MOUNTAIN PINE BEETLE INFLUENCE ON LODGEPOLE PINE STAND STRUCTURE

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ABSTRACT—Efforts to control populations of mountain pine beetle (Dendroctonus ponderosae *Hopk.) in lodgepole pine* (Pinus contorta *Dougl.) were evaluated from tree diameter distributions within treated and untreated stands. Beetle populations, where infestation period was complete, declined in approximately the same number of years, and lodgepole pine survival in the two types of stands was comparable. However, suppression measures did slow the rate of tree mortality in two stands still under attack. Mixed stands of up to 36 percent trees of other species were proportionally as susceptible to beetle infestation as those having less than 10 percent trees of other species. Survival increased with elevation, apparently because of adverse effect of temperature on beetles.*

The mountain pine beetle (*Dendroctonus ponderosae* Hopk.), one of the most aggressive of the bark beetles, kills most of the large, dominant trees in a stand of lodgepole pine (*Pinus contorta* Dougl.) before an infestation declines (*Fig. 1*). Moreover, infestations recur (as in western Wyoming and southeastern Idaho), and as a result of each such reoccurrence, large sums are expended on attempts to control the insect.

The most recent beetle outbreak in western Wyoming began in the late 1950's. Approximately 1.3 million trees on the Teton National Forest and Grand Teton National Park were treated or harvested for mountain pine beetle control between 1957 and 1968.[1] The effort was even greater on the Targhee National Forest, Idaho; over 1.7 million lodgepole pine were chemically treated or harvested from 1962 through the spring of 1969.

Methods of evaluating forest insect infestations have been described by Knight (*11*), and control procedures have been reviewed by Balch (*2*). However, the literature offers no satisfactory means of assessing the effects of bark beetle control. Earlier efforts to evaluate the effectiveness of control jobs usually were based on beetle infestation rates for short periods (a year or so) instead of on stand structure during an entire infestation period (*4, 8, 12*).

Chemicals sprayed on infested trees kill beetles beneath the bark (*7, 9, 14*), reducing the beetle population. However, as Kinghorn (*9*) noted, the amount of damage done to a stand by surviving beetles is unknown. Moreover, such treatments may not halt the outbreak. Klein and McGregor (*10*) reported a high rate of reinfestation in stands where control of beetle populations had been conducted.

If beetle control methods are to be evaluated, their effects must be analyzed for an entire infestation period.[2] Assessment must be based on comparisons of treated and untreated stands. Data must include: (1) rates of tree mortality and (2) residual volumes.

During late summer and early fall of 1969, blocks of lodgepole pine were sampled within the Teton-Targhee area. The purpose was to evaluate beetle suppression attempts. Residual stand structures in treated and untreated areas were analyzed and compared and, when possible, tree mortality rates were also considered. No attempt was made to determine whether control efforts reduced or prevented the spread of infestation. Little is known of the flight habits of the beetle; so the question remains as to whether populations build up in one stand and then move to others, or whether conditions favor the buildup of populations in a number of stands simultaneously.

The 10 areas chosen for study are typical of beetle-infested stands throughout the Teton National Forest and Grand Teton National Park, Wyoming, and the Targhee National Forest, Idaho. Areas in which the infestation had run its course were desired. However, only six met this criterion; the other four were still under attack.

Stands of trees on the sampled blocks qualified as pure or mixed merchantable lodgepole pine, although logging was not always the management goal. Attempts had been made to suppress beetle populations on six of the 10 study blocks while four were left untreated. Descriptions of stand composition, elevation and habitat type on these study blocks are presented in Table 1.

Methods

One 4-square-mile block was selected for sampling within each study area. The shape of the block varied because of vegetational irregularities. Fifty percent or more of the trees were to be lodgepole pine, a criterion

[1]Ethylene dibromide in diesel oil (EDB) sprayed on tree trunks.

[2]The infestation period for the mountain pine beetle in lodgepole pine generally lasts about eight years. The period begins when about one tree per acre is infested, peaks when approximately 32 trees per acre are under attack, and is about to end when less than one tree per acre is infested.

