Biological Evaluation
R2-07-01

Biological Evaluation of Mountain Pine Beetle and Spruce Beetle Activity in the Larson II 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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December 2006

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Abstract

Lodgepole pine mortality due to mountain pine beetles (MPB) have been increasing for several years in and around the Larson II Analysis Area on the Medicine Bow-Routt National Forests. Widespread epidemic populations of both MPB and spruce beetles (SB) are occurring on surrounding National Forest Lands. The Hahns Peak/Bears Ears Ranger District is considering a variety of silvicultural activities to remove beetle-infested and dead trees and to mitigate MPB and SB impacts on approximately 711 acres.

Lakewood Service Center-Forest Health Protection (LSC-FHP) personnel used aerial survey information for the Larson II Analysis Area and ground survey of 20 of the 46 proposed management units of the Larson II Analysis Area to determine the level of beetle infestation in these areas. MPB summary results from aerial surveys of the Larson II Analysis Areas since 2001 show an increase in the number of trees killed and the size of the infestation visible from the air. The estimated area affected by MPB-caused mortality increased from 0.3 in 2001 to 448 acres in 2006.

Ground surveys recorded the number of trees infested with MPB and SB in 2005 and 2006. Ground survey data for the sampled units within the Larson II Analysis Areas indicate that the MPB and SB infestations are increasing. The average 2006:2005 ratio of the number of trees infested by MPB was 4.7:1. The number of MPB-infested trees within the proposed treatment areas ranged from 0 to 75 newly infested trees per acre, and the number of SB-infested trees ranged from 0 to 7 newly infested trees per acre.

Variable radius plots measured during ground surveys and available stand exam data were used to determine stand susceptibility to MPB and SB. Average stand diameters, age, tree density, elevation and proximity of MPB populations indicate many stands in the proposed treatment units surveyed are 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 in the future. Spruce stands were risk rated for SB using a rating system developed by Schmid and Frye (1976). Most stands were risk rated at medium risk. Management actions to address the MPB and SB infestations in the Larson II Analysis Area are discussed.

Introduction

This biological evaluation was prepared to support the proposed efforts to reduce the impacts of increasing populations of mountain pine beetle (MPB), *Dendroctonus ponderosae* Hopkins, within the Larson II Analysis Area of the Hahns Peak/Bears Ears Ranger District of Medicine Bow-Routt National Forests and Thunder Basin National Grassland. Drought-weakened forests of dense, older lodgepole pine, *Pinus contorta* Dougl. ex Loud, stands within the Larson II Analysis Area face a serious threat from large scale MPB populations increasing in adjacent areas. Since 2002, aerial surveys of this area have detected large increases in MPB populations throughout the lodgepole pine type. Some lodgepole pine dominated areas to the east of the analysis area are experiencing 90% mortality due to MPBs.

In 1997, wind storms caused approximately 13,000 acres of blown down Engelmann spruce *Picea engelmannii* Parry ex Engelmann, primarily west of the Continental Divide in the Sierra Madre, Park and Gore Mountain ranges (Schaupp 1999). This abundant windthrown spruce and the presence of old, slow growing trees within the analysis area coupled with recent drought conditions, set the stage for increased losses to spruce beetle, *Dendroctonus rufipennis* Kirby. In some areas like the Park Range to the east of Steamboat Springs, CO, populations of spruce beetles are on the decline, whereas, other areas like the Larson II analysis areas are currently experiencing increasing spruce beetle populations. Both MPB and SB have the potential in this analysis area to play a dramatic role of recycling old forests into new ones in their respective ecosystems.

Mountain Pine Beetle

Mountain pine beetle 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 et al. 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 may be 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 MPB 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 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 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). Bentz and Mullins (1999) found that the supercooling point for larvae, used as a measure of cold tolerance, was -10 to -20° C (14 to -4º F) in early fall, dropped to -25 to -35° C (-13 to -31º F) in January, and increased again in the spring and early summer. Therefore, a very cold winter snap or 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 et al. 1977, Amman et al. 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 were 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 et al. (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 et al. 1988b). The decrease in losses could be due to a different microclimate in thinned stands compared to unthinned stands (Amman et al. 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 et al. 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 et al. 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.

Spruce Beetle

The spruce beetle (SB) is a native insect capable of killing all species of native spruce by feeding on phloem tissue and introducing blue-staining fungi, *Leptographium* spp. and *Ceratocystis* spp. In the central Rockies, SB has the greatest impact on Englemann spruce stands. Furniss and Carolin (1977) wrote "like fire and wind, the SB is a natural though destructive means of liquidating overmature forests and making way for the new." Baker and Veblen (1990) suggest that SB outbreaks may be as ecologically significant as fire in spruce-fir forests. In many of the central Rockies' spruce-fir forests, successional stages are likely to be influenced more frequently by the infestations and epidemics of SB in Englemann spruce and western balsam bark beetle, *Dryocoetes confusus* Swaine, in subalpine fir than they are by the rare high intensity fires that occur on the moist high elevation sites where the forest type occurs.

Schmid and Hinds (1974) present a successional scenario of SB-caused shifts of old spruce dominated stands to younger fir dominated stands and a more gradual transition back to spruce dominated stands over hundreds of years. Within that time span, smaller outbreaks of SB shift the spruce component to a more single storied stand while a combination of western balsam bark beetle and several pathogenic fungi reduce the abundance of mature subalpine fir. Eventually, the longer lived spruce dominates the forest and grows to maximum basal area for the site. In time, blowdown occurs and the windthrown trees provide breeding sites for a SB epidemic to develop. Widely scattered blowdown trees are especially conducive to increases in beetle populations (Wygant and Lejeune 1967) and are a prime source of outbreaks (Schmid and Frye 1977). SBs emerging from windthrown trees can infest standing live trees, when sufficient windthrown trees are unavailable. The return interval of multiple stand epidemics is dependent upon large acreages of spruce growing into an old dense condition and upon the occurrence of a triggering disturbance (Schmid and Frye 1977). A study in Colorado indicates outbreaks may be more than 115 years apart and wide-scale epidemics may be separated by 250 years or more (Veblen et al. 1994).

During a SB epidemic almost any spruce tree in the stand may be selected regardless of size and vigor (Wood 1982) and the number of live trees may be drastically reduced. During 1940's White River National Forest epidemic, 99 percent of the overstory spruce trees were killed over thousands of acres (Schmid and Hinds 1974). Furniss and Carolin (1977) point out that there is preference shown for trees of larger diameter and Schmid and Frye (1977) observed that larger trees (>20 inch diameter) growing where self pruning occurs due to competition are preferred by the beetles to open grown trees with live limbs in the basal portion. However, Schmid and Mata (1996) state that it should not be implied that SB always attack the largest trees first and then move to progressively smaller trees. Susceptibility of individual trees is influenced by more than just diameter,

so 12-inch or 16-inch trees may be attacked first when mixed with larger trees. Even in the extensive White River National Forest epidemic, scattered, single medium diameter trees survived within the devastated stands. Massey and Wygant (1954) report that trees as small as 2 inches in diameter were attacked during a 1940's Colorado epidemic but Schmid and Mata (1996) and Veblen et al. (1991) indicate trees less than 4 inches in diameter are not usually attacked. Previously suppressed small diameter spruce and fir are released following the epidemic and appear to be more important in regenerating the forest than are new seedlings (Veblen et al. 1991).

Environmental changes following a SB epidemic include increased forage, increased stream flow, species dependent wildlife habitat changes and increased fuels, although not greatly increased fire hazard due to the generally moist site conditions (Schmid and Frye 1977). Unlike lodgepole pine beetle-killed forests, the epidemic area generally remains accessible as beetle-killed spruce remain standing for a long time. Mielke (1950) found 84% of killed spruce still standing after about 25 years.

Between outbreaks, low level populations referred to as endemic populations are found infesting the lower sides or shaded portions of windthrown trees or other prostrate dying green trees or in overmature or weakened standing trees larger than about eight inches (Schmid and Frye 1977, Schmid 1981, Wood 1982).

Adult SB, often described as a bullet shape are cylindrical, ¼ inch long, and have dark brown to black with reddish-brown or black wing covers. Depending on temperature and elevation, SB may complete their life cycle in one to three years. The majority of beetles in the high elevation sites on the Larson II Analysis Area most likely follow the more typical two-year life cycle described by Massey and Wygant (1954). Emergence is temperature dependent and can occur as early as May, but more often occurs in June or July. Female beetles colonize the tree first, release an attractive chemical, called an "aggregation pheromone," that attracts both males and females. Female beetles then excavate galleries and lay eggs which hatch in late summer and the first winter is spent as larvae beneath the bark. Larvae typically mature in late spring or early summer. Pupation and transformation into adults occurs by August. A variable percentage of the adults, from 3%-88% (Knight 1961), that develop in standing trees will emerge from the tree in August and September and move down to the base of a host tree and reenter for hibernation. Snow cover insulates hibernation sites and protects young adults from woodpecker predation. Extreme cold temperature can be lethal to both larvae and adult SBs. Massey and Wygant (1954) found subcortical temperatures below -30ºF will kill all larvae and below -15ºF will kill all adults.

