Biological Evaluation

R2-06-03

Biological Evaluation of Mountain Pine Beetle Activity in the Little Snake Analysis Area on the Hahns Peak/Bears Ears Ranger District, Medicine Bow – Routt National Forests and Thunder Basin National Grassland, 2006

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Abstract

Aerial survey of lodgepole pine mortality due to mountain pine beetle (MPB) has been noticeably increasing since 2002 in the Little Snake Analysis Area north of Steamboat Springs, CO, on the Medicine Bow-Routt National Forests and Thunder Basin National Grassland. The Hahns Peak/Bears Ears Ranger District is considering a variety of silvicultural treatments on approximately 698 acres of forest land to manage MPB impacts and to remove beetle-infested and killed trees in designated areas of the Little Snake Analysis Area.

MPB infestation levels and population trends were estimated by aerial and ground surveys. Ground survey data was collected using strip samples and variable radius plots. Hahns Peak/Bears Ears personnel surveyed 67 acres in 37 proposed treatment units. Ground surveys recorded the number of trees infested in 2004 and the number of MPB-killed trees in 2003. Stand susceptibility was evaluated by summarizing ground survey data and Hahns Peak/Bears Ears Ranger District stand exam data.

Summary results from aerial surveys of the Little Snake Analysis Area show a continuing increase in both the number of trees killed and the size of the infestation visible from the air since 2002. The estimated area affected by MPB-caused mortality increased from 94 acres in 2002 to 2,577 acres in 2003 and to 6,781 acres in 2004. The estimated number of trees killed increased from 173 in 2002 to 4,661 in 2003 and to 24,949 in 2004.

Ground survey data for the sampled units within the Little Snake Analysis Area indicate that the MPB infestation is increasing. The number of MPB-infested trees within the proposed treatment areas ranged from 0 to 87.9 newly infested trees per acre, with an average of 10.7 infested trees per acre in 2004. The average 2004:2003 ratio of the number of trees infested by MPB was 3.1:1, with as much as a tenfold increase in beetle-infested trees in some units from 2003 to 2004.

Average stand diameters, age, tree density and elevation indicate all stands in the proposed treatment units surveyed are moderately to highly susceptible to MPB outbreaks. Given the trend of increasing MPB activity and the concurrence of stand characteristics that favor MPB infestation, these units are likely to sustain significant losses. Management actions to address the MPB infestation in the Little Snake Analysis Area are discussed.

Introduction

Mountain pine beetle (MPB) (*Dendroctonus ponderosae* Hopkins) is a native insect that develops in many different pine species. In Colorado, the beetle can cause significant mortality of lodgepole pine (*Pinus contorta* Doug. ex Loud), ponderosa pine (*Pinus ponderosa* var *scopulorum* Engelmann), and limber pine (*Pinus flexilis* James). MPB outbreaks can kill millions of trees over large areas, 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 (McGregor and Cole 1985). Signs of infestation include cream to dark red-colored pitch tubes on the lower and mid-bole of trees where female beetles have entered. Trees successfully attacked by MPB will also have boring dust, like sawdust, in bark crevices and around the base of the tree. In the year after a successful infestation, tree needles will fade from green to yellow and then red before falling off the tree in subsequent years. Areas with large outbreaks are evident by the many discolored trees (McCambridge and others 1979).

Adult beetles, often described as bullet shaped, are one quarter inch long, cylindrical brown to black beetles. The insect has a one year life cycle, which maybe extended to two years at high elevations. Brood adult MPB leave the fading trees in the summer, usually in July. Female beetles initiate attack and produce aggregating pheromones that attract other beetles to the tree. This process is referred to as mass attack, where many beetles attack the same tree. Vertical egg galleries 6 to 30 inches long are constructed above the point of entry under the bark. Eggs are laid along the sides of galleries. Larvae hatch in a few days and feed on the phloem perpendicular to the egg gallery. Larvae mature the following spring and construct pupal cells at the end of the larval galleries where they transform into pupae and then into adults. Trees die due to the beetle's feeding and by introducing a complex of blue stain fungi (*Ceratocystis spp.*) that turns the sapwood grayish blue and blocks the water conducting xylem tissue.

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 mountain pine beetle epidemics (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, Bartos and Schmitz 1998). 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 percent of the stand infested over a three year period and an epidemic as greater than 10 percent 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 one-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).

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 and others 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 did 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 dropped below -20º F, 50 percent were dead at – 29º F and there was 100 percent mortality when the temperature dropped below – 36º F. Lethal temperatures were less in the fall and spring months and temperatures lower than 0º F can kill eggs (Reid and Gates 1970). Therefore, an early or late freeze can result in high MPB brood mortality.

Considerable work has been done in determining the potential for MPB to infest lodgepole pine stands. Susceptibility to MPB attack has been related to tree diameter, stand density, and elevation. Several studies have found that larger lodgepole pine trees are preferentially attacked before smaller trees (Amman and others 1977, Amman and others 1988a, Cole 1973, Mitchell and Preisler 1991). In the Mitchell/Preisler analysis, small trees were not attacked unless they were close to other trees being attacked (1991). Cole and Amman (1969) found that MPB losses in 4-inch diameter trees was 1 percent compared to losses of 87 percent in 16-inch and greater diameter classes. In diameter classes 8 inches and below, 20 percent of lodgepole pine trees were killed.

Various studies have linked increased stand density with higher mortality levels caused by MPB. The first thinning in lodgepole pine was done in Colorado in 1972 and involved removing large-diameter trees. Results demonstrated 1-2 percent losses in thinned stands compared to unthinned stands that sustained greater than 30 percent losses (Cahill 1972). Studies in ponderosa pine indicate that tree densities of 120 ft^2/acre and above of basal area per acre are also more favorable to MPB than are less dense stands (Schmid and Mata 1992). The 120 ft^2/acre basal area threshold may also be pertinent in lodgepole pine stands.