Table 1. Proportion of Trees 4 inches *dbh* and Larger on Blocks in the Teton-Targhee Area According to Elevation and Habitat Type

Block Name	Elevation	Habitat type[1]	Lodgepole pine	Douglas-fir	Subalpine fir	Engelmann spruce	Whitebark-limber pines	Aspen	Trees per acre
			percent						No.
			Infestation concluded						
Treated									
Pilgrim Mt.	6,900–7,700	A/P	86.7	2.7	7.6	1.4	1.6	0.0	311.0
Hatchet	7,000–7,800	A/P	90.9	6.9	0.2	0.7	0.0	1.3	274.5
Upper Spread Creek	7,600–8,400	A/V	91.2	0.0	3.5	5.3	0.0	0.0	272.0
Untreated									
Pacific Creek	7,200–8,400	A/V	79.0	0.0	16.8	3.3	0.9	0.0	288.5
Togwotee Pass	8,700–9,300	A/V	41.9	0.0	14.5	20.1	23.5	0.0	236.0
Horseshoe-Packsaddle	6,600–6,900	A/P	64.1	14.3	15.0	0.4	0.0	6.2	233.5
			Infestation continuing						
Treated									
Signal Mt.	6,800–7,100	P/C	97.0	2.8	0.2	0.0	0.0	0.0	304.5
Warm River	5,500–5,800	P/C	93.2	5.3	0.0	0.0	0.0	1.5	271.5
Pineview	6,200	P/C	98.8	0.3	0.0	0.0	0.0	0.9	286.0
Untreated									
Pine Creek	6,000–6,500	A/P	95.7	3.2	0.4	0.7	0.0	0.0	278.5

[1] Habitat type: A/P = *Abies/Pachistima*; A/V = *Abies/Vaccinium*; P/C = *Pseudotsuga/Calamagrostis*. Classified according to Roe and Amman (1970).

Fig. 1. Snags indicate that many dominant lodgepole pine trees have been killed by the mountain pine beetle. In spite of losses, a large proportion of lodgepole pine trees have survived.

met on all blocks except one at high elevation. Twenty fixed, circular, 1/10-acre plots within each block were located in a grid pattern described by Cole and Amman (*3*). One-tenth-acre openings were avoided. The elevation of each plot was recorded and the habitat type determined by means of vegetational associations defined by Roe (*13*).

Measurements were recorded for all trees that were 4 inches *dbh* or larger. Individual trees were listed by species and as being dead or alive. Dead lodgepole pine trees were classified as having been killed by the mountain pine beetle or by some cause other than the mountain pine beetle; *i.e.*, other bark beetles (*Ips* and *Pityogenes*), tree competition, or undetermined causes.

The basal area of surviving trees that were 9 inches *dbh* or larger was used to measure the beetle's effect on the operability of a stand. The 9-inch base was chosen because it is the smallest merchantable sawtimber size considered in the logging of lodgepole pine and because trees that are 9 inches *dbh*, or more, are most commonly killed by the mountain pine beetle.

Results and Discussion

From 62-90 percent of the lodgepole pines that had a 4-inch *dbh* or more and 32-92 percent of the merchantable basal area survived the mountain pine beetle infestation. Survival of small rather than large-diameter trees was proportionally greater in all areas (*Figs. 2 and 3*). The six lodgepole pine stands in which infestation was complete sustained attack from four to nine years. The other four stands were still infested, even though outbreaks had begun from four to 14 years earlier (*Table 2*).

Percent survival and length of infestation period in both treated and untreated areas at about the same elevation were similar. Differences between areas appear to be largely related to elevation. Control efforts had slowed the rate of infestation in the two areas still under attack, but evidence suggests that the infestation will continue until percent survival in treated areas approximates that in untreated areas. Where beetle infestation had run its course, percent survival of lodgepole pine indicated that control efforts usually did not save trees.

Survival of Lodgepole Pine

The untreated Pacific Creek block had approximately the same percent survival by individual diameter class as the treated Pilgrim Mountain and Hatchet areas (*Fig. 2*). Percent survival of trees 4 inches *dbh* or more ranged from 63-69 percent and that of merchantable trees (9 inches *dbh* or more) from 36-42 percent (*Table 3*).

