Biological Evaluation
R2-05-03

Biological Evaluation of Mountain Pine Beetle Activity on the Upper Fraser Analysis Area of Sulphur Ranger District, Arapaho-Roosevelt National Forests and Pawnee National Grassland, 2005

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Abstract

A mountain pine beetle (MPB) epidemic in Grand County, Colorado, started in 1997 in the Williams Fork and Troublesome watersheds. Over the past seven years, losses of lodgepole pine to mountain pine beetle increased in these areas until most of the trees had been killed. Beginning in 2000, MPB-killed trees began to be detected in the Upper Fraser watershed. By 2004 large areas of lodgepole pine had been infested and killed by this beetle. The Sulphur Ranger District, on the Arapaho-Roosevelt National Forests and Pawnee National Grassland, is considering a variety of silvicultural treatments on approximately 2,400 acres of forest land to manage MPB impacts and remove beetle-infested and killed trees in designated areas in the Upper Fraser Analysis Area.

Lakewood Service Center Forest Health Management (LSC-FHM) surveyed ten of the proposed management units in the Upper Fraser Analysis Area to determine the level of mountain pine beetle infestation in these areas. LSC-FHM utilized aerial survey data and conducted on the ground surveys using strip samples and systematic variable radius plots. Ground surveys recorded the number of trees infested with mountain pine beetle in 2004 and the number of MPB-killed trees in 2003. Stand exam data also were used to determine stand susceptibility ratings for the management units.

Summary results from the aerial survey data indicated a rapid increase in MPB related mortality across the Upper Fraser Analysis Area over the last two years. The estimated area affected by MPB-caused mortality increased from 98 acres in 2002, to 1,588 acres in 2003, and 2,934 acres in 2004. Survey results estimate that the number of trees killed increased from 99 in 2002, to 656 in 2003, and 8,985 in 2004.

Ground survey data for the ten management units indicated that the MPB epidemic in the Upper Fraser Analysis Area is rapidly expanding in all management units, with a rapidly increasing number of trees infested and killed by the beetle. The number of MPB-infested trees ranged from 3 to 68 trees per acre. The 2004:2003 ratio of the number of trees infested by MPB ranged from 1.4:1 to 10.8:1, with nine of ten management units exceeding 3:1. The 2004:2003 ratio averaged over all ten units was 4.9:1.

Average tree diameter, tree age, tree density, and elevation for the ten management units indicate that the associated stands are highly susceptible to MPB infestation. Given the abundance of MPB within the management units and concurrence of stand characteristics that favor MPB infestation, these units are all likely to sustain major losses to MPB over the course of this epidemic. Management actions to address the MPB infestation occurring in the Upper Fraser Analysis area are discussed.

Introduction

Mountain pine beetle (MPB) (*Dendroctonus ponderosae* Hopkins) is a native insect that plays a major ecological role in maturing lodgepole pine (*Pinus contorta* Dougl. ex Loud) forests. MPB epidemics can cause dramatic tree mortality over extensive areas and the insect has been described as the most important biotic agent of change in western pine forests (Amman *et al*. 1989). MPB kills trees by feeding on the phloem tissue and by introducing a blue stain fungus (*Ceratocystis montia* (Rumb) Hunt) which blocks the water conducting xylem tissue. MPB outbreaks reduce average stand diameter and age, and influence such things as canopy closure, stand structure, species composition, forage production, wildlife habitat, fuel loading, water yield and aesthetics. Downfall and woody debris following infestations can also hamper access by livestock, big game and humans (McGregor and Cole 1985).

Amman *et al*. (1977) developed a risk rating system for classifying lodgepole stand susceptibility for MPB epidemics based on average diameter at breast height (dbh), average age, and stand elevation and latitude. Lodgepole pine stands that are highly susceptible to MPB typically have the following characteristics: average dbh > 8 inches; average age > 80 years; and a suitable climate for beetle development determined by elevation and latitude (Amman *et al*. 1977). Based on the latitude for the Upper Fraser Analysis Area, this system estimates risk to be moderate between 9,000 and 10,000 feet and high below 9,000 feet. However, warmer than average temperatures in recent years appear to have allowed beetles to be more successful at higher elevations. Ground and aerial surveys in 2003 and 2004 have identified robust MPB populations at elevations above 10,500 feet. A 2004 study near Fraser, CO showed that MPB emergence trends did not differ significantly between elevations of 8,760, 9,200, and 9,900 feet (Tishmack *et al*. in preparation). The author's suggest that the upper elevation for the highly susceptible category should be raised to $\geq$ 10,000 feet. Close proximity of MPB populations also increases the risk for tree mortality in susceptible stands (Shore and Safranyik 1992). An extensive and severe epidemic that began in the late 1990s in the William's Fork watershed has expanded towards the Upper Fraser Analysis Area from the west.

Studies in ponderosa pine (*Pinus ponderosa* Dougl. ex Laws) indicate that tree densities above 120 sq. feet of basal area per acre are also more favorable to MPB than are less dense stands (Schmid and Mata 1992). The 120 sq. ft. basal area threshold may also be pertinent in lodgepole pine stands. A multi-year study in lodgepole pine found greater losses in stands thinned to 120 sq. ft. basal area and in unthinned control plots compared to stands thinned to 100 or less sq. ft. basal area per acre (McGregor *et al*. 1987).

Outbreaks of MPB tend to occur at intervals of fifteen to twenty years in older Rocky Mountain lodgepole pine forests and may last for six to ten years (Cole and Amman 1980). Schmid and Mata (1996) write "an epidemic may last several

years in a particular stand whereas the epidemic as part of a drainage may last for ten or more years."

Between outbreaks, low level populations referred to as endemic populations persist by selecting weakened or damaged trees, but no such selection is evident during epidemic populations (Furniss and Carolin 1977). Endemic MPB populations are usually associated with single trees that are lightening-struck or diseased, cohabitating therein with other scolytids such as *Ips* (Schmid and Mata 1996). Finding infested trees when populations are endemic can be difficult. Lessard (1982) made the assumption in his study of MPB in the Black Hills ponderosa pines that fewer than one tree per acre is considered an endemic population. He described a building population as greater than one tree per acre and less than 10% of the stand infested over a three year period and an epidemic as greater than 10% of the stand infested over a three year period. Cole and Amman (1980) in a more detailed study of the course of a MPB infestation in lodgepole pine described an endemic population as having less than half a tree per acre infested, a building outbreak as having between one half and five infested trees per acre and an outbreak as having more than five infested trees per acre. Once an epidemic is underway, most large trees in the outbreak area may be attacked (Cole and Amman 1980).

Smaller diameter and younger trees in and near outbreaks may be attacked and killed, but small trees alone are not capable of sustaining an outbreak (McGregor and Cole 1985). Stands having a high proportion of large diameter trees with thick phloem are most likely to be infested and will suffer proportionately greater losses (Amman *et al*. 1977). Stress factors, such as current drought conditions, may contribute to stand susceptibility, but the exact triggering mechanism of MPB outbreaks is not known. MPB epidemics do not require a landscape disturbance, such as fire or windthrow to be initiated or to spread. When factors favorable to MPB population increases coincide with host susceptibility, beetle outbreaks can result.

The course of MPB epidemics have been altered by extremely adverse weather conditions. The very cold winter of 1984 -1985 is reported to have contributed to the collapse of a MPB epidemic that began in 1980 in Grand County, Colorado (Lessard *et al*. 1987). An unpublished study (Wygant 1938) determined critical low temperature ranges for MPB larvae at different months of the year. The study did not consider the insulating effect of the bark or the duration of the cold temperatures but does shed some light on the seasonal cold hardiness of MPB. During the winter months of December, January and February, larvae taken from lodgepole pine began dying when temperatures went below -20º F, 50 % were dead at - 29º F and there was 100% mortality when the temperature dropped below - 36º F. Critical temperature varied incrementally in the fall and spring months.

