75

Proceedings of
the IUFRO Conference on

The Role of the Host in the Population Dynamics of Forest Insects

L. Safranyik (Editor)

Joint Meeting of IUFRO Working Parties S2-07-05 & S2-07-06. Banff Centre,
September 4-7, 1983

Published jointly by
Canadian Forestry Service
and
USDA Forest Service

Prepared for publication at the
Pacific Forest Research Centre
of the Canadian Forestry Service, Victoria, B.C.

1985

Reducing or preventing mountain pine beetle outbreaks in lodgepole pine stands by selective cutting

Walter E. Cole
Intermountain Forest and Range Experiment Station, Ogden, Utah 84401

Mark D. McGregor
Cooperative Forestry and Pest Management, Missoula, Montana 59807

Abstract

Selective cuts based on dbh and phloem thickness reduced lodgepole pine losses to the mountain pine beetle. Loss reductions were proportional to the intensity of cut. According to the Rate of Loss Model, the 100-leave-tree cut was the best deterrent of recurring infestation, measured in terms of total mortality and length of time of the infestation. The 100-leave-tree cut also should provide the best regeneration and has the added benefit of reducing dwarf mistletoe infection.

Résumé

Grâce à des coupes sélectives fondées sur le diamètre à hauteur de poitrine et sur l'épaisseur du phloème, on a réduit les pertes de pin tordu causées par le dendroctone du pin ponderosa. La réduction des pertes a été proportionnelle à l'intensité de la coupe. Selon le modèle de calcul des pertes, le fait de laisser 100 arbres était le meilleur moyen, mesuré par la mortalité totale et la durée de l'infestation, d'empêcher le retour de cette dernière. Ce type de coupe devrait aussi assurer la meilleure régénération et elle a comme avantage supplémentaire de réduire l'infec[illegible]on par le faux-qui.

Introduction

Numerous control programs have been used to reduce lodgepole pine losses to the mountain pine beetle. None has been lastingly successful. Silvicultural practices formulated in light of what is known about the mountain pine beetle offer the most promise for reducing losses.

A 14-year study of mortality factors operating within epidemic mountain pine beetle populations showed that none offered any help in reducing these populations (Cole 1981). Only unseasonal cold temperatures and a rapid rate of drying of the phloem in the spring changed population levels. The closer these two factors were in sequence, the greater the population reduction. Unfortunately, neither factor is manageable. Food is an important regulatory factor of the survival of mountain pine beetle broods (Amman 1969), and food (phloem thickness) is directly related to tree diameter (Cole and Amman 1969). During the course of a mountain pine beetle infestation, large-diameter trees are usually infested and killed first each year, as well as over the life of the infestation. Large trees usually produce more beetles per unit area of bark and more per tree due to their greater surface area (Cole and Amman 1969). Beetles completing development in small trees having thin phloem are usually smaller than beetles completing development in larger trees (Safranyik and Jahren 1970), and possibly are of lower quality.

The most logical approach to the problem was to develop a management strategy to reduce or prevent potential buildup of mountain pine beetle populations by reducing the beetles' food supply.

Since brood production by mountain pine beetle has been shown to be positively correlated with phloem thickness (Amman 1969) and phloem thickness positively correlated with tree diameter (Amman 1972), then distribution of phloem thickness over diameter becomes an effective measurement of infestation potential in lodgepole pine stands. Based on these same measurements, one should be able to implement certain harvesting strategies to eliminate or greatly reduce the hazard of outbreaks of mountain pine beetle. For example, by selectively logging those trees or diameter classes of trees which are most susceptible to attack, i.e., those 12 inches (30.5 cm) dbh and larger or those with phloem thickness ≥ 0.10 inch (2.5 mm), then the beetles' food supply could be much reduced.

In developing a plan for management of specific drainages, considerations for particular sites are to: i) protect or enhance key resource values, ii) remove susceptible or high-hazard merchantable material through a commercial timber sale, iii) develop permanent access roads for general land use and management, and iv) improve forest cover growing conditions through disease control and stocking to attain timber production potentials on regulated lands. Partial cuts help attain these management objectives and also minimize potential beetle-caused losses in treated stands.

In this paper we report two field demonstrations that reflect the effectiveness of these cutting strategies.

