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Characteristics of Endemic-Level Mountain Pine Beetle Populations in South-Central Wyoming

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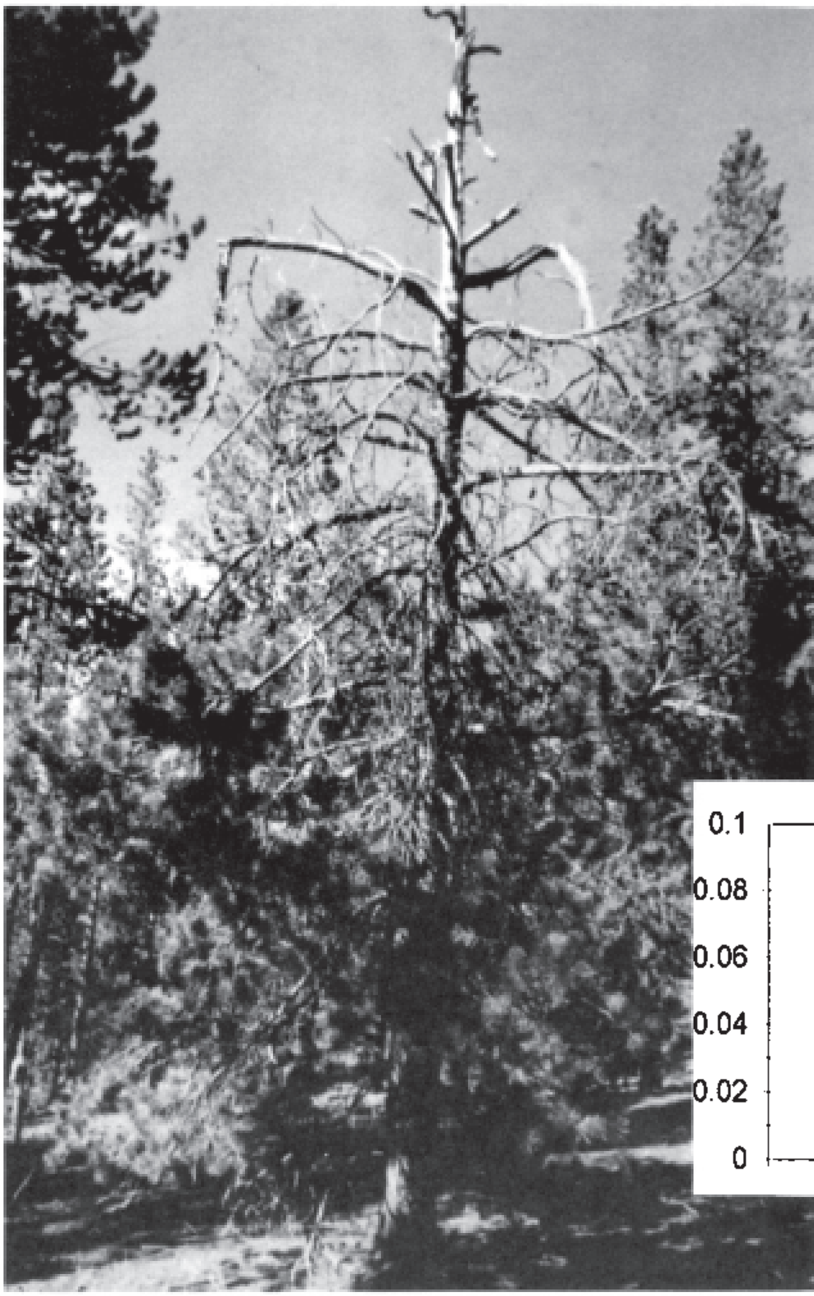

