Biological Evaluation
R2-05-05

Biological Evaluation of Spruce Beetle and Mountain Pine Beetle Activity on the French Creek Analysis Area of Brush Creek/Hayden Ranger District, Medicine Bow-Routt National Forests and Thunder Basin National Grassland, 2005

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Abstract

Engelmann spruce mortality due to spruce beetle (SB) and lodgepole pine mortality due to mountain pine beetle (MPB) beetle have been increasing for several years within the French Creek watershed on the Medicine Bow-Routt National Forests and Thunder Basin National Grasslands. Widespread epidemic populations of both bark beetle species are occurring on National Forest Lands to the south. The Brush Creek Hayden Ranger District has designated a French Creek Analysis Area and is considering a variety of silvicultural activities to remove beetle-infested and dead trees and to mitigate SB impacts on approximately 2,700 acres of spruce-fir forest and MPB impacts on about 700 acres of lodgepole pine forests.

Lakewood Service Center-Forest Health Management (LSC-FHM) personnel used aerial survey information for the Medicine Bow Mountains and ground survey of six of the proposed management units in the spruce-fir component of the French Creek Analysis Area to determine the level of beetle infestation in these areas. Ground surveys recorded the number of trees infested with SB in 2004 and 2003. Results indicate an increasing population trend. The 2004:2003 ratio averaged 4:1 for all six units surveyed and ranged from 0:0 to 19:1. Additional ground survey of proposed treatment areas in the lodgepole pine component of the analysis area are planned to be conducted in spring of 2005.

Variable radius plots measured during ground surveys and available stand exam data were used to determine stand susceptibility to SB. Stands were risk rated using a rating system developed by Schmid and Frye (1976). Risk rated stands ranged from medium to medium high risk. Site index was the only moderating factor for many of the higher risk stands. Given the average tree size, stand density and abundance of spruce in the stands, and the concurrence of rapidly increasing SB populations trending toward epidemic levels, these units are likely to sustain major losses to SB over the course of an epidemic.

Management actions to address the SB infestation occurring in the French Creek Analysis Area are discussed. A supplement to this biological evaluation will be prepared to address the MPB infestation occurring in the French Creek Analysis Area once ground surveys of the lodgepole pine areas are completed.

Introduction

This biological evaluation was prepared to support the proposed efforts to reduce the impacts of increasing populations of spruce beetle (SB), *Dendroctonus rufipennis* Kirby, and mountain pine beetle (MPB), *Dendroctonus ponderosae* Hopkins, within the French Creek Analysis Area of the Brush Creek-Hayden District of Medicine Bow-Routt National Forests and Thunder Basin National Grassland. Wind storms causing large areas of blown down Engelmann spruce *Picea engelmannii* Parry ex Engelmann, in the late 1990's, extensive stands of old, slow growing trees, recent drought conditions over the last five years, and increasing populations of SB have set the stage for potentially serious losses of Englemann spruce due to this bark beetle. Drought-weakened forests of older, dense lodgepole pine, *Pinus contorta* Dougl. ex Loud, stands within the French Creek Analysis Area face a similar threat from increasing populations of MPB. Both of these beetles can play a dramatic role of recycling old forests into new ones in their respective ecosystems.

Spruce Beetle

The spruce beetle 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. SBs emerging from windthrown trees infest standing, live trees when sufficient windthrown trees are unavailable. Widely scattered blowdown is especially conducive to increases in beetle populations (Wygant and Lejeune 1967) and is a prime source of outbreaks (Schmid and Frye 1977). Outbreaks may be more than 115 years apart and wide-scale epidemics may be separated by 250 years or more (Veblen *et al*. 1994). 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).

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 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, Wood 1982).

Although a one-year life cycle has been observed at warmer sites on the Routt National Forest, the more typical two-year life cycle described by Massey and Wygant (1954) occurs in the high elevation sites on the French Creek Analysis Area. Emergence is temperature dependent and can occur as early as May, but more often occurs in June or July. Pheromone trap studies in the French Creek Analysis Area showed peak beetle flights the fourth week of July in 2003 and the second week of July in 2004 (Bergher unpublished report). Most of the attacks in the French Creek Analysis Area

occur in July and early August. Female beetles 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 temperatures below -30ºF will kill all larvae and below -15ºF will kill all adults.

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 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. 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, the residuals must be removed or treated.

Mountain Pine Beetle

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

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

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

Outbreaks of MPB tend to occur at intervals of fifteen to twenty years in older Rocky Mountain lodgepole pine forests and may last for six to ten years (Cole and Amman 1980). Schmid and Mata (1996) write “an epidemic may last several years in a particular stand whereas the epidemic as part of a drainage may last for ten or more years.”

