Research Note

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
INTERMOUNTAIN FOREST & RANGE EXPERIMENT STATION
OGDEN, UTAH 84401

USDA Forest Service
Research Note INT-171

July 1973

LODGEPOLE PINE LOSSES TO MOUNTAIN PINE BEETLE RELATED TO ELEVATION

Gene D. Amman, Bruce H. Baker, and Lawrence E. Stipe [1]

ABSTRACT

Mortality caused by the mountain pine beetle was related inversely to elevation and ranged from less than 1 to 17 percent of the lodgepole pine trees 4 inches d.b.h. and larger. Mortality of trees 9 inches d.b.h. and larger (those most often infested by mountain pine beetle), ranged from 2 percent of the stems or 0.8 percent of the basal area at the highest elevation to 36.5 percent of the stems or 36 percent of the basal area at the lowest elevation. Climate probably is the single most important factor accounting for variation in mortality of lodgepole pine at the different elevations because of its effect on the biology of the beetle.

The relation of lodgepole pine (*Pinus contorta* Dougl.) mortality caused by the mountain pine beetle (*Dendroctonus ponderosae* Hopk.) to various environmental factors is of importance in making control decisions. Control efforts might not be needed or might be deferred where risk of loss to the beetle is low. The relation of damage to habitat type (Roe and Amman 1970) on the Teton and Targhee National Forests is a step in this direction.

The principal objective of our study was to determine the relation of lodgepole pine mortality caused by the mountain pine beetle to elevation. The study was conducted on the North Slope of the Uinta Mountains in northern Utah and southern Wyoming where widespread infestation of the beetle occurred between 1956 and 1963 after which the infestation subsided.

[1] Respectively, Research Entomologist, USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, Utah 84401; and Entomologists, Division of Timber Management, USDA Forest Service, Intermountain Region, Ogden, Utah 84401. Mr. Baker presently is located with the Alaska Region, Juneau 99801.

METHODS

Ten blocks consisting of approximately 4 square miles each were selected for sampling between Hoop Lake on the east to Mansfield Meadows on the west, a distance of approximately 20 airline miles. In this area, a major portion of the damage by the beetle occurred.

Twenty 1/10-acre plots were located in a grid pattern within each block. Patches of timber had to be sampled at low elevations because sagebrush predominated. Stands that were sampled were between 8,725 and 10,450 feet elevation because most lodgepole pine grows within this range of elevations on the North Slope of the Uinta Mountains.

All trees (both standing and on the ground) 4.0 inches diameter breast height (d.b.h.) and larger were recorded according to 1-inch d.b.h. classes (4.0-4.9, etc.). Similar records were made on other species of trees; however, these records were taken only from one-third of the plots sampled. If death was caused by the mountain pine beetle, such was noted. Phloem thickness was measured (in hundredths of inches) on opposite sides of each of two green lodgepole pine trees in each diameter class represented on each plot. The elevation of each plot also was recorded.

RESULTS AND DISCUSSION

Our sample data showed that lodgepole pine trees predominated at all elevations (table 1). Mortality of all lodgepole pine trees attributable to the mountain pine beetle ranged from less than 1 percent to 17 percent of the trees and was inversely related to elevation. At the lowest elevation, losses of trees 9 inches d.b.h. and larger were 36.5 percent of the stems or 36 percent of the basal area (fig. 1). At the highest elevation, these losses were 2 percent of the stems, or less than 1 percent of the basal area.

Although the regressions shown in figure 1 can be regarded as statistically significant, the scatter about the regression is large relative to the mean as indicated by $S_{y \cdot x}$. Therefore, the curves should be used primarily for estimating gross relations to elevation and not specific responses for 1/10-acre plots within elevational levels.

The principal cause for variance in mortality of lodgepole pine among elevations probably is related to differences in climatic conditions that occur within the elevational strata; specifically, the effects of such differences on the biology and survival of the beetle. At high elevations on the Teton National Forest, cool temperatures delayed development so that a large proportion of the population entered the winter as eggs, and 1st and 2nd instars. In these stages, mortality was abnormally high under subfreezing conditions (Amman, in press).