Upper Spread Creek, Togwotee Pass and Horseshoe-Packsaddle, the other three blocks in which infestation had ended, showed different survival curves (*Fig. 2*). In Upper Spread Creek, percent survival of all lodgepole pines (4 inches *dbh*, or more) was 74 percent and the merchantable basal area, 61 percent. Some chemical control and extensive logging of trees most susceptible to attack or already infested may have reduced the potential for beetle population buildup and resulted in greater survival in residual leave strips. Elevational differences may be important, as well.

Percent survival of both stems and basal area was highest on the untreated Togwotte Pass block. This increased survival is probably attributable to elevation-related climatic conditions that adversely affect the beetle.[3]

The Horseshoe-Packsaddle area shows a slightly different survival pattern by diameter class: the larger *dbh* trees were reduced proportionally more than in any other sampled block. Survival for trees 4 inches *dbh* and over was 68 percent, which compares favorably with areas mentioned above, but only 32 percent of the merchantable basal area survived. Horseshoe-Packsaddle had the lowest elevation of blocks in which the infestation period was complete.

The remaining blocks support current infestations. The Signal Mountain block is of interest because it is still under attack after 14 years. The infestation was treated during 10 of these years and the mortality rate slowed. However, when treatment was stopped, the beetle population increased and, in 1969, 24 trees per acre were infested. Survival of lodgepole stems 4 inches *dbh*, and larger, has been reduced to 76 percent and survival of the merchantable basal area to 46 percent—not unlike the Pilgrim Mountain, Hatchet and Pacific Creek blocks. The large, current beetle population indicates that additional mortality can be expected on Signal Mountain and that pine survival eventually will be comparable to that in other areas in which the infestation period has ended.

The relatively favorable survival of lodgepole pine in the Pine Creek, Pineview and Warm River blocks reflects recent infestations (*Fig. 3*). Basal area survival figures are also favorable. However, after three years of

[3] Research Work Unit 2201, unpublished data, U.S. Forest Serv., Intmtn. Forest and Range Exp. Sta., Ogden, Utah.

Table 2. Periods of Mountain Pine Beetle Infestation and Treatment

	Years					
	Infestation			Treatment		
Block name	Start	End	Length	Start	End	Length
	Infestation concluded					
Treated						
Pilgrim Mt.	1960	1968	9	1961	1967	7
Hatchet	1960	1968	9	1962	1968	7
Upper Spread Creek	1961	1968	8	1965	1968	4
Untreated						
Pacific Creek	1961	1968	8	None	—	—
Togwotee Pass	1965	1968[1]	4	None	—	—
Horseshoe-Packsaddle	1961	1968	8	None	—	—
	Infestation continuing					
Treated						
Signal Mt.	1956	Current	14	1957	1966	10
Warm River	1965	Current	5	1966	Current	4
Pineview	1966	Current	4	1967	Current	3
Untreated						
Pine Creek	1966	Current	4	None	—	—

[1] Subtle increase and decline in infestation was difficult to date. The main infestation period was 1965–68.

Fig. 2. Lodgepole pine survival curves for study areas in which the mountain pine beetle infestation had ended. 1 = Togwotee Pass; 2 = Upper Spread Creek; 3 = Pilgrim Mountain; 4 = Pacific Creek; 5 = Hatchet; and 6 = Horseshoe-Packsaddle.