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

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

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

Current Situation

The French Creek Analysis Area is located southeast of Saratoga, Wyoming in the Snowy Range of the Medicine Bow Mountains on the Brush Creek-Hayden Ranger District on the Medicine Bow-Routt National Forests and Thunder Basin National Grassland (Figure 1). The analysis area includes 66,830 acres of National Forest lands and 853 acres of private land. The high elevation portions of the French Creek Analysis Area are dominated by spruce-fir forests and the lower elevations on the western side of the analysis area are dominated by lodgepole pine (Figure 2).

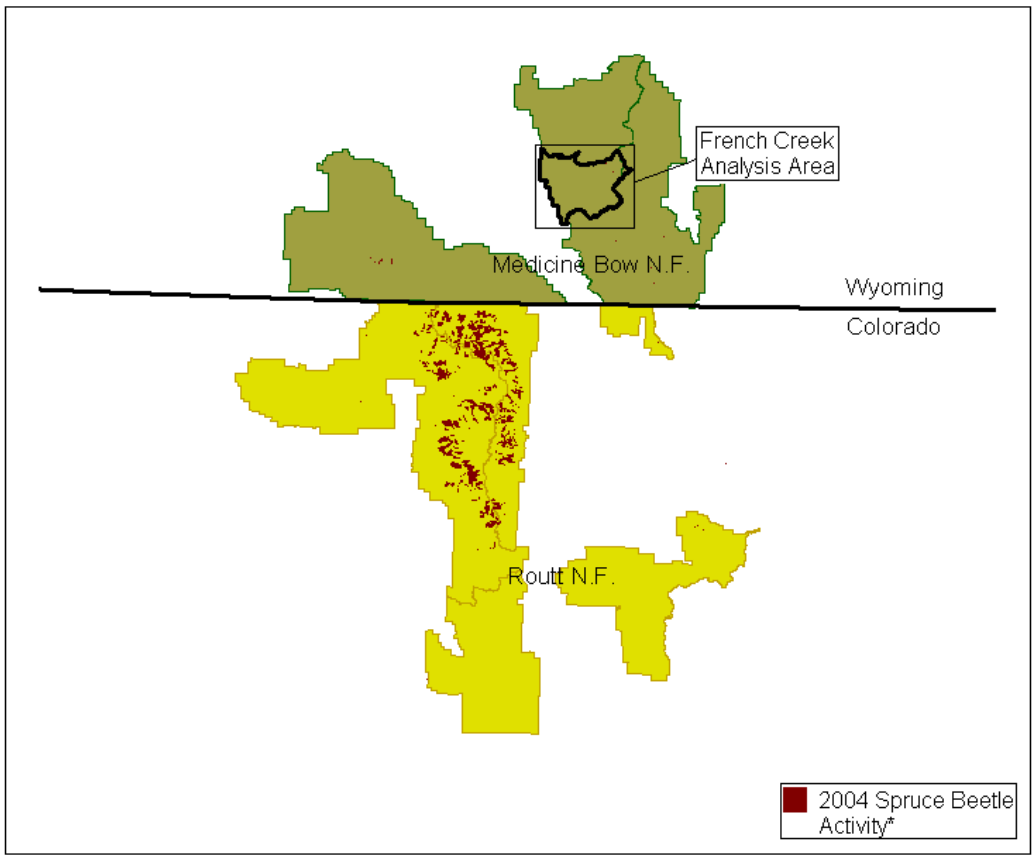

Figure 1. SB mortality detected by aerial survey on the Medicine Bow-Routt National Forests in 2004 and the location of the French Creek Analysis Area.

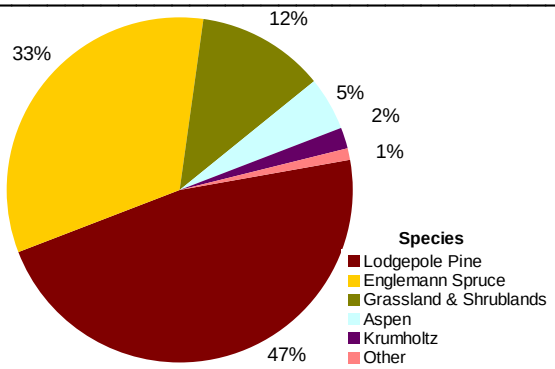

Figure 2. Species mix within the French Creek Analysis Area (Delay 2005)

Recent SB Activity within the French Creek Analysis Area

Conditions in the Rocky Mountain Region have been favorable for the development of SB epidemics in recent years. A large epidemic south of the French Creek Analysis Area has been expanding through standing Englemann spruce on the Routt National Forest since 2000 (Figure 1). This epidemic was triggered by a large spruce windthrow event in 1997.

