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Attack Pattern of Mountain Pine Beetle in Sugar Pine Stands

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ABSTRACT: Data accumulated for more than 25 years from old-growth sugar pine stands in central California showed that the mountain pine beetle preferred to attack mature and overmature trees with the most decadent crowns. Analyses included four age groups and eight crown types. Beetle outbreaks in second-growth sugar pine were nondiscriminating between trees. These outbreaks developed during drought when heavy populations were reared in snow-breakage debris.

The mountain pine beetle (Dendroctonus monticolae Hopk.)[1] is recognized as the principal killer of sugar pine (Pinus lambertiana Dougl.) stands throughout the range of this tree in California and southern Oregon. This destructive insect also attacks many other western pine species (4). Its tree-killing attacks on sugar pine stands may occur among all age classes and all sizes larger than 2 inches in diameter. The problem is most severe in virgin old-growth stands that have large-diameter trees, where sizable beetle broods may develop. It has been aggravated by recent severe outbreaks of this insect in second-growth sugar pine forests. The most serious infestations are often in the best growing sites. If stands could be harvest cut to remove trees likely to be attacked, we could reduce the chances of serious outbreaks and also lessen losses. Such a technique has been used successfully against the western pine beetle (D. brevicomis Lec.) in ponderosa pine (P. ponderosa Laws.) (7).

The Pacific Southwest Forest and Range Experiment Station has records that go back 25 years or more of mountain pine beetle attacks in sugar pine. We decided to review these records to see if we could determine the symptoms by which susceptible trees can be recognized. The major premise was that the mountain pine beetle attacks trees with observable weaknesses or measurable declines. As the criteria for use in distinguishing susceptible trees, we investigated differences in age, crown characteristics, and radial growth.

Outbreaks in second-growth sugar pine were unrecorded before 1952. They have been similar in intensity to previously reported

[1]= *D. ponderosa* (8).

mountain pine beetle attacks in pole-size ponderosa pine.[2] Losses in the Miami-Lewis Creek basins, Sierra National Forest, California, dating from 1949 were estimated at more than 10,000 trees within an area of 2,000 to 3,000 acres. Research on the characteristics of these killed trees (1) indicated that high stand density and weakened understory sugar pines were the key conditions. But more detailed information was desirable.

METHODS

INFESTATIONS IN OLD-GROWTH STANDS

Post-mortem analysis.--The first approach to determine symptoms that indicated susceptibility to beetle attacks was to examine infested trees. Green, dying, and recently faded sugar pines were felled, examined critically, and described in detail. Attempts were made to group the trees by the age and crown classes recognized in ponderosa pine (2, 5) and to develop usable criteria for the assignment of risk against the beetle (6). Available were the records of 222 individual trees from drainage systems southward from the Stanislaus to the Kings River in the central Sierra Nevada. They covered the period 1931 to 1939. To these were added records of 169 trees, covering the years 1956 and 1957, most of them in northern Sierra forests.

Mortality experience.--The second approach was to record killing by the mountain pine beetle among tagged trees on plots established in virgin stands preserved in Yosemite National Park. In 1941 a 20-acre plot containing 230 serially numbered, fully described, living sugar pines over 10 inches in diameter at breast height was established. Its purpose was to study and develop patterns of crown types which could be identified and correlated with beetle attacks. Eight crown types were designated--from the most thrifty (A) through the most decadent (H) (fig. 1).

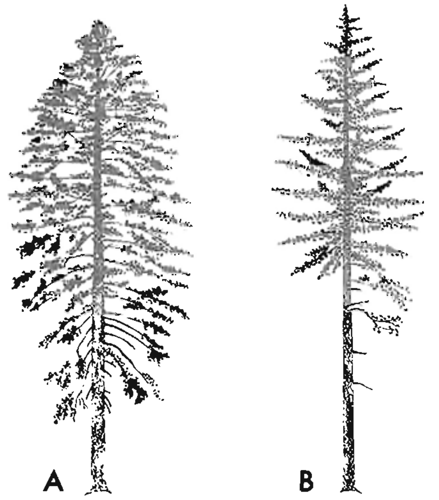
The usefulness of these types in relation to beetle attacks was judged by measuring cumulative tree mortality each year. By 1950 it was apparent that an even broader base would be necessary; 824 additional trees in three plots were tagged and grouped by types and age categories (table 1). The record of mortality through 1963 was distributed among these 1,054 sugar pines.

INFESTATIONS IN SECOND-GROWTH STANDS

Visual tree and stand differences between infested and non-infested second-growth sugar pines were sought to develop practical criteria as guides to lessening beetle hazard. The approach was to record differences in crown fullness and length, radial growth rate,

[2] Miller, J. M. Examination of Fandango, Lassen, Buck Creek, and Davis Creek basins--Modoc National Forest. 4 pp. 1920. (Unpublished rpt. on file at Pacific SW. Forest & Range Expt. Sta., U.S. Forest Serv., Berkeley, Calif.)

Figure 1.--Crown types.