Materials and methods

West Yellowstone demonstration area

In 1974, a cutting experiment was conducted on six 40-acre (98.8-ha) lodgepole pine stands containing mountain pine beetle infestations on the Hebgen Lake Ranger District, Gallatin National Forest at West Yellowstone, Montana. Each block received one of the following harvesting prescriptions prior to beetle flight in 1975.

1. Remove all infested trees and those green trees ≥ 7 inches (17.8 cm) dbh regardless of phloem thickness.
2. Remove all infested trees and those green trees ≥ 10 inches (25.4 cm) dbh regardless of phloem thickness.
3. Remove all infest trees and those green trees ≥ 12 inches (30.5 cm) dbh regardless of phloem thickness.
4. Remove all infest trees and those green trees with 0.10 inch (2.5 mm) phloem thickness (based on an average of two chip samples taken at breast height from each tree) with a dbh of at least 5 inches (12.7 cm).
5. Remove no trees on two check blocks.

Habitat types were identified by National Forest personnel and follow the nomenclature of Pfister *et al.* (1974). Physical, biological, and silvicultural characteristics are shown in Table I.

To evaluate beetle flight activity within the cut blocks, sets of three passive traps (Schmitz *et al.* 1981) were distributed within each block except for the 12-inch block. The three-trap vertical sets were hung from horizontal lines between trees, with a passive trap at the top crown (average height 30.4 ft [9.3 m], range 28-37 ft [8.5-11.2 m], mid-crown (average height 17 ft [5.2 m], range 15-19 ft [1.5-2.1 m] levels. Traps were not placed in the 12-inch block because distance and travel restrictions prohibited making weekly collections from traps.

The reduction in infestation levels in each study area was expected to be proportional to amount of timber removed which was high risk (i.e., dbh greater than 8 inches or phloem thickness of at least 0.10 inch).

Shoshone demonstration area

In 1979, a second experiment was conducted on Shoshone National Forest, Wyoming. The same diameter-limit cuts were used as described earlier with the addition of 100-leave-tree and clearcuts. A total of 37 cutting units and one check block unit were laid out and cut between January 1979 and February 1981.

Results and discussion

West Yellowstone demonstration area

Based on percentage of trees containing phloem at least 0.10 inch thick (Cole and Cahill 1976), Check Block (B) had the highest probability of supporting an epidemic and would sustain the greatest loss of trees due to the mountain pine beetle. The probability of loss, in descending order, for the other treatments were as follows: 12-inch Block, Check Block (A), Phloem Block, 10-inch Block, and 7-inch Block.

Essentially, the entire range of host material was virtually eliminated in the 7-inch Block, but trees killed per acre increased from 0.2 (0.5/ha) in 1975 to 2.1 (5.1/ha) in 1979, then sharply declined to 0.9 (2.2/ha) in 1980 (Table II). A total of 10.4 trees were killed per acre (25.8/ha) from 1975 through 1980. Residual basal area was 52.1 ft²/acre (11.6 m²/ha). Less than 1 tree per acre (2.4/ha) was classed as pitchout in 1975, 21.3 (52.6/ha) in 1976, 49.5 (122.3/ha) in 1977, 0.9 (2.2/ha) in 1978, and 1.5 trees per acre (3.7/ha) in 1980.

In the 12-inch cut block, after the selective cut was completed, the average phloem thickness of all remaining trees was 0.07 inch (1.8 mm), and 10.4% of the remaining trees had a phloem thickness of ≥ 0.10 inch (2.5 mm). A total of 10.2 trees were killed per acre (25.2/ha) from 1975 through 1980. Trees killed per acre increased from 1.0 in 1975 to 4.8 (2.4 to 11.8/ha) in 1978, declined to 0.6 (1.4/ha)

Table I. Summary of preharvest sampling for mountain pine beetle study plots, Gallatin National Forest, Montana, 1974