SB populations have been increasing within the French Creek Analysis Area of the Brush Creek-Hayden District since 1998-1999. Three easterly windstorm events occurred in the late 1990's, causing considerable tree blowdown across a widespread area of the forest in the French Creek watershed (Schaupp 2000). The prolonged drought conditions throughout the central Rocky Mountains over the past five years has increased stress on trees, increased competition for moisture among the trees, and reduced the ability of trees to produce defensive chemicals that may kill beetles as they attack trees. About 2,500 acres of blowdown occurred in 1998 and 1999 within and near the stands proposed for treatment in the analysis area (Delay 2005). A site visit to the area in the fall of 1999 reported varying levels of SB present in the windthrown spruce (Schaupp 2000). In October 2004, several large SB infestations were identified in the Four Corners and Foxpark areas of the Medicine Bow Mountains (Witcosky 2005). The Four Corners and Foxpark areas are located on the Laramie Ranger District just to the south of the French Creek Analysis Area. The increase of SB populations within abundant blowdown, the occurrence of susceptible forest conditions, movement of SB into standing trees, and the prolonged drought provide the main ingredients required to initiate and sustain a large SB epidemic in the area.

Since 2000, the Brush Creek-Hayden Ranger District has been actively managing an increasing SB infestation in the 54-acre Silver Lake Campground,

which is within the French Creek Analysis Area (Witcosky 2002, Cain 2003). District staff used trap trees, cut and peeled beetle-infested spruce trees, and cut and removed beetle-infested trees to suppress the SB infestation. In 2001, 24 infested trees were felled and peeled. In 2003, 124 infested trees were felled and removed through a timber sale. In 2004, an additional 54 campground trees were attacked by the SB. They also utilized preventive treatments to further limit SB attacks on healthy trees, including the application of insecticides to the boles of high-value, uninfested trees and the deployment of the SB anti-aggregation pheromone, methylcyclohexenone (MCH), to disrupt beetle aggregation on uninfested trees within the campground. These suppression and prevention actions have helped to slow the rapid increase of the SB infestation within the Silver Lake Campground. Nevertheless, increasing SB infestations in adjacent areas continue to put beetle pressure on trees within the campground.

Recent MPB Activity within the French Creek Analysis Area

The lower and middle elevations of French Creek and adjacent watersheds are dominated by mature stands of lodgepole pine over 100 years in age that are considered to be at moderate to high hazard to MPB infestation (Delay 2005). Conditions in northern Colorado and southern Wyoming have been favorable for the buildup of MPB since the late 1990's. The Medicine Bow-Routt National Forests have numerous areas where MPB numbers are above endemic levels. The 2004 aerial survey detected new infestations in and near the French Creek Analysis Area.

Ground surveys conducted during a campground hazard tree evaluation by LSC staff indicated that many lodgepole pines in the Ryan Park Campground had been infested recently by the MPB (Burns 2005). In 2004, the Brush Creek/Hayden District removed over 100 MPB-infested trees in the South Brush Campground, at the west end of the French Creek Analysis Area. Also, MPB-infested trees have been discovered in the fuels treatment units within Ryan Park North Stewardship project area.

Proposed Action for the French Creek Analysis Area

The Brush Creek-Hayden Ranger District has proposed management activities on 3,418 acres within the French Creek Analysis Area to reduce the impact from SB and MPB (Table1 and Figure 3). Suppression and prevention tactics have been included in the strategy. Suppression actions include identifying infested trees and removing them and the beetles they harbor through a commercial timber sale where possible or cutting infested trees into sections and removing the bark on-site to kill the beetles. In SB infested areas, trap trees may also be used to concentrate beetles that will subsequently be destroyed by removing the bark. In the spruce-fir areas this could include thinning to reduce basal area, removing the large diameter spruce to release a younger understory forest, or shift the species dominance on a site away from spruce.

Two large areas of MPB activity occur in the vicinity of Ryan Park/Slash Ridge and Barrett Ridge and have been proposed for sanitation and salvage by the Brush Creek/Hayden Ranger District. Prevention activities proposed include changing stand conditions that predispose them to bark beetle attack. In lodgepole pine areas this will include some thinning and spacing of the trees in addition to the sanitation of infested trees.

Table 1. Proposed management actions within the French Creek Analysis Area.