Trees containing successful SB attacks have reddish-brown boring dust in the beetle's entrance holes, in bark crevices and around the base of the tree. SB infested trees are often noticed when trees with green needles are partially debarked by woodpeckers. Woodpeckers flake off pieces of bark to eat beetle larvae and adults. Woodpeckers are the most important predator of the SB and can cause up to 100% brood mortality in a spruce tree (Masey and Wygant 1954).

There are no precise guidelines for cutting old growth spruce to maintain low SB populations. Schmid and Hinds (1974) analyzed four infestations and suggest some stand characteristics favorable for outbreaks: (1) spruce-fir stands that are predominantly spruce in the canopy – the higher the percentage of spruce the greater the potential; (2) basal area (BA) per acre greater than 150 sq. ft. per acre, with the BA concentrated in the older larger-diameter spruce; (3) single- or two-storied stands; and (4) an average rate of diameter growth of .04 inch or less per 10 years. Schmid and Frye (1976) went on to describe high risk stands as those located on well-drained sites in creek bottoms, having an average diameter of live spruce more than 16 inches diameter at breast height (dbh), having a BA over 150 sq. ft. per acre and a proportion of more than 65% spruce in the canopy. They suggest that maintaining stand characteristics below the high risk level may be an effective management guideline. Additional studies in Alaska concluded that SB does not necessary prefer larger diameter trees, but prefers slower growing trees that are correlated with larger diameters and more trees per hectare (Hard et al. 1983 and Hard 1985). Holsten et al. (1999) state a principle strategy should consist of silvicultural treatments of moderate to high hazard stands that result in maintaining their health with moderate growth. Silvicultural strategies may be more effective if beetle populations are not immediately threatening resource values (Holsten et al. 1999). Where beetle populations are threatening resource values, suppression methods used can include infested and susceptible tree removal, treatment of logging residuals or windthrown trees by bark peeling, solarizing or burning, and the use of trap trees, aggregating and anti-aggregating pheromones, and preventive insecticides (Holsten et al. 1999).

Epidemics have also been reported to have originated from logging residuals from right-of-way cuttings (Wygant and Lejeune 1967) and logging operations (McCambridge and Knight 1972). Guidelines for handling logging residuals are presented by Schmid (1977). Stump height should be kept below 18 inches and cull logs and tops should be limbed, cut into short lengths and either peeled or left unshaded, unpiled and exposed to sunlight. Where a substantial SB population exists in the adjacent forest, it may be wiser to leave the logging residuals rather than remove or destroy them immediately after cutting. Suitable residuals will attract beetles and reduce mortality of standing trees. After infestation and before the following year's flight, the residuals must be removed or treated.

Analysis Area Description

The Larson II Analysis Area is located approximately one mile west of Steamboat Lake on the Hahns Peak/Bears Ears Ranger District of the Medicine Bow–Routt National Forests and Thunder Basin National Grassland (Figure 1). Lakewood Service Center-Forest Health Protection (LSC-FHP) personnel ground survey data indicated that proposed treatment areas are dominated either by lodgepole pine, Engelmann spruce-subalpine fir (*Abies lasiocarpa* (Hook.) Nutt), or a mixed conifer component of lodgepole pine, Engelmann spruce, subalpine fir and aspen (*Populus tremuloides* Michx.) (Figure 2). Proposed treatment unit elevations range from approximately 8,200 to 9,100 feet.

The analysis area includes a mix of treatments activities on 711 acres of National Forest lands designed to salvage dead and infested trees, prevent and suppress the spread of SB and MBP, and reduce fuel loads (Table 1, Figure 3).

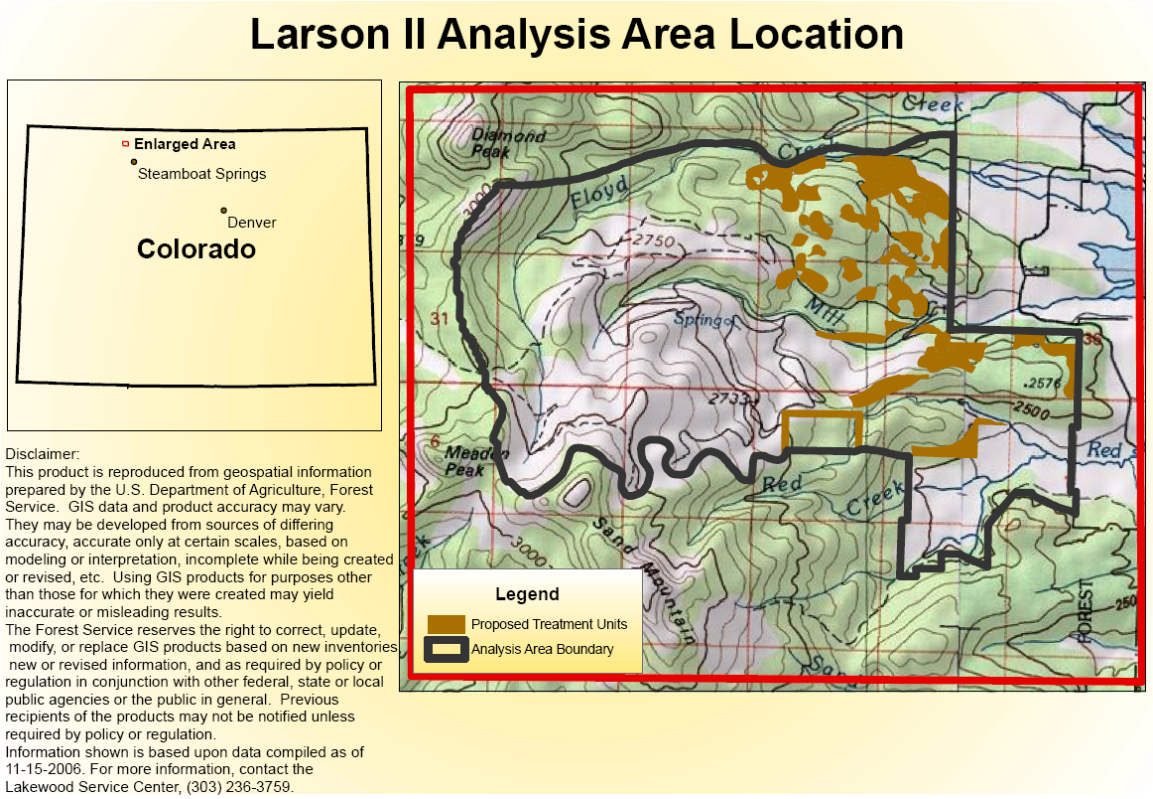

Figure 1. Location of proposed Larson II Analysis Area.

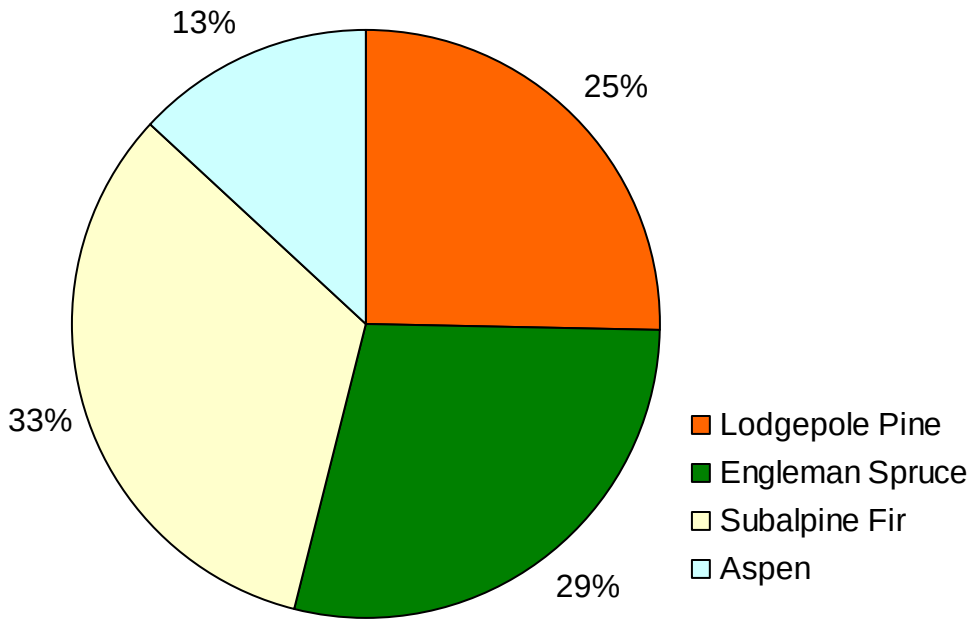

Figure 2. Tree species mix in variable radius (VR) plots sampled by LSC-FHP personnel in the Larson II Analysis Area.