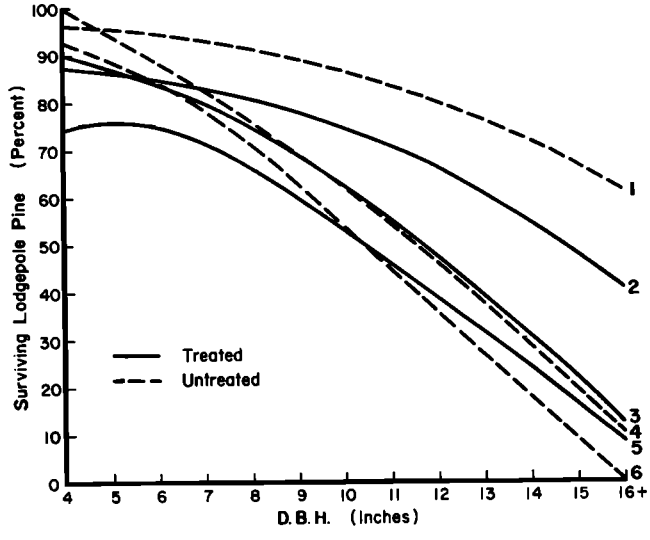

Fig. 3. Lodgepole pine survival curves for study areas where the mountain pine beetle infestation was current. 1 = Pineview; 2 = Warm River; 3 = Pine Creek; and 4 = Signal Mountain.

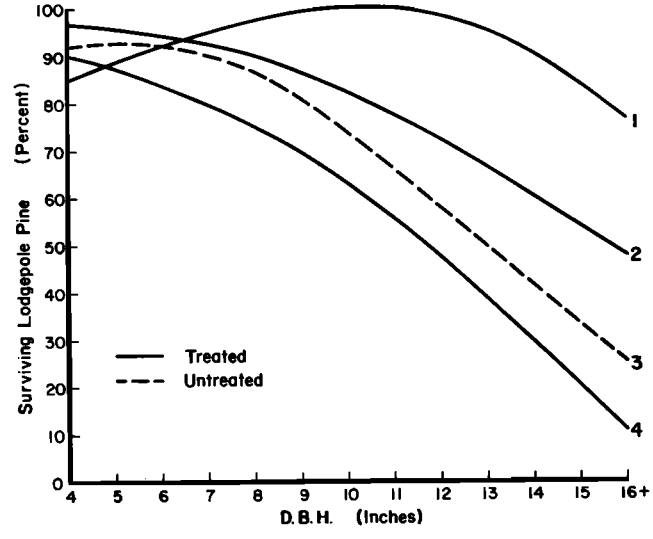

Fig. 4. Harvesting of lodgepole pine in the Upper Spread Creek area reduced residual stand susceptibility and consequently cut losses to the mountain pine beetle.

infestation, the Pine Creek block has lower numbers of surviving trees in the large diameter classes than the Pineview and Warm River stands after three and four years of infestation, respectively. Also, only 56 percent of the basal area in the Pine Creek block was alive, compared to 92 percent in the Pineview block and 77 percent in the Warm River stand. These differences probably indicate that the infestation rate on the Pineview and Warm River blocks has been slowed by control attempts. Ultimate survival is yet to be determined.

Duration of Infestation

In areas where mountain pine beetle populations had subsided, infestations lasted eight to nine years. Togwotee Pass, where infestation lasted only four years, was the single exception. Pilgrim Mountain, Hatchet and Upper Spread Creek stands were treated, but the other three, Pacific Creek, Horseshoe-Packsaddle and Togwotee Pass, were not—an indication that control attempts did not slow the rate of infestation in these areas.

Control attempts in the Signal Mountain and Pineview stands and in the Warm River block apparently have reduced the rate of infestation. Signal Mountain has been under attack for 14 years. Control efforts in that stand were discontinued four years ago, and the beetle population has increased since. This buildup suggests that factors believed to contribute to increases in populations still exist, *e.g.*, trees having thick phloem and large diameter (*1, 3*).

After four years of beetle activity, the low amount of tree mortality on the Pineview block indicates that the control effort has slowed the rate of infestation. Over 90 percent of the stems are still alive. Moreover, most tree mortality was attributable to other insects (*Ips* or *Pityogenes*).

The effectiveness of a chemical control project in reducing mountain pine beetle populations is related to at least seven operational factors: (1) steepness of terrain; (2) ease of access; (3) training of control personnel; (4) experience of control personnel; (5) radius of treatment application around the stand of protected trees; (6) acreage infested; and (7) initiation of control efforts while infestation is small. Most of these factors were optimal within the Pineview area, which may account for the apparent success of control.