Treatment	Estimated Acres
Overstory Removal	334
Shelterwood-Seed Cut	459
SB Sanitation/Salvage	1,520
MPB Sanitation/Salvage	700
Salvage and Non-Commercial	405
TOTAL	3,418

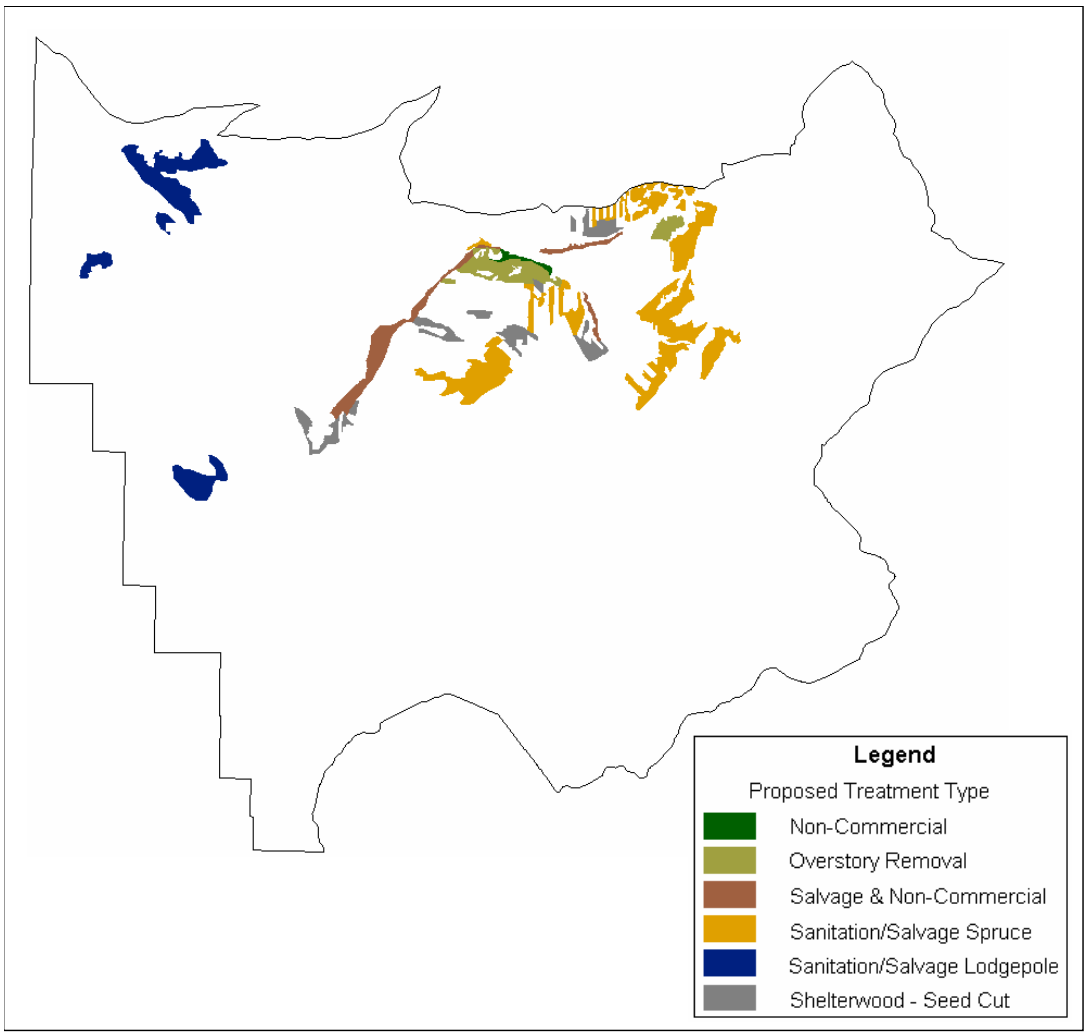

Figure 3. Proposed treatments in the French Creek Analysis Area

Purpose

This evaluation documents the current status of SB and MPB in the French Creek Analysis Area and discusses the proposed treatments to suppress these bark beetles, prevent their spread to uninfested stands, and salvage areas already impacted. A supplement to this biological evaluation will be issued once ground surveys for MPB have been completed for proposed lodgepole pine treatment units recently added to the French Creek Analysis Area.

Methods

Current SB conditions for the French Creek Analysis Area were estimated by aerial survey, strip samples, variable radius plot samples, available stand exam data, and information on recent beetle activity in the area documented in Lakewood Service Center site visits.

Aerial Survey

Aerial surveys were conducted from a fixed wing aircraft about 1,500 feet above the ground at approximately 100 miles per hour in August after infested trees begin to fade. LCS-FHM personnel and the U. S. Forest Service Rocky Mountain Region Aerial Survey Program Manager performed the aerial surveys. Areas of spruce killed by SB and lodgepole pine killed by MPB were sketchmapped on to 1:100,000 scale USGS 30X60 minute topographic maps. Estimated tree mortality and acres affected by SB and MPB across all land ownerships in the Upper Fraser Analysis Area were summarized for the past six years.

