Research Note

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MOUNTAIN PINE BEETLE INFESTATIONS IN RELATION TO LODGEPOLE PINE DIAMETERS

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ABSTRACT

Tree losses resulting from infestation by the mountain pine beetle (Dendroctonus ponderosae *Hopkins) were measured in two stands of lodgepole pine (*Pinus contorta *Dougl.) where the beetle population had previously been epidemic. Measurement data showed that larger diameter trees were infested and killed first. Tree losses ranged from 1 percent of trees 4 inches (d.b.h.) to 87 percent of those 16 inches and greater d.b.h. Numbers of adult beetle emergence holes averaged 1.3 per square foot of bark area in trees 7 inches d.b.h. and 62 in trees 18 inches and greater d.b.h. The observations indicate that large infestations of mountain pine beetle depend on the presence of large diameter trees within a stand of lodgepole pine, thus implying that beetle population growth is food-limited.*

The infestation by the mountain pine beetle (*Dendroctonus ponderosae* Hopkins), that started in the early 1960's in western Wyoming and eastern Idaho, has destroyed over 3 million lodgepole pine (*Pinus contorta* Dougl.) trees in that area. As a result, studies were conducted to determine if a relationship exists between beetle populations and the sizes of the trees that are infested. Specifically, the objectives were to (1) verify the relationship between infestations of the mountain pine beetle and the diameter of lodgepole pine within large stands, and (2) demonstrate the relationship between diameter of lodgepole pine and numbers of emergence holes made by brood adults.

Gibson (1943) observed that the mountain pine beetle attacked a greater proportion of large rather than small diameter lodgepole pine trees. Hopping and Beall (1948) found a direct relationship between tree diameter and percentage of trees infested by the mountain pine beetle. Bedard (1938, 1939) found in western white pine that more mountain pine beetles developed to maturity per square foot of bark in the larger diameter trees. Reid (1963) reported similar findings for the mountain pine beetle in lodgepole pine. Shepherd (1966) indicated that the beetle has evolved a searching image (large dark objects against a light background) for large diameter trees. The evolution of such behavior should be advantageous when the greater survival of beetles in trees of large diameter is considered.

METHODS

Two stands of lodgepole pine were selected in which the mountain pine beetle population had risen to epidemic level for several years but recently has declined to a relatively low level. These were located in the Teton National Forest and Teton National Park in northwestern Wyoming. Twenty 1/10-acre nonvariable plots were located in a grid pattern within a 2-mile-square unit within each of the two stands. All trees that were 4 inches and larger in diameter were measured and the year of death for each tree was determined within these plots.

The following characteristics were used to determine the year in which the tree was killed: (1) foliage green, fresh boring frass, eggs or larvae present--tree killed in current year; (2) foliage bright orange to straw color--tree killed in previous year; (3) foliage dull orange and most retained--tree killed in second year past; (4) foliage dull orange to gray and most lost--tree killed in third year past; (5) no foliage, most small twigs lost which had supported needle fascicles--tree killed in fourth year past; (6) bark peeling--tree dead for 5 or more years.

In the plots within one 2-mile-square unit, the numbers of emergence holes were counted on two 6-inch-square areas of bark selected at random at diameter breast height (d.b.h.) on each tree that had been killed by the mountain pine beetle.