Table 1. Proposed management actions within the Larson II Analysis Area including treatments and acres.

Treatment	Acres
Conifer Overstory Removal	115.47
Commercial Thinning	38.22
Clearcut	82.39
Shelterwood Cut	111.85
Sanitation/Salvage	73.59
Fuels Reduction	289.40
Total	710.92

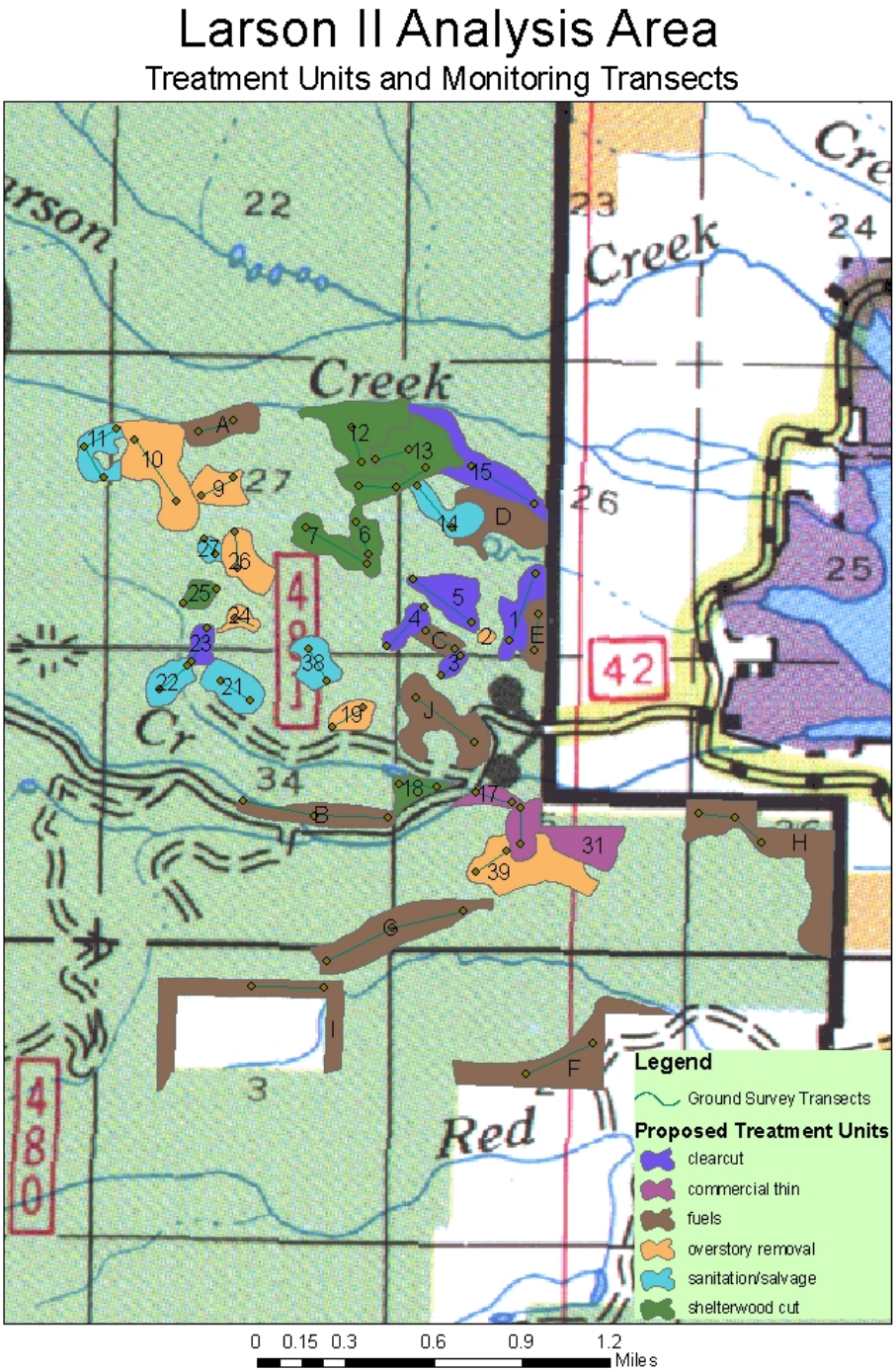

Figure 3. Proposed treatment areas within the Larson II Analysis Area and LSC-FHP strip surveys.

Purpose

This evaluation documents the status of MPB and SB on the Larson II Analysis Area and discusses the proposed treatments for reducing the spread of MPB and SB to uninfested stands and salvaging areas already impacted.

Methods

MPB and SB conditions for the Larson II Analysis Area were estimated by aerial survey, strip samples, variable radius plot samples conducted by the LSC-FHP personnel and available stand exam data provided by the Hahns Peak/Bears Ears Ranger District personnel.

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 2001-2006 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-FHP personnel and the US Forest Service Region 2 Aerial Survey Program Manager performed the aerial survey. Areas of lodgepole pine killed by MPB and Englemann spruce killed by SB were sketch mapped onto 1:100,000 scale USGS 30X60 minute topographic maps and digitized into a GIS compatible format.

Stand Conditions

Ground surveys were conducted in mid-September 2006 by LSC-FHP personnel and covered 26.2 acres within 711 acres. 20 of the 46 proposed treatment units were sampled with 66 foot wide transects (strip samples) (Figure 3). Strip samples tallied 2005 and 2006 MPB- and SB-killed trees in plots one chain wide and of variable length. Lodgepole pine trees classified as MPB-infested in 2006 had green needles, fresh pitch tubes on the bole and boring dust around the base of the tree. Lodgepole pines classified as having been killed by MPB infestation in 2005 had yellow to red foliage, dry pitch tubes, and weathered boring dust at the base of the tree. Englemann spruce trees classified as SB-infested in 2006 had green needles, boring dust and occasional pitch tubes at the attack sites. Englemann spruce classified as having been killed by SB infestation in 2005 had slightly-off color needles or a loss of needles, weathered boring dust at the base of the tree, and often had signs of woodpecker foraging activity. Variable radius (VR) plots were sampled at least every one quarter mile. A 10 basal area factor prism was used to select sampled trees. VR plots provided data on stand density, species mix and average diameter of the trees (Appendix A). Stand exam data for the proposed treatment units or from representative stands were provided by Brian Waugh of the

Hahns Peak/Bears Ears Ranger District. Stand exam data was 10-25 years and utilized to ascertain average stand age and site index (Appendix B).

Results and Discussion

Mountain Pine Beetle: Aerial Survey

Aerial surveys indicate that MPB populations are increasing within the Larson II Analysis Area. Estimated tree mortality within and immediately adjacent to the proposed treatment areas of the Larson II Analysis Area are summarized for the last six years in Table 2 and Figure 4. The estimated area affected by MPB-caused mortality increased from 0.3 acres in 2001 to 448 acres in 2006. The estimated number of trees killed increased from 1 in 2001 to 1,222 in 2006.

Table 2. Aerial survey results of acres affected and estimated number of trees killed by mountain pine beetle (MPB) for the Larson II Analysis Area, Hahns Peak/Bears Ears Ranger District, Medicine Bow - Routt National Forests and Thunder Basin National Grassland, from 2001 through 2006.

Year	Area Impacted by MPB* (Acres)	Estimated Number of Trees Killed by MPB*
2006	448	1,222
2005	72	284
2004	317	166
2003	14	10
2002	2	1
2001	0.3	1

* 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.