McGregor and others (1987) found MPB-caused tree losses were significantly less in partial cutting treatments (4.0 to 38.6 percent of trees) compared to unthinned check stands (73.1 to 93.8 percent of trees). These thinning treatments were based on a diameter limit cut, ≥10 and ≥12 inches removed, or a basal area per acre cut to 80, 100, and 120 ft^2/acre, and both types of thinning demonstrated reduced MPB losses. Only the 120 ft^2/acre treatment had larger losses of 38.6 percent. Spaced thinnings and diameter limit cuts on the Shoshone National Forest in Wyoming also resulted in decreased losses to MPB in thinned stands (Amman and others 1988b). The decrease in losses could be due to a different microclimate in thinned stands compared to unthinned stands (Amman and others 1988b, Bartos and Amman 1989, Waring and Pitman 1985).

Elevation is also known to affect MPB brood production. Tree survival from beetle infestation was found to be positively related to increasing elevation (Amman and others 1977). Furthermore, at high elevations up to two years can be required to complete beetle development. The elevation response is most likely due to cooler temperatures at higher elevations slowing beetle growth. 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 and others 2005).

Studies in lodgepole pine demonstrated that a close proximity of MPB populations also increases the risk for tree mortality in susceptible stands (Shore and Safranyik 1992). Stress factors, such as recent drought conditions, may contribute to stand susceptibility. For example, Shrimpton and Thompson (1983) found that the start of outbreaks coincided with reduced incremental growth rate, possibly due to climatic factors such as drought, 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 increase coincide with host susceptibility, beetle outbreaks can result and once an outbreak is started healthy trees are subject to attack.

Current Situation

The Little Snake Analysis Area is located on the Hahns Peak/Bears Ears Ranger District to the north of Steamboat Springs, CO, and west of the Sierra Madre Mountain Range (Figure 1). Proposed treatment unit elevations range from 8,500 to 9,200 feet and are dominated by lodgepole pine and spruce (*Pìcea englemánnii* Parry ex Engelm.). Proposed treatment units are predominantly lodgepole pine with intermixed spruce. Scattered aspen (*Populus tremuloides* Michx.) stands were also found in the Analysis Area.

Local conditions and prolonged drought in the area likely contributed to the expanding beetle population. Notable increases in MPB-caused mortality in lodgepole pine stands began in 2002 and epidemic populations developed within the Analysis Area over the next couple of years.

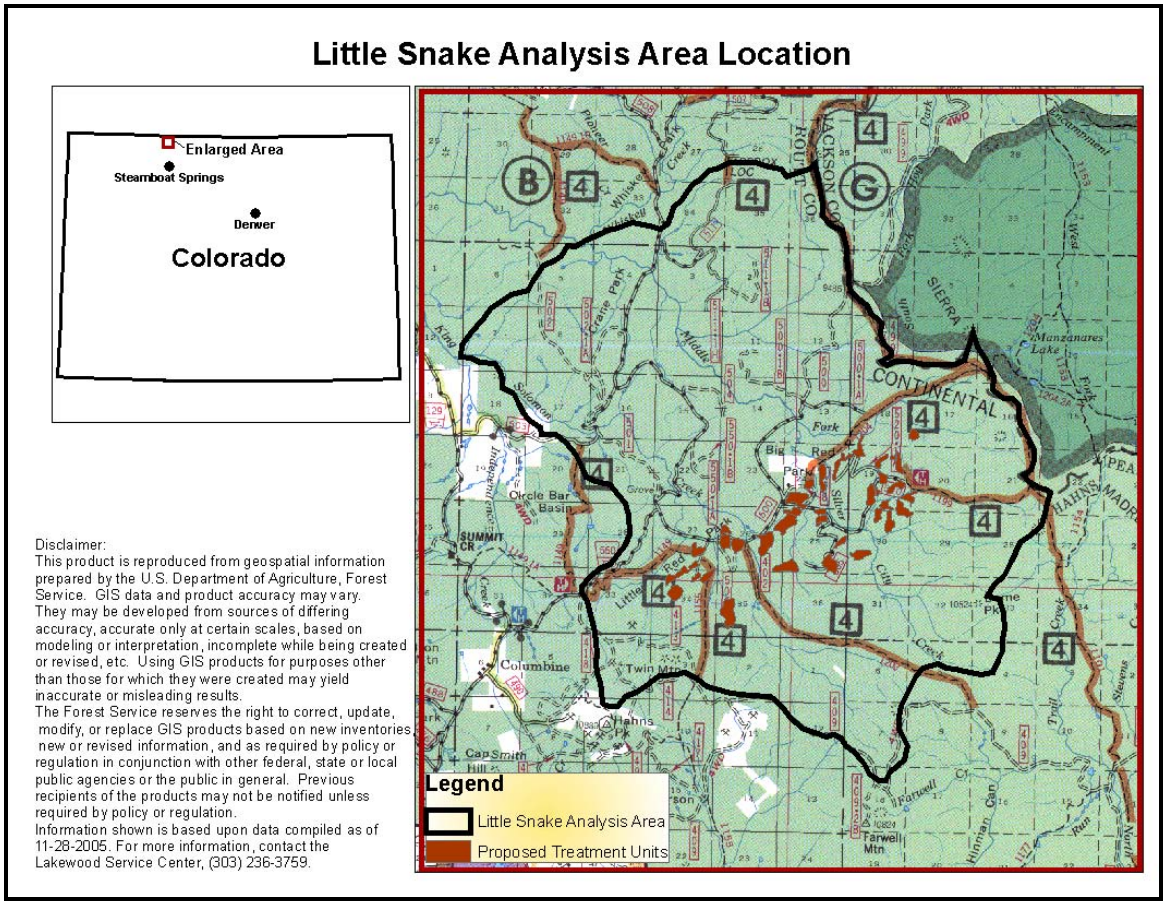

Figure 1. Location of proposed Little Snake Analysis Area treatment units.