RESULTS AND DISCUSSION

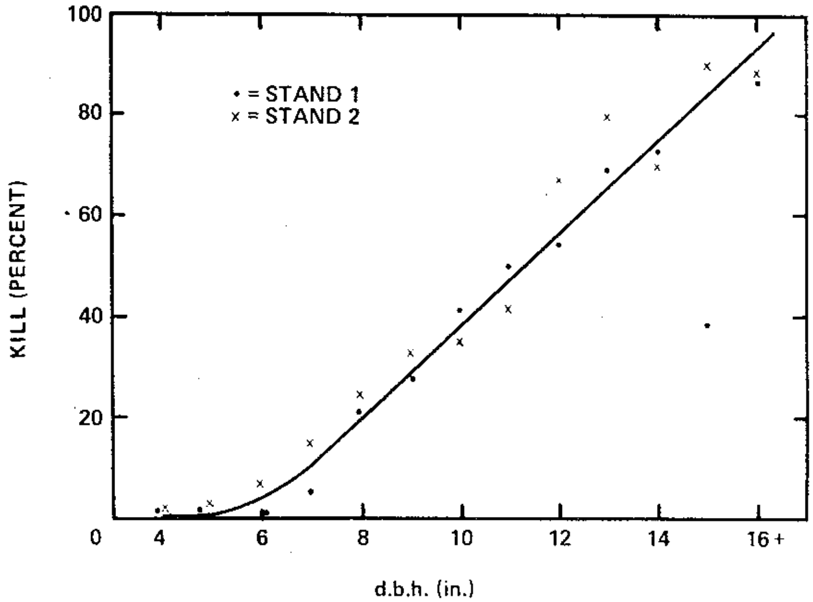
Sizes of trees killed.--The results demonstrate that the mountain pine beetle strongly favors the trees of larger diameter each year, as well as over the life of the infestation, and verify the observations of Gibson (1943) and Hopping and Beall (1948). As the larger diameter trees are killed, the beetles infest the residual smaller diameter trees or possibly migrate in search of the larger trees in adjoining areas.

Estimates of the average diameter of trees killed by the beetle per year gave standard errors that were usually less than 10 percent of the mean. The proportions of trees killed in the various diameter classes in the two units were remarkably similar and varied from 1.1 percent in the 4-inch-diameter class to 87.5 percent in the 16-inch-and-greater class (fig. 1). Correlations between diameters of trees killed and year of kill were highly significant ($r = 0.46$ and 0.58, $P < 0.01$), with the larger trees being selected by the beetle in the early years of the infestation (fig. 2). In the latter stages of the infestation (beetle and infested tree populations decreasing) the beetles were working in the smaller diameter trees. This is not to infer that all nonsurviving trees were killed by the mountain pine beetle. The proportion of lodgepole trees killed by the beetle is shown in table 1.

The pattern of infestation, i.e., average diameter killed by percent of trees killed over years of infestation, is shown in figure 3. Again, the preference of the beetle for the larger diameter trees by year is evident.

The infestations rose from approximately 0.5 to 5 trees per acre in 1962 to a peak of 26 to 31 trees per acre in 1964. They then declined to 2 to 3.5 trees per acre by 1967, when most of the larger diameter trees had been killed. The intense period of the infestation was relatively short, lasting approximately 6 years (fig. 4). The data of Gibson (1943) for an infestation occurring during the 1930's indicate a comparable period of time. The similarity in the three curves depicting the percentages of trees killed by year for these plots supports the accuracy of our determination of the year of tree kill.

Figure 1.--Proportion of lodgepole pine trees killed within the combined study stands, by diameter class, 1962-67.



In the two stands, 155 trees, or 68 percent, and 192 trees, or 71 percent, of those trees that were 4 inches and greater in diameter were still living in 1967. Survival varied from 100 percent in the 4-inch-diameter class of trees to 12.5 percent in the 16-inch-and-greater class.

Not all dead trees in the study areas were killed by the mountain pine beetle. It is evident that *Ips* species infested and killed some of the smaller diameter trees (table 1). It is also assumed that a relationship exists between the mountain pine beetle and *Ips*; that is, the *Ips* alone might not have caused as high a loss as it appears. *Ips* infest the trees above the part infested by the mountain pine beetle.