Current Situation

The Upper Fraser Analysis Area is located on the Sulphur Ranger District of the Arapaho-Roosevelt National Forests and Pawnee National Grassland west of Hwy 40 between Winter Park and Tabernash. It includes NFS, BLM, Fraser Experimental Forest, and State and private lands in the St. Louis Creek, Crooked Creek, Elk Creek, Vasquez Creek and Little Vasquez Creek watersheds. Elevation ranges from 8,600 to over 12,000 feet. Lodgepole pine and scattered aspen dominate the forested areas in the lower elevation range and Englemann spruce and subalpine fir are found on the wetter, north and east facing aspects and higher forest sites (Figure 1 a.). The proposed treatment areas are dominated by lodgepole pine forests (Figure 1 b.).

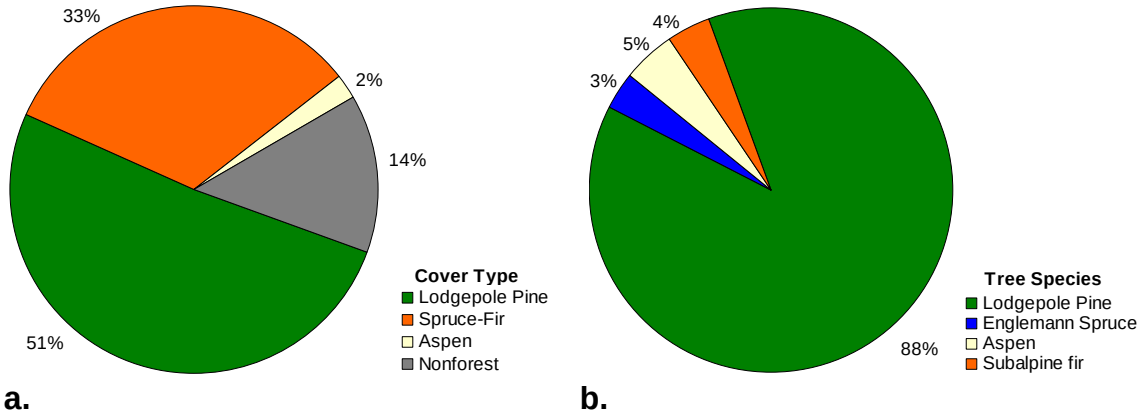

Figure 1. a. Tree species distribution within the Upper Fraser Analysis Area based on stand exam data provided by the Sulphur Ranger District. b. Tree species distribution in VR plots sampled by LSC-FHM personnel in the proposed treatment areas in the Upper Fraser Analysis Area.

Aerial survey detected tree mortality from MPB in the Upper Fraser Analysis Area beginning in 2002 and a dramatic increase was seen in 2003 and 2004. Much of the current beetle activity is occurring in moderately and highly susceptible lodgepole pines stands based on tree size and density. There is potential for this MPB epidemic to affect contiguous lodgepole pine forests on National Forest, Bureau of Land Management, state and private lands.

The proposed action presents three alternatives for the Upper Fraser Analysis Area. Alternative 1 is a no action plan that will continue existing management strategies such as preventive insecticide application to high value trees on recreation sites and hazard tree removal. Alternatives 2 and 3 include a mix of

treatment activities designed to prevent and suppress the spread of MPB from currently infested lodgepole pines to uninfested lodgepole pines and to salvage dead and infested trees. Proposed treatments ranked by area for the alternatives are presented in Table 1 (Caissie 2004). Areas that are not currently infested but have a moderate to high risk for MPB infestation are proposed to be thinned to reduce the susceptibility to beetles. Alternatives 2 and 3 propose silvicultural treatments on approximately 2,400 acres within the Analysis Area. These two alternatives differ based on the amount of MPB-infested and killed trees at the time of implementation. Alternative 3 assumes a greater impact from MPB and includes more salvage clearcuts and regeneration of beetle-killed stands. Given the high numbers of beetles currently active in many of the proposed treatment areas, it is likely that treatments would focus on sanitation, salvage and stand regeneration.

Table 1. Silvicultural activity in proposed treatment alternatives in the Upper Fraser Analysis Area (Caissie 2004).

Treatment	Alternative 1 Acres	Alternative 2 Acres	Alternative 3 Acres
Clearcut	0	154	1,388
Sanitation-Salvage/ Thin	0	1,094	0
Sanitation/Salvage	0	75	75
Fuel Break/ Reduction	0	967	731
Spray/Hazard Tree Removal	114	114	114
Total	114	2,404	2,308

Purpose

This evaluation documents the current status of MPB in the Upper Fraser Analysis Area and discusses the proposed treatments to suppress MPB, prevent its spread to uninfested stands, and salvage areas already impacted.

Methods

Current MPB conditions for the Upper Fraser Analysis Area were estimated by aerial survey, strip samples, variable radius plot samples and available stand exam data.

Aerial Survey

Aerial surveys were conducted from a fixed wing single engine aircraft about 1,500 feet above the ground at approximately 100 miles per hour in August after infested trees began to fade. LSC-FHM personnel and the US Forest Service Region 2 Aerial Survey Program Manager performed the aerial surveys. Areas of lodgepole pine killed by mountain pine beetle were sketch mapped onto 1:100,000 scale USGS 30X60 minute topographic maps. Estimated tree mortality and acres affected by MPB across all land ownerships in the Upper Fraser Analysis Area were summarized for the past six years.

Stand Conditions

Proposed treatment areas within the Upper Fraser Analysis Area were determined by the Sulphur Ranger District based on management direction within the Arapaho & Roosevelt National Forests and Pawnee National Grassland Forest Plan.

LSC-FHM personnel surveyed 107.2 acres within 13.4 miles of 66 foot wide transects (strip samples) in ten of the proposed treatment areas designated by the Sulphur Ranger District (Figure 2). Strip samples recorded one year old MPB-killed trees and currently infested trees. Variable radius (VR) plots were sampled every one quarter mile or at least once per transect. A 10 basal area factor (BAF) prism was used to select trees in the plots and determine basal area. Species and dbh were recorded for all “in” trees at each plot and averaged for each strip sample (Appendix A).

Existing stand exam data were provided for proposed treatment areas by the Sulphur Ranger District. Plot data from stands at least 50% within the proposed treatment area boundaries were used to determine average age, diameter and basal area. Nine stands with a total of 676 acres and 70 variable radius plots met this criterion. Data were weighted by the area of the stand.