The proposed action includes a mix of treatment activities on 698 acres designed to prevent and suppress the spread of MPB, to salvage dead and infested trees, and to reduce fuels (Table 1). Areas that were not infested in 2004, but have a moderate to high risk for MPB infestation will be thinned to reduce the susceptibility to beetles. Given the high numbers of beetles currently active in many of the proposed treatment areas, it is likely that treatments will focus on sanitation and salvage in these areas.

Table 1. Proposed management actions within the Little Snake Analysis Area.

Treatment	Estimated Acres
Sanitation Salvage	317
Clearcut	161
Commercial Thinning	109
2nd Step Cut Tree Marked	62
Cut Tree Marked	26
Overstory Removal	23
Total	698

Purpose

This evaluation documents the status of MPB on the Little Snake Analysis Area and discusses the proposed treatments for suppressing MPB, preventing its spread to uninfested stands, and salvaging areas already impacted.

Methods

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

Aerial Survey

Aerial survey was conducted from a fixed wing single engine aircraft about 1,500 feet above the ground at approximately 100 miles per hour in late summer 1999-2004 after infested trees began to fade. Aerial survey only reports the trees attacked the previous year that have begun to discolor. It does not detect currently infested trees. LSC-FHM personnel and the US Forest Service Region 2 Aerial Survey Program Manager performed the aerial survey. Areas of lodgepole pine killed by MPB and spruce killed by spruce beetle (*Dendroctonus rufipennis* Kirby) were sketch mapped onto 1:100,000 scale USGS 30X60 minute topographic maps and digitized into a GIS compatible format. The aerial survey results and discussion section includes data for both spruce beetle and MPB.

However, spruce beetle is not specifically addressed in this biological evaluation because none of the proposed treatment units include spruce stands.

Stand Conditions

Ground surveys were conducted in June 2005 by Hahns Peak/Bears Ears Ranger District personnel and covered 8.4 miles and 67 acres within 698 acres of 66 foot wide transects (strip samples) in 37 of the proposed treatment units (Figure 2). Strip samples tallied 2003 and 2004 MPB-killed trees in plots one chain wide and of variable length. Lodgepole pines classified as having been killed by MPB infestation in 2003 had red foliage, dry pitch tubes, and weathered boring dust at the base of the tree. Trees classified as infested in 2004 had green to yellow needles, pitch tubes on the bole and boring dust around the base of the tree. Variable radius (VR) plots were sampled at the beginning and end of each transect and every one quarter mile. A 10 basal area factor prism was used to select sampled trees. VR plots provided data on stand density. Stand exam data for the proposed treatment units or from representative stands were provided by Andy Cadenhead of the Hahns Peak/Bears Ears Ranger District. Stand exam data were relatively recent, averaging eight years old, and were utilized to ascertain average tree diameters and stand age (Table 3).

