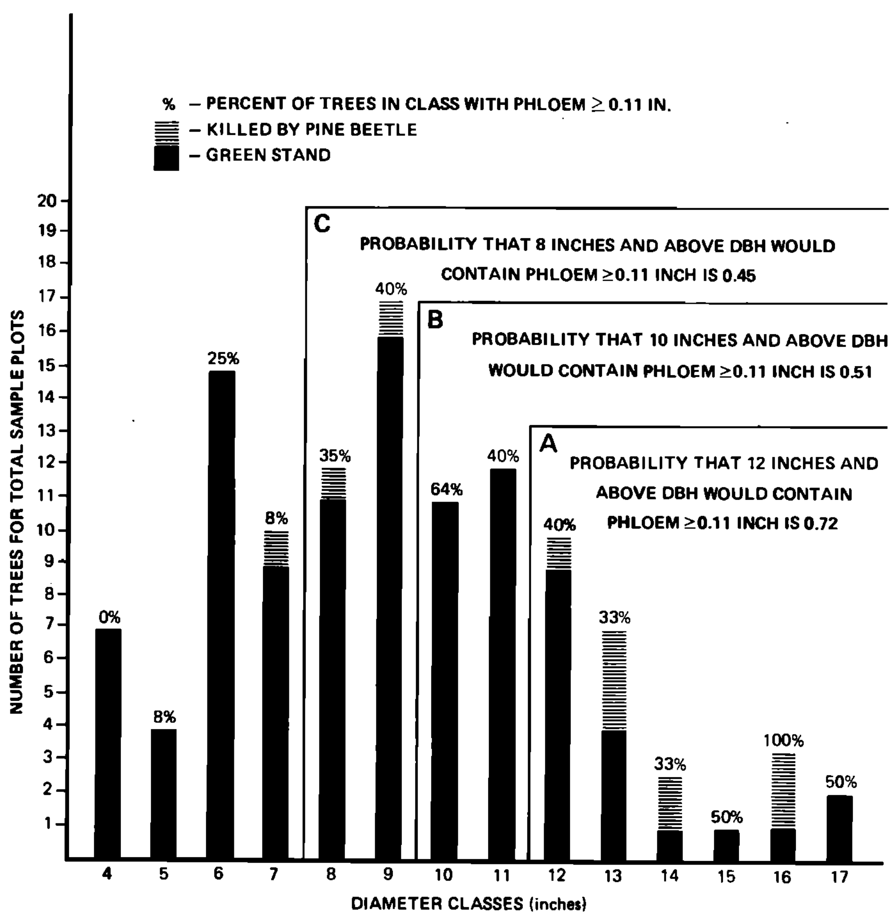

Figure 4. Buffalo Peak stand. Land manager's alternatives: A, remove host trees 12 inches dbh and larger; B, remove host trees 10 inches dbh and larger; C, harvest in this case would approximate a clearcut because most of the trees are in the larger classes.