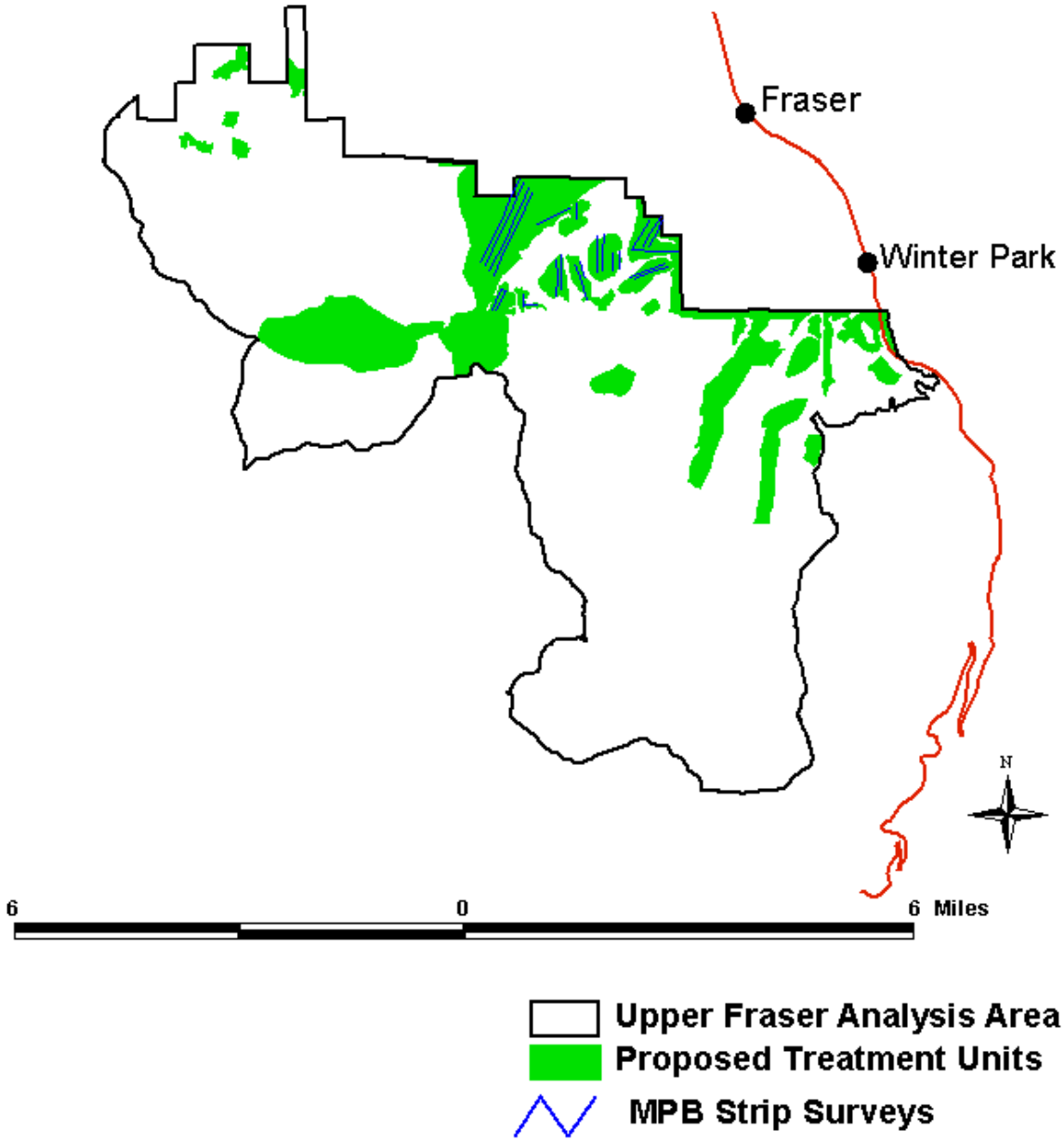

Figure 2. Proposed treatment units within the Upper Fraser Analysis Area and MPB strip samples. Proposed treatment areas for Alternatives 2 and 3 are within this area.

Results and Discussion

Aerial Survey

Aerial survey data provide only general trend information on pest activity because flying conditions and surveyors may vary from year to year. Aerial survey data indicate a rapidly increasing population for MPB throughout the Upper Fraser Analysis Area over the last several years (Table 2 and Figure 3). The area impacted by MPB detected from the air increased thirty-fold between 2002 and 2004. The estimated number of trees killed increased ninety-fold during the same period. Aerial survey only reports the trees attacked the previous year that have begun to discolor. It does not detect the currently infested trees. Ground surveys in the area indicate that MPB continued its explosive expansion in 2004.

Table 2. Aerial Survey results for Upper Fraser Analysis Area.

Year	Area Impacted by MPB* (Acres)	Estimated Number of Trees Killed by MPB*
2004	2934	8985
2003	1588	656
2002	98	99
2001	11	25
2000	15	12
1999	4	4
1998	12	28
1997	3	15
1996	<1	3

* Due to the nature of aerial survey these numbers are rough estimates and are presented only to show trends and not to be used in data analysis.

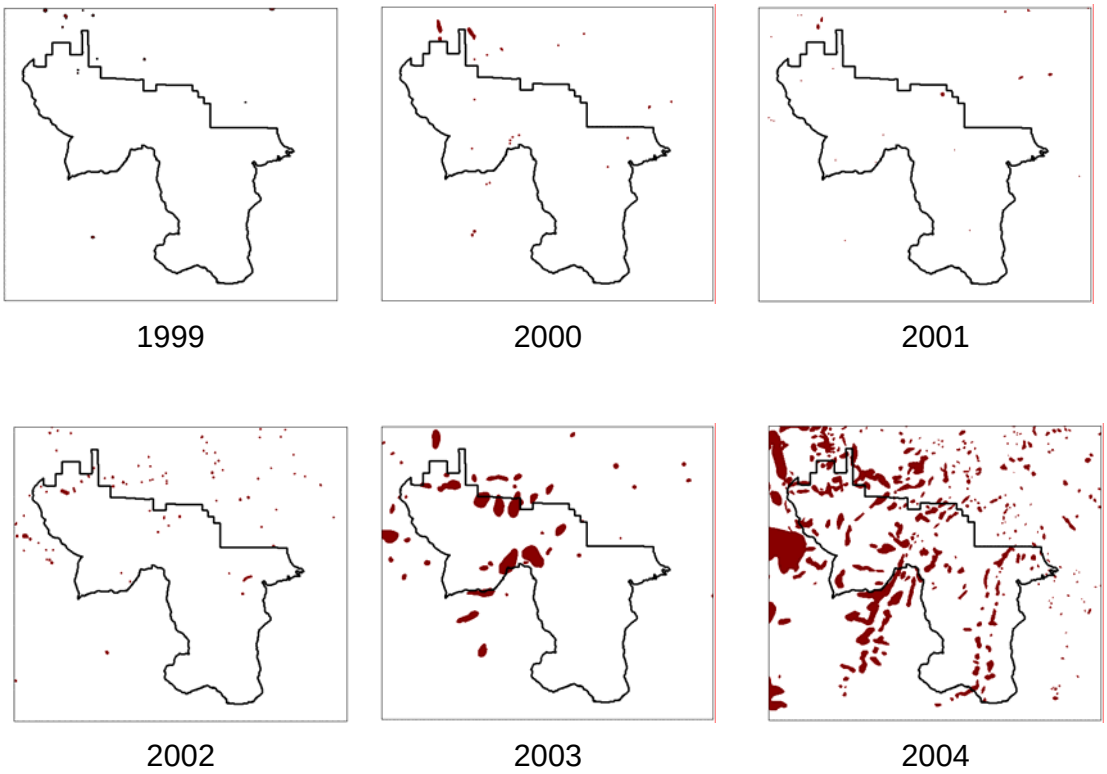

Figure 3. MPB activity detected by aerial surveys* conducted 1999-2004 over the Upper Fraser Analysis Area and adjacent lands.

***Disclaimer**: Due to the nature of aerial surveys, the data on this map will only provide rough estimates of location, and the resulting trend information. These data should only be used as an indicator of insect and disease activity, and should be validated on the ground for actual location and casual agent. Shaded areas show locations where trees were killed. Intensity of damage is variable and not all trees in shaded areas are dead. The data represented on this map are available digitally from the USDA Forest Service, R2 FHM. The cooperators reserve the right to correct, update, modify or replace GIS products. Using this map for purposes other than those for which it was intended may yield inaccurate or misleading results.