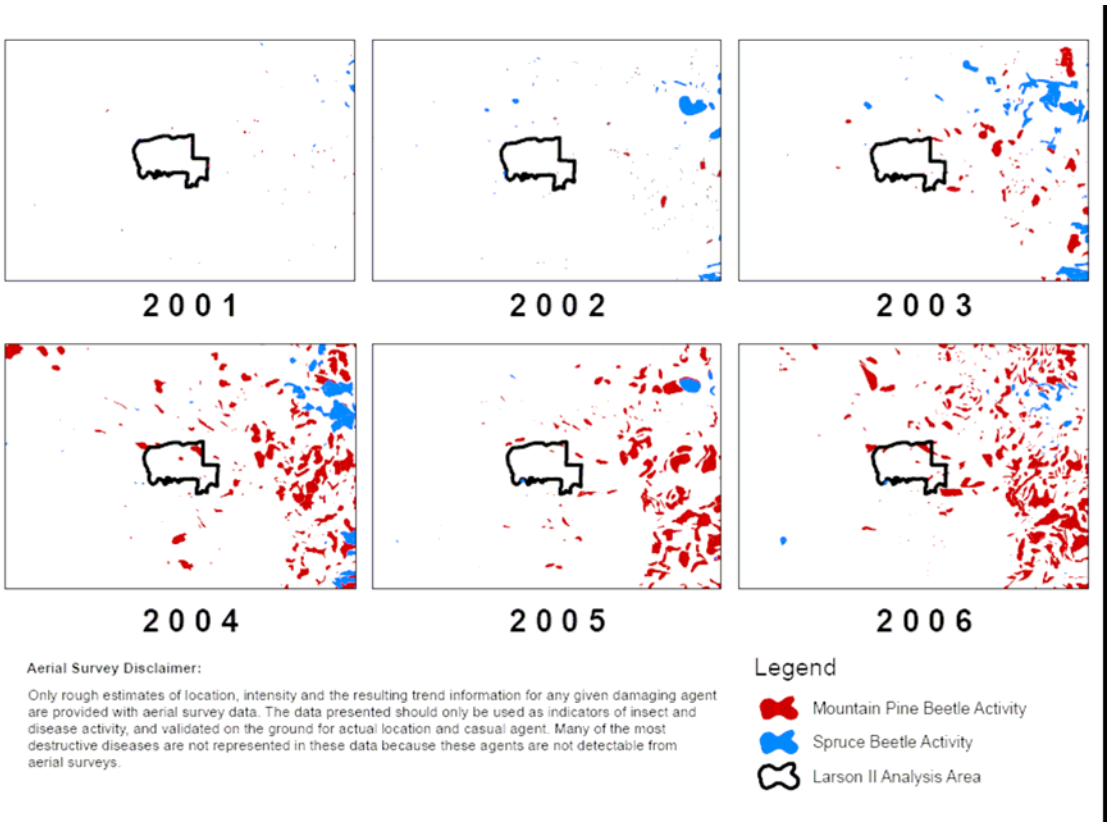

Figure 4. Mountain pine beetle and spruce beetle activity detected by aerial surveys from 2001 to 2006 over the Larson II Analysis Area, Hahns Peak/Bears Ears Ranger District.

***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 FHP. 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.

Mountain Pine Beetle: Ground Survey

Ground surveys provide an estimate of currently infested and recently killed trees (Table 3). A comparison of numbers of trees infested from year to year as a ratio indicates whether a population is increasing, decreasing, or static and how quickly it may change. Ground surveys indicate a patchy distribution of building beetle populations in the area. The overall 2006:2005 ratio was 4.7:1 for the proposed treatment units surveyed, which totaled about 352 acres. On twelve of twenty proposed treatment units surveyed the population trend was increasing. Two of these proposed units had a 42.1:1 and 10.7:1 increase in the number of infested trees. The other 10 units had between 1.0 and 59.0 trees per acre infested in 2006 (Table 3). Many of the remaining eight units without increasing MPB infestations were dominated by Englemann spruce and subalpine fir or

had a mixture of Engelmann spruce, subalpine fir, aspen and lodgepole pine, explaining the lower numbers of 2006 MPB infested trees.

Table 3. Summarized survey results for mountain pine beetle strip surveys in proposed treatment units in the Larson II Analysis Area sampled by the LSC-FHM personnel and Hanhs Peak/Bears Ears District Personnel (Hahns Peak/Bears Ears Ranger District, Medicine Bow - Routt National Forests and Thunder Basin National Grassland, September, 2006). Averages are weighted by the size of the stand.

Unit Number	Size of Unit (acres)	Acres Surveyed	2006 MPB Infested Trees/Acre	2005 MPB Infested Trees/Acre	2006:2005 MPB Attack Ratio
3	4.06	0.8	0.0	0.0	0.0
4	8.31	1.5	36.0	15.3	2.4:1.0
5	18.47	2.0	59.0	12.0	4.9:1.0
6	9.81	1.0	2.0	0.0	(-)[1]
7	16.62	2.0	2.0	0.0	(-)[1]
9	12.49	1.0	14.0	8.0	1.8:1.0
10	38.78	2.0	0.5	0.5	1.0:1.0
11	13.8	1.0	5.0	0.0	(-)[1]
12	36.06	1.0	2.0	0.0	(-)[1]
13	35.73	2.0	3.0	0.0	(-)[1]
17	6.85	1.0	2.0	4.0	0.5:1.0
18	8.21	1.0	1.0	0.0	(-)[1]
21	16.32	1.0	75.0	7.0	10.7:1.0
23	6.61	1.0	1.0	1.0	1.0:1.0
24	4.94	0.8	54.7	1.3	42.1:1.0
25	6.05	1.0	0.0	1.0	0.0:1.0
31	31.73	1.0	2.0	1.0	2.0:1.0
38	13.13	1.0	0.0	0.0	0.0
B	21.52	2.2	0.0	0.0	0.0
I	42.71	2.0	1.5	2.0	0.8:1.0
Total	352.2	26.2			
Weighted Average			10.0	2.1	4.7:1

[1]Mathematically undefined.

Cole and Amman's 1980 study of the course of MPB infestations in lodgepole pine described an endemic population as having less than 0.5 tree per acre infested, a building

outbreak as having between 0.5 and 5.0 infested trees per acre and during the peak of an outbreak as many as 26 to 31 trees per acre were infested. In 2006, ground surveys indicated 0 to 75 infested trees per acre and an average of 10.0 trees per acre in the Larson II Analysis Area. Furthermore, 15 out of 20 units surveyed had more than 0.5 infested trees per acre, indicating that MPB populations were above endemic levels on 75% of the proposed treatment unit acres (Table 3). Based on Cole's and Amman's (1980) description of MPB outbreak, population data collected by the Lakewood Service Center demonstrates that some portions of the Larson II Analysis Area are in the early stages of a MPB epidemic, whereas other portions are in the peak of an outbreak.

Mountain Pine Beetle: Stand Conditions

In addition to MPB populations, stand conditions as they relate to potential MPB epidemics were also assessed by looking at variable plot data and available stand exam data. 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). The weighted average dbh of lodgepole pine in the LSC-FHM variable radius plots sampled was 10.6 inches. According to stand exam data for the Larson II Analysis Area, stands were between 80 and 226 years-old (Appendix A).

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 Larson II Analysis Area is classified as moderate risk between 8,800 and 9,800 feet and as high risk below 8,800 feet. Treatment unit elevations ranged between 8,200 and 9,100 feet, and most units were below 8,800 feet. Additionally, warm temperatures in recent years appear to have allowed beetles to be more successful at higher elevations. Ground and aerial surveys in 2005-2006 have identified robust MPB populations above 10,500 feet. A 2004 study of MPB 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, and 9,900 feet (Tishmack et al. 2005). The authors suggest that the upper elevation limit for the highly susceptible category should be raised to ≥ 10,000 feet. All units examined in the Larson II Analysis Area are below 10,000 feet. Based on these criteria, stand data summarized from variable radius plots and stand exam data indicate current stands are at high risk for continued losses to MPB (Table 3).

Stand basal area and proximity of beetle populations 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 beetle in ponderosa pine stands (Schmid 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 Larson II

Analysis Area averaged 134.9 sq. ft. per acre, weighted by the size of the stand. Additionally and probably more importantly, close proximity of MPB populations also increases the risk for tree mortality in susceptible stands (Shore and Safranyik 1992). Large populations of MPBs most likely moved from easterly locations and a quickly increasing population spreading west of Steamboat Lake has become evident (Figure 4).

The large diameters, age, high basal areas, and proximity to MPB infestations, all contribute to the high risk of continual MPB-caused tree mortality in the Larson II Analysis Area.