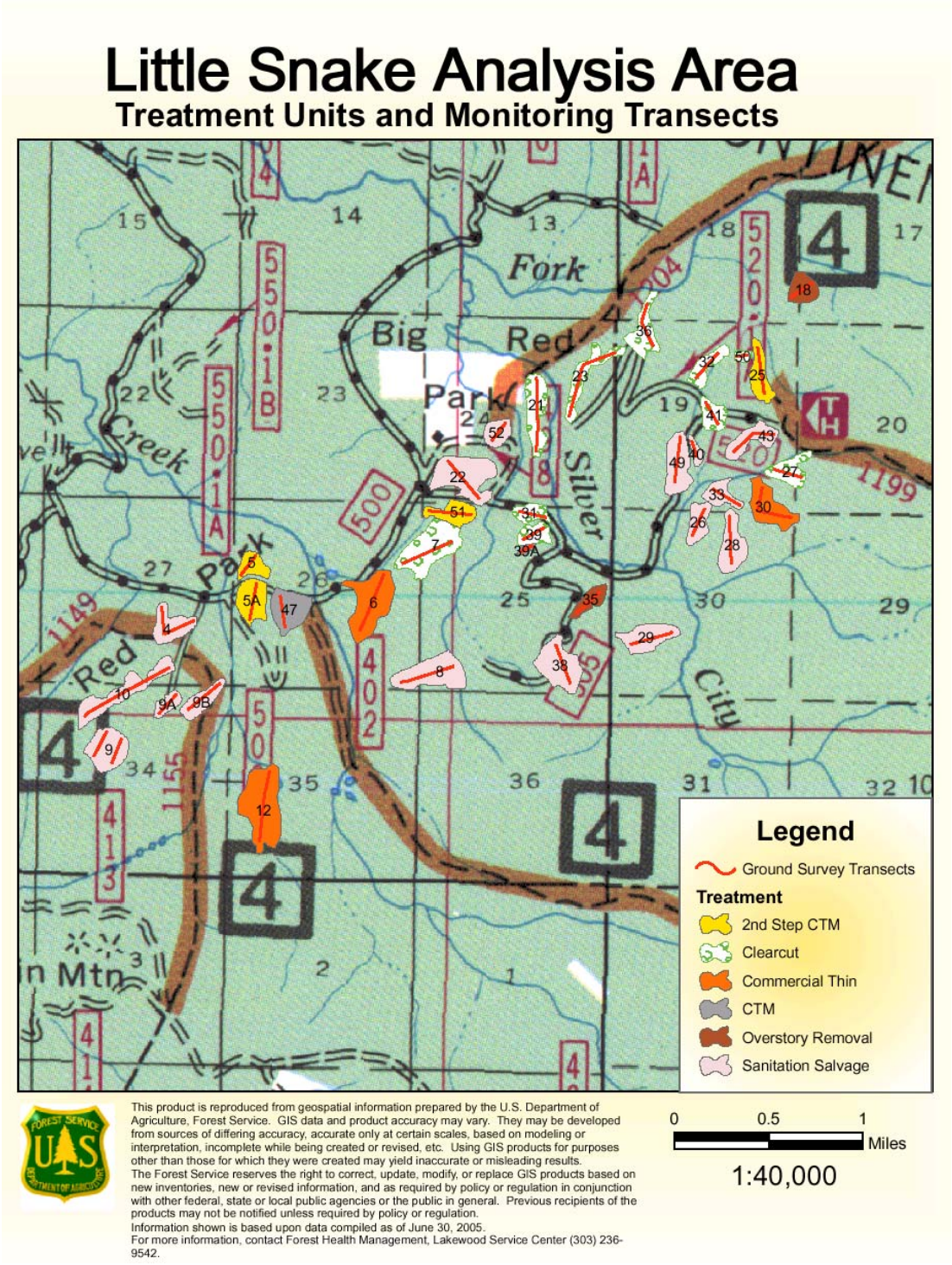

Figure 2. Proposed treatment areas within the Little Snake Analysis Area and Hahns Peak/Bears Ears Ranger District personnel strip surveys.

Results and Discussion

Aerial Survey

Aerial survey data provide only a general informational trend on pest activity because flying conditions and surveyors may vary from year to year. Aerial survey maps of MPB activity in lodgepole pine across all land ownerships in the Little Snake Analysis Area and the adjacent lands for the past six years are presented in Figure 3. Estimated tree mortality within and immediately adjacent to the proposed treatment areas of the Little Snake Analysis Area are summarized for the last six years in Table 2. Aerial survey indicates that MPB populations are increasing and spruce beetle populations are decreasing within the Little Snake Analysis Area.

Table 2. Areas impacted and trees killed by mountain pine beetle (MPB) and spruce beetle (SB) detected by aerial surveys of the Little Snake Analysis Area from 1999 – 2004.

Year	Area[1] Impacted by MPB (acres)	Estimated[1] number of trees killed by MPB	Area[1] impacted by SB (acres)	Estimated[1] number of trees killed by SB
2004	6,781	24,949	3,276	8,086
2003	2,577	4,661	5,270	29,667
2002	94	173	2,937	11,928
2001	6	36	315	1,319
2000	1	1	0	0
1999	15	20	0	0

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

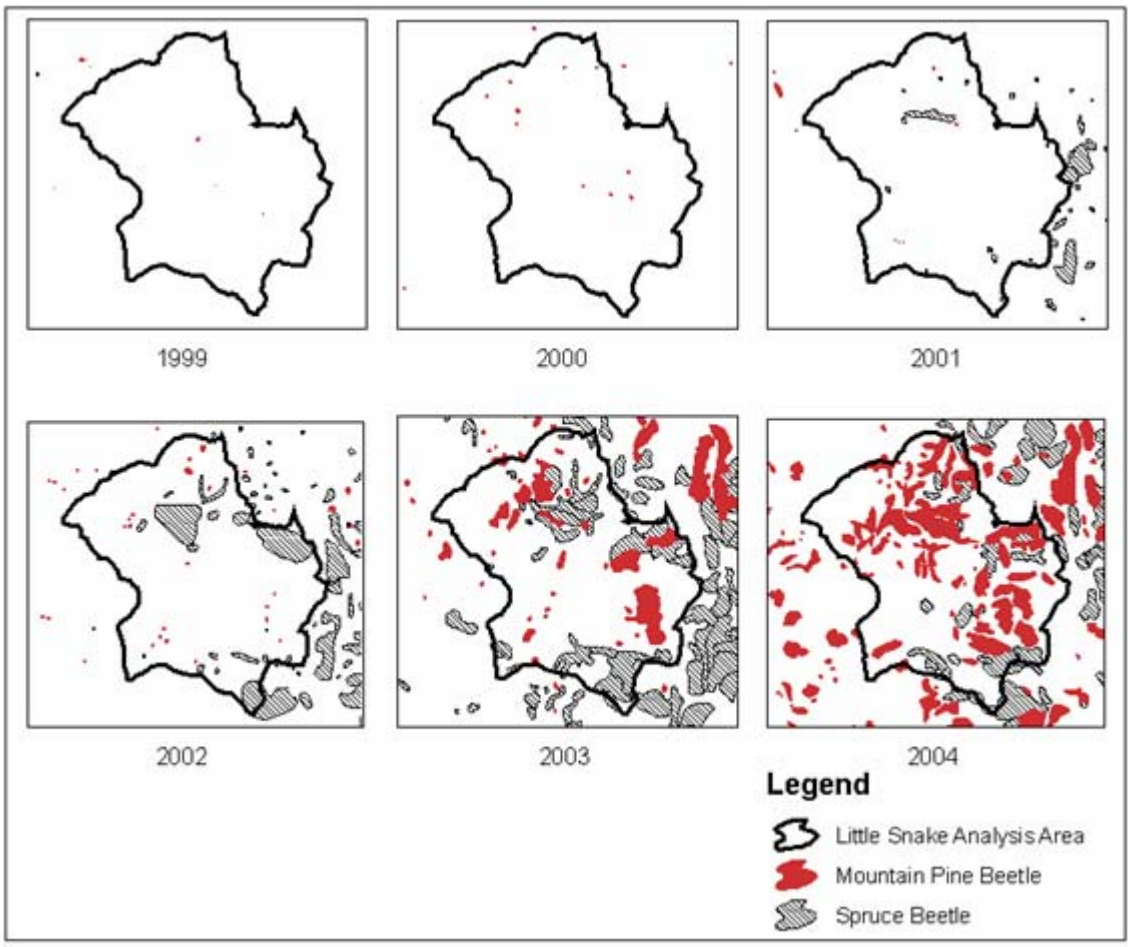

Figure 3. MPB activity detected by aerial surveys* conducted 1999-2004 over the Little Snake Analysis Area and adjacent lands.

***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.

MPB Ground Survey

MPB Ground surveys provide an estimate of 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 be changing.