Stand Conditions

Stand data summarized from variable radius plots taken within the proposed treatment units by LSC-FHM personnel indicate current stand conditions are favorable for continued losses to MPB. Amman *et al*. (1977) developed a risk rating system for classifying stand susceptibility for MPB epidemics based on average dbh, average age, and stand elevation and latitude (Table 3). Risk factors (1-3) are multiplied to obtain a stand's susceptibility classification (1-9 = low risk, 12-18 = moderate risk, 27 = high risk).

Table 3. Factors for determining stand susceptibility to MPB (Amman *et al* 1977).

Elevation at Lat. 40º		Average Age		Average DBH	
< 9,000 feet	(3)	> 80	(3)	> 8 inches	(3)
9,000 – 10,000 feet	(2)	60 – 80	(2)	7–8 inches	(2)
> 10,000 feet	(1)	< 60	(1)	< 7 inches	(1)

Beetle emergence studies conducted in 2004 by the Rocky Mountain Research Station suggest that the elevation component of this risk rating system may no longer be relevant (Tishmack *et al*. in preparation). Observations of current MPB outbreaks in northern Colorado in the William's Fork and Troublesome Creek watersheds also illustrate that elevation appears to be a poor indicator of stand susceptibility under higher than average temperatures seen in recent years. Stand mortality in susceptible size classes within these outbreak areas has approached 100% at elevations above 10,000 feet.

The weighted average dbh of lodgepole pine in the LSC-FHM sample is 8.42 inches (Table 4) and the unweighted average is 8.46 inches (Appendix A). Seventy-one percent of the lodgepole pines sampled by LSC-FHM are over 8 inches in diameter (Figure 4). Available stand exam data are limited and indicate that most of the stands are greater than 60 years old (Table 4) and many are over 80 years old. Most stands are at or above 9,000 feet and would be rated moderately susceptible to MPB outbreaks based on elevation. However, given the recent observations of severe infestations at high elevation (Tishmack *et al*. in preparation) it is likely that the influence of elevation is not significant under recent climate conditions.

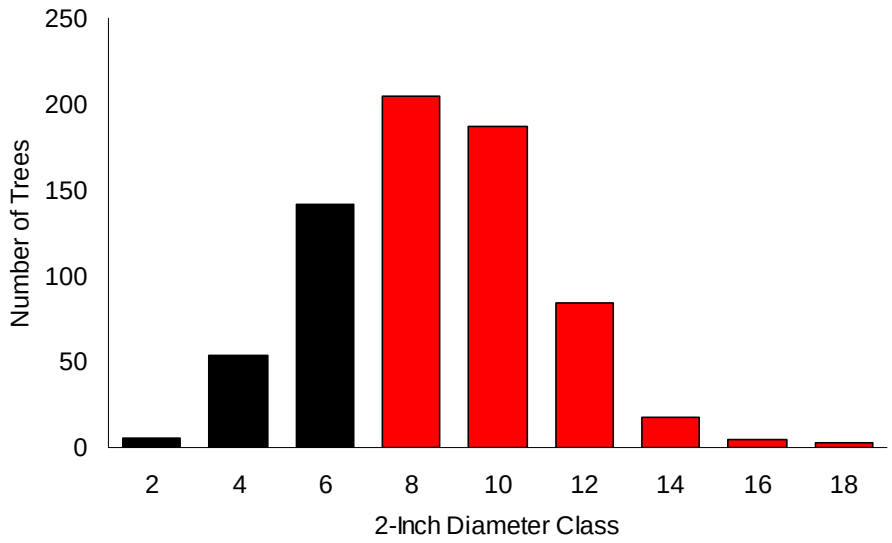

Figure 4. Distribution of lodgepole pine diameter in 50 VR plots sampled by LSC-FHM staff in the Upper Fraser Analysis Area.

Table 4. Stand data by source for the Upper Fraser Analysis Area.

Data Source	Number of Variable Radius Plots	Average DBH of Lodgepole Pine (Inches)	Average Age of Lodgepole Pine (Years)	Average Basal Area of All Species (Sq. Ft./Ac)
LSC-FHM Variable Radius Plots (10 BAF)	98	8.42*	Not collected	155*
Available Stand Exam Data (includes stands partially out of the proposed treatment areas)	70	9.27	67.4**	209**

*Averages were determined by weighting the mean for individual proposed treatment area data based on the percent of acreage each treatment area occupied of the total acres of all proposed treatment areas surveyed.
**Averages were determined by weighting the mean for individual stand data based on the percent of acreage each stand occupied of the total acres of all stands considered.

Stand basal areas can also be an indicator of susceptibility to MPB. Basal areas above 120 sq. ft. per acre have been shown more likely to be attacked by MPB in ponderosa pine stands (Shmid and Mata 1992) and there are studies that indicate the same may be true for lodgepole pine stands (McGregor *et al*. 1987). Basal area data collected by the LSC-FHM in the Upper Fraser Analysis Area averaged 166 with 84 % of the VR plots above the 120 sq. ft./ac critical threshold (Figure 5).

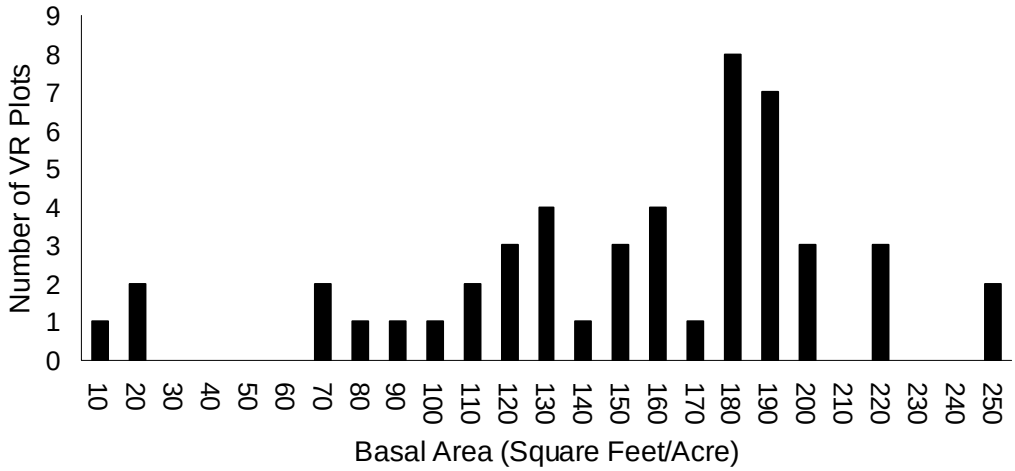

Figure 5. Distribution of basal area/acre within 50 variable radius plots sampled by LSC-FHM personnel. Stands with basal areas above 120 sq. ft./acre are considered at greater risk to MPB infestation than are less dense stands.

Close proximity of MPB populations also increases the risk for tree mortality in susceptible stands (Shore and Safranyik 1992). A mountain pine beetle epidemic in the Williams Fork watershed to the west has expanded over the mountain passes into the Upper Fraser Analysis Area.