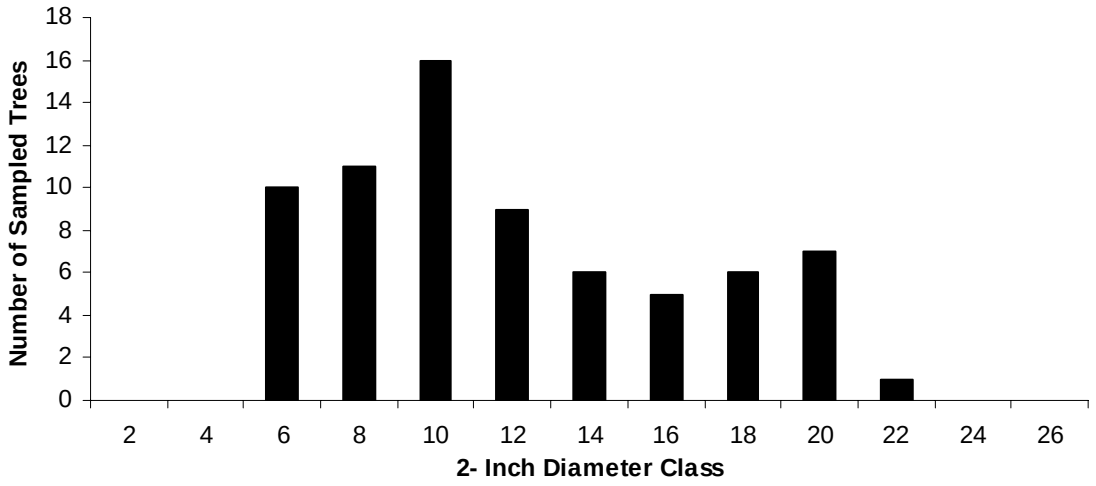

Figure 5. Lodgepole pine dbh distribution that fall within 2-inch diameter classes from variable radius plots surveyed by LSC-FHP in the Larson II Analysis Area.

Spruce Beetle: Aerial Survey

Although aerial surveys did not detect SB mortality within the analysis area, there was mortality in surrounding areas. Furthermore, aerial survey only reports trees that have begun to discolor. SB-killed trees can take 2-3 years before the infested tree appear discolored. In addition, spruce trees dying from SB attack are difficult to spot from the air because they discolor to a light green not bright orange like lodgepole pines.

Spruce Beetle: Ground Survey

Bentz and Munson (2000) considered a population to be approaching the epidemic phase when there are more than two clumps of at least five standing infested trees per five

acres. Ground surveys in the Larson II Analysis Area indicate some units had active SB populations with at least one unit approaching epidemic status.

In examining the Lakewood Service Center ground surveys and stand exam data provided by the Hahns Peak/Bears Ears Ranger District, nine proposed treatment units had a large component of spruce. Based on variable radius plot data, four of these units had new SB attacks with one unit having 7.0 newly infested trees per acre (Table 3).

Table 4. Summarized strip survey results for spruce beetle (SB) infestation in proposed treatment areas sampled by LSC-FHP personnel.

Unit Number	Size of Unit (acres)	Acres Surveyed	2006 SB Infested Trees/Acre	2005 SB Infested Trees/Acre
3	4.06	0.8	0.0	0.0
4	8.31	1.5	0.0	0.0
5	18.47	2.0	0.0	0.0
6	9.81	1.0	0.0	0.0
7	16.62	2.0	1.0	0.0
9	12.49	1.0	0.0	0.0
10	38.78	2.0	0.0	0.0
11	13.8	1.0	0.0	0.0
12	36.06	1.0	0.0	0.0
13	35.73	2.0	0.5	0.0
17	6.85	1.0	0.0	0.0
18	8.21	1.0	1.0	0.0
21	16.32	1.0	0.0	0.0
23	6.61	1.0	0.0	0.0
24	4.94	0.8	0.0	0.0
25	6.05	1.0	0.0	0.0
31	31.73	1.0	7.0	0.0
38	13.13	1.0	0.0	0.0
B	21.52	2.2	0.0	0.0
I	42.71	2.0	0.0	0.0

Spruce Beetle: Stand Conditions

In addition to SB populations, stand conditions as they relate to potential SB epidemics also were assessed by looking at variable radius plot data and available stand exam data. Schmid and Frye (1976) described high risk stands as those located on well-drained sites

in creek bottoms, having an average diameter of live spruce more than 16 inches diameter at breast height (dbh), having a BA over 150 sq. ft. per acre, and a proportion of more than 65% spruce in the canopy (Table 5). They suggest that maintaining stand characteristics below the high risk level may be an effective management guideline. Holsten et al. (1999) state a principle SB management strategy should consist of silvicultural treatments of moderate to high hazard stands that result in maintaining their health with moderate growth. However, Bentz and Munson (2000) point out that silvicultural strategies such as thinning, to reduce stand susceptibility to SB have not yet been tested.

Table 5. Risk categories for potential spruce beetle outbreaks for each stand characteristic (from Schmid and Frye 1976).

Risk Category[1]	**Physiographic Location – Site Index (SI)**	**Average Diameter (inches) of Live Spruce above 10 inches DBH**	**Basal Area (square feet per acre)**	**Percent of spruce in the canopy**
High (3)	**Well-drained creek bottoms SI > 120**	**>16**	**>150**	**>65**
Medium (2)	**SI of 80 to 120**	**12-16**	**100-150**	**50-65**
Low (1)	**SI of 40 to 80**	**< 12**	**< 100**	**< 50**

[1] Number in parentheses indicates arbitrary value to be used in calculating stand priority and is used only for convenience.

Table 6. Stand risk rating values for particular stands by summing risk category values for each stand characteristics presented in Table 7 (Schmid and Frye 1976).

Stand Risk Value	Potential Outbreak Rating
11-12	High
10	Medium-High
7-9	Medium
6	Low-Medium
4-5	Low

The Schmid and Frye (1976) risk rating criteria use site index, average dbh of live spruce above 10 inches, basal area, and percent spruce in the canopy are assigned a value of one through three according to determined risk categories and values are added together to

obtain a stand risk value (Tables 5 and 6). This rating system was used to score and assign a risk rating to spruce-fir dominated stands surveyed by LSC-FHP in September 2006. Summarized data from the nine spruce-fir dominated stands surveyed are presented in Table 7. Eight of the nine were classified as moderate risk and one stand was classified as low risk.

Table 7. Stand data from variable radius plots and spruce beetle risk rating for proposed treatment units in spruce-fir stands in the Larson II Analysis Area sampled by LSC-FHP. [1]

Unit	Acres	DBH (Average of sampled PIEN)	Average BA (All Species)	% Spruce[1] of total BA	Site Index[2]	Spruce Beetle Stand Risk Rating (score)
6	9.81	20.4	150	27	68 (PIEN) [3]	Medium
7	16.62	17.8	210	52	68 (PIEN)	Medium
10	38.78	7.7	160	56	69 (PICO)	Medium
12	36.06	10.4	90	67	82 (PIEN)	Medium
13	35.73	15.9	130	46	80 (PIEN)	Medium
17	6.85	11.6	180	22	90 (PIEN)	Medium
18	8.21	17.4	150	47	81 (PIEN)	Medium
25	6.05	13.2	90	22	73 (PIEN)	Low
31	31.73	13.9	230	39	80 (PICO)	Medium
Total	189.84					
Weighted Average[4]		13.1	155	49		

[1]Percent spruce of total BA is used as an estimate of percent spruce in the canopy.
[2]Site index from stand exam data provided by the Hahns Peak/Bears Ears Ranger District.
[3]PIEN=Engelmann spruce, PICO=lodgepole pine.
[4]Weighted average by total stand acres.

Approximately half of the Engelmann spruce trees sampled had diameters ≥16 inches, indicating a high risk for this variable (Figure 6.). Engelmann spruce diameter data from the 2006 survey indicate that average diameters for all variable radius plots ranged from 7.7 to 20.4 inches dbh (Table 7).

The LSC-FHP survey found basal area per acre ranged from 60 ft^2/acre to 230 ft^2/acre and the average basal area was 134.9 ft^2/acre, which indicates a moderate to high risk to stands according to this variable (Figure 7 and Appendix A). Stand exam data indicated stand basal areas ranged from 80 ft^2/acre to 181 ft^2/acre (Appendix B).

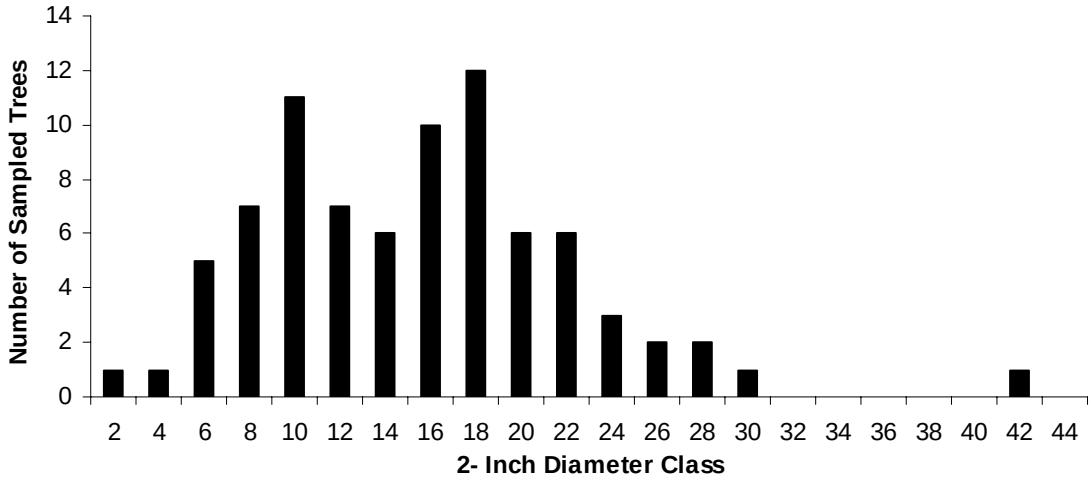

Figure 6. Engelmann spruce DBH distribution that fall within 2-inch diameter classes from variable radius plots surveyed by LSC-FHP in the Larson II Analysis Area.