Ranger District	Plot elevation (feet)	Average stand age (years)	Habitat types(s)	Average tree diameter (inches)	Average number of infested trees/acre	% of phloem samples 0.10-inch thick	Mean phloem thickness (inches)	% of stand lodgepole pine
Hebgen Lake								
7-inch block	6 660	75	*Pinus contorta/ Purshia tridentata*	9.0	2.0	—	0.070	100.0
10-inch block	6 660	193	*Pinus contorta/ Purshia tridentata*	8.9	2.3	4.46	0.064	100.0
Phloem block	6 660	76	*Pinus contorta/ Purshia tridentata*	8.7	2.0	12.00	0.076	100.0
Check Block A	6 660	75	*Pinus contorta/ Purshia tridentata*	7.5	2.3	13.80	0.074	100.0
Gallatin								
12-inch block	7 400	162	*Pseudotsuga mensiesii/ Linnaea borealis*	9.9	4.0	17.40	0.078	77.0
Check block B	6 200	97	*Abies lasiocarpa/ Linnaea borealis*	7.0	16.0	20.00	0.088	84.7

Table II. Mountain pine beetle infested lodgepole pine in demonstration blocks, Gallatin National Forest, Montana, 1975-1980

	Mean number of successfully infested trees/acre						Total trees killed/ acre	Mean diameter of attacked trees (inches)						Percentage of attacked trees classed as pitchouts						Residual BA LPP
Ranger District	1975	1976	1977	1978	1979	1980		1975	1976	1977	1978	1979	1980	1975	1976	1977	1978	1979	1980	(ft^2/acre)
Hebgen Lake																				
7-inch block	0.2	2.1	5.8	0.8	16.0	0.9	25.8	7.2	5.6	6.2	7.1	6.7	6.4	0.1	5.9	26.5	0.1	—	1.1	52.1
10-inch block	4.2	2.0	1.2	6.1	25.9	0.7	40.0	12.2	8.0	7.8	8.0	7.8	7.8	<1.0	21.3	49.5	0.9	—	1.5	39.1
Phloem block	4.1	8.9	23.6	8.5	1.3	1.9	47.4	11.3	9.7	9.2	7.2	11.9	8.3	<1.0	21.8	20.3	1.5	—	1.2	57.3
Check block A	2.8	8.1	26.8	21.7	17.4	2.2	81.0	10.3	9.8	9.9	9.9	7.5	10.6	<1.0	1.9	11.4	4.1	—	25.2	52.1
Bozeman-Gallatin																				
12-inch block	1.0	0.5	1.4	4.8	1.8	0.6	10.3	13.3	10.1	10.0	5.1	10.3	10.4	17.0	28.1	46.2	0.2	—	0.3	25.8
Check block B	40.1	20.7	3.9	2.9	0	0	67.6	8.7	7.5	7.2	8.5	0	0	48.4	35.0	62.4	6.0	—	0	55.8

in 1980. Pitchouts increased from 17.0 in 1974 to 46.2 per acre (42 to 114/ha) in 1977, declined to 0.3 per acre (0.7/ha) through 1980. Residual basal area was 25.8 ft²/acre (5.75 m²/ha) (Table II).

In the phloem cut block, this represented a low of 0% cut in the 5- and 6-inch (13.5- to 15.7-cm) diameter classes to a high of 100% cut in the 15-inch (39-cm) and larger diameter classes. Removal of the thicker phloem trees was expected to result in reduced mountain pine beetle buildup potential due to a reduction in food (phloem) supply, but not necessarily a reduction in the number of trees attacked. The phloem cut conceivably could leave large-diameter trees with thin phloem vulnerable to attack, but such trees would not be strong producers of mountain pine beetle brood. This strategy was used as a specific test of phloem-brood relationship, and not as a prospective strategy for operational use. Following harvesting, killed trees increased from 4.1 per acre (10.1/ha) in 1975 to 23.6 (58.3/ha) in 1977, declining to 8.5 (21/ha) in 1978 and 1.9 (4.6/ha) in 1980. Average dbh of infested trees exceeded 9.0 inches (23 cm) with the exception of 1978 when infested trees averaged 7.2 inches (19.5 cm) dbh (Table II). The average dbh of attacked trees increased to 11.9 inches (30.1 cm) in 1979, then declined to 8.3 inches (25.5 cm) in 1980. Virtually all large-diameter trees, including those with thick phloem, were eliminated from this block. Residual basal area was 57.3 ft²/acre (12.7 m²/ha).