Stand Conditions

Ground surveys were conducted by LSC-FHM personnel on 49.6 acres in six of the spruce-fir areas identified for possible sanitation/salvage treatment by the Brush Creek/Hayden Ranger District. The ground survey techniques used included strip samples and variable radius plots. Strip samples tally one year-old and currently infested trees in plots one chain in width and of variable length. Spruce trees that were classified as being infested for over one year (i.e., attacked and killed by SB in 2003) generally had green or slightly off-color foliage, had weathered boring dust at the base of the tree, had occasional pitch tubes on the bole of the tree, and often had signs of woodpecker foraging activity. Trees classified as currently infested (i.e., attacked and killed by SB in 2004) were still green, and had boring dust and occasional pitch tubes at the attack sites. Variable radius plots were sampled every one quarter mile or at least one per transect. A 30 BAF prism was used to select sampled trees. Variable radius plots provided data on the stand density, species mix, and average diameter of the trees (Appendix A).

Existing stand exam data were provided for proposed treatment areas by the Brush Creek-Hayden Ranger District (Appendix B). Much of these data were over twenty years old, which limited its current usefulness for diameter and basal area assessments. These data were more helpful in assessing species composition and stand age. Data were weighted by the area of the stand.

Results and Discussion

Aerial Survey

Aerial survey data indicate an increasing population trend for SB and MPB within the French Creek Analysis Area (Table 2 and Figure 4). Aerial survey data provide only general trend information on pest activity because flying conditions and surveyors may vary from year to year. Aerial survey does not detect currently infested trees and can greatly underestimate the current beetle activity if populations are rapidly expanding. It only reports trees that have begun to discolor. SB-killed trees can take 2-3 years before the infested tree appears obviously discolored. MPB-killed lodgepole pines usually begin to fade the next summer after the trees are infested.

A notable increase in spruce killed by SB was detected in aerial surveys in 2004. Area impacted went from 8 acres in 2003 to 178 acres in 2004 and the intensity increased from one tree killed per acre to two trees killed per acre. This level of infestation is above the endemic level described by Bentz and Munson (2000) as having the majority of the beetle population confined to windthrown trees and only one or two standing infested trees over five acres.

Aerial surveys show an increase in trees killed by MPB in the French Creek Analysis Area since 2001. The detectable area impacted by MPB expanded to 885 acres within the analysis area in 2004 (Table 2). Approximately 0.65 trees were killed per affected acre. This level of infested trees per acre occurs in the early stages of a MPB epidemic based on the course of an infestation described by Cole and Amman (1980). Aerial survey data only provide a general estimate of beetle activity and must be verified and augmented with ground surveys.

Table 2. USDA Forest Service Rocky Mountain Region aerial survey data for the French Creek Analysis Area from 1997 – 2004.

Year Surveyed	MPB		SB	
	Acres[1] Impacted	Trees[1] Killed	Acres[1] Impacted	Trees[1] Killed
1997	0.1	2.0	0	0
1998	Not flown	Not flown	Not flown	Not flown
1999	83.0	49.3	0	0
2000	39.4	34.1	0	0
2001	178.3	389.8	10.6	10.0
2002	227.0	243.7	0	0
2003	581.1	635.0	8.1	8.0
2004	885.0	574.6	178.1	356.2

[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.