MPB Ground Survey

Ground surveys provide an estimate of currently infested and recently killed trees. A comparison of the numbers of trees infested from year to year expressed as a ratio indicates whether a population is increasing, decreasing, or static and how quickly it may change. Cole and Amman (1980) measured MPB infestations in Forest Service Regions 2 and 4 and described the following pattern of an outbreak that is helpful for determining the current status of an

infestation based on ground survey data. Infested trees numbered from 0.5 to 5.0 trees per acre in the early years of an outbreak, increased to as many as 26 to 31 trees per acre during the peak of an outbreak, and declined to 2 to 3.5 trees per acre following the peak of an outbreak. Cole and Amman (1980) found that most of the large diameter trees were killed by the time the outbreak subsided. They also report that an epidemic averages six years to run its course in a given stand but emphasize that once infestations build up, a large amount of immigration may occur. This leads to more rapid tree losses and shorter epidemic periods in adjacent stands. Immigration of beetles from the infestation that began in the Williams Fork drainage, as well as the movement of beetles from outbreaks already present within the Analysis Area, will continue the rapid spread to susceptible stands.

LSC-FHM staff surveyed ten proposed treatment units in the Upper Fraser Analysis Area (Figure 6). Infestation levels within the proposed treatment areas surveyed varied from 3 new infested trees per acre on a 12 acre sample to 68.25 infested trees per acre on one 4 acre strip sample (Table 5 and Appendix A).

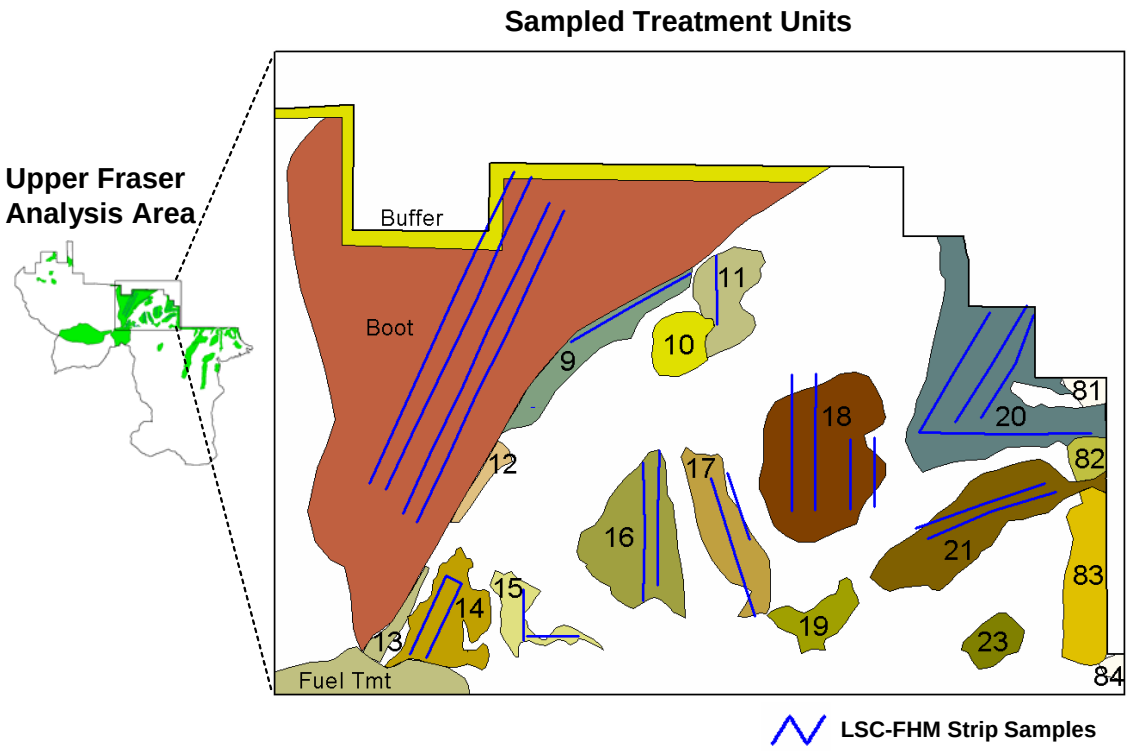

Figure 6. Location of proposed treatment units sampled by LSC-FHM personnel.

Table 5. Summarized survey results for proposed treatment units sampled by LSC-FHM personnel (Appendix A). Unit locations are shown in Figure 10.

Unit Designation	Size of Unit (Acres)	Acres Surveyed	2004 Infested Trees/Acre	2004:2003 Attack Ratio
Boot	893	40	12.0	4.7:1
9	47	4	29.0	3.8:1
11	41	4	68.2	5.5:1
14	56	6	43.0	10.75:1
15	24	3	8.3	8.3:0
16	89	8	13.0	4.3:1
17	56	6	3.8	1.43:1
18	136	12	3.1	3.1:1
20	176	17	18.7	4.4:1
21	98	8	3.7	3.3:1

Based on the course of an infestation described by Cole and Amman (1980), LSC-FHM survey data in the Upper Fraser Analysis Area indicate that an outbreak is underway in most of the areas sampled (Figure 7). Strip samples reveal the beetle populations are increasing rapidly. There is an average of 15.28 currently infested trees per acre and ground data show nearly a five-fold increase in infested trees from 2003 to 2004 (Table 6). Beetle pressure on susceptible lodgepole pine throughout the area will continue to be high. Some proposed treatment units may lose most of the larger diameter trees within two to three years, assuming the infestation continues at the current level.

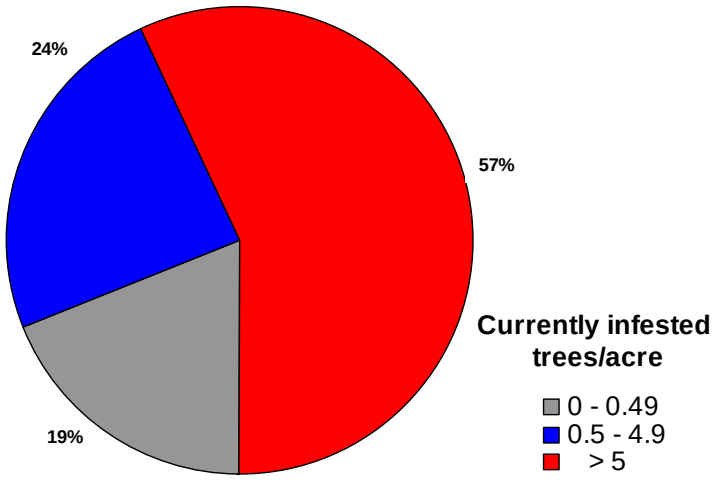

Figure 7. Percentage of 53 MPB monitoring transects established in the Upper Fraser Analysis Area by the LSC-FHM staff that fall within three current MPB-infested trees per acre classes as described by Cole and Amman (1980).

Table 6. Upper Fraser Analysis Area summary of strip samples and the 2004:2003 MPB attack ratio (Appendix A).

Data Source	**LSC-FHM**
Acres Surveyed	107.2
New (2004) Infested Trees	1638
Old (2003) Infested Trees	337
New Infested Trees per Acre	15.28
Old Infested Trees per Acre	3.14
Ratio 2004:2003	4.86

Conclusion

LSC-FHM personnel surveyed 107 acres of the Upper Fraser Analysis Area within 10 of the areas proposed for treatment by the Sulphur Ranger District. A rapidly expanding MPB infestation is present in all of the treatment areas sampled. Because the proximity of infested to uninfested trees is a factor in the short term risk to a given stand of trees (Shore and Safranyik 1992), MPB will likely have a significant impact on all susceptible lodgepole stands within this area.