Mortality in the two check blocks was very similar (Table II). In Check Block (A), a total of 81 trees were killed per acre (200/ha), leaving a residual basal area of 52.1 ft²/acre (11.62 m²/ha). Mortality increased steadily through 1977, then declined through 1980. Pitchouts increased to 11.4 per acre (28.1/ha) in 1977, declined to 4.1 per acre (10.1/ha) in 1978, then increased to 25.2 per acre (62.2/ha) in 1980. In Check Block (B), mortality increased from 16.2 trees per acre (4.0/ha) to 40.1 per acre (99/ha) in 1975, then declined to 0 by 1979. Virtually all susceptible trees (large diameters) had been killed, leaving a residual basal area of 55.8 ft²/acre (12.44 m²/ha). Residual lodgepole pine average 6.8 inches (17.2 cm) dbh. No successfully attacked trees or pitchouts occurred in this block from 1979 to 1981.

Cutting from above did reduce tree mortality in all blocks as compared to the checks. Total trees killed per acre were fewest in the 7-inch cuts (25.8 per acre [63.7/ha]), increasing to 10.2 per acre (25.2/ha) in the 12-inch block, 54 per acre (133/ha) in the 10-inch block, 60 per acre (148/ha) in the phloem cut, and 81 and 83 per acre (200/ha and 205/ha) in two check blocks.

Tree growth increased in all stands but was greatest in the 7-inch diameter cut, followed by the 10-inch, Check Block (A), 12-inch, and phloem-cut blocks. Tree growth may have been greater in the 12-inch block; however, this is at a much higher elevation than other blocks, and growth is relatively slow at best.

Core measurements from 33 to 35 sample trees per block were analyzed to determine differences in diameter growth between treatment blocks. Measurements included the last 5-year radial growth and the previous 5-year growth.

Using Tukey's Test of Significance, growth on the 7-inch (17.78-cm) cut block differed significantly from the check, while there was no statistically significant difference between the check, 10-inch (25.4-cm), 12-inch, or phloem cuts (Table III). Following cutting, greatest growth occurred in the 7-inch cut block. Growth response was the same in the 12-inch cut and phloem cut, and both produced less growth than the 7-inch cut. Growth response in the 10-inch cut block was less than all other cuts, with least amount of growth response occurring in the check blocks (Table III).

Table III. Tukey's test of significance of mean diameter growth of of trees among harvest treatments

Treatments	$\bar{x}$	$\bar{x} - 3.42$ in.	$\bar{x} - 3.65$ in.	$\bar{x} - 4.01$ in.	$\bar{x} - 4.01$ in.
7-inch cut	4.89	1.47	1.24	0.88	0.88
12-inch cut	4.01	0.59	0.36	0	
Phloem cut	4.01	0.59	0.36		
10-inch cut	3.65	0.23			
Check block	3.42				

$D = \sqrt{3.67/33.6} \times 3.68 = 1.27$[1]

$Q = 3.86$

---

[1] Differences between means ≤ to this figure are significant at p ≤ 0.05.

Tree mortality may have been less in all cutting units had logging been completed several years prior to the ensuing epidemic. The infestation began in 1970-71, cutting occurred in 1974 and 1975, and the beetle populations that were generated from larger diameter trees adjacent to harvested units undoubtedly influenced the amount of tree mortality yearly. Mortality declined to 1 tree per acre (2.4/ha) in the 7-inch, 10-inch, and 12-inch blocks following the cold temperatures during winter 1978-79, which caused a dramatic reduction in beetle populations on the Gallatin National Forest, and outside of the study areas, showed that the average number of infested trees declined from 45 to 18 per acre (108/ha to 43.2/ha) from 1978 to 1979. These data are also reflected in beetle catch in flight traps from 1978, 1979, and 1980.

Trapping of beetles did not begin until 1978, three years after the cuts were completed. The majority of beetles were flying (caught) at the mid-crown level in all three years of trapping (fig. 1). The flying beetle population was distributed fairly evenly among the cut and check blocks for each of the three years of trapping