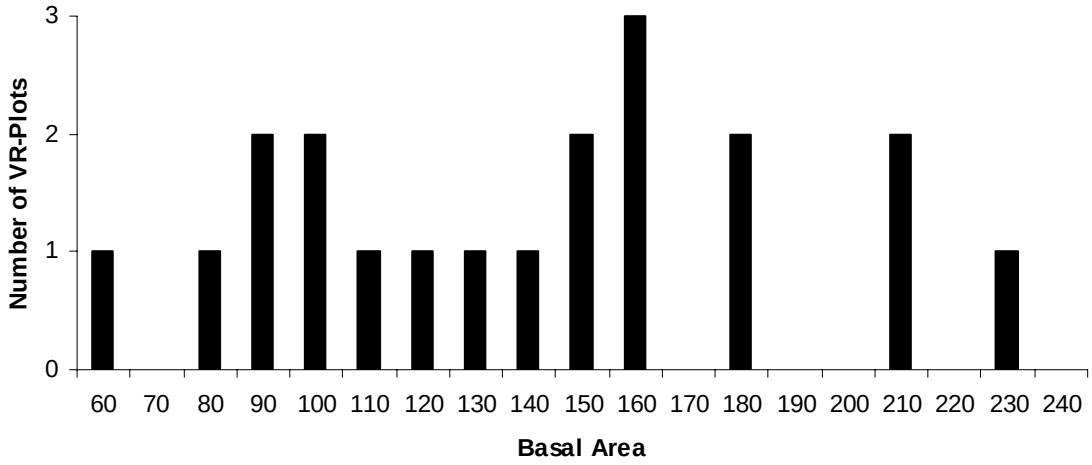

Figure 7. Distribution of stand density in variable radius plots surveyed by LSC-FHP in the Larson II Analysis Area.

The Schmid and Frye (1976) risk rating system also considers the percent of spruce in the canopy as a variable. The percent of spruce in the canopy was approximated using the percent of spruce in the LSC-FHP variable radius plots. Within the nine spruce-fir dominate stands, spruce comprised 49% of the species mix and the average percent

spruce ranged from 22% to 67% per unit (Table 7). Stand exam data indicated that the proportion of spruce range from 20% to 98% of the basal area in units with a large spruce component. The proportion of spruce was over 50% in 6 of the proposed treatment units (Appendix B).

Conclusions

Given the MPB populations surrounding and stand conditions within the Larson II Analysis Area, the building MPB infestations in the Larson II Analysis Area are not likely to depart from the projected rapid increases 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 et al. 1987), and in the SB epidemic in the Flat Tops area 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 moderate to high populations of 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. Thinning in areas dominated with lodgepole before beetle flight may reduce losses, however current mountain pine beetle populations are so large that stands are likely to experience large losses regardless of thinning treatments. Detailed alternatives and considerations for managing MPB impacts are provided in the Appendix C.

In most units spruce beetles were at low levels, however enough spruce beetles are active in the Larson II Analysis Area to warrant management for this insect. Most of the literature on managing SB deals with direct suppression or protecting individual trees. Carbaryl, permethrin and bifenthrin have been shown to be effective insecticides for the protection of uninfested trees from bark beetle attack. Preventative treatments should be completed late spring before the beginning of SB flight which coincides with snow melt and a flight temperature threshold of 61°F (Schmid and Frye 1977). A detailed review by Lister et al. (2002) of management strategies against SB that includes silvicultural practices, direct suppression actions, and prevention strategies is provided in Appendix D. For building SB populations a combination of treatments is more effective than any single treatment. In addition to the proposed silvicultural treatments, the district can use trap trees and cut and peel or remove beetle-infested spruce trees to suppress localized SB infestations.

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Appendix A. Larson II Analysis Area SB and MPB Ground Survey Summary Data

Unit	Size of Unit (Acres)	Acres Surveyed	Lodge-pole Pine BA ft²/acre	Lodge-pole Pine Mean DBH	Engle-mann Spruce BA ft²/acre	Engle-mann Spruce Mean DBH	Sub-alpine Fir BA ft²/acre	Sub-alpine Fir Mean DBH	Aspen Fir BA ft²/acre	Aspen Fir Mean DBH	Total BA ft²/acre
4	8.31	1.5	110	13.9	*	*	*	*	10	12.8	120
5	18.47	2.0	110	14.7	*	*	10	5.7	20	15	140
6	9.81	1.0	*	*	40	20.4	40	10	70	8.2	150
7	16.62	2.0	*	*	110	17.8	100	9.6	*	*	210
9	12.49	1.0	*	*	*	*	100	9.5	*	*	100
10	38.78	2.0	40	10.2	90	7.7	30	9.5	*	*	160
11	13.8	1.0	90	11.5	30	15.7	60	8.4	*	*	180
12	36.06	1.0	*	*	60	10.4	30	8.8	*	*	90
13	35.73	2.0	*	*	60	15.9	70	11.6	*	*	130
17	6.85	1.0	20	10.7	40	11.6	40	10.9	80	12	180
18	8.21	1.0	*	*	70	17.4	80	6.2	*	*	150
21	16.32	1.0	30	17.3	*	*	*	*	100	9.5	130
23	6.61	1.0	10	5.6	30	11.3	70	5.5	*	*	110
24	4.94	0.8	140	11.7	20	11.3	50	10.2	*	*	210
25	6.05	1.0	*	*	20	13.2	70	6.3	*	*	90
31	31.73	1.0	60	9	90	13.9	*	*	80	10.4	230
38	13.13	1.0	30	18.4	60	27.7	60	11.6	10	16	160
B	21.52	2.2	10	7.4	30	15.8	40	10.9	*	*	80
I	42.71	2.0	50	6.8	*	*	10	6.6	*	*	60
Total Acres	223.2	25.5									
Weighted Average			52.7	10.6	64.0	14.1	45.2	9.0	57.2	11.8	134.9

*No individuals of this species in variable radius plot.

Appendix B. Variable Radius Plot Data and Stand Exam Data.

Variable radius plots were surveyed in 2004 by LSC-FHP personnel. Stand data from stand exams were done in the Larson II Analysis Area 25 to 10 years ago and provided by the Hahns Peak/Bears Ears Ranger District. Data were obtained from RMRIS, Tree X Species, DBH Class datasheets and unit layout sheets of stand exam data. These data may not reflect increased tree diameter growth or changes in basal area or percentage of trees due to growth of tree mortality since that time.

		LSC-FHP Variable Radius Plot Data			**Hahns Peak/Bears Ears Ranger District Stand Exam Data**				
Units Sampled	**Acres**	**DBH (Average of sampled PIEN)**	**Average BA (All Species)**	**% Spruce of total BA**	**Stand Age**	**Average Dia. of Spruce**	**Average Basal Area ft^2/acre**	**% Spruce of total BA**	**Site Index**
3	4.06	No variable radius plot sampled			107	8	131	5	71 (PICO)
4	8.31	*	120	*	107	8	131	5	80 (PICO)
5	18.47	*	140	*	^	10	^	3	75 (PICO)
6	9.81	20.4	150	27	128	7.9	151	45	68 (PIEN)
7	16.62	17.8	210	52	128	7.9	151	35	68 (PIEN)
9	12.49	*	100	*	154	6.9	131	30	69 (PICO)
10	38.78	7.7	160	56	154	6.9	131	50	69 (PICO)
11	13.8	15.7	180	17	130	10	200	30	80 (PICO)
12	36.06	10.4	90	67	^	11.4	120	90	82 (PIEN)
13	35.73	15.9	130	46	^	12	80	65	80 (PIEN)
17	6.85	11.6	180	22	110	10.8	^	70	90 (PIEN)
18	8.21	17.4	150	47	110	9.4	181	98	81 (PIEN)
21	16.32	*	130	*	^	9	^	^	80 (PICO)
23	6.61	11.3	110	27	226	9	124	30	73 (PICO)
24	4.94	11.3	210	10	80	9	^	10	75 (PICO)
25	6.05	13.2	90	22	226	9	124	70	73 (PIEN)
31	31.73	13.9	230	39	110	10.6	180	20	80 (PICO)

		LSC-FHP Variable Radius Plot Data			Hahns Peak/Bears Ears Ranger District Stand Exam Data				
Units Sampled	**Acres**	**DBH (Average of sampled PIEN)**	**Average BA (All Species)**	**% Spruce of total BA**	**Stand Age**	**Average Dia. of Spruce**	**Average Basal Area ft2/acre**	**% Spruce of total BA**	**Site Index**
38	13.13	27.7	160	38	^	^	^	^	^
B	21.52	15.8	80	38	^	^	^	^	^
I	42.71	*	60	*	^	^	^	^	^

*No individuals of this species in variable radius plot.
^Data not available

Appendix C

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 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. 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 et al. 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 et al. 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 et al. 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 et al. 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 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:

<u>Low Windfall Risk Situations</u>:
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.