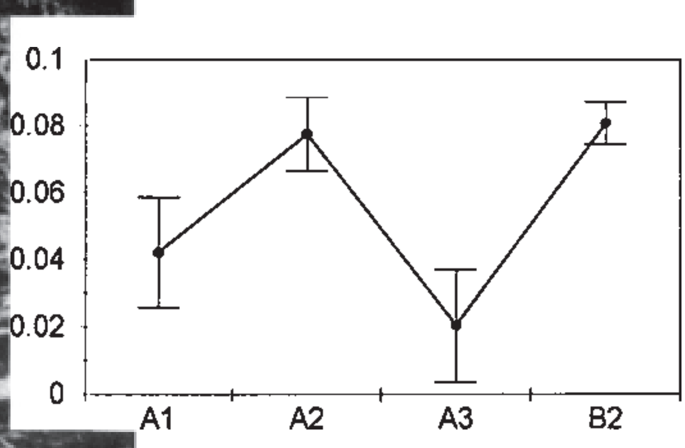

Abstract

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This study was conducted to evaluate the dynamics of endemic populations of mountain pine beetle (*Dendroctonus ponderosae* Hopkins). In addition, we extended the geographical range of an existing data base recorded in Utah with similar data from Wyoming. This work was accomplished in lodgepole pine (*Pinus contorta* Dougl. Var. *latifolia* Engelm.) stands on the Medicine Bow National Forest in south-central Wyoming. Thirty-eight variable-radius paired plots (BAF 10) were measured during the summer of 1987. Host-tree condition and mountain pine beetle infestation characteristics were determined from currently and previously infested trees. Presence and severity of Armillaria root disease and stem pathogens was determined. Tree condition and infestation patterns were similar at this site to those found in earlier studies. Trees selected by endemic mountain pine beetle populations were infested with Comandra blister rust (*Cronartium Comandra* PK) and root disease (*Armillaria* spp.). Host-tree condition and mountain pine beetle infestation patterns recorded in this study parallel those identified earlier in Utah and will help land managers identify trees to cut to reduce stand hazard to mountain pine beetle infestation.

Keywords: Armillaria, pathogens, root disease, blister rust, *Dendroctonus ponderosae* Hopkins, lodgepole pine

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Characteristics of Endemic-Level Mountain Pine Beetle Populations in South-Central Wyoming

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Introduction

Bark beetles (Coleoptera: Scolytidae) are the most serious insect threat to maintaining optimum productivity of lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) in western North America. These beetles can infest and kill trees in a single growing season. The most common species of bark beetle that infests lodgepole pine in this area are mountain pine beetle (*Dendroctonus ponderosae* Hopkins), pine engraver beetle (*Ips pini* Say), *Pityopthorus confertus* Swaine, *Pityogenes knechteli* Swaine, *Ips latidens* (LeConte), lodgepole pine beetle (*Dendroctonus murrayanae* Hopkins), and red turpentine beetle (*Dendroctonus valens* LeConte). Of these seven species, mountain pine beetle currently causes the greatest threat to the productivity of lodgepole pine stands because at outbreak levels it kills most lodgepole pine 15.2 cm dbh (diameter at breast height) and larger (Amman and Cole 1983; McGregor and others 1987). Although methods exist for suppressing mountain pine beetle infestations, including logging and applications of insecticides, none sufficiently suppress outbreaks over the extensive areas commonly infested in the United States and Canada.

Prevention of outbreaks, a more effective approach, depends upon identifying and understanding the interactions of endemic or low levels of populations. In this report, such populations are those at an abundance level causing tree killing below a tolerable threshold. For land managers, this threshold is usually single, widely scattered trees (for example, 1 per 10 ha).

Outbreak levels are those at which tree killing exceeds tolerable levels and is characterized by groups of infested trees commonly totaling 150 per ha or more. To date, most mountain pine beetle research concerns the dynamics of outbreak-level populations, partly because the extent of these infestations are detectable from the air. In contrast, less is known about the dynamics of endemic populations due to the difficulty of locating single infested trees and the sustaining long-term commitment needed for an adequate data base. This study was undertaken to extend the geographical range of the data base and compare infestation patterns with those in an earlier evaluation of endemic populations in Utah (Tkacz and Schmitz 1986). Additionally, knowledge from measures of endemic populations will be used to refine and validate a prototype expert system designed to predict population trends of endemic level mountain pine beetle infestations (Downing and Bartos 1991).

Earlier observation and assessments of single-tree infestations in unmanaged stands within a lodgepole pine type has revealed that the upper bole is often infested in May by one or more associated bark beetles; usually, pine engraver beetle, *Pityopthorus confertus*, or *Pityogenes knechteli*. Mountain pine beetle follows this infestation in July, invading the portion of the bole uninfested; usually, the basal 1 to 2 m (Schmitz 1989). The extent to which olfactory stimuli are involved is unclear. The trees selected are usually small-diameter, suppressed, diseased trees or those girdled by porcupines (Amman and Schmitz 1988). Amman and others (1974) found that *P. confertus,* common in lodgepole pines infested by outbreak levels of mountain pine beetle, commonly infested the tops and limbs unoccupied by mountain pine beetle.

Most previous documentation about the association between stem and root diseases and bark beetle infestations concerns mountain pine beetle population densities exceeding the single, scattered tree endemic level (Gara and others 1985), considered in this report or host-tree species other than lodgepole pine (Blackman 1931; Cobb and others 1974; Craighead 1925; Eckberg and others 1994; Kulhavy and others 1984; Lessard, 1985). When both stem and root disease are present, determing which is responsible for predisposing host trees to mountain pine beetle infestations is difficult. Rasmussen (1987) assessed the interaction of mistletoe (*Arceuthobium americanum* Hutt ex Engelm) and comandra blister rust (*Cronartium commandra* PK) on endemic mountain pine beetle attack behavior on 45 lodgepole pines in Wyoming and Idaho. The only statistically significant difference was in the Idaho site where six of 18 beetle attacked trees were infested with comandra blister rust while only one of 18 unattacked trees were infested.