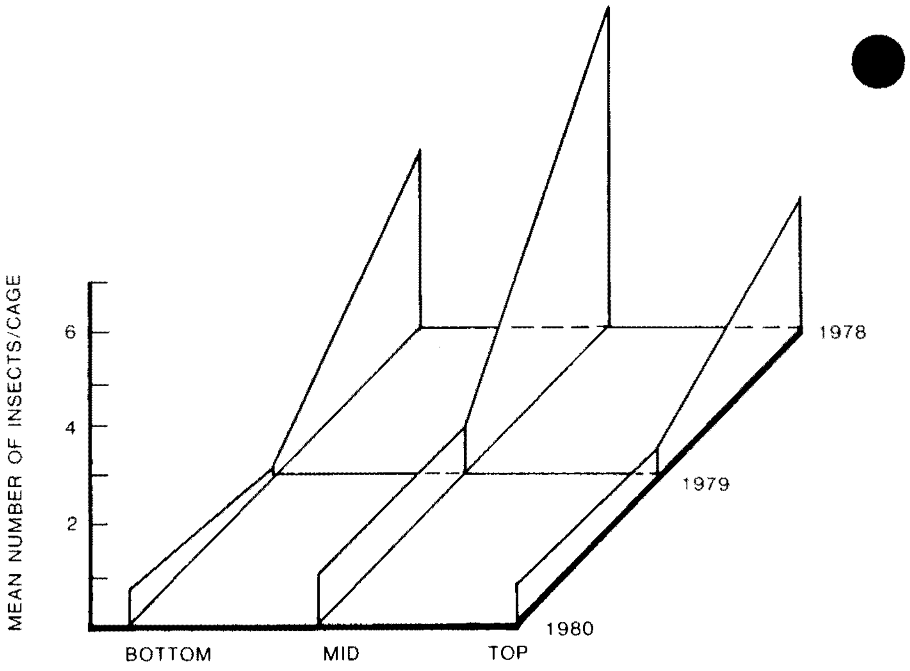

Fig. 1a. Distribution of beetle catch by year and height in stand.

(fig. 1b). Sampling indicates that cutting had little effect on the flying beetle population passing through blocks; each block was subjected to an equal number of beetles that could attack trees. However, tree mortality was related to cutting intensity, thus we postulate the microenvironmental factor also may have influenced beetle attack. There was a high population of flying beetles caught in 1978, and a severe decline during 1979 and 1980 (fig. 1c). The decline in beetle population in 1980 was attributed to mortality of broods resulting from low temperature (−34° to −51°F [−37° to −47°C]) for 7 to 8 consecutive days during December 1978 and January 1979. Temperatures were as low as −62°F (−50°C) for short peaks of less than an hour (Gibson and Bennett 1979).

Shoshone demonstration area

The stand structure changed proportionally to the intensity of harvest cut used in each block. Considering only the trees killed by the mountain pine beetle, the trend for the tree years was rather dramatic. In all cutting blocks, the number