Cole and Amman (1980) measured MPB infestations in Forest Service's Regions 2 and 4 lodgepole pine forests 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 migration may occur. This leads to more rapid tree losses and shorter epidemic periods in adjacent stands.

Based on Cole's and Amman's (1980) description of MPB outbreak, population data collected by the Hahns Peak/Bears Ears beetle crew indicates clearly that a MPB epidemic is underway in the Little Snake Analysis Area (Table 3). Beetle populations are increasing in most of the proposed treatment areas and are declining in a few areas. Ground surveys indicated an average of 10.7 infested trees per acre in 2004, weighted by the size of the proposed treatment area. The 2004:2003 attack ratio was 3.1:1. Infestation levels within the proposed treatment areas surveyed varied from 0 to 87.9 newly infested trees per acre with as much as a ten-fold increase in beetles within two units from 2003 to 2004.

Lessard (1982) made the assumption in his study of MPB in the Black Hills ponderosa pines that less than one tree per acre is considered an endemic population and a building population is greater than one tree per acre. Using Lessard's (1982) definitions, sample data in the Little Snake Analysis Area indicates a MPB outbreak is underway. Of the 37 units surveyed, 32 had more than one MPB-infested tree per acre indicating that MPB populations were above endemic levels on 86 percent of the proposed treatment acres using Lessard's (1982) one tree per acre threshold.

Stand Conditions

Stand exam data and data summarized from variable radius plots surveyed within the proposed treatment units during June of 2005 by Hahns Peak/Bears Ears Ranger District personnel are summarized in Table 3. When averaging among units, weighted by total stand acres, the mean diameter of trees sampled was 10.9 inches, basal area was 180 ft^2/acre and stands were an average of 116 years-old. According to risk rating systems, stand data indicates current stand conditions are favorable for continued losses to MPB.

Table 3. Stand data from proposed treatment units or representative stands within the Little Snake Analysis Area and mountain pine beetle (MPB) strip survey results within proposed treatment units in the Little Snake Analysis Area sampled by the Hahns Peak/Bears Ears beetle survey crew. Averages are weighted by the size of the stand.

Unit Number	Acres	QMD[2]	BA[3]	Stand Age	2004 MPB-Infested Trees/Acre	2004:2003 MPB Attack Ratio
4	18.6	7.9	159	146	3.5	9.0:1
5	10.8	11.6	208	155	3.7	4.0:1
5A	20.1	11.6	208	155	1.2	2.0:1
6	38.2	11.4	180	121	1.2	0.7:1
7	38.0	10.9	165	98	1.3	3.0:1
8	33.1	9.0	154	123	8.4	8.4:0
9	24.7	9.6	171	107	0.9	0.9:0
9A	7.3	9.6	171	107	1.8	2.0:1
9B	13.7	9.6	171	107	9.0	8.0:1
10	29.5	10.1	190	108	0.2	1.0:1
12	46.9	10.9	249	113	1.4	4.0:1
18	13.1	6.8	165	176	4.4	0.2:1
21	23.2	11.1	183	119	0.6	2.0:1
22	37.7	12.9	177	119	4.3	0.8:1
23	19.3	9.0	190	148	4.3	1.8:1
25	15.9	10.2	107	103	11.4	1.9:1
26	13.0	13.6	114	97	6.1	1.1:1
27	15.3	13.6	114	97	87.9	7.7:1
28	21.4	12.9	189	102	4.9	10.1:1
29	21.4	12.9	170	99	22.9	10.5:1
30	23.8	8.5	270	107	43.0	6.7:1
31	9.4	11.0	200	92	3.3	1.0:1
32	12.3	9.2	180	94	11.6	1.3:1
33	11.5	12.2	169	81	12.5	1.2:1
35	10.3	11.1	179	100	24.3	5.5:1
36	18.0	11.3	165	114	7.3	7.2:0
38	29.7	11.0	182	130	4.0	3.5:1
39	10.6	8.7	240	101	0.0	0:0
39A	2.4	8.7	240	101	1.9	1.0:1
40	4.5	14.4	180	102	1.4	1.0:1
41	11.7	9.1	204	132	35.8	4.9:1
43	16.8	11.5	112	113	41.3	3.7:1
47	23.2	9.2	168	134	0.7	0:0
49	23.5	13.6	169	96	46.1	3.5:1
50	3.2	10.1	150	128	32.6	1.0:1
51	15.1	13.1	181	106	1.6	3.0:1
52	10.9	12.8	174	133	3.1	1.0:1
Weighted[1] Average		10.9	180	116	10.7	3.1:1

[1] Weighted average by total stand acres.
[2] Average derived from the quadratic mean of tree diameters in treatment units based on stand exam data.
[3] Based on stand origin date provided in stand exam data. Stand age may vary within the proposed treatment units.

Amman and others (1997) 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 and others 1997). Shore and Safranyik (1992) developed a similar risk rating that included a susceptibility index comprised of factors such as average age, location (elevation and latitude), as well as a measure of basal area and density of the stand. Also included in this model is a measure of beetle pressure related to the size and proximity of a MPB population affecting the stand.

Amman and others (1977) indicates that susceptibility to MPB increases where average diameters are over 8 inches. The average quadratic mean of lodgepole pine tree diameters in treatment units in the Little Snake Analysis treatment areas is 10.9 inches (Table 3 and Figure 4).