Table 1.--*Stand composition (trees 4 inches d.b.h. and larger) by elevational levels at the start of the infestation*

Elevational level	Species and numbers and percent of trees per acre										Total
	Lodgepole pine		Douglas-fir		Engelmann spruce		Subalpine fir		Aspen		
	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent	
8,725-8,999	197	74	8	3	8	3	0	0	53	20	266
9,000-9,199	248	71	0	0	5	1	18	5	79	23	350
9,200-9,399	366	96	0	0	1	<1	10	3	4	1	381
9,400-9,599	293	100	0	0	0	0	0	0	0	0	293
9,600-9,799	311	88	0	0	25	7	18	5	0	0	354
9,800-9,999	308	83	0	0	34	9	30	8	0	0	372
10,000-10,400	320	88	0	0	30	8	15	4	0	0	365

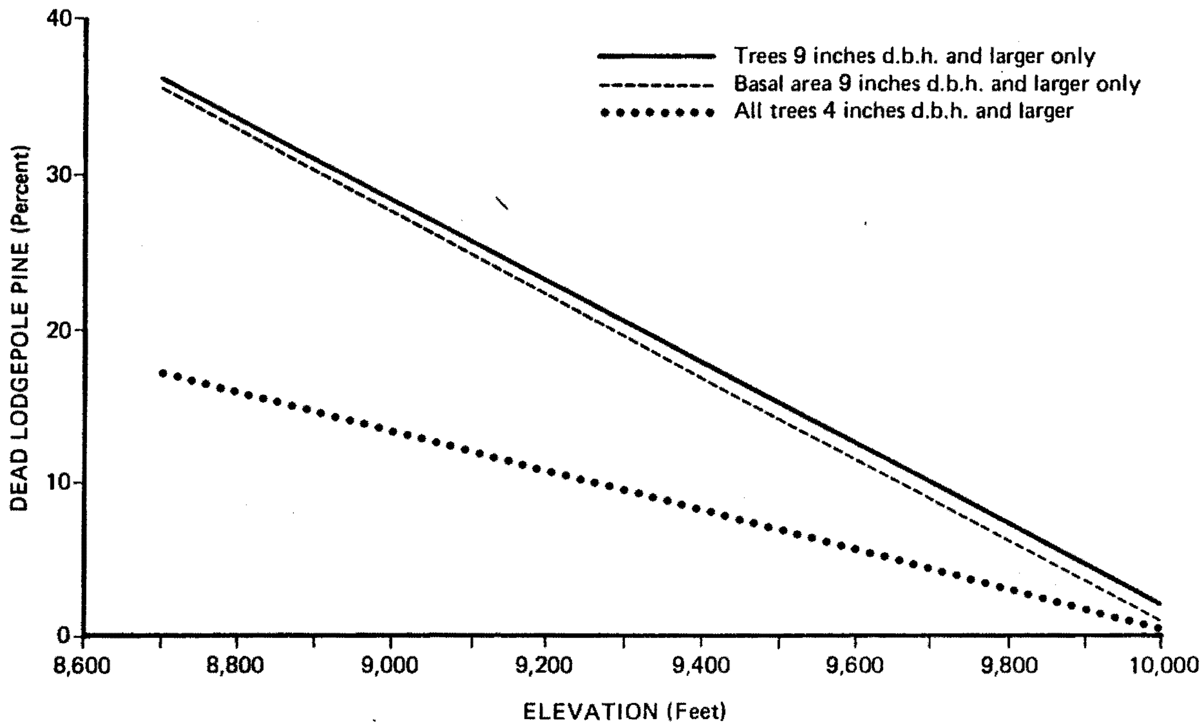

Figure 1.--Proportions of lodgepole pine stems and basal area killed by the mountain pine beetle in relation to elevation on the North Slope of the Uinta Mountains. (See Appendix for regression equations used to calculate these curves.)

Consequently, we compared data from this study with that obtained by Amman and Baker (1972) on the Teton National Forest in northwest Wyoming and adjacent Targhee National Forest in Idaho. In order to do this, we cast the Amman-Baker data according to elevational levels, and accounted for the difference in latitude by subtracting 700 feet from each North Slope elevation.