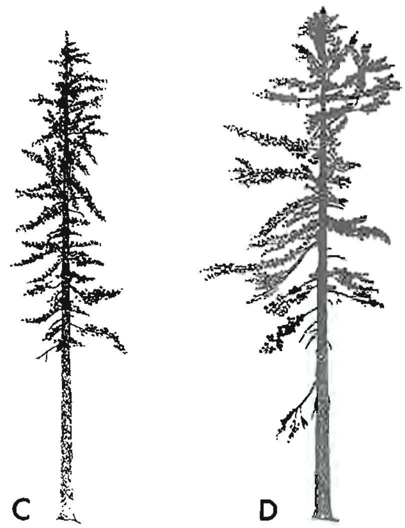


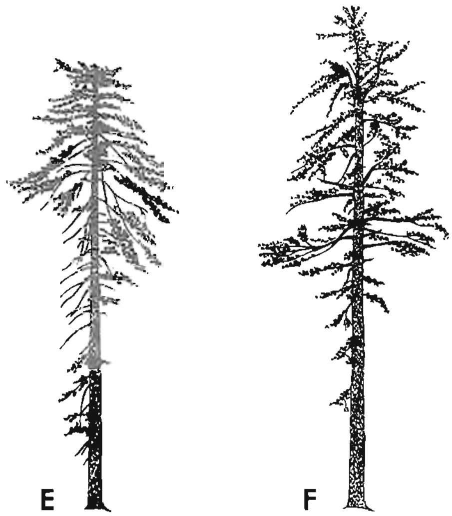
A: Heavy, full, symmetrical crown with blue-green to dark-green foliage and pointed or rounded top, without evidence of injury.

B: Moderately heavy, symmetrical crown with pointed top, having dark- to bluish-green foliage, without evidence of injury.

C: Medium full, symmetrical crown with pointed top, having light-green to bluish-green foliage, often with light twig flags or light mistletoe infection.

D: Medium full, somehwat irregular crown with slightly rounded top, having light- to bluish-green foliage, often with light twig flags or light mistletoe infection or both.



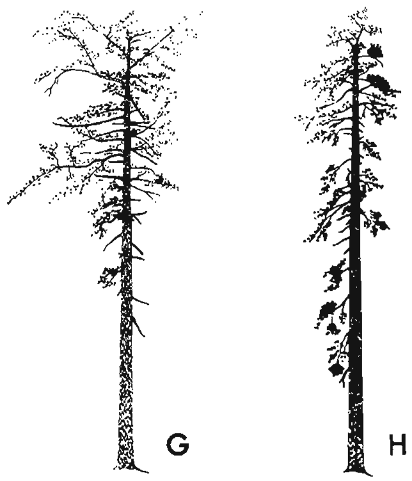


E: Medium to thin, irregular or one-sided crown with top flat or somewhat rounded, having light- to dark-green foliage, with light or heavy twig flags, some branch kill, often with mistletoe.

F: Medium to thin, irregular or one-sided crown with flat top, having light-green foliage, twig flags and branch kill common, often with mistletoe infection.

G: Thin, irregular or one-sided crown with flat top, foliage thin, yellowish in top and light green elsewhere, twig and branch injury variable but numerous, often with mistletoe infection.

H: Thin, irregular or one-sided crown with flat top, having yellowish foliage throughout, heavy twig and branch injury, heavy mistletoe infection causing witches'-broom from top to bottom.



and stand density competition for light and moisture. Wind damage, snow breakage, or logging practices that favored a beetle buildup were to be considered.

From 1954 through 1963, year-by-year observations were made in five stands identified as potentially hazardous for attacks (table 2). Each of these was heavily stocked with mixed conifers in which sugar pine between 60 and 80 years old predominated.

RESULTS

MORTALITY IN OLD-GROWTH STANDS

Summaries[3] in 1956 and 1958 of post-mortem analyses by the California Forest Pest Control Action Council indicated similarities in the types of trees killed. Mature and overmature trees slightly outnumbered younger trees attacked by the mountain pine beetle; killing in older trees amounted to 60 percent among the examinations completed in 1956 and 1957. The Council reports concluded that "silvicultural control measures for mountain pine beetle control in sugar pine must arise from deeper insight into the insect-host relationship."

Records of mortality through 1963 showed that beetles preferred older and more decadent trees in two of the four plots (table 3 and 4). Among 230 trees classified in 1941, the number beetle-killed amounted to 11.3 percent. Among trees classified in three plots in 1950, the beetle-caused mortality amounted to 8 percent of the trees in the Tuolumne plot and 1.3 percent of the trees in the other two plots. The insects showed a strong preference for the three most decadent crown types--F, G, and H. There was a broader spread in selections in the Mariposa and Tuolumne plots (site I) (3) than in the other two plots (site II). Trees more than 225 years old with types E to H crowns were killed 4 times to more than 10 times more often than younger trees with types A to D crowns.