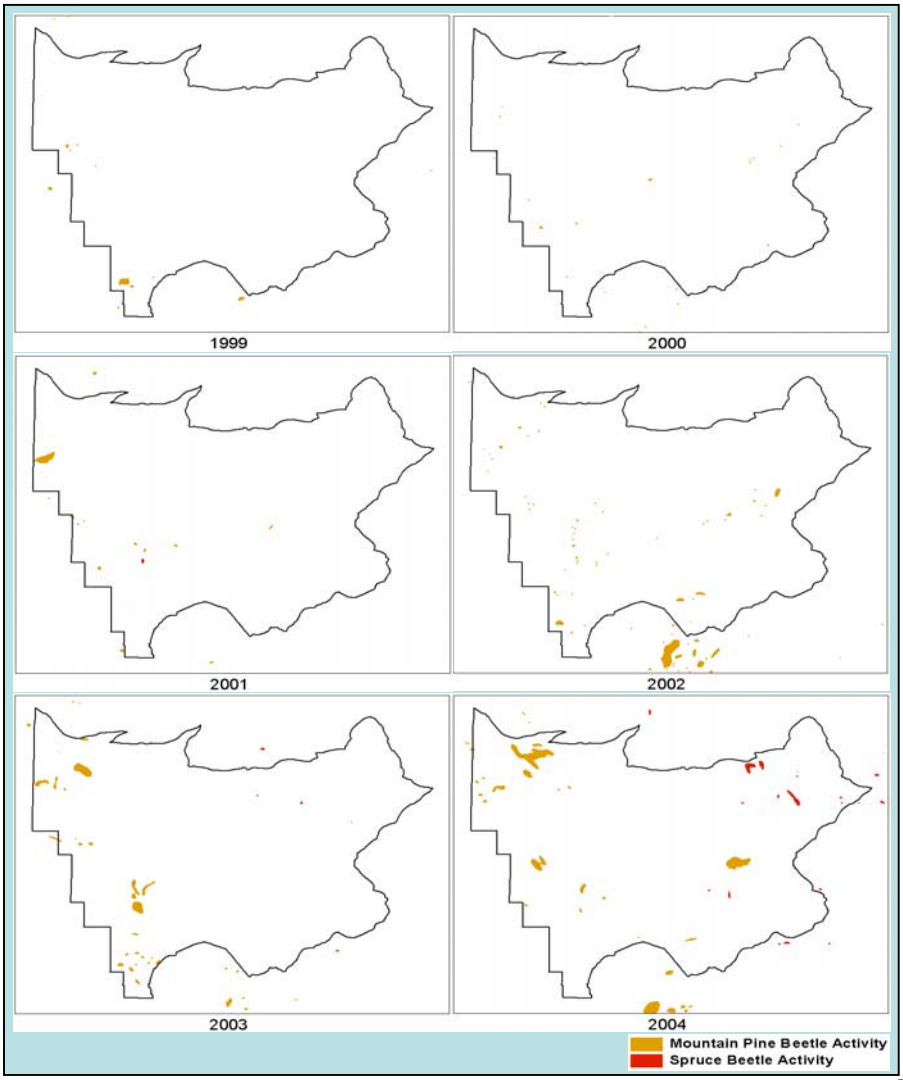

Figure 4. SB and MPB activity detected by aerial surveys[1] conducted 1999-2004 over the French Creek Analysis Area and adjacent lands.

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

Stand Conditions in Surveyed Spruce-Fir Forest Areas

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 dbh, having a BA over 150 sq. ft. per acre, and a proportion of more than 65% spruce in the canopy (Table 3). 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. Bentz and Munson (2000) point out that silvicultural strategies, such as thinning, to reduce stand susceptibility to SB have not yet been tested.

Table 3. Risk categories for potential SB outbreaks for each stand characteristic (from Shmid 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 4. Stand risk rating values for particular stands by summing risk category values for each stand characteristics presented in Table 3 (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

Stand Conditions and SB Risk in the French Creek Analysis Area

Surveys conducted by LSC-FHM in August and September 2004 and existing stand exam data collected from 1980 – 1988 were used to assess stand conditions relative to potential spruce beetle attack. The Schmid and Frye (1976) risk rating criteria were used to score and assign a risk rating to surveyed stands. This rating system along with the current trend in the SB population may be helpful in prioritizing and selecting treatment alternatives to minimize SB impacts. Higher risk stands have the ingredients necessary for SB populations to develop to epidemic levels. During an epidemic, susceptible spruce in lower risk stands within the epidemic area are also likely to be attacked.

Summarized data from 25 variable radius plots in six proposed treatment areas measured by LSC-FHM are presented in Table 5. All of the plots were in units proposed for sanitation salvage treatments.

Summarized stand exam data collected between 1980 and 1988 from 21 stands within 19 of the 35 proposed treatment units in spruce-fir were provided by the Brush Creek-Hayden Ranger District. Pertinent stand exam data are presented in Appendix B and summarized by proposed treatment type in Table 6. For each of the 16 proposed units where no stand data were available, the district identified a representative "locsite" which is an adjacent stand that has similar species makeup and stand structure and for which stand exam data are available.

Table 5. Stand data from variable radius plots within proposed treatment units in spruce-fir stands in the French Creek Analysis Area sampled by LSC-FHM. Averages are weighted by the size of the stand.

Unit	Acres	Average DBH of Spruce over 10 inches	Average BA	% Spruce[1] of total BA	Site Index	Stand Risk Rating (score)
1	189.6	20.0	232	72	56	Medium-High (10)
6	122.5	23.2	160	63	58	Medium (9)
29	37.2	25.6	60	100	50	Medium (8)
30	88.6	22.3	220	50	73	Medium (9)
34	115.9	21.9	180	42	52/53	Medium (8)
35	305.13	20.7	156	46	53	Medium (8)
Overall	858.93	20.9[2]	179[3]	56.4[3]	56[3]	Medium (9)

[1] Percent spruce of total BA is used as an estimate of percent spruce in the canopy.
[2] Unweighted average of individual tree diameters >10 inches in all plots
[3] Weighted average by total stand acres.

Table 6. Summary of both actual and representative stand exam data for spruce-fir forests in the French Creek Analysis Area by the proposed treatment activity (Appendix B). **These stand exam data average 23 years old and may not reflect tree growth and mortality since that time.** It is presented only to give insight into potential stand conditions across a broader area.