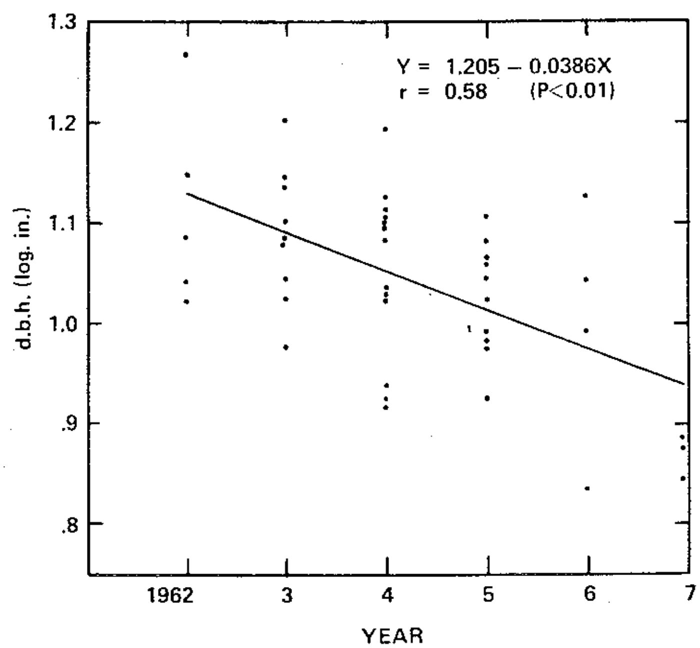


Figure 2.--Correlation between diameters of lodgepole pine trees killed by the mountain pine beetle, and year of kill; for example, within study stand 2, 1962-67.

Table 1.--Proportion of lodgepole pine trees by diameter class killed per acre by the mountain pine beetle, 1962-67

Diameter class (inches)	Number of trees/acre: Surviving	Killed by MPB	Killed by other causes[1]	Total	Percent killed by MPB
	PACIFIC CREEK - TETON NATIONAL FOREST				
Stand 1					
4	12.5	0.0	0.0	12.5	0.0
5	17.5	.0	1.0	18.5	.0
6	22.5	.0	.0	22.5	.0
7	25.0	1.5	1.5	28.0	5.6
8	17.5	5.0	1.5	24.0	20.8
9	19.5	8.0	.5	28.0	28.6
10	14.0	10.0	.0	24.0	41.7
11	9.5	10.0	.5	20.0	50.0
12	5.5	6.5	.0	12.0	54.2
13	4.0	9.0	.0	13.0	69.2
14	2.0	5.5	.0	7.5	73.0
15	4.0	2.5	.0	6.5	38.5
16	.5	3.5	.0	4.0	87.5
17	.5	3.0	.0	3.5	85.7
18+	.5	3.5	.0	4.0	87.5
Totals	155.0	68.0	5.0	228.0	29.8
	PILGRIM CREEK - TETON NATIONAL PARK				
Stand 2					
4	21.5	0.0	2.5	24.0	0.0
5	25.0	.5	1.0	26.5	1.9
6	37.0	3.0	2.0	42.0	7.1
7	37.0	7.0	1.5	45.5	15.4
8	27.5	9.0	.0	36.5	24.7
9	15.0	.0	1.5	24.5	32.7
10	15.0	8.5	1.0	24.5	34.7
11	6.0	5.0	1.0	12.0	41.7
12	4.5	9.0	.0	13.5	66.7
13	1.5	6.0	.0	7.5	80.0
14	1.0	3.0	.0	4.0	75.0
15	.5	4.5	.0	5.0	90.0
16	.0	1.0	.0	1.0	100.0
17	.0	.5	.0	.5	100.0
18+	.5	2.0	.0	2.5	80.0
Totals	192.0	67.0	10.5	269.5	24.9

[1]Most killed by *Ips* species.

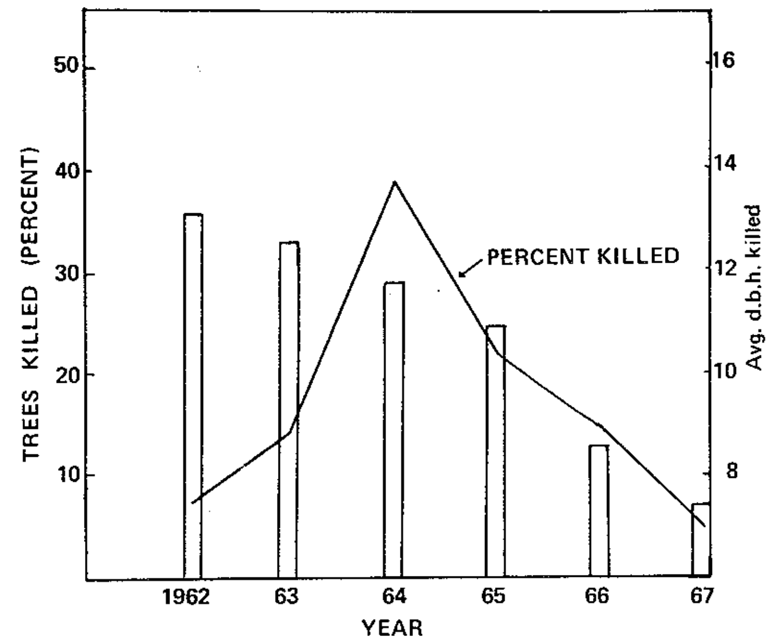


Figure 3.--Proportion and average diameter of lodgepole pine trees killed, by year of infestation; for example, within study stand 2, 1962-67.