<u>Moderate Windfall Risk Situations:</u>
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.

<u>High Windfall Risk Situations:</u>
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 et al. 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 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 et al. 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.

The anti-aggregation pheromone, verbenone (4,6,6-trimethylbicyclo{3.1.1}hept-3-en-2-one) has also shown some effectiveness in protecting trees from MPB attack. Verbenone is a bark beetle produced pheromone that acts as an intra-specific chemical cue. When

MPBs first attack a tree several pheromones are produced, including small amounts of verbenone. As the numbers of beetles attacking the same tree increase, the amount of verbenone also increases and acts as a signal that repels additional beetles from attacking the same tree. A plethora of studies testing the efficiency of verbenone as protectant against mountain pine beetles have been performed with mixed results. There are many different factors most likely contributing the effectiveness of verbenone. For example, Progar (2005) found verbenone was effective in reducing MPB attacks at the beginning of an epidemic, but as the epidemic intensified trees in verbenone treated stands were attacked at rates comparable to control stands. Other factors that have lead to inconsistent results could include how verbenone is delivered (bubble cap, pouch, flake form) or the condition of tree host (drought stress, etc.). In some situations where chemical sprays cannot be applied, applying verbenone is the best option. However, due to the mixed results and relatively high cost of verbenone, ground sprays are still the preferred option for tree protection where possible.

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Appendix D

ACTION ALTERNATIVES AGAINST SPRUCE BEETLE

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January 2002

MANAGEMENT STRATEGIES

Forest managers can develop various strategies to avoid or reduce resource losses to spruce beetles. Before developing a strategy, the forest manager must evaluate the resource values and economics of management actions for each stand in light of management objectives. The beetle population level must also be considered, because population levels will determine the priority of management actions and the type of strategy to be invoked. Landscape considerations are important, because both stand susceptibility and beetle population levels in adjacent and nearby stands will influence bark beetle caused tree mortality in stands under consideration.

The primary strategy should be silvicultural treatments of potentially susceptible stands in order to maintain their health with a moderate growth rate. These silvicultural strategies should be implemented well in advance of an epidemic. The first step in this strategy is to risk-rate spruce stands, which will indicate the most susceptible stands and areas where susceptible stands are concentrated. The stands can then be treated with harvesting directed at the most susceptible stands and areas. Infested logging residuals seldom become a significant contributor to spruce beetle populations if stump height is kept below 18 inches (45 cm) and cull logs and tops are limbed, cut into short lengths, and left unshaded, unpiled, and exposed to sunlight. Silvicultural treatments have greater long-term effectiveness, because these treatments modify stand conditions.

The primary strategy assumes, in general, beetle populations are not immediately threatening resource values. If beetle populations are threatening, then strategies involving suppression are more appropriate. Suppression methods including silvicultural, physical and chemical measures are available to forest managers for reducing spruce beetle populations. Some methods are suitable only for populations in windthrown host material; other methods are better suited for infestations in standing trees. Most suppression methods are short-term responses to existing beetle populations and, therefore, correct only the immediate situation (Holsten *et al*. 1999).

A long-term goal of reducing susceptibility to spruce beetle involves creating a mosaic of age classes and stand conditions across entire landscapes. Without substantial interference, each major spruce beetle epidemic sets the stage for the epidemic to be repeated, as the forest regenerates and grows again into a susceptible condition. Because landscape-level spruce beetle epidemics are infrequent, the opportunity exists to modify landscape conditions in areas where these large beetle-caused disturbances conflict with management objectives. In this way, major spruce beetle epidemics may not necessarily be repeated in the distant future.

TREATMENT OPTIONS
SILVICULTURAL TREATMENT

Silvicultural practices and priorities can be developed if clear and well-defined management objectives exist. In determining treatment or cutting unit priorities, spruce beetle susceptibility should be integrated with all the other treatment objectives to best attain management goals and objectives. Three stand ratings, utilizing the potential outbreak rating or risk, provide guides that should be used in determining overall stand treatment priorities.

1. High. Susceptibility to attack and damage is a primary concern in reaching or maintaining management objectives where the potential spruce beetle risk is high or medium. This concern may be addressed by evaluation of probable spruce beetle population trends, possible impacts, and so forth, conducted by pest management specialists. In the event of an outbreak, a majority of spruce in the larger diameter classes (> 12 inches DBH) will be killed.
2. Medium. Susceptibility to attack and damage is a concern in attaining management objectives, but is definitely less than in high rated stands. The degree of concern will depend upon management objectives for the area and how a potential spruce beetle outbreak might affect them.
3. Low. Susceptibility to attack and damage by spruce beetle is not a concern.

An important consideration in any silvicultural treatment is wounding of residual trees. Great care must be exercised in any mechanical entry to avoid wounding. Especially with subalpine fir and, to a lesser degree, spruce species, as wounds provide entry courts for decay and root disease fungi. Not only can the pathogens lead to tree mortality, it is likely that there is an interaction between spruce beetle and infected trees, rendering them more susceptible to beetle attack.

Cutting Methods in Susceptible Stands

Once a spruce beetle infestation reaches epidemic proportions in susceptible stands, chances for control are greatly reduced. Hence vegetation management strategies aimed at preventing the accumulation of numerous high-risk stands and other high-risk beetle situations are the preferred management approach.

Intermediate Cutting Methods

A. Sanitation/Salvage. During an outbreak, beetle-infested, dead, and highly vulnerable large diameter spruce are removed in an effort to maximize utilization of attacked material. Salvage of significant blowdown material within 1 to 2 years, particularly when it occurs in and adjacent to highly susceptible stands, is recommended where it meets overall management objectives.

B. Presalvage. With the imminent threat of an outbreak, large diameter, slow growing spruce are removed from highly susceptible stands. Presalvage is the removal of merchantable trees in anticipation of losses likely to occur before definitive regeneration cuts (Smith 1986). In some situations, presalvage may achieve the same results as a shelterwood cut.

C. Precommercial thinning. Thinning young stands to regulate stocking and species composition may be appropriate when commensurate with other stand objectives.

D. Commercial thinning. Thinning at 20 or 30 year intervals will improve stand vigor. While thinned stands have higher average diameter, benefits from improved vigor likely outweigh risks associated with having larger diameter trees. Thinning pine stands susceptible to mountain pine beetle indicates that the habitat modification provided by thinning is an important contributor to reduced stand susceptibility. Spacing between trees is the critical factor in this, rather than just reducing tree density. It is likely that habitat modification in thinned spruce stands would play a similar role of reducing stand susceptibility to spruce beetle. However, windthrow is a significant concern when increasing inter-tree spacing. A long term goal of thinning more appropriate to spruce/fir stands may be to create a mosaic of age classes rather than trying to maintain a single age class.

Even-aged Regeneration Cutting Methods

A. Clearcutting. This method effectively eliminates bark beetle risk on treated acres for a considerable period of time. However, if faced with large acreages of unmanaged, highly susceptible stands, clearcut regeneration techniques will require decades to achieve a level of management where beetle risk is diminished. Where locations have a mix of low, medium, and high-risk stands, clearcutting the high risk stands over one or two decades may diminish the overall beetle risk. Regeneration needs will significantly affect the location and degree to which this method is employed.

B. Shelterwood. This method has advantages over clearcutting when an objective is to reduce beetle susceptibility within a location in a minimum of time. For a given sale quantity, shelterwood cuts would require treatment of more acres than clearcutting. Shelterwood prescriptions should provide opportunities to remove trees at high risk to bark beetle, such as damaged trees, trees already infested, or poor vigor dominants and codominants. Where more than the recommended basal area to be removed is in high risk trees, a decision of whether to accept the risk of spruce beetle attacks or to accept the risk of windthrow by removing additional susceptible trees will have to be addressed (Alexander 1986). Two or three entries may be required to meet the desired condition (Alexander 1986).

Uneven Aged Regeneration Cutting Methods

In situations where stands are clearly irregular in structure, maintaining the irregular stand structure is desirable, and the risk to spruce is apparent and undesirable, selection or group selection cutting methods are applicable. Selection regeneration methods may have advantages in managing spruce beetle susceptible stands in these situations by allowing regulation of stocking, basal area, and controlling diameter distribution while maintaining stand characteristics valuable to management objectives.