Hopkins' Bioclimatic Law called for a somewhat greater adjustment; however, factors other than elevation, latitude, and longitude enter into phenological comparisons between areas (Hopkins 1919).

The comparison in figure 2 shows a slight difference in the slopes of the regression lines; they crossed at about 8,500 feet. However, the differences in mortality for a given elevation when adjusted for latitude are minor; they range from about 3 percent at 8,000 feet to 4 percent at 9,000 feet (fig. 3). Therefore, most of the differences in mortality occurring at similar elevations can be accounted for by differences in latitude.

The number and proportion of large lodgepole pine trees per acre increased with elevation as shown in table 2. Therefore, stands at the higher elevations should have been more conducive to buildup of beetle populations than stands at the lower elevations because large infested trees usually produce more beetles per unit area of bark than do small trees (Reid 1963; Cole and Amman 1969). However, this did not occur, as reflected in figure 4.

Some feel that logging for railroad ties on the North Slope during the last century might have had some effect on the number of large trees growing at the time of the beetle infestation. Equally plausible, however, the stands could have reached a structure that would have been conducive to a beetle infestation before the 1950's without such cutting. If such had occurred, the mortality of trees probably would not have been any greater than our sampling showed.

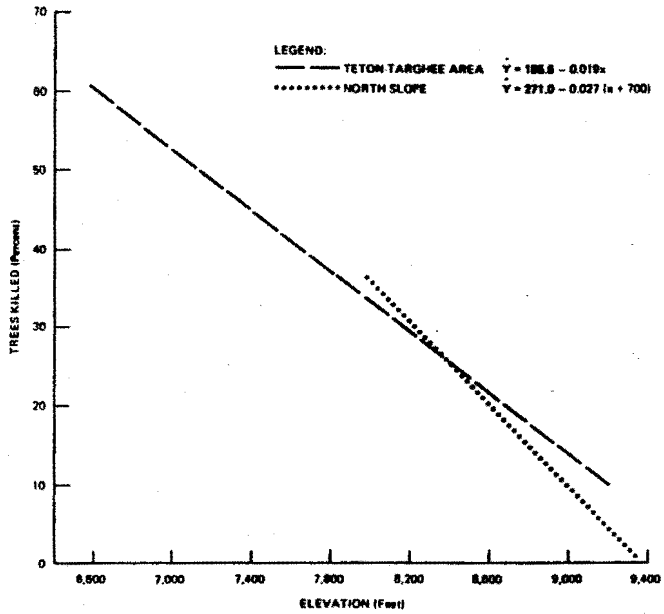

Figure 2.--Proportions of lodgepole pine stems 9 inches d.b.h. and larger killed by mountain pine beetles in relation to elevation on the Teton and Targhee National Forests and on the North Slope of the Uinta Mountains.

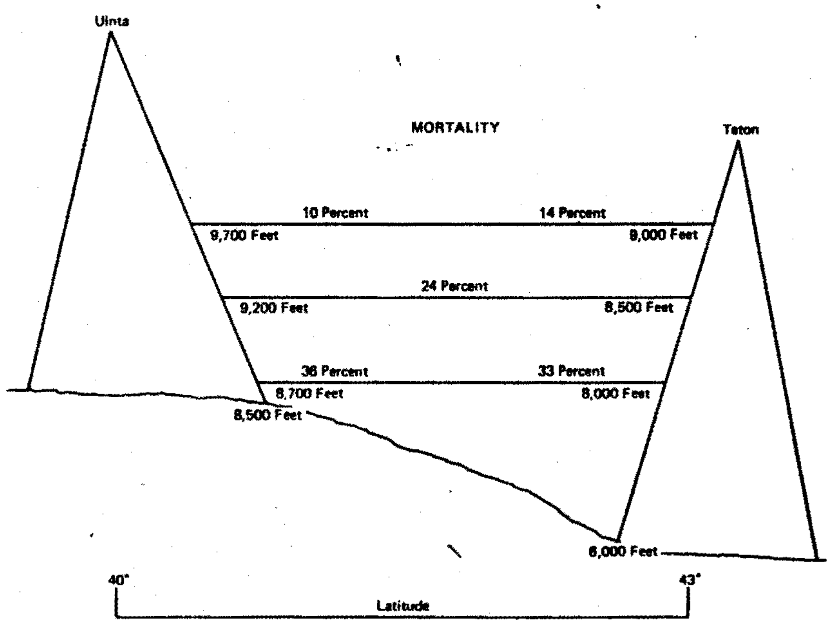

Figure 3.--Mortality of lodgepole pine in the Teton-Targhee area and North Slope of the Uinta Mountains attributable to the mountain pine beetle was approximately equal when elevation is corrected for differences in latitude.