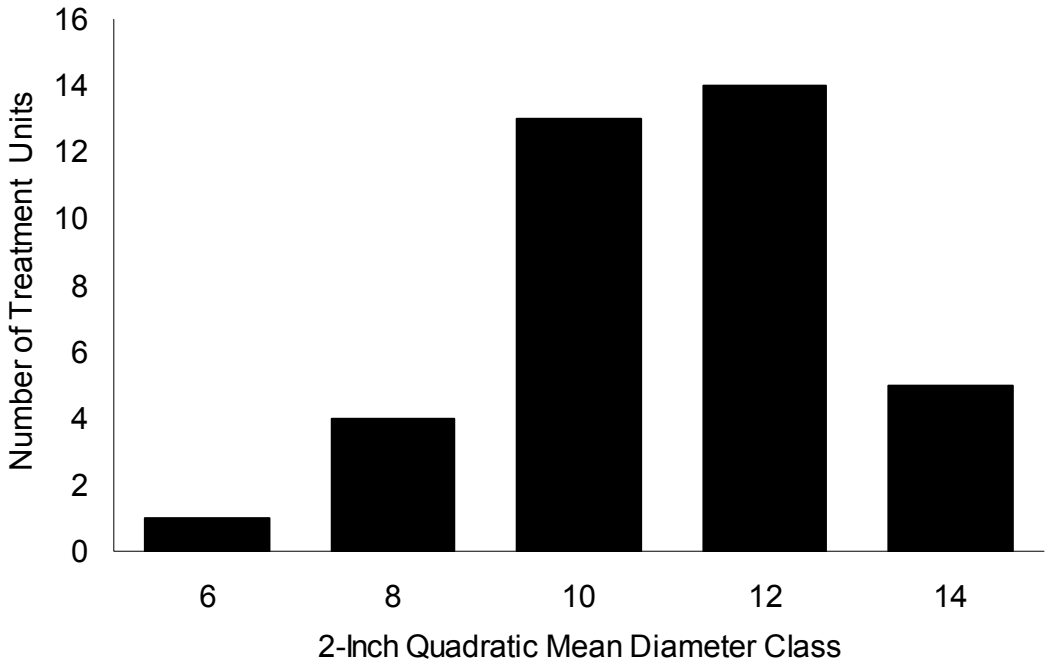

Figure 4. Distribution of average lodgepole pine quadratic mean diameters of treatment units within 2-inch diameter classes provided by Hahns Peak/Bears Ears Ranger District personnel in the Little Snake Analysis Area.

Amman and others (1997) also indicates that susceptibility to MPB increases when stands are over 80 years old. Stand exam data indicates that stands within the proposed treatment units are over 80 years-old. The overall average stand age weighted by unit size was 116 years (Table 3).

The final factor in Amman's (1977) risk rating system is a suitable climate for beetle development. According to this risk rating system, suitable climate for beetle development based on the latitude of the Little Snake Analysis Area is classified as moderate risk between 8,800 and 9,800 feet and as high risk below 8,800 feet. Almost one-half of the treatment units (17 of 37) are below 8,800 feet and all other units are between 8,800 and 9,800 feet. Climate is suitable for beetle development in all of the proposed units. A 2004 study of mountain pine beetle emergence at three elevations in nearby Grand County, Colorado, indicates that beetle emergence trends did not differ significantly between elevations of 8,760, 9,200 or 9,900 feet (Tishmack and others 2005). The authors suggest that the upper elevational limit for the highly susceptible category should be raised to ≥10,000 feet, rather than the 8,800 feet limit determined using Amman and others (1977). Based on the recent work by Tishmack and others (2005), all of the units in the Little Snake Analysis Area would be considered at high risk for mountain pine beetle infestation.

Stand basal areas can be an indicator of susceptibility to MPB. Basal areas of 120 ft^2/acre and above have been shown more likely to be attacked by MPB in ponderosa pine stands (Schmid and Mata 1992) and lodgepole pine stands (McGregor and others 1987). Basal area data from available stand exam data in the Little Snake Analysis Area averaged 180 ft^2/acre in the proposed treatment areas surveyed (Table 3 and Figure 5).

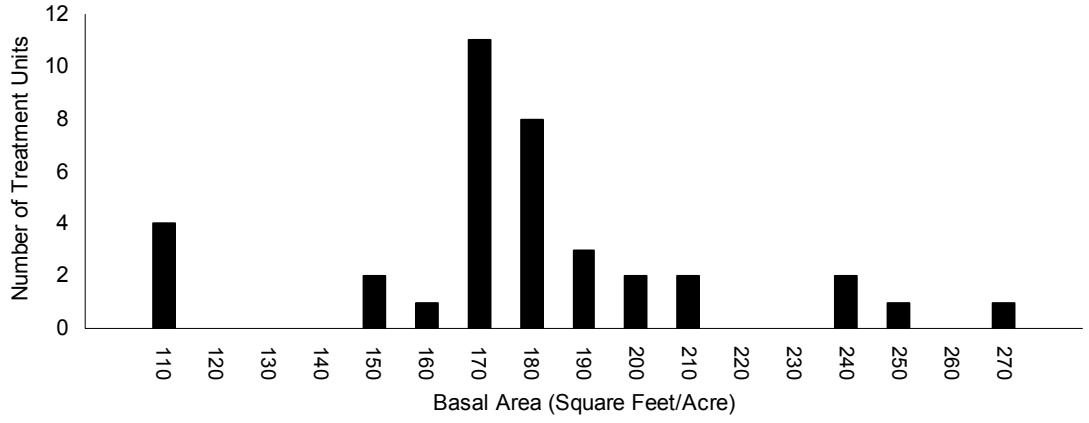

Figure 5. Distribution of basal area/acre within treatment units sampled by Hahns Peak/Bears Ears Ranger District personnel.

Close proximity of MPB populations also increases the risk for tree mortality in susceptible stands (Shore and Safranyik 1992). Elevated MPB populations within and adjacent to the Little Snake Analysis Area will likely spread to susceptible stands within the Analysis Area.