No specific information or guidelines are available on the implementation of uneven-aged cutting methods in spruce beetle susceptible stands. Multiple entries may be required to achieve the desired stocking and diameter distribution. However, where visual quality is important, suggested stand structure objectives could be a growing stock level of 100 to 120 sq. ft. of basal area on most sites, a maximum tree diameter of 24 inches, and a diameter distribution approaching a Q of 1.3 to 2.0 (Alexander and Edminster 1977). Where lowered susceptibility to spruce beetle is needed, fewer large diameter trees are desirable, so that an average stand diameter less than or equal to 12-14 inches for spruce is suggested. As with commercial thinning, the improved stand vigor and modified habitat conditions which would result from cutting in uneven aged stands is predicted to lower stand susceptibility to spruce beetle attack and tree killing.

Minimizing Spruce Beetle Build-up in Logging Slash and Debris

The following guidelines can be utilized to minimize spruce beetle population increases in logging slash and debris:

A. Cut trees as low to the ground as possible, preferable stump height of no more than 12 inches.

B. Cull logs and larger diameter slash material can be used to "trap" beetles to further reduce populations and lessen the risk of attack to standing trees, if this material is left in the cutting unit and then removed or treated after beetle flight. This trap material must be removed prior to the next beetle flight. If they are not removed, beetles produced in this material will increase the chance of attacks to surrounding standing spruce (Schmid 1977). Utilize C-Provisions, R0-C-6.46, R0-C6.47, R0-CT-6.46, and R0-CT-6.47 as deemed necessary.

CULTURAL TREATMENT

Trap Tree Method

Trap trees are green trees with a diameter greater than 18 inches DBH that are felled, preferably before the spring beetle flight (Holsten *et al*. 1999). Trap trees should be left in their "natural state" with no limbing being done, because the limbs shade the bole and make the trees more attractive to spruce beetles. Trap trees are used to attract and decoy emerging beetles away from living, standing green spruce trees. Traditional trap tree usage is more effective for absorbing beetles than baiting standing green trees for the following reasons: 1) beetles prefer downed material over standing green trees; 2) beetles infest a greater percentage of the bole; and 3) the mean attack density is greater.

Once the trap tree is infested with beetles, it must be treated by milling, burning, solar heating, or insecticidal application (Schmid and Frye 1977).

Trap tree treatment considerations to be aware of are as follows: 1) beetles are effectively attracted up to one-quarter mile from the felled tree, becoming less effective with an increase in distance; 2) trees felled in the shade are preferred over those felled in the sun (Nagel *et al*. 1957); and 3) trap trees, by attracting beetles, may lead to attacks on standing spruce adjacent to them. Unbucked trees provide more shade, increasing beetle suitability and reducing both fungal development and competition from *Ips* species, because branches provide increased shade and serve to hold the bole above ground. By keeping the bole off the ground, more of the shaded underside is available for colonization. The number of trap trees felled is relative to the attacking beetle population and the size of the felled host. A trap tree may absorb 10 times the number of beetles a standing tree will absorb (Schmid and Frye 1977). Nagel *et al*. (1957) recommends one trap tree for every four to five infested standing trees. Schmid and Frye (1977) include a table for more precise estimates of the number of trap trees to be felled based on the current infestation level.

Sanitation of Infested Trees

This treatment strategy does not differ in principle from silvicultural treatments where trees currently infested by spruce beetle are removed or treated to kill the beetles within them. In practice, this treatment differs from silvicultural treatments in that fewer trees are removed and mechanical means may or may not be used. Prompt identification and treatment of infested trees before the inhabiting beetles emerge will remove a local source of contagion. It can afford a degree of protection to nearby susceptible trees and stands. Consideration must be given to the relative susceptibility of the adjoining landscape and the local "beetle pressure." Where both are at a high level, sanitation of a few infested individual trees is not likely to have a positive benefit due to immigration of beetles and because the number of trees removed may not alter susceptible stand conditions.

CHEMICAL

Lethal Trap Tree Method

Lethal trap trees, a modification of the traditional trap tree method, are another effective option to attract, hold and eliminate beetles from the forest (Frye and Wygant 1971, Buffam 1971, Buffam *et al*. 1973, Lister *et al*. 1976). Lethal trap trees eliminate the need to remove infested material from the forest and can be especially useful in areas where removal of material is prohibitive. Prior to felling, the trap tree is injected with a silvicide, making it a lethal trap tree. Currently, no silvicides are registered for use in the United States.

A variation of the lethal trap tree method is to apply an insecticide to the felled trees so that attacking beetles are killed as they attempt to bore into the treated tree. Currently, several insecticides are registered and available for this use in the United States.

Insecticides Preventing Infestation

Insecticides can be applied to the boles of uninfested trees to kill attacking beetles and protect high value trees. Application of these insecticides will not kill larvae or adults already present in the phloem. These insecticides work directly on the attacking adults attempting to bore into the tree and therefore need to be applied prior to the tree being attacked by spruce beetles. Only insecticides labeled for this use can be applied. Pruning the lower branches from the base of the tree prior to spraying should increase the effectiveness of the application and create warm, unfavorable conditions to the spruce beetle.

Pheromones

Pheromones, or message bearing chemicals, are emitted by the spruce beetle and serve to coordinate and regulate their attack behavior. Synthetic versions of these chemicals are available that either attract or repel spruce beetles. Synthetic pheromone production and pheromone dissemination methods need to be improved to take full advantage of pheromone technology. In addition, variation in results of operational synthetic pheromone use indicate that we do not fully understand regional variations in the chemical components of spruce beetle pheromones and the role(s) played by host volatiles. A summary discussion of operational and potential spruce beetle pheromone uses with literature citations was provided by Skillen *et al*. (1997). Operational uses of spruce beetle pheromones at present include trap out and attack disruption. However, results are inconsistent.

The trap out tactic uses attractant pheromones to lure spruce beetles into traps or trap trees and thereby reduce beetle populations to a more acceptable level. This would work best in isolated, lower level beetle populations where immigration would not erase the impact of trapping. Treatment trials using this have shown that the synthetic attractant pheromones do not compete well with natural attractant pheromones and may have varying attractiveness, as currently formulated, in every region of the spruce beetle range. However, the trap-out tactic has been successful on isolated populations in Utah as part of an integrated strategy employing several tactics (Bentz and Munson 2000).

In general, the use of attractant pheromones does not constitute a treatment tactic on its own, but is employed to augment silvicultural treatments or trap tree methods. For example, to retain or bring beetles into an area scheduled for a regeneration cut, one could place tree baits in the stand to be treated. Similarly, one can place tree baits containing attractant pheromone on trap trees or lethal trap trees to render them more attractive. It must be stressed that spillover attacks on trees adjacent to those baited is a common occurrence. Failure to treat baited and adjacent attacked trees in a timely manner can lead to exceptionally high tree mortality.

Deploying the spruce beetles' repellent pheromone prior to the attack period might reduce tree mortality from spruce beetle. The natural repellent pheromone or anti-aggregant pheromone of the spruce beetle is MCH or 3,2-MCH (3-methyl - 2-cyclohexen

- 1-one). As colonization of a tree proceeds, the amount of MCH released into the air increases. Apparently, a certain threshold of MCH signals to other beetles that the tree is fully occupied and no longer suitable for colonization. Beetles searching for host material are thus repelled by such trees and search elsewhere for suitable material.

MCH has been used successfully to disrupt attack and colonization by spruce beetle in host trees and shown to reduce the attraction of spruce beetles on infested logs. In addition, MCH has recently been shown to be effective in preventing attack by Douglas-fir beetle (*Dendroctonus pseudotsugae*) on small, valuable stands of Douglas-fir. However, equivocal results in recent trials in Utah suggest that operational use of MCH against spruce beetle cannot be universally successful in all areas.

A potential use of MCH would be to deploy MCH in an area in an attempt to disrupt attack and colonization there, causing dispersal of beetles. This would be done with methods similar to those used against Douglas-fir beetle. It may be that this tactic is only successful at lower beetle population levels and that effectiveness ceases above some population threshold. Another potential use of MCH would be deploying it to "push" spruce beetles from a stand or area needing protection while at the same time "pulling" them into a nearby stand or area scheduled for regeneration harvest with attractant pheromones. Neither of these tactics has been successfully demonstrated against spruce beetle as yet.

One inhibition to the development of operational MCH use has recently been eliminated. The USDA Forest Service under the authority of the US Environmental Protection Agency currently registers MCH for use in the United States. Not all States, however, have reviewed this recent development and given their approval against the Douglas-fir beetle and spruce beetle.

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