Proposed Treatment (Area)	QMD[1] of Spruce over 10 inches DBH[2]	Average Basal Area (BA) per Acre[2]	% Spruce of total BA[2]	Site Index	Individual Stand Risk Rating Scores from Appendix B[3]	Average Risk Rating (Score[4])
Salvage and Non-Commercial (405 Acres)	**18.5[4]**	**183**	**43**	**73[4]**	**-,-,-,-,8**	**Medium (9)**
Overstory Removal (334 Acres)	**18.5[4]**	**111**	**38**	**53[4]**	**9,-,-**	**Medium (7)**
Shelterwood/ Seed Cut (459 Acres)	**16.9**	**114**	**66**	**60**	**8,8,8,10,5,7, 8,8,10,8,8**	**Medium (9)**
Sanitation Salvage (1,520 Acres)	**17.6[4]**	**137.9**	**55**	**54[4]**	**9,10,10,10,9,7,7, 7,8,-,7,10,10,-,7,7**	**Medium (8)**
All Proposed Treatments	**17.5[4]**	**137.7**	**53**	**56[4]**		**Medium (9)**

[1] Quadratic mean diameter
[2] Weighted average based on the size of the proposed units.
[3] "-" indicates unrated stands due to missing data field(s).
[4] Includes all data available for each data field. Some stands are missing diameter or site index information.

Engelmann spruce diameter data from both the 2004 survey and the old stand exams indicate that average diameters are above 16 inches, which is a high risk indicator for this variable. Engelmann spruce diameters in the LSC-FHM sample ranged from 6 inches to 36 inches DBH and averaged 20.1 inches (Appendix A and Figure 5). The average of spruce over 10 inches which is used in the risk rating system was 20.1 inches (Table 5). The weighted average DBH by stand area was 21.5 inches.

Old stand exam data indicated that the QMD of spruce over 10 inches in diameter ranged from 11.2 inches to 24.4 inches and averaged 17.5 inches when weighted by stand area. Diameter information was available for 28 of the proposed treatment units and averaged greater than 16 inches in 24 of the proposed units.

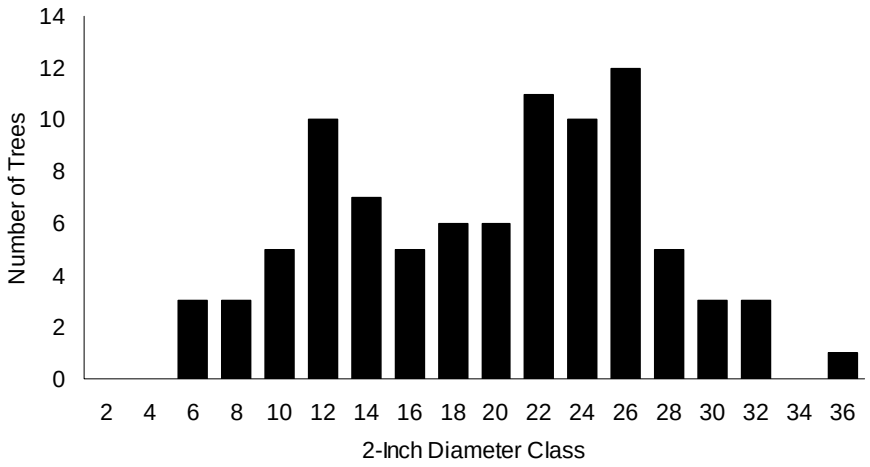

Figure 5. Engelmann spruce DBH distribution that fall within 2-inch diameter classes from variable radius plots surveyed by LSC-FHM in the French Creek Analysis Area.

The LSC-FHM survey found basal area per acre ranged from 60 sq. ft. per acre to 540 sq. ft. per acre and averaged 184 sq. ft. per acre in all plots (Figure 6). The weighted average basal area per acre by unit area was 179 sq. ft. per acre (Table 5). This represents an overall high risk of SB attack based on this variable with one surveyed unit having a low risk based on stand density.

Old stand exam data, which do not consider the last 17-25 years of growth or mortality, indicate a range in basal area from 65 sq. ft. per acre to 214 sq. ft. per acre with an overall weighted average of all proposed treatment units of 138 sq. ft. per ac. This indicates an overall medium risk for the variable with 17 proposed units having high risk densities over 150 sq. ft. per acre, 7 proposed units having medium risk, and 12 proposed units with low risk for the development of SB outbreaks.