Conclusion

The proximity of MPB-infested to uninfested trees is a factor in the short term risk to a given stand of trees (Shore and Safranyik 1992). The high level of MPB activity in the Little Snake Analysis Area indicates a high risk of infestation to all susceptible stands in the proposed treatment areas. The building MPB epidemic on the Little Snake Analysis Area is not likely to depart from the projected rapid increase in beetle numbers and in losses to lodgepole pine unless a period of prolonged and severe low temperatures (< -30º F) occurs during late fall-winter-early spring months. An extremely severe cold weather event may result in the death of large numbers of the developing bark beetle broods and bring this epidemic to an end, as happened during the MPB outbreak in Grand County Colorado in 1984-1985 (Lessard and others 1987), and in the spruce beetle epidemic in the Flat Tops Wilderness on the White River National Forest in 1951 (Schmid and Frye 1977).

Many lodgepole pine stands within the proposed treatment areas have already been infested with MPB. In these areas direct suppression through removal of infested trees as well as making stand conditions in adjacent uninfested or lightly infested stands less favorable for MPB may help to reduce impacts. Cutting, followed by removal or treatment of beetle-infested trees, should be considered a priority before beetles begin emergence in July. Logs can be hauled to a sawmill 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. Detailed alternatives and considerations for managing MPB impacts are provided in the Appendix A.

Where lodgepole pine mortality due to MPB is currently low to moderate, silvicultural strategies to reduce stand susceptibility by thinning stands to below 100 ft^2/acre 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 and others 1987, Amman and others 1988b). Reducing basal area to between 60 and 80 ft^2/acre 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 (Mata and others 2003) and intensifying dwarf mistletoe infection present within the stands. LSC-FHM can provide additional information and assistance with developing dwarf mistletoe management strategies where necessary. Guidelines prepared for managing dwarf mistletoe are provided in Appendix B. These concerns should be addressed before partial cutting to reduce MPB impacts.

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Appendix A

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

USDA Forest Service, Rocky Mountain Region, 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 and others 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. Succession 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 MPB-caused tree mortality (Amman 1989; Schmid and Mata 1992, Mata and others 2003). 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, at a

given latitude, where average tree diameter exceeds 8 inches and average tree age exceeds 80 years (Amman and others 1977). However, a more recent study near Fraser, CO, found no difference in MPB emergence trends at elevations of 8,760, 9,200 and 9,900 feet, indicating that under favorable weather conditions trees at higher elevations maybe also be at high risk to MPB (Tishmack and others 2005).

Favorable conditions for MPB in ponderosa pine stands in the Black Hills of South Dakota are those where average tree diameter is greater than or equal to 8 inches and basal area is greater than or equal to 120 ft^2/acre (Schmid and Mata 1992). More recently, a study in the Black Hills indicates that basal areas lower than 120 ft^2/acre can be suitable for MPB (Schmid and Mata 2005). Schmid and Mata (2005) reported that only the plots with 75 ft^2/acre sustained less than 10 percent mortality. Poorer site conditions found in Colorado's Front Range ponderosa pine sites may lead to low basal area levels that are susceptible to MPB infestation. Negron and Popp (2004) found increased likelihood of MPB infestation when basal area was higher than 74 ft^2/acre in a study in Colorado's Front Range on the Arapaho-Roosevelt National Forests.

Studies in lodgepole pine have also found greater losses in stands with high basal area. Lodgepole pine stands thinned to 100 or less ft^2/acre basal area sustained fewer MPB attacks than stands thinned to 120 ft^2/acre and unthinned control plots (McGregor and others 1987). Partial cutting that reduces stands to 60 - 80 ft^2/acre 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 and others 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 and others 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 and others 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 differ 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 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, permethrin, bifenthrin 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, permethrin, and bifenthrin 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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Appendix B

Dwarf Mistletoe Management Recommendations

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Management of dwarf mistletoes is done most effectively and economically through various silvicultural practices (Hawksworth and Wiens 1996). Hawksworth and Johnson (1989) developed a detailed guide on the biology and management of lodgepole pine dwarf mistletoe in the Rocky Mountains that provides useful information on specific treatment options for various types of stands.

Dwarf mistletoes have many characteristics that make them excellent candidates for silvicultural control:

- Because dwarf mistletoes are obligate parasites they die when the tree dies and there is no need to treat or dispose of slash.
- Dwarf mistletoes are generally host specific so non-host species can be encouraged during stand treatments.
- Dwarf mistletoes have long life cycles so it takes a long time for them to become established and spread is fairly slow, particularly in even-aged stands.
- Dwarf mistletoe seeds may be dispersed a maximum of 60 feet but this dispersal length is only observed in open areas. In closed, dense stands seed dispersal lengths are greatly reduced.
- Dwarf mistletoe-infected trees are easy to identify, however, infections can become latent over time and are able to reactivate when stands are thinned or opened up.

Management of dwarf mistletoes involves detection, evaluation, prevention, and suppression of the pathogen. Dwarf mistletoe management often needs to be integrated with management of other damaging agents, particularly bark beetles. Management strategies should focus on prevention wherever possible since control measures once the disease is established may require significant resources and time. Specific management strategies for controlling dwarf mistletoe depend on the spatial distribution and intensity of infections and stand characteristics. Pretreatment surveys can be conducted to determine stocking levels and the distribution and incidence of dwarf mistletoe. Region 2 Forest Health Management personnel are available for training and to help set these surveys up.

Dwarf Mistletoe Control in Lightly Infested Stands: Stand DMR from 0.0 to 0.5

Sanitation thinning is the process of removing all infected trees during a single entry. Sanitation thinning is practical in lightly infested stands with a stand DMR less than 0.5, however, to ensure a true sanitation, all infected trees must be marked for removal. These stands should be monitored for latent infections every 3-5 years. Protecting uninfected and/or lightly infected stands from heavily infected adjacent stands can be done by creating a disease-free buffer in between stands. Removal of infected trees along the border of uninfected stands can be done in stages in which the most heavily infested trees (DMR 5-6) are removed in the first rotation. During a second entry within 10-15 years the residual infected trees (DMR > 3) should be removed once the regeneration has had a chance to establish itself.