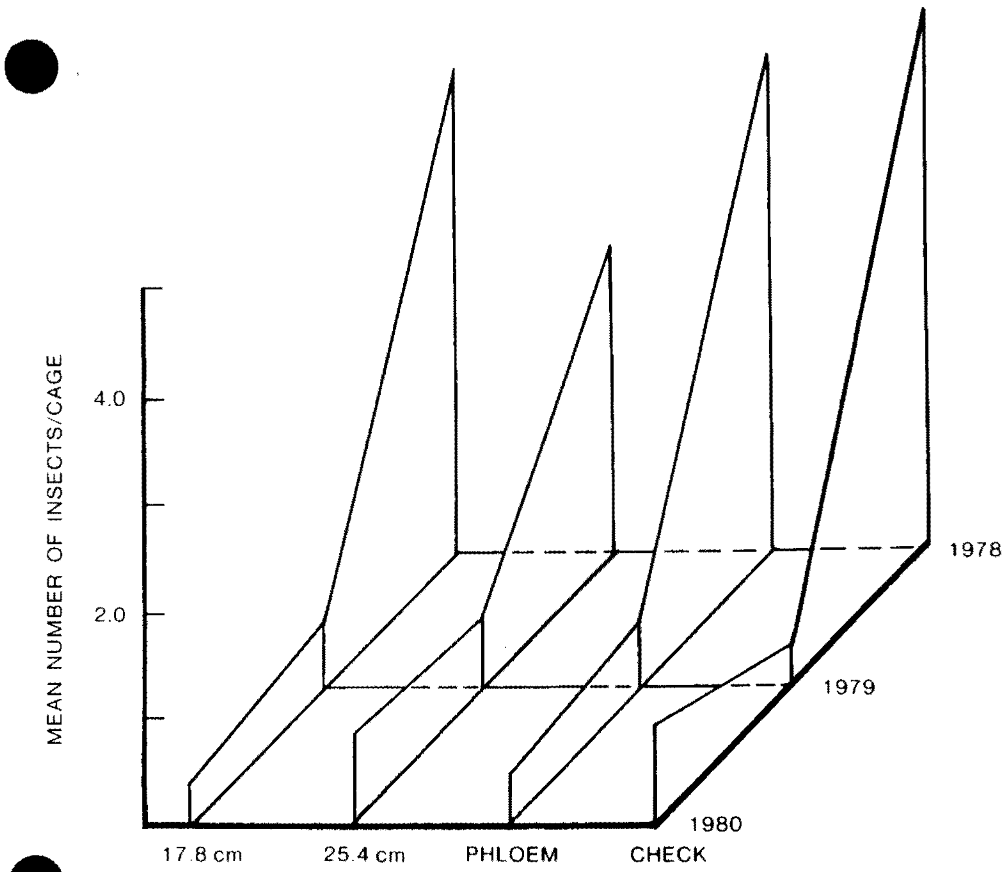

Fig. 1b. Distribution of beetle catch by year and treatment area.

of trees infested declined considerably after harvest; the check block continued to lose trees to the beetle at about the same rate as before harvest. However, all cutting blocks now contain almost the same number of live trees per acre, which is about one-half the number of live trees per acre now in the check block, although the average stand diameter changed. Residual basal area followed the level of cut, as would be expected. Using the check blocks as a base, 66% of the basal area was removed in the 7-inch blocks; 55% in the 10-inch blocks; 45% in the 12-inch blocks; and 63% in the 100 leave tree blocks. This does not necessarily reflect release by cutting, because only 1-2 years of growth occurred since cutting was started.

Having seen the immediate results of the cutting regimes, the question now is of the future of the stands on the Shoshone National Forest and other stands where partial cuts are initiated with respect to the activity of the beetle and stand