Root pathogens have been repeatedly implicated as important agents responsible for predisposing conifers to beetle attack. However, definitive evidence documenting how host trees become susceptible to attack has seldom been documented (Cobb and others 1974). The time and effort required to excavate root systems and accurately determine incidence and severity of disease has limited the number and extent of these investigations. Understanding the role of root disease in the dynamics of endemic beetle populations has been hampered by the difficulty of sustaining long-term research commitments needed to define interactions between the host tree, its pathogens, and survival of beetle populations, and to develop effective management strategies. For the most part, root pathogens are thought to increase the likelihood that resin exudation at the point of beetle attack will be reduced, which increases the probability of successful beetle attack and survival.

In contrast, recent measures of the total flow of lodgepole pine oleoresin in relation to wound size, diameter class, disease status, and aspect revealed a general trend toward increased flow with an increase in tree diameter, and a general trend for more flow in diseased trees (Nebeker and others 1995a). Three diseases were included in the study: Armillaria root rot (*Armillaria* spp.), lodgepole pine dwarf mistletoe, and comandra blister rust. Disease also had a significant effect on tree growth. Trees infected with comandra blister rust grew significantly less than trees infected with either of the other diseases. More recent findings suggest that stem and root pathogens may alter host trees in ways favoring survival of endemic populations of mountain pine beetle (Nebeker and others 1995b). In a companion study, comparisons of the terpenoid and phenyl propanoid content of xylem resin and phloem nitrogen and carbohydrate levels of lodgepole pines infected with the same three diseases and uninfested trees were made to determine if differences existed that might influence their susceptibility to mountain pine beetle attack. Levels of five volatiles (Tricyclene, α-pinene, camphene, γ-terpinene, and bornyl acetate) were significantly higher in trees with one or more disease than in the control trees (Nebeker and others 1995a). Four volatiles (myrcene, camphor, 4-allylanisole, and γ-terpineol) were significantly lower in diseased trees. Control trees had significantly higher starch, total nitrogen, and free amino-N contents than diseased trees (Nebeker and others 1995b). These findings, together with the knowledge that diseased lodgepole pines are commonly infested by endemic mountain pine beetle populations, suggest that a biochemical basis may exist that favors beetle selection of diseased trees.

Study Area

This study was conducted in lodgepole pine stands within the Medicine Bow National Forest, in south-central Wyoming. Ground and aerial surveys, conducted in 1986 by entomologists from the USDA Forest Service, Forest Health Management Group, Lakewood Colorado, determined that scattered single-tree infestations were present within the Mullen and French Creek drainages at elevations from 2,440 to 2,774 m, approximately 35 km east of Encampment, WY. These stands had a mean age of 181 yrs, diameter at breast height (dbh) 15.1 cm, and a basal area of 31.3 m per ha. According to Hoffman and Alexander (1980), the habitat type was lodgepole pine/buffaloberry (*Pinus contorta*/*Shepherdia canadensis)*. Earlier hydrologic studies (Knight and others 1985) in the French Creek drainage determined that total annual precipitation for 1979 was 79 cm, 1980 was 80 cm, and 1981 was 61 cm. Rainfall averaged 41 percent of the total precipitation received over the 3 year period and was most abundant in May; the remaining 59 percent fell as snow (Knight and others 1985).

Methods

Thirty-eight variable-radius paired plots (BAF 10) were located in the lodgepole pine stands during the summer of 1987. A tree infested by mountain pine beetle in July or August 1987 was used to establish the centers of one set of 19 plots (A plots). Companion paired plots (B plots) were centered on the lodgepole pine, of comparable diameter, growing nearest to a point 40.24 m (two chains) distant from the A plot center. Direction from the A plots to their respective companion paired plot was selected at random. This design provided comparisons of tree and infestation characteristics, especially disease symptoms between trees from the A plots and the B plots. When more than one old infested or green tree were on the A plots, the first one encountered in a clockwise rotation from plot center was considered the sample tree for that plot. In the case of the B plots (centered on a green uninfested tree), if currently infested trees or old infested trees were present, the representative sample trees for these two categories were located in the same manner as that used for the A plots.

Tree characteristics recorded included: tree height, diameter breast height (dbh), age, crown class, percent of live crown, and phloem thickness. Phloem thickness measurements from old infested trees were limited to those infested but not killed during 1986 with enough live phloem to take representative samples. Infestation characteristics measured included: height of bole infested, presence of associated bark beetles, and brood survival statistics. Two, 15.25 x 30.5 cm bark samples were removed from each infested tree to record the number of mountain pine beetle attacks and emergence holes, and the total mountain pine beetle egg gallery. The location of the first two samples was randomly selected from one of the four cardinal directions. The second sample was located 180° from the first.