The effects of control on the Warm River infestation rate are not as apparent as in the Signal Mountain and Pineview blocks. However, the rate of tree mortality is slightly less than that in the untreated Pine Creek block.

Cost-benefit ratios become an important consideration when treatment periods extend over a number of years. For example, on Signal Mountain in Grand Teton National Park, the preservation of aesthetic values would be of primary concern. However, in spite of 10 years of control work (1956-1966), the mountain pine beetle population has increased again and, more than likely, the infestation will proceed until the proportional survival by diameter class is similar to that observed in the Pilgrim Mountain, Pacific Creek and Hatchet samples. Beetle activity is almost certain to continue until most trees of thick phloem are killed. It would appear that attempts to suppress beetle populations in national parks or in other areas where timber products are not involved, are of little or no value and that the eventual survival of lodgepole pine will be about the same whether or not the stand is treated. However, tree cover will persist because many of the smaller lodgepole pines survive and other tree species, such as subalpine fir and Douglas-fir, become more abundant as they succeed lodgepole pine (*13*).

In stands such as Pineview and Warm River where timber products are involved, a thorough economic analysis may be helpful to the land manager. It should be emphasized that protected timber should be utilized before the stand volume falls below a merchantable threshold and before the cost of protection exceeds the value of protected volume. Protection, to be justified, must be for a predetermined period of time so that the volume at time of cutting will warrant treatment expenditures. As an example, if 50 percent survival of lodgepole volume, or merchantable basal area, is arbitrarily set as the level at which a stand can no longer be logged profitably, then sufficient basal area remains in only two of the sampled blocks where the infestation has ended. Both of these blocks—the treated Upper Spread Creek and the untreated Togwotee Pass—are at high elevations. Surviving basal area was reduced to less than 50 percent in the other four stands within eight to nine years after the start of infestation.

Elevational Differences

The effect of elevation on proportional survival of lodgepole pine 9 inches *dbh* and larger is apparent in all sampled blocks where the beetle population has declined (*Fig. 5*) and seems to account for much of the difference noted in lodgepole pine survival. Percent survival of lodgepole pine ranged from 37 percent in the lowest block (average elevation, 6,800 feet) to 74 percent in the highest block (average elevation, 8,900 feet). A similar relationship holds for basal area, which ranged from 32 percent at the lowest elevation to 71 percent at the highest. Elevation-related temperature differences and their effects on beetle biology probably are responsible. Current studies at the Intermountain Forest and Range Experiment Station at Ogden (see footnote 2) indicate that at higher elevations the beetle is out of its range for optimal development. Its biological activities are poorly synchronized with seasonal weather changes; so a two-year life cycle and low brood-survival frequently result.

The effect of mixed species stands (lodgepole pine was 42 percent of the stems in the Togwotee Pass block) was also considered. However, Flint (*5*) observed no difference in lodgepole mortality in mixed species stands. In addition, Roe and Amman (*13*) pointed out that the beetle is the primary agent in lodgepole pine removal and so provides for succession by other tree species in stands unaffected by wildfires. They found the beetle active in stands where lodgepole pine totaled less than 40 percent of the stems.

The relationship between lodgepole pine survival and elevation existed whether or not blocks were treated, an indication that the land manager probably would not have to consider immediate harvesting of stands above about 8,000 feet in elevation. These stands would be relatively safe from severe damage by the mountain pine beetle.

Differences in lodgepole pine survival associated with elevation are consistent with the observations of Gibson (*6*), who found greater lodgepole survival at the upper ends of his strips, and with the work of Roe and Amman (*13*) in which three habitat types in lodgepole pine forests were defined, which generally are related to elevation but vary with slope and aspect. Risks of losing lodgepole pine to the mountain pine beetle in the three

Table 3. Lodgepole Pine Basal Area (sq. ft./acre) Living and Dead on 10 Blocks in the Teton-Targhee Area for Trees 9 inches *dbh* and Larger