Table 2.--*Numbers*[1] *per acre of lodgepole pine trees surviving (S), killed by the mountain pine beetle (MPB), and by other causes (OC) in seven elevation levels on the North Slope of the Uinta Mountains*

Tree size (d.b.h., inches)	Elevation levels (feet)																				
	8,725-8,999 (21)[2]			9,000-9,199 (39)			9,200-9,399 (29)			9,400-9,599 (32)			9,600-9,799 (40)			9,800-9,999 (25)			10,000-10,400 (14)		
	S	MPB	OC	S	MPB	OC	S	MPB	OC	S	MPB	OC	S	MPB	OC	S	MPB	OC	S	MPB	OC
4	40	0	1	47	[3]<1	3	81	0	6	42	0	3	45	0	1	58	0	2	33	0	0
5	31	1	4	44	1	3	68	0	7	47	<1	3	42	0	2	45	0	4	34	0	4
6	19	3	0	36	1	1	56	1	5	35	1	3	46	1	2	42	0	1	40	0	1
7	18	6	1	28	1	2	34	2	3	33	2	3	41	0	2	36	0	<1	39	0	1
8	16	6	<1	17	1	2	29	2	<1	33	4	3	36	2	1	31	<1	<1	36	0	1
9	12	7	1	13	3	<1	22	3	1	21	2	1	28	1	1	21	<1	0	24	0	3
10	6	4	<1	11	4	1	13	2	1	14	2	1	16	3	1	22	<1	<1	24	1	1
11	3	3	0	11	2	0	9	2	0	10	2	2	13	3	1	15	<1	0	21	0	1
12	7	1	0	7	2	0	6	3	0	8	3	0	8	2	1	9	0	0	18	0	0
13	2	2	0	2	2	0	2	1	1	4	1	0	5	1	1	5	0	0	11	0	0
14	<1	0	0	2	1	0	1	1	0	2	0	0	3	1	0	4	0	0	11	0	0
15	1	0	0	2	<1	0	2	1	0	2	<1	0	1	<1	0	5	0	0	9	0	1
16+	1	<1	0	1	1	0	1	2	0	5	2	0	3	2	<1	3	0	<1	8	0	0
Total trees/acre[4]	----197----			----248----			----366----			----293----			----311----			----308----			----320----		

[1]Numbers rounded to the nearest whole number except when less than one-half tree per acre.
[2]Number of 1/10-acre plots.
[3]<1 indicates less than one-half tree per acre.
[4]Number recorded on 1/10-acre plots, not summation of rounded numbers in this table.