Presence and severity of Armillaria root disease was determined by excavating the roots of each sample tree to a point 0.9 m from the root collar and 0.5 m below ground level. The root collar was examined for evidence of resinosis or mycelial fans. Three roots, beginning on the north side and moving clockwise, were selected and examined for resin-encrusted lesions or subcortical mycelial fans with rhizomorphs, which are external indicators of Armillaria root disease (fig. 1).

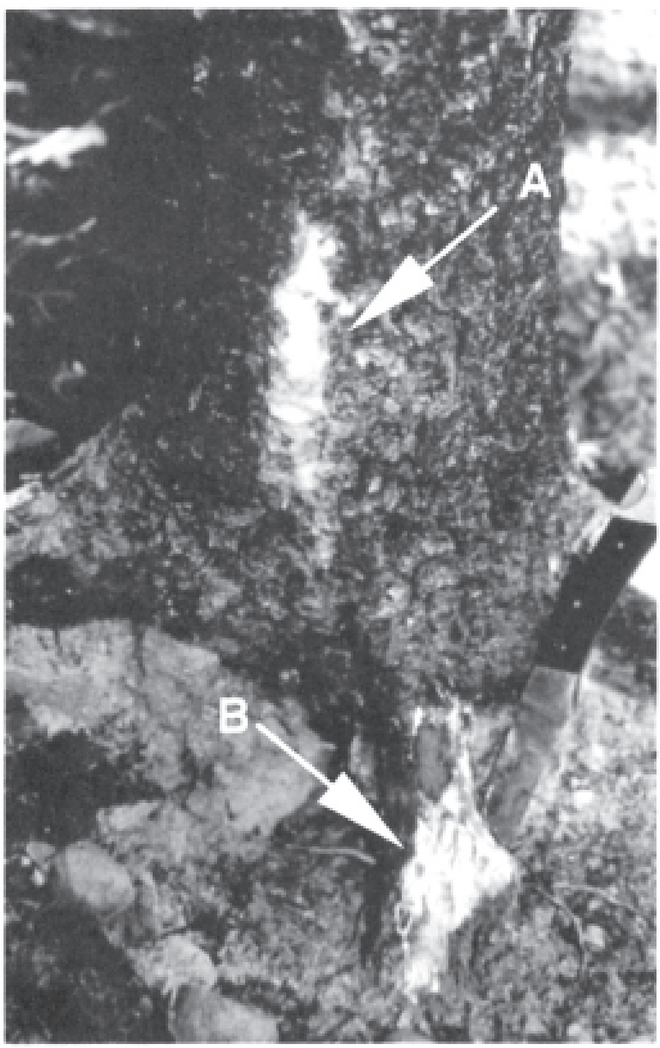

Figure 1—Presence of resinosis (A) and mycelial fans (B) was determined by excavating the soil 0.9 m from the root collar to 0.5 m below ground level.

Resinosis on the roots indicates parasitic infection (Cobb and others 1974). All trees were rated for degree of dwarf mistletoe infection using the Hawksworth (1977) six-class system. Application of this system involves visually dividing the live crown into three sections, then rating each third for degree of infection (0 = no infection, 1 = <50 percent infected, 2 = >50 percent infected). Ratings for each third are totaled to obtain the tree rating.

The system used for rating severity of comandra blister rust also involved visually dividing the total live and dead crown length into thirds and then determining whether the most damaging canker in each third was girdling or nongirdling (Brown 1977). Rating for girdling cankers were given twice the numerical rating of non-girdling cankers. A girdling canker in the lower third was rated 8 while a similar injury in the midcrown was rated 4 and upper crown was rated 2. Ratings ranged from 0 to 8.

Results and Discussion

Individual tree and stand characteristics for the 19 A and B plots were compared to identify host-tree characteristics common to single tree mountain pine beetle infestations (table 1). Tree and stand data from the arbitrarily selected A plots and the randomly located B plots were similar as shown in the following tabulation:

Stand/tree characteristic	Plot type A	Plot type B
Mean dbh (cm)	37.1	39.6
Mean height (m)	22.0	24.1
Mean age (yrs)	182	181
Mean basal area (m^2/ha)	31.0	31.5

Earlier observations suggest that mountain pine beetle commonly infests the smaller diameter trees that are diseased or infested by other scolytids (Amman and Schmitz 1988). Analysis of Medicine Bow data revealed that there was no significant difference in mean dbh between currently infested, green infested and old infested trees on the A plots nor between these trees and the green uninfested trees on the B plots as determined by ANOVA (P>.05). Means were not significantly different, however, values obtained are useful to interpret these data. Mean dbh recorded was 41.9 cm for the currently infested trees, 36.1 cm for the green uninfested trees, and 33.3 cm for the old infested trees (fig. 2). Mean dbh of the green uninfested trees (39.6 cm) on the B plots was slightly less than that recorded for the currently infested (41.9 cm), but larger than that for the green uninfested (36.1 cm) or old infested (33.3 cm) on the A plots.