Block name	Basal area						
	Surviving		Killed by mountain pine beetle		Killed by other causes		Total
	sq. ft.	*percent*	*sq. ft.*	*percent*	*sq. ft.*	*percent*	*sq. ft.*
			Infestation concluded				
Treated							
Pilgrim Mt.	28	38.1	43	58.7	2	3.2	73
Hatchet	22	36.1	39	62.4	1	1.5	62
Upper Spread Creek	54	60.7	29	33.3	5	6.0	88
Untreated							
Pacific Creek	43	42.4	57	56.7	1	0.9	101
Togwotee Pass	53	71.3	18	24.5	3	4.2	74
Horseshoe-Packsaddle	14	31.9	29	66.8	1	1.3	44
			Infestation continuing				
Treated							
Signal Mt.	26	45.6	30	54.0	<1	0.4	56
Warm River	49	77.3	14	22.0	1	0.7	64
Pineview	45	92.4	3	5.4	1	2.2	49
Untreated							
Pine Creek	30	56.0	23	42.4	1	1.6	54

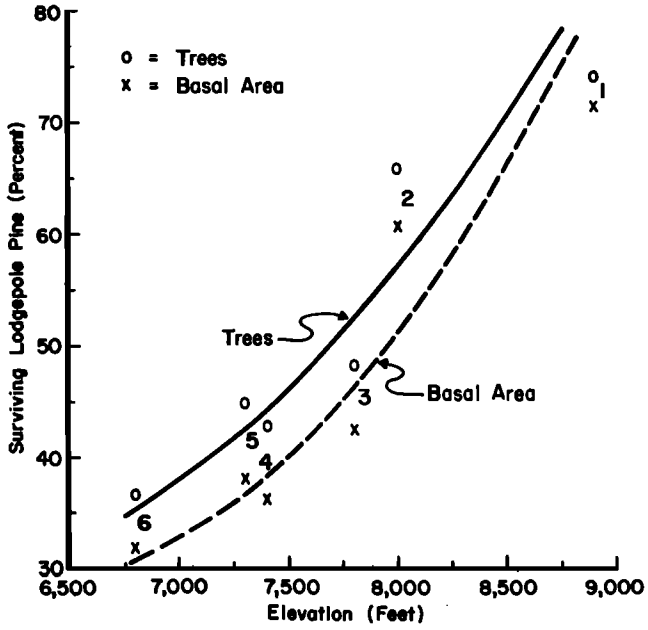

Fig. 5. Survival of lodgepole pine 9 inches *dbh*, and larger, from mountain pine beetle attack increased directly with elevation. 1 = Togwotee Pass (untreated); 2 = Upper Spread Creek (treated); 3 = Pacific Creek (untreated); 4 = Pilgrim Mountain (treated); 5 = Hatchet (treated); and 6 = Horseshoe-Packsaddle (untreated).

habitat types were lowest in the *Abies lasiocarpa/Vaccinium scoparium* association (high elevations), highest in the *Abies lasiocarpa/Pachistima myrsinites* association (mid-elevations), and intermediate in the *Pseudotsuga menziesii/Calamagrostis rubescens* association (low elevations). Our data follow the same trend for the *Abies/Vaccinium* and *Abies/Pachistima* associations. However, we did not have data from a block in the *Pseudotsuga/Calamagrostis* association, where the infestation period had already ended. Basing risk on habitat type rather than elevation alone would permit consideration of differences in slope, aspect and latitude.

Mixed Species

Mixed species composition has been considered a means of reducing timber losses to many insects (*2*). However, our data on the mountain pine beetle do not support this supposition. Percent survival of lodgepole pine was no greater in the Horseshoe-Packsaddle block that contained 36 percent other species than in blocks that had less than 10 percent other species. About 68 percent of the lodgepole pine stems survived on the Horseshoe-Packsaddle block, but only 32 percent of the merchantable basal area lived. Although Togwotee Pass contained the highest proportion of other tree species (58 percent), the increased survival of lodgepole pine was attributed to the effect of climate on the biology of the mountain pine beetle. The proportion of other species would have to be considerably more than 36 percent in the elevational zone of optimal beetle development for lodgepole pine in mixed species forests to be less susceptible to mountain pine beetle damage. Flint (*5*) and Roe and Amman (*13*) also found no difference in susceptibility of lodgepole pine in mixed and pure stands to mountain pine beetle attacks. However, once a beetle infestation is concluded, mixed stands will have a higher total residual stocking due to the presence of other species.