Partial harvesting or small patch cuts could be an effective management strategy in stands that are very lightly infested (0-25% infection).

Dwarf Mistletoe Control in Moderately Infested Stands: Stand DMR from 0.5-3.0

In moderately infected stands, non-hosts should be encouraged and/or planted. Thinning is recommended in moderately infested stands with a stand DMR less than 3. This is not a true sanitation, but rather an effort to maintain the stand at a lower stand DMR to reduce losses. It is important that while removing infected trees adequate stocking levels are maintained. Additionally, opening stands up can reactivate latent dwarf mistletoe infections, so stands need to be monitored every 3-5 years with possible follow-up treatments. Regeneration should be monitored and sanitized to protect the future stand.

Residual infected trees can also be pruned to improve their overall health and vigor (Hawksworth and Johnson 1989). Pruning is effective on trees with a DMR less than or equal to 3 as long as infections are concentrated in the lower half of the crown. Prune all live branches in the 2 whorls above the last infected branch while maintaining 50% of the live crown. Trees need to be monitored for latent infections every 3-5 years.

Heavily Infested Stands: Stand DMR greater than 3.0

In heavily infested stands, the most effective way to eliminate dwarf mistletoe is by clearcutting. In order to effectively reduce or eliminate infection and protect regeneration, the area immediately adjacent to the replaced stand must be free of disease, or the area of the replaced stand must be large enough (greater than 20 acres) that infection from edges is insignificant (Hawksworth and Johnson

1989). Clearcut boundaries should be placed through natural or human-made openings such as meadows or roads. As clearcuts decrease in size below 20 acres, the percentage of area within a half chain of the adjacent infected stand increases significantly. For example, a 1-acre clearcut has over 50 percent of its area within a half chain (33 feet) of the border, the average maximum distance dwarf mistletoe seeds are dispersed.

In recreation areas or other sensitive areas where clearcutting is not an option, management should focus on introducing or encouraging non-host species and pruning witches' brooms to prolong the life of individual trees. Heavily infested stands can be regenerated using several entries over a long time period as well. Because partial harvesting leaves an infected overstory surrounding the replaced patch, residual blocks need to be removed before the regenerating stand is either 3 feet tall or 10 years old. The intensity and distribution of mistletoe in the adjacent stand, the density of the adjacent stand, existing natural barriers, and plans for future stand treatments all will impact the success of partial or patch cutting. Regeneration needs to be monitored and sanitized to protect the future stand. In general, partial harvest systems are only recommended for heavily infested stands when a cutting cycle of 10-15 years is used, in which all of the most heavily infested trees (DMR 4-6) are removed during each cycle.

Specific Silvicultural Strategies for Dwarf Mistletoe-Infested Stands

1) **Plant or Favor Non-Host Species:** Plant non-host species in the understory of infested stands to eventually replace the stand when the overstory is removed or falls apart. Plant species adapted to the site and moisture conditions of the area. In lodgepole pine areas some species to plant and/or favor include Engelmann spruce, Douglas-fir, subalpine fir, aspen, bristlecone pine, and limber pine.

2) **Prune Witches' Brooms and Infected Branches:** Pruning is done to reduce dwarf mistletoe spread and improve tree vigor. Pruning is only recommended in high value areas because it is both labor-intensive and expensive. Pruning is effective on trees with a DMR less than or equal to 3 as long as infections are concentrated in the lower half of the crown. Prune all live branches in the 2 whorls above the last infected branch while maintaining 50% of the live crown. Trees need to be monitored for latent infections every 3-5 years.

3) **Chemical Controls:** Ethephon is a naturally occurring plant growth regulator that has been used as a chemical control for dwarf mistletoe infested stands. When sprayed on infected trees in the fall, ethephon causes dwarf mistletoe shoots to drop off host trees before seeds are dispersed. This type of treatment may be beneficial in areas where planting non-host species in the understory is not an option. Ethephon does not kill the entire mistletoe plant but it provides short-term protection

(1-3 years). Reapplication is necessary until the infected overstory can be removed. Generally, pruning is more economical and effective than ethephon spraying

4) **Remove Infected Trees:**

   a) **Create Buffer Strips:** Remove all infected trees within 33-50 feet of an area that needs to be protected such as an uninfected stand or an area that has just been treated. *Thirty-three feet is the average maximum distance that dwarf mistletoe seeds will spread*.

   b) **Sanitation Thin:** Sanitation thinning is the removal of all infected overstory and understory trees. A strict sanitation can only be done in lightly infested stands (Stand DMR less than 0.5 = 40 % infection) otherwise the removal of too many trees would leave stands understocked. Generally, thinning is recommended in stands with a DMR less than 3. This is not a true sanitation, but rather an effort to maintain the stand at a lower stand DMR to reduce losses. Opening stands up can reactivate latent dwarf mistletoe infections, so stands need to be monitored every 3-5 years with possible follow-up management.

   c) **Even-Aged Management (Harvest and Regenerate the Stand):** Even-aged management, either through clearcutting or shelterwood harvests, is the most effective way to eliminate dwarf mistletoe from heavily infested stands. In order to successfully reduce or eliminate infection and protect regeneration, the area immediately adjacent to the replaced stand must be free of disease, or the area of the replaced stand must be large enough (greater than 20 acres) that infection from edges is insignificant. Boundaries should be placed through natural or manmade openings such as meadows or roads.

   d) **Uneven-aged Management (Partial Cutting):** Uneven-aged management is generally not recommended in heavily infested stands because the small units and presence of scattered infected overstory trees leaves stands very susceptible to rapid reinvasion from the overstory to the new regeneration. As a general guideline, small group selection or patch clearcuts should only be used in areas where only 15-25% of trees are infected. To avoid the problems associated with partial harvest systems in heavily infested stands, a cutting cycle of 10-15 years must be used, in which all of the most heavily infested trees (DMR 4-6) are removed during each cycle.

Literature Cited

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