Table 1—Individual tree and stand characteristics measured for the 19 A plots for the current, green, and old infested trees.

	Plot	Current	Green	Old	dbh[a] cm	inf[b] m	MPB[c]	ips[d]	pity[e]	arm[f]	CBR[g]	DMT[h]
	1A	1A1			35.6	8.5	1	1	1	1	2	6
			1A4		37.1	0	0	0	0	0	4	6
				1A3	51.8	0	1	0	0	1	0	6
	2A	2A1			59.7	6.7	0	0	0	0	0	6
				2A2	42.4	6.7	0	1	1	1	4	6
			2A3		26.9	0	0	0	0	0	0	6
	3A	3A1			30.2	0	1	1	1	1	6	6
			3A2		30.2	0	0	0	0	0	0	6
	4A	4A1			35.8	0	0	0	0	1	0	5
			4A2		38.4	0	0	0	0	1	0	5
	5A	5A1			21.6	0	1	1	0	1	0	5
			5A2		21.3	0	0	0	0	1	0	5
	6A	6A1			41.2	10.7	1	1	0	0	2	3
			6A2		38.9	0	0	0	0	0	0	4
				6A5	34.3	6.4	1	0	0	0	2	0
				6A6	38.4	9.1	1	0	0	1	0	6
	7A			7A1	29.5	3.7	1	1	1	1	0	6
		7A2			27.9	3.1	1	0	0	1	0	6
			7A3		39.4	0	0	0	0	0	0	0
	8A	8A1			38.6	7.3	1	0	0	0	0	6
			8A2		33.3	0	0	0	0	1	0	6
	9A	9A1			38.6	3.1	1	1	0	1	0	6
			9A2		33.5	0	0	0	0	0	0	6
	10A	10A1			30.7	.9	1	1	0	0	4	6
			10A2		34.8	0	0	0	0	0	0	6
	11A	11A1			30.2	0	1	1	0	1	0	6
			11A3		29.0	0	0	0	0	1	0	6
	12A	12A1			49.5	12.5	1	0	0	0	0	6
			12A2		46.0	0	0	0	0	0	0	6
	13A	13A1			27.2	3.7	1	0	1	1	0	5
			13A2		20.1	0	0	0	0	0	0	5
	14A	14A1			56.1	0	0	1	1	1	0	6
			14A2		42.7	0	0	0	0	0	0	6
	15A			15A1	41.2	1.5	1	1	0	1	0	6
		15A5			36.8	0	0	1	1	1	0	6
			15A2		32.3	0	0	0	0	0	0	6
	16A	16A1			29.7	0	1	0	0	0	0	6
			16A2		33.0	0	0	0	0	0	0	6
	17A	17A1			44.5	3.7	1	1	1	1	0	6
			17A2		38.1	0	0	0	0	0	0	6
				17A5	47.0	0	1	1	1	0	0	6
				17A3	35.3	0	1	0	1	0	0	6
				17A4	34.0	0	1	1	1	0	0	6
				17A6	27.2		1	1	1	1	0	6
				17A7	28.2		0	1	1	1	0	5
				17A8	32.0		1	1	1	1	2	6
				17A9	31.5		1	1	0	1	0	6
				17A10	24.1		0	1	1	1	0	6
	18A	18A1			46.0	10.7	1	0	0	1	4	5
			18A2		33.3	4.6	0	0	0	0	0	5
	19A	19A1			45.7	4.6	1	1	1	0	0	6
			19A2		36.6	0	0	0	0	0	0	6
N	19	19	19	14	52	18	26	21	16	26	9	50

[a]Diameter breast height
[b]Length of infested bole
[c]Mountain pine beetle
[d]*Ips* spp.
[e]*Pityopthorus* spp.
[f]*Armillaria* spp.
[g]Comandra blister rust
[h]Dwarf mistletoe

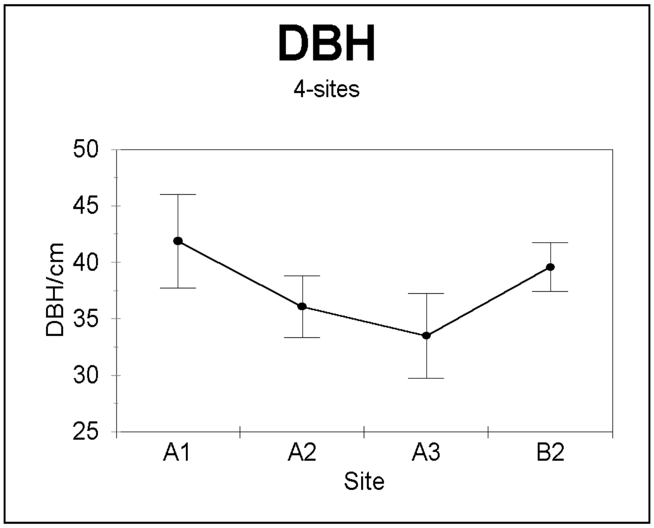

Figure 2—Mean and confidence interval for tree dbh for four plot types.