Conclusions

As a result of this study, the authors recommend:

- That management goals be well defined ahead of beetle control decisions and that land uses be thoroughly evaluated. When harvest opportunities are threatened, chemical controls that might slow the rate of infestation may or may not withstand economic and environmental scrutiny. Where recreational or aesthetic considerations are the only threatened resource values, chemical treatment is not recommended. Tree cover will persist because of lodgepole pine survival in the smaller classes and succession by other tree species.
- That a commercial lodgepole pine stand (having many trees of large diameter and thick phloem) be harvested immediately if a pine beetle infestation is observed. High elevation stands (over 8,000 feet) are an exception. Harvesting removes the potential for beetle epidemics and the need for chemical treatment. If harvesting of an infested stand of lodgepole pine is attempted, it should be timely to prevent tree losses from reaching the point where the operation becomes economically unsound.
- That creation of lodgepole pine blocks of different ages and separation of blocks of similar age, a management alternative suggested by Roe and Amman (*13*), would prevent large areas of pine from becoming susceptible simultaneously to mountain pine beetle infestation, and would make the recommendation of immediate harvest easier to fulfill.

Literature Cited

1. Amman, Gene D. 1969. Mountain pine beetle emergence in relation to depth of lodgepole pine bark. USDA Forest Serv. Res. Note INT-96, 8 p.
2. Balch, R. E. 1958. Control of forest insects. Ann. Rev. Entomol. 3:449-468.
3. Cole, Walter E., and Gene D. Amman. 1969. Mountain pine beetle infestations in relation to lodgepole pine diameters. USDA Forest Serv. Res. Note INT-95, 7 p.
4. Craighead, F. C., J. M. Miller, J. C. Evenden, and F. P. Keen. 1931. Control work against bark beetles in western forests and an appraisal of its results. J. Forestry 29:1001-1018.
5. Flint, H. R. 1924. Various aspects of the insect problem in the lodgepole pine region. U.S. Forest Serv. D-1 Appl. Forestry Notes 54, 4 p.
6. Gibson, A. L. 1943. Status and effect of a mountain pine beetle infestation on lodgepole pine stands. Mimeo. Rep., USDA Bur. Entomol., Forest Insect Lab., Coeur d'Alene, Idaho, 34 p.
7. ———— 1943. Penetrating sprays to control the mountain pine beetle. J. Econ. Entomol. 36:396-398.
8. Johnson, Philip C., and Richard F. Schmitz. 1965. *Dendroctonus ponderosae* Hopkins (Coleoptera: Scolytidae), a pest of western white and ponderosa pines in the Northern Rocky Mountains. A Problem Analysis, USDA Forest Serv., Intmtn. Forest and Range Exp. Sta., Ogden, Utah, 87 p.
9. Kinghorn, J. M. 1955. Chemical control of the mountain pine beetle and Douglas-fir beetle. J. Econ. Entomol. 48:501-504.
10. Klein, W. H., and M. D. McGregor. 1966. Forest insect conditions in the Intermountain States during 1965. USDA Forest Serv., Region 4, Div. Timber Manage., Ogden, Utah, 13 p.
11. Knight, Fred B. 1967. Evaluation of forest insect infestations. Ann. Rev. Entomol. 12:207-228.
12. Miller, J. M., and F. P. Keen. 1960. Biology and control of the western pine beetle. USDA Forest Serv. Misc. Pub. 800, 381 p.
13. Roe, Arthur L., and Gene D. Amman. 1970. The mountain pine beetle in lodgepole pine forests. USDA Forest Serv. Res. Pap. INT-71, 23 p.
14. Wickman, B. E., and R. L. Lyon. 1962. Experimental control of the mountain pine beetle in lodgepole pine with Lindane. J. Forestry 60:395-399.