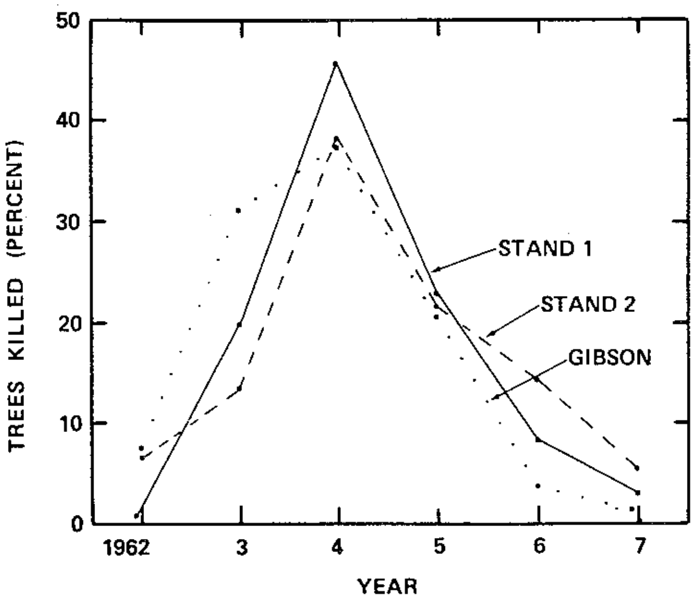


Figure 4.--Comparison of percents of trees killed by the mountain pine beetle in stands 1 and 2 during 1962-67 with those reported by Gibson (1943) for an infestation during the 1930's.

Relation of beetle population to diameter.--The number of emergence holes made by brood adults which completed development and left the tree was usually greater in the larger diameter trees. Average numbers of emergence holes varied from 1.3 per square foot of bark area for trees 7 inches d.b.h. to 62 for trees 18 inches and greater in d.b.h. (fig. 5). Reid (1963) observed that beetle survival increased with diameter of tree. Amman[1] also noted that the number emerging per hole increases as the density of beetles increases per unit area of bark. Therefore, the number of beetles emerging from large diameter trees would be much greater than indicated by emergence holes.

[1]Unpublished data, authors' files.

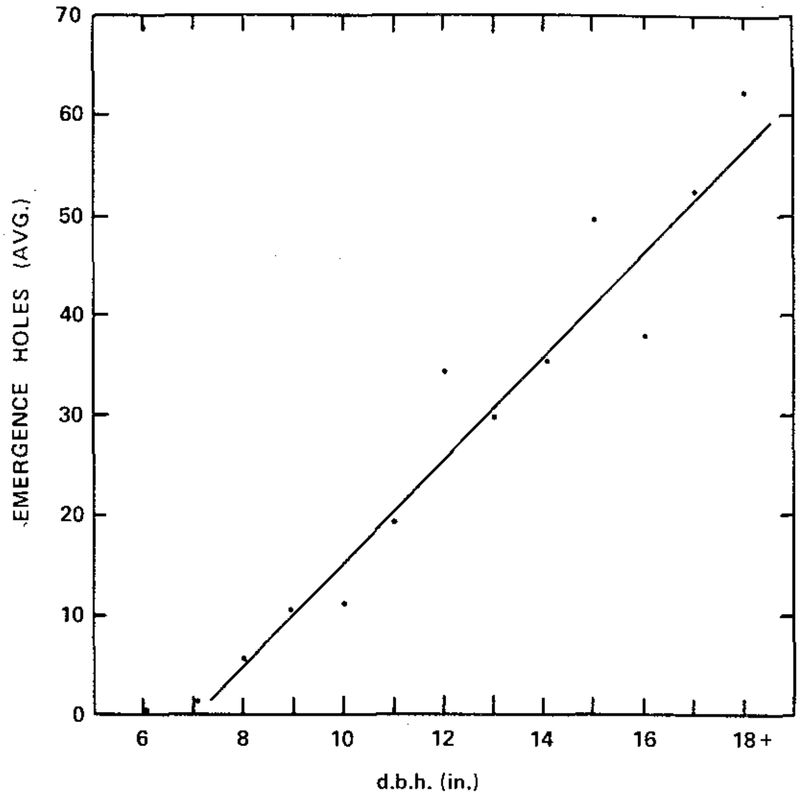


Figure 5.--Average number of emergence holes per square foot of bark, by diameter class.