Similarly, analysis to determine if differences in tree height exist between the same four categories of trees revealed no significant difference between currently infested (23.7 m), green uninfested (21.1 m), and old infested (21.2 m), nor between these trees and the green uninfested trees (24.1 m) on the B plots (ANOVA p>0.05) (fig. 3). Heights of the currently infested trees (22.2 m) on the A plots and green uninfested trees (24.1 m) on the B plots were slightly greater than green uninfested (21.1 m) and old infested (21.1 m) trees on the A plots. This contrasts with results from stands measured in earlier studies of endemic mountain pine beetle populations (Amman & Schmitz 1988) where suppressed trees were present and commonly infested by beetles.

The minimal difference in the diameter or height of trees attacked by mountain pine beetle in this study may be attributable to the advanced age of the test stands. No trees on either the A or B plots were categorized as suppressed suggesting this crown class is no longer present in these stands; likely having been out-competed by the dominant, codominant, and intermediate class trees.

Comparison of phloem thickness (fig. 4) among the four categories of test trees revealed phloem was significantly thinner in currently infested (0.042 mm) and old infested (0.020 mm) trees than green uninfested trees on the A plots and green uninfested trees on the B plots (ANOVA p>0.05). There was no significant difference in phloem thickness between green uninfested trees on the A (0.077 mm) and B plots (0.081 mm).

Exposure of each of the four categories of trees as measured in degrees (0 to 360^o) around plot center revealed no significant difference in location on the plots except old infested trees tended to be located in a more westerly direction than the other three tree categories (fig. 5).

Measure of tree position relative to percent slope from the horizontal revealed that the position of the old infested trees was significantly different than the other three categories of trees. The old infested trees were located on sites with slightly less slope than any of the other three categories of tree (fig. 6).

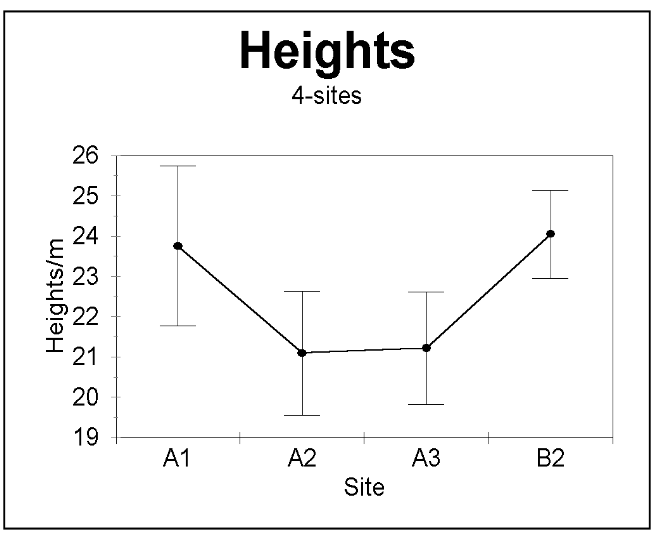

Figure 3—Mean and confidence interval for tree height for four plot types.

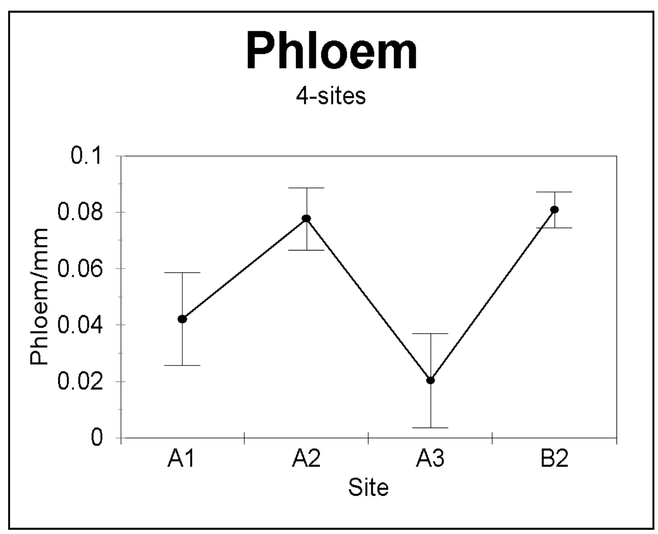

Figure 4—Mean and confidence interval for phloem thickness for four plot types.