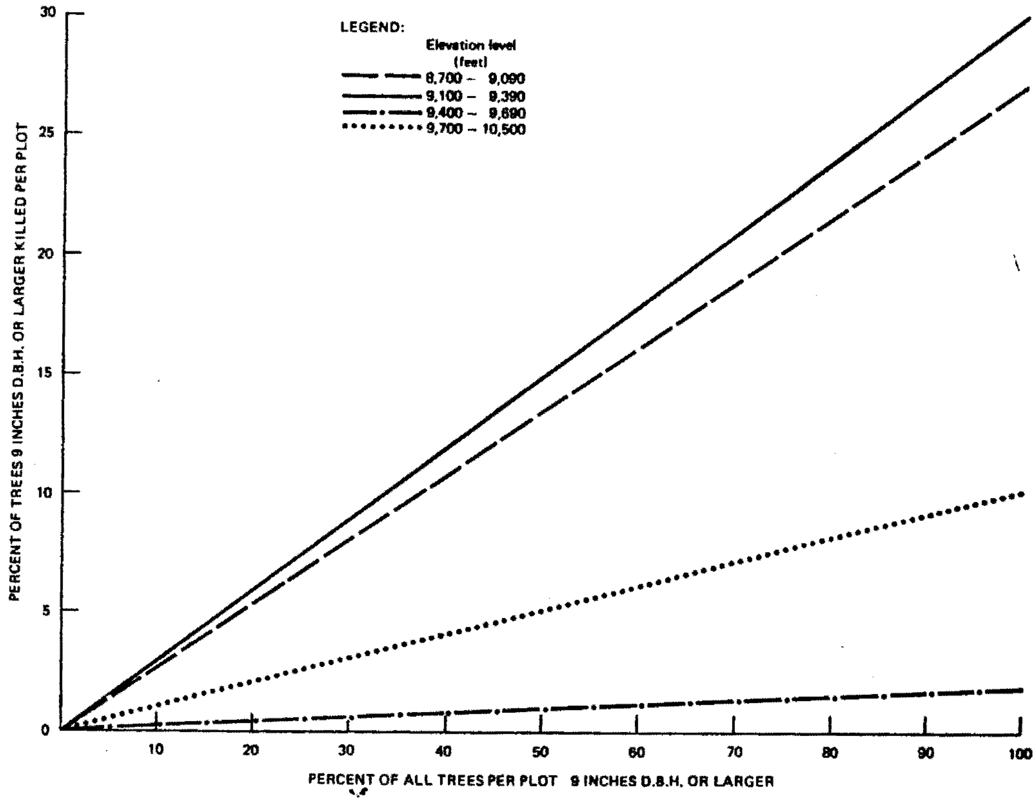

Figure 4.--Proportion of lodgepole pine trees 9 inches d.b.h. and larger killed by the mountain pine beetle in each 1/10-acre plot at different elevations in relation to the proportion of all lodgepole pine trees (4 inches d.b.h. or larger) that were 9 inches d.b.h. and larger in each 1/10-acre plot on the North Slope of the Uinta Mountains. (For regression equations, see Appendix.)

Average food conditions were about the same at all elevations. This was based on measurements made of phloem thickness, which is considered the principal factor regulating brood production of the mountain pine beetle in lodgepole pine forests where temperatures are optimum for development of the beetle (Amman 1969, 1972). The difference in average phloem thickness for trees 9 inches d.b.h. and larger was less than 0.01 inch (range of means 0.102 to 0.110 inch) (table 3). The small range in means probably can be attributed to ingrowth that occurred on residual trees at the lower elevations where mortality was greatest between the end of the infestation and the time we took our measurements. However, the potential for beetle infestation was much greater at the higher elevations because the number of phloem samples per acre equal to or exceeding 0.11 inch ranged between 30 at the lowest elevation to 113 at the highest elevation. Laboratory studies indicate that phloem thickness of 0.11 inch or greater could result in an increase in beetle populations (Amman 1972); therefore, it appears that the beetle was unable to utilize the food supply available at the higher elevations during the recent beetle infestation.

The effects of control treatments could not be evaluated. These included (a) chemical treatment (ethylene dibromide in diesel oil), (b) burning of individual standing trees, (c) logging, and (d) Operation Pushover, in which large blocks of trees were pulled over using a chain hooked between two crawler tractors and then burned. However, the close association of mortality with elevation indicates that a similar relation probably would have occurred if these control treatments had not been used. Furthermore, an evaluation of control based on stand structure in treated and untreated stands in the Teton and Targhee National Forests indicated that mortality was not reduced nor was the length of the infestation shortened (Amman and Baker 1972) as a result

Table 3.--*Number*[1] *and proportion of samples 0.11 inch or more thick per acre by diameter class, and average phloem thickness of all phloem samples for lodgepole pine 9 inches d.b.h. and larger*