MORTALITY IN SECOND-GROWTH STANDS

In second-growth stands the amount of killing among the various tree classes through 1957 disclosed no associations between attacks and the criteria of radial growth, crown vigor, and stand density. After 1957 (table 5), tree losses increased at two locations--Lewis Creek and Soquel. In 1961 the loss at Soquel was at about the same level as 1960, but at Lewis Creek it increased to outbreak proportions. After 1961 the records from Miami Creek and Lewis Creek basins also showed increased losses and outbreak infestations in 1962, followed by sharp

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[3]Insect problems affecting sugar pine management. 1956. Summary of post-mortem study--insect problems affecting sugar pine management. 1958. (Both unpub. rpts. on file at Dept. Ent. and Parasitol., Univ. Calif., Berkeley.)

declines in 1963. At Shaver Lake, infestations were again evident after 3 years of inactivity. Infestations remained low in the Sequoia locations.

A primary factor associated with the rapid local buildups after 1960 was an abundance of trees broken by snow during the winter 1959-1960. Much evidence of mountain pine beetle breeding was seen in broken sugar pine stems on the ground and in standing stubs.

Among the trees attacked in 1961 and 1962, selections were indiscriminate. Infested, vigorous dominants were twice as numerous as intermediate and suppressed trees in 1960, but were greatly outnumbered by the others in 1961 and 1962.

The amount of soil moisture available to and presumably affecting the resistance of sugar pine to beetle attacks may have been critical by August 1961. Within the Lewis Creek drainage especially, the possibility of deficient moisture was indicated by the complete drying of permanent springs for the first time in 25 years.

DISCUSSION

A generally consistent pattern of attacks by the mountain pine beetle was followed in old-growth sugar pine older than 225 years. Mature and overmature trees with thin, flat-topped crowns (types E to H) were killed several times more often than full-crowned trees (types A to D) of the same or younger ages. No single crown deterioration factor or combination was associated. The killing was more broadly distributed in site I than site II plots among all ages and crown types.

Second-growth sugar pines were attacked indiscriminately, though varying broadly in crown fullness and shape and in rate of growth. There were few resin exudations or pitch tubes in these trees, which normally indicate host-tree resistance to attacks.

These results indicate the complex nature of conditions giving rise to tree-killing attacks by the mountain pine beetle. There are still no simple guides by which individual trees may be predetermined immune from, or susceptible to attacks. The evidence does indicate that the older and more decadent sugar pines in old-growth stands as a whole are more likely to be attacked than the closely associated fuller crowned older and younger trees. In second-growth sugar pine, evidence likewise links outbreaks with heavy snow breakage and drought conditions.

Table 1. *Distribution of sugar pine trees by age and crown types*

Plot	Date established	Site	Acres	Age group (years)				Crown type							
				0-50	50-225	225-350	over 350	A	B	C	D	E	F	G	H
				Number of trees											
Mariposa	1941	I	20	--	114	97	19	11	20	49	34	56	40	16	3
Tuolumne	1950	I	52	166	171	106	40	12	54	88	100	91	82	37	22
Cuneo	1950	II	8	14	47	56	59	0	2	15	22	31	45	48	12
Chinquapin	1950	II	76	--	--	135	30	0	0	1	20	52	44	34	13

Table 2. *Second-growth sugar pine stands observed*

National Forest	Location	Approx. acreage
Sequoia	Millwood	1,500
	Indian Basin	2,000
Sierra	Shaver Lake	3,000
	Soquel	5,000
	Miami-Lewis Creek	1,500

Table 3. *Proportional distribution of beetle-killed trees, by age class*

Plot	Years' record	Percent in each age class		
		Young (50-225 yrs.)	Mature (225-350 yrs.)	Overmature (over 350 yrs.)
Mariposa	22	5.5	20.4	29.4
Tuolumne	13	4.4	15.6	15.0
Cuneo	13	0.0	5.4	1.7
Chinquapin	13	0.0	2.2	6.7

Table 4. *Proportional distribution of beetle-killed trees, by crown type*

Plot	Percent killed in each crown type							
	A	B	C	D	E	F	G	H
Mariposa	0.0	10.0	4.1	11.8	5.3	15.0	43.7	66.6
Tuolumne	0.0	3.8	0.0	6.0	5.6	11.9	12.5	42.1
Cuneo	0.0	0.0	0.0	0.0	0.0	4.3	2.1	8.3
Chinquapin	0.0	0.0	0.0	0.0	1.9	2.3	8.6	0.0

Table 5. *Number of trees killed*[1] *at each location between 1958 and 1963*

Location	Area (acres)	Number of trees killed						
		1958	1959	1960	1961	1962	1963	Total
Millwood	1,500	0	2	0	3	--	--	5
Indian Basin	2,000	0	0	0	0	--	--	0
Shaver Lake	3,000	0	0	0	17	18	150+	185+
Soquel	3,000	0	0	14	19	8	25+	66+
Lewis Creek	500	0	0	37	190	1,200+	200	1,627
Miami Creek	1,000	0	4	0	150	6,000+	500	6,654

[1]Average diameter about 12 inches.

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