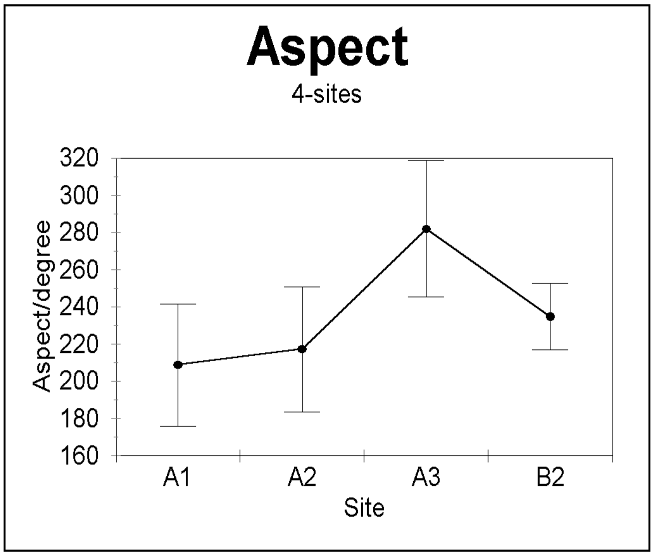

Figure 5—Mean and confidence interval for aspect of site for four plot types.

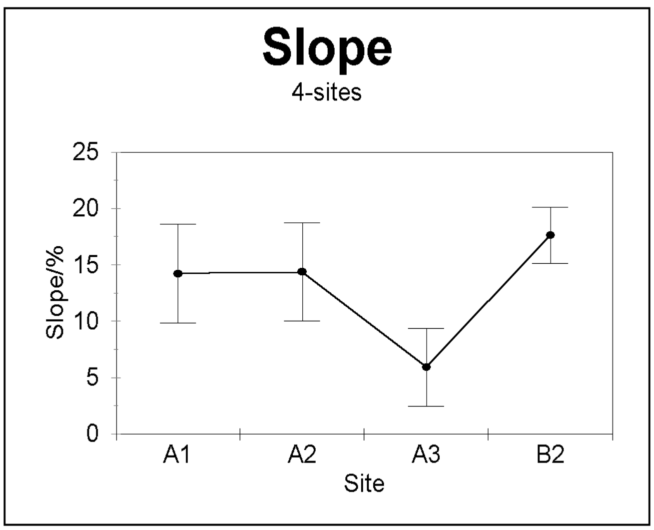

Figure 6—Mean and confidence interval for percent slope for four plot types.

Figure 7—Trees infested by endemic mountain pine beetle population were commonly infected with Armillaria root disease as indicated by the basal bleeding of resin (A).

All of the 19 A plots contained currently infested lodgepole pine because of the plot selection criteria (table 1). In contrast, none of the randomly located B plots included currently infested lodgepole pine. Further, parasitic Armillaria root disease was present in 15 of the 19 currently infested trees, and 2 of the remaining 4 Armillaria-free trees were infected with a brown cubicle rot of undetermined identity (fig. 7). Armillaria root disease was present in only six of the 19 trees located on the B plots. The associated scolytids, either *Ips* spp. or *Pityopthorus* spp., infested 10 of the 19 currently infested trees on the A plots and none of the trees on the B plots. The following tabulation lists the bark beetles present in the lodgepole pine that was sampled on each of the two plots categories:

	Plots	
Infestation category	**A**	**B**
Trees infested w/mountain pine beetle	19	0
Trees infested w/secondary scolytids	10	0
Trees infested w/*Ips* alone	5	0
Trees infested w/*Ips* & *Pityopthorus*	3	0
Trees infested w/*Pityopthorus*	2	0

These findings support earlier work suggesting that lodgepole pine infested with root disease (Gara and others 1984; Tkacz and Schmitz 1986) and/or infested by associated bark beetles are commonly infested by endemic-level mountain pine beetle populations.

In a study conducted in Utah (Tkacz and Schmitz 1986) involving 42 trees, two of 20 live uninfested trees (10 percent) were infested with parasitic Armillaria root disease. In contrast, in the current study, 50 trees on the A plots, and four of 19 uninfested trees (20 percent) were infested with parasitic Armillaria root disease. Further, in Utah, 11 of 12 currently infested trees (82 percent) were infected by Armillaria root disease, while 12 of 19 currently infested trees (63 percent) in the current study were infected with parasitic Armillaria root disease. Finally, eight of 10 old infested trees (80 percent) in Utah were infected with Armillaria root disease, while 10 of 14 old infested trees (71 percent) in the current study were infected with parasitic Armillaria.