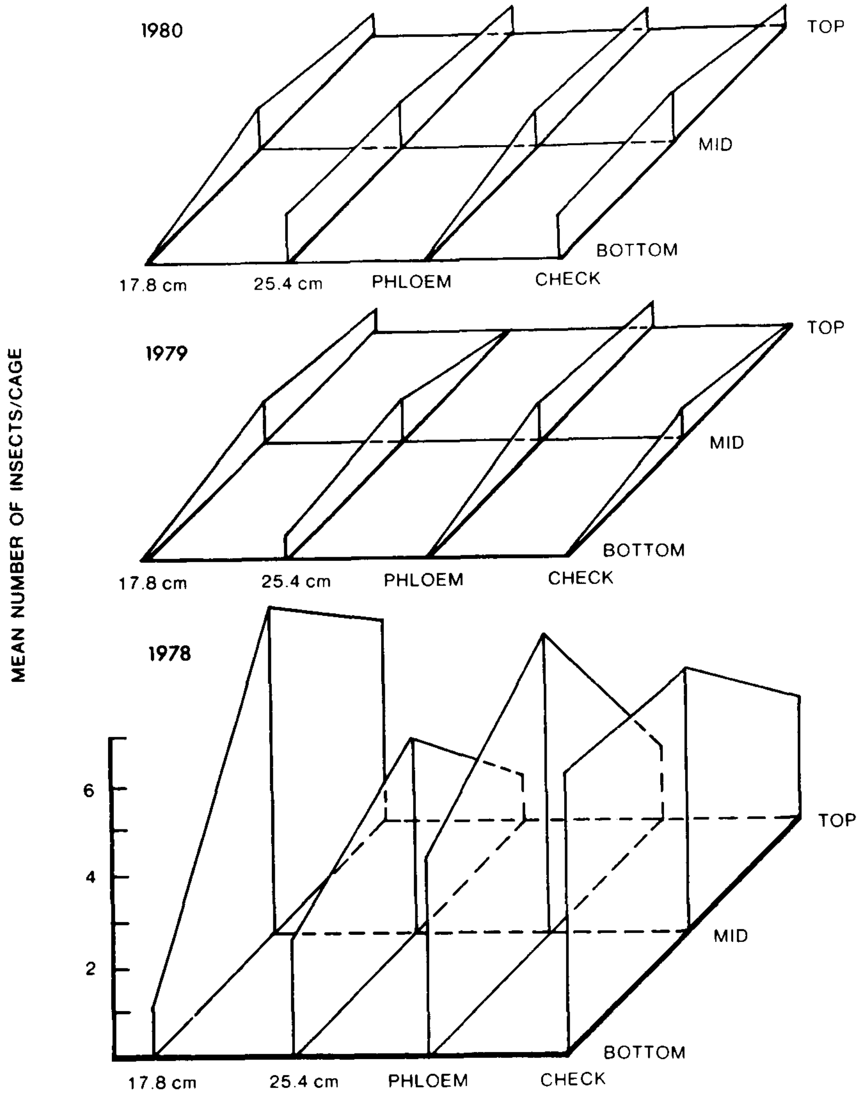

Fig. 1c. Distribution of beetle catch by treatment, height in stand and year.

development. The harvest levels reduced the current level of loss somewhat proportionally, but will the beetle resume killing trees at the same ratio as before treatment or has a change been induced in the course of the infestation? To project an answer to this question, these mortality data were used in the Rate of Loss Model (Cole and McGregor 1984) to predict the rate of future tree loss and the duration of such an infestation.

This projection predicted that the infestation within the check area should peak about 1981, with 46.9 trees killed per acre (115.8/ha), and subside to 1.1 trees per acre (2.7/ha) by 1989, tailing to 0.02 trees per acre (0.048/ha) by 1993. the diameter limit cuts reduced the peak loss rather proportionally to the extent of cutting; for example, peak kill was greater in the 12-inch cuts than in the 7-inch cuts. The expected length of infestation changed accordingly with the longest period of outbreak expected for the 7-inch cut. The exception was the 100-leave-tree cut. This cut extended the predicted life of the infestation to the year 2012 with peak tree loss of only 1.5 trees per acre (3.7/ha) in the year 1993.

The 100-leave-tree cut, according to these predictions, would reduce tree loss from the mountain pine beetle. This cut would also be advantageous in reducing or minimizing dwarf mistletoe. Once the area is reseeded and the regeneration height exceeds snow depth, the leave trees should be removed. The small target area of the regeneration, the washing action of the snow in removing dwarf mistletoe seeds, and the young stand being immune to the mountain pine beetle may well be the keys to producing a healthy new stand of lodgepole pine.

References

Amman, G.D. 1969. Mountain pine beetle emergence in relation to depth of lodgepole pine bark. U.S. Dept. Agric. For. Serv., Res. Note INT-96.

Amman, G.D. 1972. Mountain pine beetle brood production in relation to thickness of lodgepole pine phloem. J. Econ. Entomol. 64: 138-140.

Cole, W.E. 1981. Some risks and causes of mortality in mountain pine beetle populations: A long-term analysis. Res. Popul. Ecol. 23: 116-144.

Cole, W.E. and G.D. Amman. 1969. Mountain pine beetle infestations in relation to lodgepole pine diameters. U.S. Dept. Agric. For. Serv. Res. Note INT-95.

Cole, W.E. and M.D. McGregor. 1984. Estimating the rate and amount of tree loss from mountain pine beetle infestation. U.S. Dept. Agric. For. Serv. Res. Pap. INT-183.

Gibson, K.E. and D. Bennett. 1979. Overwintering survival of mountain pine beetle larvae and resultant effect on beetle populations in the Northern Region in 1979. U.S. Dept. Agric. For. Serv., Northern Region, Rep. 79-15.

Pfister, R.D. B.L., Kovalchik, S.F. Arno, and R.C. Presby. 1974. Forest habitat types of Montana. U.S. Dept. Agric. For. Serv. Gen. Tech Rep. INT-34.

Safranyik, L. and R. Jahren. 1970. Host characteristics, brood density, and size of mountain pine beetles emerging from lodgepole pine. Can. For. Serv., Bi-monthly Res. Notes 26: 35-36.

Schmitz, R.F., M.D. McGregor, and G.D. Amman. 1981. Mountain pine beetle response to lodgepole pine stands of different characteristics. *In*: Proceedings of the second IUFRO Conference on Dispersal of Forest Insects: Evaluation, Theory and Management Implications. A.A. Berryman and L.S. Safranyik, Eds. pp. 234-343.