Because outbreak MPB populations already exist in many parts of the Analysis Area, direct suppression through removal of infested trees before beetle emergence in July should be considered a priority. Logs can be hauled to sawmills where milling will kill the beetles or to “safe sites” at least one mile away from host trees susceptible to the emerging beetles. If infested logs are left in or near developed recreation sites, direct suppression of the beetles will be necessary to reduce the threat to uninfested trees. Treatment strategies to kill the beetles before emergence include debarking, chipping, burning, burying, or solar treating. Ultimately, a mosaic of age classes across the braoder landscape should be the most successful means of reducing dramatic tree losses to MPB in future outbreaks

Where lodgepole pine mortality due to MPB is currently low to moderate, silvicultural strategies to reduce stand susceptibility by thinning stands to below 100 sq. ft. of basal area per acre and reducing the average tree diameter to less than 8 inches may help prevent outbreak populations from building in treated stands (McGregor *et al*. 1987; Amman 1989). Reducing basal area to between 60 and 80 sq. ft. per acre will increase the length of time that stands are resistant to MPB attack. Stands cut to 60 basal area per acre should remain relatively unsusceptible for about 50 years, those cut to basal area 80 for about 25 – 30 years, and those cut to 100 for about 11 to 15 years (Schmid and Amman 1992). Partial cutting lodgepole pine stands presents risk of losing additional trees to windfall and intensifying dwarf mistletoe infection present within the stands. These concerns should be addressed before partial cutting to reduce MPB impacts.

Detailed alternatives and considerations for managing MPB impacts are provided in Appendix B.

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Appendix A

UPPER FRASER ANALYSIS AREA MPB SURVEY SUMMARY DATA

Page 1

Unit	TRANS/VR PLOT	SURVEYED ACRES	NEW MPB HITS/ACRE	OLD MPB HITS/ACRE	NEW/ OLD	MEAN TOTAL BA	MEAN PICO BA	MEAN PICO DBH	MEAN SPRUCE BA	MEAN SPRUCE DBH	MEAN ASPEN BA	MEAN ASPEN DBH	MEAN SUBALPINE FIR BA	MEAN SUBALPINE FIR DBH
Upper Fraser	Analysis area summary	107.20	15.28	3.14	4.86	165.83	153.12	8.46	6.06	10.97	7.97	7.10	6.16	9.38
Boot	T1/1					200	130	10.5	10	5.6	60	7.5	0	
Boot	T1/2					180	90	8.9	0		50	8.9	40	7.2
Boot	T1/3					130	110	8.8	10	10.5	0		10	5.7
Boot	T1/4					70	70	9.5	0		0		0	
Boot	T1/5					80	60	11.5	20	10.5	0		0	
Boot	T2/1					70	70	7.0	0		0		0	
Boot	T2/2					130	130	6.5	0		0		0	
Boot	T2/3					150	110	9.0	30	14.2	0		10	2.5
Boot	T2/4					180	180	6.8	0		0		0	
Boot	T2/5					120	120	9.0	0		0		0	
Boot	T3/1					120	100	9.9	0		20	7.1	0	
Boot	T3/2					200	0	0.0	10	21.8	150	7.8	40	11.7
Boot	T3/3					190	180	9.5	0		10	4.7	0	
Boot	T3/4					130	130	8.5	0		0		0	
Boot	T3/5					180	180	5.5	0		0		0	
Boot	T3/6					20	20	8.4	0		0		0	
Boot	T4/1					220	220	7.3	0		0		0	
Boot	T4/2					120	120	9.7	0		0		0	
Boot	T4/3					160	30	14.8	40	14.9	40	8.4	50	11.2
Boot	Summary	40.00	12.00	2.55		139.47	107.89	8.41	6.32	13.43	17.37	7.85	7.89	9.31
9	T1/1					190	190	11.1			0	0		
9	T1/2					130	110	11.7			20	6.3		
9	Summary	4.00	29.00	7.50		160.00	150.00	11.32			10.00	6.30		
11	T1/1					190	190	7.9						
11	Summary	4.00	68.25	12.50		190.00	190.00	7.90						
14	T1/1					90	80	7.7	0	0			10	4
14	T1/2					220	190	8.6	10	8.6			20	6.4
14	T1/3					180	160	8.6	0	0			20	8.0
14	Summary	5.50	43.09	4.18		163.33	143.33	8.40	5.10	8.60			11.38	6.56

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Unit	TRANS/VR PLOT	SURVEYED ACRES	NEW MPB HITS/ACRE	OLD MPB HITS/ACRE	NEW/ OLD	MEAN TOTAL BA	MEAN PICO BA	MEAN PICO DBH	MEAN SPRUCE BA	MEAN SPRUCE DBH	MEAN ASPEN BA	MEAN ASPEN DBH	MEAN SUBALPINE FIR BA	MEAN SUBALPINE FIR DBH
15	T1/1					200	170	8.9	10	5.1			20	7.2
15	T2/2					160	160	7.2	0	0			0	0.0
15	Summary	3.00	8.33	0.00		180.00	165.00	8.07	5.00	5.10			10.00	7.15
16	T1/1					190	180	8.4	10	11.4			0	0.0
16	T1/2					180	140	7.2	20	11.2			20	17.4
16	T2/1					180	180	6.8	0	0			0	0
16	T2/2					180	180	8.1	0	0			0	0
16	Summary	8.00	13.00	3.00		182.50	170.00	7.64	7.50	11.23			5.00	17.40
17	T1/1					190	190	6.4					0	0
17	T1/2					180	180	7.9					0	0
17	T2/1					100	100	9.0					0	0
17	T2/2					10	0	0					10	7.5
17	Summary	6.00	3.83	2.67		120.00	117.50	7.53					2.50	7.50
18	T1/1					150	130	10.9	20	15.3			0	0
18	T1/2					190	190	8.3	0	0			0	0
18	T2/1					150	150	9.5	0	0			0	0
18	T2/2					170	120	7.4	40	4.1			10	10.3
18	T4/1 no T3/1					190	180	7.7	0	0			10	12
18	Summary	12.00	3.08	1.00		170.00	154.00	8.70	12.00	7.85			4.00	11.15

UPPER FRASER ANALYSIS AREA MPB SURVEY SUMMARY DATA

Page 3

Unit	TRANS/VR PLOT	SURVEYED ACRES	NEW MPB HITS/ACRE	OLD MPB HITS/ACRE	NEW/ OLD	MEAN TOTAL BA	MEAN PICO BA	MEAN PICO DBH	MEAN SPRUCE BA	MEAN SPRUCE DBH	MEAN ASPEN BA	MEAN ASPEN DBH	MEAN SUBALPINE FIR BA	MEAN SUBALPINE FIR DBH
20	T1/3					250	220	6.8	10	18.1	0	0	20	9.0
20	T2/1					160	150	8.9	10	15.3	0	0	0	0
20	T2/2					160	140	8.0	0	0	10	6	10	9.7
20	T3/1					220	220	8.5	0	0	0	0	0	0
20	T3/2					250	250	8.3	0	0	0	0	0	0
20	Summary	16.70	18.74	4.25		208.00	196.00	8.08	4.00	16.70	2.00	6.00	6.00	9.20
21	T1/1					140	120	9.2	10	13.9	0	0	10	14.8
21	T1/2					200	200	7.4	0	0	0	0	0	0
21	T2/1					130	130	9.2	0	0	0	0	0	0
21	T2/2					110	100	10.5	0	0	10	6	0	0
21	Summary	8.00	3.75	1.13		145.00	137.50	8.77	2.50	13.90	2.50	6.00	2.50	14.80

Appendix B

Action Alternatives for Managing Mountain Pine Beetle Impacts in Lodgepole Pine Stands

USDA Forest Service, Region 2 Forest Health Management

Management Alternatives

Several actions are available to reduce pine mortality due to attack by mountain pine beetle (MPB), *Dendroctonus ponderosae* Hopkins (Order Coleoptera; Family Scolytidae). Reduction of MPB-caused tree mortality can be accomplished by management of host stand conditions (indirect actions) or by management of the MPB population (direct actions). Suppression of large-scale MPB epidemics is hypothetically possible, especially during the early phase of an epidemic, but it is unlikely due to the major physical and financial commitment required. Prevention should be emphasized where MPB impacts are undesirable. The only strategy is to alter stand conditions to be less susceptible to mortality from MPB. Once undesirable MPB-caused mortality has begun, the intent of forest management should be to reduce adverse impacts to affected areas and minimize spread to adjacent stands. The decision to take a particular action(s) should be based on management objectives, economic factors, MPB population status and trends, stand conditions, location, resource values at risk, and other relevant issues. Consideration of MPB in the context of overall land management is important. Focusing on MPB alone may amplify other problems, such as dwarf mistletoe infestation (Hawksworth and Johnson 1989). One or a combination of the following action alternatives may be useful in most situations.