Elevational level	Diameter class (inches) 9-10		11-12		13-14		15-16+		Total samples 0.11+	Phloem thickness all samples	
	No.	*Percent*	*No.*	*Percent*	*No.*	*Percent*	*No.*	*Percent*		*Mean*	*Standard deviation*
8,800	12	33	13	64	3	60	2	38	30	0.105	0.0030
9,000	18	37	15	42	5	57	5	83	43	.104	.0036
9,200	23	33	17	57	4	72	4	64	48	.104	.0033
9,400	17	25	20	55	6	53	9	61	52	.103	.0036
9,600	44	50	20	48	7	46	2	20	73	.106	.0034
9,800	35	41	23	47	10	54	10	61	78	.110	.0039
10,000	37	39	39	50	17	38	20	59	113	.105	.0041

[1] Two samples were taken per tree.

of those treatments. In stands where treatment slowed the rate of tree mortality in the Teton-Targhee area, the infestation was prolonged; however, the ultimate amount of mortality was approximately the same both in treated and untreated stands.

As a result of Operation Pushover, a small portion of the North Slope is now covered by blocks of different-age stands of lodgepole pine, replacing what had been a large even-age forest. The North Slope possibly would be least susceptible to widespread beetle infestations in the future if more of these different-age stands could be created over a larger portion of the Slope. Obviously, it would be much easier to combat infestations in scattered stands than it would be within an extensive forest because individual stands can be logged quickly.

REFERENCES

Amman, Gene D.
1969. Mountain pine beetle emergence in relation to depth of lodgepole pine bark. USDA For. Serv. Res. Note INT-96, 8 p., illus.

Amman, Gene D.
1972. Mountain pine beetle brood production in relation to thickness of lodgepole pine phloem. J. Econ. Entomol. 65(1):138-140.

Amman, Gene D.
Population changes of the mountain pine beetle in relation to elevation. J. Environ. Entomol. (In press).

Amman, Gene D., and Bruce H. Baker
1972. Mountain pine beetle influence on lodgepole pine stand structure: an analysis of treated and untreated stands. J. For. 40:204-209, illus.

Cole, Walter E., and Gene D. Amman
1969. Mountain pine beetle infestations in relation to lodgepole pine diameters. USDA For. Serv. Res. Note INT-95, 7 p., illus.

Hopkins, Andrew D.
1919. The bioclimatic law as applied to entomological research and farm practice. Sci. Mon. 8:496-513.

Reid, R. W.
1963. Biology of the mountain pine beetle, *Dendroctonus monticolae* Hopkins, in the east Kootenay Region of British Columbia. III. Interaction between the beetle and its host, with emphasis on brood mortality and survival. Can. Entomol. 95:225-238.

Roe, Arthur L., and Gene D. Amman
1970. The mountain pine beetle in lodgepole pine forests. USDA For. Serv. Res. Pap. INT-71, 23 p., illus.

APPENDIX

The following regression equations, which are based on individual observations from 1/10-acre plots were used to calculate the curves shown in figure 1:

(1) Stems 4 inches d.b.h. and larger--$\hat{Y} = 129.8 - 0.0129\ X$; $\overline{Y} = 7 \cdot 7$; $S_{y \cdot x} = 14$; $r^2 = 0.11$; $N = 200$; $P < 0.005$.

(2) Stems 9 inches d.b.h. and larger--$\hat{Y} = 268 - 0.0266\ X$; $\overline{Y} = 16.4$; $S_{y \cdot x} = 26.9$; $r^2 = 0.13$; $N = 193$; $P < 0.005$.

(3) Basal area of stems 9 inches d.b.h. and larger--$\hat{Y} = 275.5 - 0.0275\ X$; $\overline{Y} = 16$($S_{y \cdot x}$ and r^2 not meaningful because the regression is on means).

Regression equations used to calculate curves shown in figure 4:

(1) 8,700-9,090 feet; $\hat{Y} = 0.0815 + 0.2704\ X$; $\overline{Y} = 0.18$; $S_{y \cdot x} = 0.21$; $r^2 = 0.10$; $P < 0.10$.

(2) 9,100-9,390 feet; $\hat{Y} = -\ 0.0112 + 0.3015\ X$; $\overline{Y} = 0.08$; $S_{y \cdot x} = 0.13$; $r^2 = 0.27$; $P < 0.005$.

(3) Regressions for the two highest elevations were not significantly different from zero.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1973 — 784-484 / 15 REGION NO. 8