Comparison of the presence of stem disease, Armillaria root disease, and associated scolytids between currently infested and old infested lodgepole pines on the A plots (table 1) are summarized below:

Presence of:	Currently infested	Old infested	Green uninfested
	- - - - - - - - *Percent*	- - - - - - - -	
Stem disease	100	88	95
Armillaria root disease	58	88	21
Associated scolytids	68	25	0
Number evaluated	19	8	19

These data reveal that stem disease, dwarf mistletoe, and commandra blister rust are common regardless of infestation category. However, the incidence of Armillaria root disease in old and currently infested trees is 2.5 to 4 times higher than that in green uninfested trees (fig. 8). The incidence of associated scolytids was highest in currently infested trees followed by that in old infested trees. Deterioration in the bark of old infested trees often precluded an accurate assessment of associated scolytid activity. Only eight of 19 plots contained old infested trees with bark sufficiently intact to accurately assess the presence of associated scolytids. Survival of mountain pine beetle broods in the currently infested (A) trees is summarized in table 2. Mountain pine beetle attacks ranged from one to eight per 30.5 by 30.5 cm of bark. Total egg gallery per 30.5 x 30.5 cm ranged from 18 to 198 cm. In contrast, the equivalent attack densities averaged 3.6 cm and egg gallery density averaged 134.6 cm from outbreak-level mountain pine beetle populations (Amman 1984).

The length of infested bole ranged from 0.8 to 12.5 m (mean 4.27 m) or from 2 percent to 47 percent (mean 19 percent) of the total bole length. These findings are similar to those reported by Cahill (1960). He found the maximum height of attack by outbreak-level mountain pine beetle populations ranged from 3.05 to 13.72 m for lodgepole pine trees (dbh 20.32 to 38.10 cm).

Figure 8—Trees infected by stem disease, which eventually killed the tree top, were commonly infested by endemic mountain pine beetle populations and associated scolytids.

Emergence of new adults, as evidenced by emergence holes, ranged from 0 to 46 per 30.5 x 30.5 cm (mean four per 30.5 x 30.5 cm). Adult emergence during outbreaks averaged 3.2 per m^2 (Amman 1984). The attack density, egg gallery density, and new adult emergence were similar to those observed earlier; however, the length of bole infested was greater (Amman and Schmitz 1988). Again, the advanced age and size of trees included in this study along with the lack of small suppressed trees likely contributed to the increase in infested length.

Table 2—Summary statistics and mountain pine beetle brood survival for the currently infested (A) trees.

Plot	dbh cm	Tree Ht m	Attack #s / 30.5 x 30.5 cm	Infested length m	Infested length Percent total Ht	Egg gal cm / 30.5 x 30.5 cm	Emer holes #s/30.5 x 30.5 cm
1A1	35.6	22.9	3	8.5	37	76	0
2A1	59.7	22.6	7	6.7	30	130	3
3A1	30.2	36.3	1	0.8	2	18	0
4A1	35.8	24.7	5	strip	—	66	3
5A1	21.6	16.2	1	3.1	19	18	0
6A1	41.1	19.2	6	1.9	10	130	0
7A1	29.5	18.9	1	3.7	19	61	5
8A1	38.6	19.8	3	7.3	37	94	0
9A1	38.6	26.2	1	3.1	12	18	0
10A1	30.7	19.2	2	0.9	5	114	0
11A1	30.2	17.1	1	1.2	7	28	5
12A1	49.5	29.9	8	12.5	42	147	5
13A1	27.2	32.6	6	3.7	11	119	1
14A1	56.1	28.0	5	2.4	9	31	0
15A1	36.8	23.5	1	1.5	6	71	3
16A1	29.7	21.6	2	1.2	6	18	0
17A1	44.5	20.7	2	3.7	18	41	1
18A1	46.0	22.9	4	10.7	47	198	46
19A1	45.7	23.8	3	4.6	19	46	2
Mean	38.4	23.5	3	4.3	18.7	74	4

Conclusions

Tree condition and infestation patterns recorded in this south-central Wyoming study were similar to those recorded in Utah (Tkacz and Schmitz 1986). Most importantly, trees selected by endemic mountain pine beetle populations were commonly infested by stem and root disease, especially Armillaria root disease and comandra blister rust. Such knowledge is useful to land managers for identifying trees to be cut when partial cutting strategies are used to reduce stand hazard to mountain pine beetle infestations (McGregor and others 1987). Specifically, visual indicators, such as the basal bleeding of resin (Armillaria root disease) and presence of stem cankers (comandra blister rust), can be used to identify trees most likely to harbor endemic mountain pine beetle infestations. Recent findings describing how stem and root disease infesting lodgepole pine increased resin flow and the amount of five volatiles (Tricyclene, α-pinene, camphene, γ-terpinene, and bornyl acetate) while decreasing other volatiles (myrcene, camphor, 4-allylanisole, and γ-terpineol), suggests that a biochemical basis may exist that favors beetle selection of diseased trees (Nebeker and others 1995b). Resin components serve as primary bark beetle attractants and precursors to bark beetle pheromone production (Lingren and Borden 1989)

The role that secondary bark beetles play in endemic mountain pine beetle infestations is unclear; however, they prefer weakened or diseased trees. The relationship between mountain pine beetle and associated scolytids reaffirms the need to remove suppressed trees and those weakened by disease because they are likely to harbor endemic populations of the more damaging mountain pine beetle.

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