Alternative 1: No Action

The “No Action” alternative accepts MPB-caused tree mortality and associated impacts as a natural phenomenon. As a native insect, MPB has been active for thousands of years and is one of the most important biotic causes of pine mortality across the West (Amman *et al*. 1989). MPB populations increase and decrease without obvious direct human influence but some human activities may benefit the beetle. Fire suppression has helped create stand conditions that are more susceptible to MPB infestation. Construction injury to trees from home and road building can contribute to MPB survival by creating susceptible trees near MPB-infested trees and thereby decrease dispersal-related beetle mortality. Epidemics of MPB have many ramifications in addition to the creation of dead pine trees (Schmid and Amman 1992). These impacts vary depending upon the extent, intensity, and duration of the MPB epidemic.

Where to use – Use where other alternative actions are not desired, cannot be implemented or will not be effective. One example may be designated wilderness areas.

Advantages – No mechanical site disturbance or introduction of foreign materials into the environment will occur. Understory vegetation may prosper. From extensive and intense MPB epidemics, water yield and possibly annual stream flow will increase for a time interval before stands regenerate (McGregor and Cole 1985). Tree regeneration may be facilitated by increased sunlight reaching the forest floor. Changes in vegetation and cover may be advantageous to certain wildlife species, particularly those that utilize dead trees. Successional trends may benefit management objectives. Some people will prefer the decision to let nature take its course. Resources could be redirected to managing uninfested stands to minimize future MPB impacts.

Disadvantages – The "no action" alternative means no silvicultural or chemical activity will be undertaken to change a stand's resistance to MPB population increase and spread. Dead trees can become safety hazards over time as they rot and fall. Timber values are reduced or lost. Increased stream flow could affect stream bank stabilization. MPB epidemics may adversely affect visual quality by creating large numbers of dead and dying trees. The presence of fallen trees may affect travel and recreation within affected stands. Fire hazard and ignition potential will be increased during the period when dry needles are present on recently killed pines and there will be increased heavy fuel buildup after dead trees fall to the ground (Cole and Amman 1980). Regeneration may be inhibited due to loss of seed source in severe widespread epidemics, the covering effect of dead fallen trees, and lack of seedbed preparation. Changes in vegetation and cover may not be advantageous to certain wildlife species. Successional trends may not meet management objectives. Public sentiment may be unfavorable, even in situations where a MPB epidemic cannot be stopped by direct action. The aforementioned disadvantages may be compounded in settings like the wildland-urban interface, where some management response is warranted.

Alternative 2: Silvicultural Treatment

Silvicultural prescriptions improving stand health, enhancing tree growth, and increasing tree spacing will reduce or prevent MPB-caused tree mortality (Amman 1989; Schmid and Mata 1992). The most recommended long-term tactic to minimize losses to MPB is to partially cut susceptible stands or harvest and subsequently replace susceptible stands. Removal of individual pines of low vigor and poor health will lessen the chance of a MPB outbreak. Lodgepole pine stands at high risk to MPB are those at lower elevation-latitudes where average

tree diameter exceeds 8 inches and average tree age exceeds 80 years (Amman *et al*. 1977). Favorable conditions for MPB in ponderosa pine stands are those where average tree diameter is greater or equal to than 8 inches and basal area is greater than or equal to 120 square feet per acre (Schmid and Mata 1992). The 120 sq. ft. basal area threshold may also be pertinent in lodgepole pine stands. Studies in lodgepole pine found greater losses in stands thinned to 120 sq. ft. basal area and in unthinned control plots compared to stands thinned to 100 or less sq. ft. basal area per acre (McGregor *et al*. 1987). Partial cutting that reduces stands to 60 - 80 square feet of basal area per acre or less and average tree diameter to below 8 inches reduces stand susceptibility to MPB. When partially cutting susceptible stands, care must be taken to avoid leaving dense pockets of mature pines, because these areas can serve as foci for MPB attack (McGregor *et al*. 1987).

The risk of windfall must also be considered when partially cutting lodgepole pine stands but is usually not a problem in ponderosa pine stands. Soil depth and stand density contribute to wind firmness as does stand exposure. Alexander (1972) describes windfall risk based on exposure as follows:

Low Windfall Risk Situations

1. Valley bottoms except where parallel to prevailing winds and all flat areas.
2. All lower and gentle middle north and east facing slopes.
3. All lower gentle middle south and west facing slopes that are protected by considerably higher ground not far to windward.

Moderate Windfall Risk Situations

1. Valley bottoms parallel to the direction of prevailing winds.
2. All lower and gentle middle south and west facing slopes not protected to the windward direction.
3. Moderate to steep middle and all upper north and east facing slopes.
4. Moderate to steep middle south and west facing slopes protected by considerable higher ground not far to windward.

High Windfall Risk Situations

1. Ridgetops.
2. Moderate to steep middle south and west facing slopes not protected to the windward, and all upper south and west facing slopes.
3. Saddles on ridgetops.

Windfall risk is increased in the above situations by poor drainage, shallow soil and defective roots and boles

Acceptable cutting methods recommended to reduce a stand's risk to MPB include commercial thinning, shelterwood cutting, and overstory removal. Seed tree cuts can work with ponderosa pine but generally should not be considered for lodgepole pine due to the likelihood of windfall. Seed tree cuts that are part of a two- or three-step shelterwood cut and are instigated after one or two partial cuts may be more windfirm and could be considered in lodgepole pine stands. In lodgepole pine stands that are lightly infested with MPB, all trees that are attacked may be removed along with the most susceptible trees without going below standard basal area prescriptions. Heavily infested stands can be addressed with greater partial cuts in ponderosa pine but are generally not advised in lodgepole pine stands because of windthrow problems.

Clearcutting is also a useful tool to create conditions favorable to regenerating lodgepole pine and converting mature stands to younger stands. Block or patch cutting within extensive areas of pure even aged stands of lodgepole pine can reduce the potential for MPB epidemics by reducing the area likely to be infested at one time. In addition, clearcutting is generally preferable to partial cutting in lodgepole stands that are understocked or heavily infested by dwarf mistletoe (Alexander 1974). Partial cutting is not recommended where the stand dwarf mistletoe rating is above 3 (Hawksworth and Johnson 1989).

Where to use – Partial cutting is a preventive treatment that addresses long-term tree and stand health. It should be incorporated into land management activity wherever MPB impacts are considered undesirable or are to be minimized. It is particularly important where timber values are the highest priority. It can also be used in and around campgrounds, and in wildland/urban interface areas.