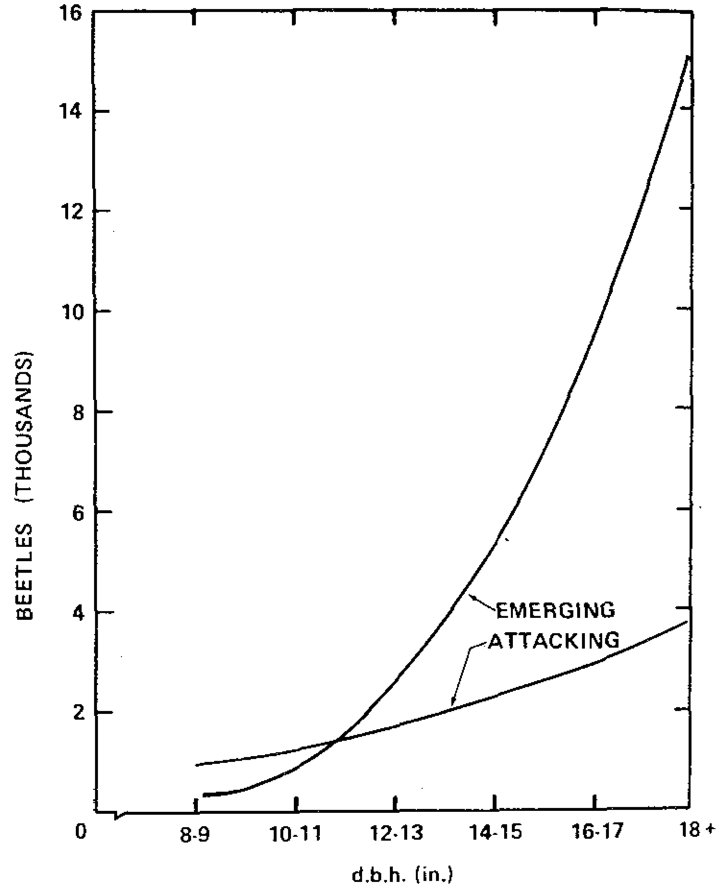
Large trees produce not only more beetles per unit area of bark, but also more per tree because of their greater surface area. Cahill (1960) observed that the boles of lodgepole pines of different diameter were infested to different heights by the mountain pine beetle. The figures by Cahill for infestation height and our figures on beetle emergence were used to calculate the populations of beetles produced in trees. These showed beetle production could vary from 300 for trees 8 to 9 inches d.b.h. to more than 15,000 for trees 18 inches d.b.h.

Assuming an infestation rate of 12 female beetles per square foot of bark surface, the rate commonly observed in the field, and a 1:1 sex ratio, 24 beetles per square foot would be sufficient to infest and kill a tree. Thus, a tree 8 to 9 inches d.b.h. would produce only one-third enough beetles to infest and kill a green tree (fig. 6). Only when the infested trees are 12 to 13 inches d.b.h. do they produce a surplus of beetles. And if we assume that one-third to one-half of the beetles that emerge are killed in flight (a conservative assumption), then only trees 14 inches or larger d.b.h. would produce enough beetles to increase the infestation or maintain it at the previous year's level.

CONCLUSIONS

The conclusions derived from this study follow: (1) The beetle strongly favors the larger diameter trees each year, as well as over the life of the infestation; and (2) if only trees 14 inches and greater in diameter produce enough beetles to maintain or increase the infestation and if, in fact, the beetle progressively destroys its preferable food supply, then this insect is apparently food-limited in its population growth within a given area. Such a decrease in food supply could be a stimulus for search. It then follows that the searching capabilities of the insect may also be a factor limiting population growth.

Figure 6.--A comparison of the number of beetles that emerged from trees, by diameter class, with the number of beetles sufficient to infest a tree within a corresponding diameter class.



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