Advantages – Silvicultural treatment reduces the susceptibility of trees to MPB attack and has been shown to limit pine mortality from MPB in forest stands (Amman and others 1977). While this alternative does not guarantee immunity from MPB infestation, it enhances tree growth and decreases susceptibility to MPB infestation. Cutting green trees prior to MPB infestation maximizes economic return from timber resources, because MPB-killed trees are usually less valuable. If applied on a landscape scale, silvicultural treatments could result in a mosaic of stand susceptibility to MPB, which may reduce the development of large-scale MPB epidemics. Silvicultural treatments may allow managers to manipulate the landscape to meet management objectives better than what might be achieved through MPB epidemics and stand replacing fires. Silvicultural treatments in combination with fuels mitigation yield multiple resource benefits.

Disadvantages – This action is not suitable for areas where tree cutting is undesirable, unaffordable or prohibited. Examples of such areas may include wilderness, steep slopes, and where the visual quality of cut areas

would be less than that of dead trees. Silvicultural activities are not possible in areas where timber harvesting firms do not exist. There are varying opinions about whether cutting during the beetle flight period may attract beetles to an area and exacerbate the problem. Fresh cut logs and stumps emit volatile compounds such as myrcene, alpha-pinene, and terpinolene which have shown a weak attractiveness to MPB. For large landowners, the forest health benefits ought to outweigh an increased risk of MPB infestations.

Alternative 3: Sanitation and Salvage Harvesting

Sanitation harvesting is a treatment applied to currently infested pine stands. Green trees with immature MPB developing under the bark are cut and removed to an area at least one mile from susceptible pines or processed at a mill prior to MPB emergence. Sanitation must be completed prior to July, when MPB emerges, to be effective. Salvage harvesting is the cutting of MPB-killed trees from which the beetles have emerged and are no longer present. Salvage does not reduce MPB populations but is commonly done in conjunction with sanitation.

Where to use – Stands that are currently under attack where reduction of the MPB population and recovery of timber resource values is desirable and where timber harvesting activity is acceptable. Especially appropriate are infested stands in proximity to uninfested, susceptible high value stands where mortality from MPB would threaten land management objectives. Sanitation could also be used concurrently with silvicultural treatment in stands where the MPB population has not yet reached epidemic levels. Sanitation harvests also are appropriate for private landowners, the wildland/urban interface and developed recreation sites.

Advantages – MPB populations can be significantly reduced by removing most or all infested trees prior to the emergence of the next generation of beetles. Sanitation provides a degree of protection to surrounding, uninfested trees and stands by removing a nearby source of beetles. Timber value could be recovered that would otherwise be lost. Initial increased fire potential from dead trees holding dry needles is reduced and future fire danger from heavy fuels created by dead and down trees is reduced. The visual impact of dead and dying trees is reduced. The hazard from falling trees is lowered. Pine regeneration will be encouraged by both the site disturbance and the reduction in shade. Sanitation cutting combined with partial cutting to include susceptible trees along with infested trees can potentially suppress outbreaks.

Disadvantages – Trees must be removed before MPB emergence. Sanitation/salvage harvesting has not been demonstrated to suppress MPB populations on a scale larger than the individual stand, although this

may occur in some cases. It should not be considered an effective control tactic across large landscapes or during severe MPB epidemics where MPB immigration into treated stands is likely. Sanitation/salvage harvesting undertaken without additional considerations for stand health and survival can lead to residual conditions that have other significant problems, such as increased spread and intensification of dwarf mistletoe (McGregor and Cole 1985) or increased risk of wind fall. Tree removal may not be aesthetically acceptable in some areas. Adverse site and soil disturbance may occur.

Alternative 4: Individual Infested Tree Treatment

Individual MPB-infested trees can be cut and treated in a variety of ways to kill and prevent beetle brood from emerging. Any action that kills most or all of the MPB within infested trees prior to MPB emergence falls under this direct control action alternative. **The following methods do not work in all situations and are not all supported by rigorous research results.** Examples of infested tree treatment techniques are: (1) Cut and burn on site; (2) Cut and bury at least 6 inches deep on site; (3) Cut and chip; (4) Cut and remove the bark from infested portions of logs before the immature MPB transform to adult beetles; (5) Cut and expose to direct sunlight such that the trunk surface receives sufficient heat to kill the beetles under the bark, rotating the trunk to ensure complete exposure (Negron *et al*. 2001); (6) Cut and cover with thick clear plastic such that the trunk surface receives sufficient heat to kill the beetles under the bark (Negron *et al*. 2001). It is important to check any treatment near the end of June before adult beetle emergence. Each of these methods needs to be completed before the MPB emergence period. Infested-tree treatments differs from sanitation harvesting (Alternative 3) because it is usually applied on a smaller scale and is often not conducted in conjunction with salvage harvesting.

Where to use – This alternative is most appropriate for treating small spots in areas of great concern, such as those adjacent to residences and within developed recreation sites. It may also be appropriate in unroaded areas, on slopes too steep to harvest with conventional methods, in areas where the disturbance from conventional harvest activity is unacceptable, and in areas where there is no possibility of sanitation/salvage harvesting due to insufficient volume, no bids or other reasons.

Advantages – Much of the immature MPB population can be eliminated from the treated area. Infested-tree treatment reduces risk to surrounding uninfested trees is reduced by removing a nearby source of beetles. This alternative may also provide time for silvicultural treatment to be implemented. The fire hazard from the presence of dead pines retaining dry needles is lowered. The visual impact of dead and dying trees is reduced. The subsequent hazard from falling trees is lowered. Pine

regeneration may be encouraged by the reduction of shade. Firewood may be recovered from this treatment.

Disadvantages – There is little time for implementation, because the developing MPB brood must be destroyed before the next emergence period in July. Localized beetle populations can be suppressed by this action, but it rarely reduces a stand's susceptibility to MPB attack. Additional follow-up treatments may be needed in subsequent years because it can be difficult to locate and treat all infested trees in an area. Infested trees may be inadvertently moved as firewood prior to MPB emergence, possibly spreading the infestation. Once beetle populations are increasing exponentially, it is difficult to effectively reduce beetle numbers. There is a very short window of time between discovery of a developing MPB population and initiating direct control measures. Direct control measures must be undertaken in suitable locations. Unsuitable locations include slopes with northern aspects and dense residual stands that will reduce the solar radiation enough not to kill the beetle brood. If solar treatments are not conducted properly, and the infested trees are moved as firewood to locations next to buildings, the risk of creating infested trees near structures is increased.

Alternative 5: Protection of High Value Trees

High value trees can be protected from MPB attack by spraying their boles with an EPA-approved insecticide prior to the MPB attack period.

Where to use – This action is appropriate for individual trees of high value in developed recreation sites, ski areas and the wildland/urban interface when there is a threat from active MPB populations in the vicinity. Because specialized equipment may be required, trees must be relatively accessible. This action is not effective for trees that are already infested by MPB.

Advantages – Controlled experiments and operational experiences have established this action as very effective in protecting individual pines from infestation. Specific formulations of carbaryl and permethrin are currently labeled for this use. Protection using carbaryl has been demonstrated to last from 10 - 18 months, meaning that a late spring application may afford two years of protection (Hastings and others 2001).

Disadvantages – Carbaryl and permethrin are toxic to insects other than MPB. Insecticide applied as protection does not effectively reduce the beetle population or address stand susceptibility to future MPB outbreaks. It does not guarantee absolute protection, especially if the application is not thorough and complete. Insecticide treatment can be very expensive,

especially if many trees require treatment. Potential environmental hazards exist from improper use, storage or disposal of chemicals and chemically treated wood. There may be a shortage of qualified pesticide applicators. Many citizens have concerns about environmental contamination and safety.

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