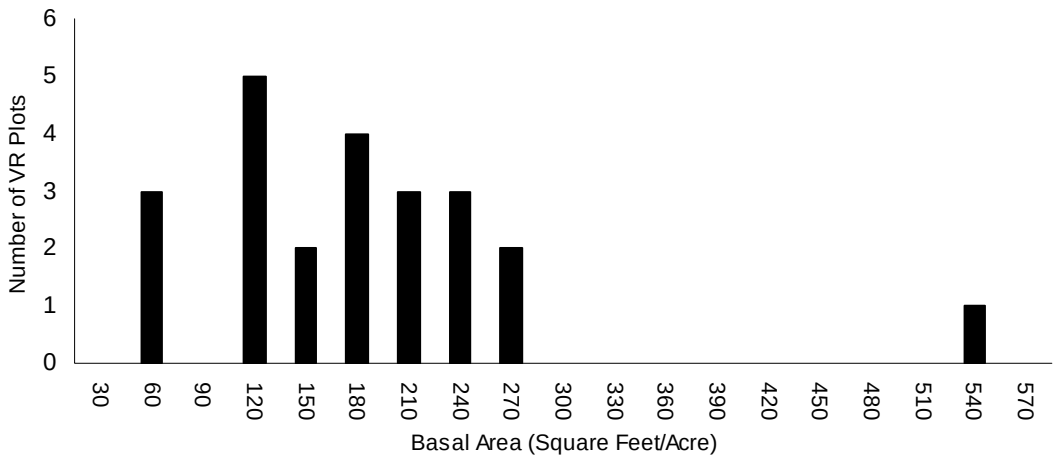

Figure 6. Distribution of stand density in variable radius plots sampled by LSC-FHM in spruce-fir stands within the French Creek Analysis Area.

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 variable radius plots is a better estimate of the percent of spruce in the canopy than is the percent of spruce in a fixed area plot expressed as trees per acre.

Engelmann spruce made up 63.8% of all of the trees in the LSC-FHM variable radius plot sample (Figure 7) and ranged from an average of 42% to 72% in the six units sampled. The overall percentage of Engelmann spruce in the basal area plots when weighted by the size of the units sampled was 56.4% (Table 5).

The old stand exam data (Appendix B) showed the proportion of spruce ranged from 27 – 96% of the basal area in the proposed treatment units. The weighted overall average was 53%. The proportion of spruce was over 65% in 15 of the proposed units which is a high risk based on this variable.

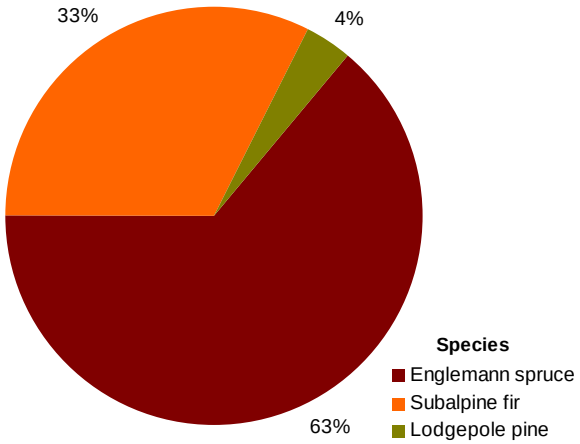

Figure 7. Tree species distribution in variable radius plots sampled by LSC-FHM within six proposed treatment areas in the French Creek Analysis Area.

Stand exam data provided site index information for 27 of the proposed treatment units. Site indexes ranged from 48 – 73 and all fell within the low risk category. Observations in ongoing SB epidemics in Utah indicate that site index may be the least significant of the four components of the Schmid and Frye (1976) risk rating system particularly if beetle populations are rising in adjacent stands (Liz Hebertson, personal communication). If site index is not considered, one of the six proposed units sampled by LSC-FHM would move to a high risk rating and two proposed units would move to a medium high risk rating. Similarly, seven proposed units would move to a high risk rating from a medium-high risk rating and 3 units would move to a medium high risk rating based on old stand exam data.

SB Ground Survey

Ground surveys provide an estimate of currently infested and recently killed trees. Bentz and Munson (2000) considered a population to be approaching the epidemic phase when there were more than two clumps of at least five standing infested trees per five acres. They considered a population to be endemic when the majority of the beetle population was confined to windthrown trees and only one or two standing infested trees over five acres were present.

Infestation levels within the six proposed treatment areas surveyed by LSC-FHM (Figure 8) varied from no new attacks on twelve two acre strip samples to 8 new infested trees on one two acre strip sample (Appendix A). The average number

of new hits per acre for all six units was 1.23, with units 30 and 35 having 1.83 and 1.9 new hits per acre, respectively (Table 7). This population level is above the endemic levels described by Bentz and Munson (2000) and the population trajectory appears to be heading towards epidemic levels. 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. The 2004:2003 attack ratio ranged from 0 to 19:1 with an average of 4.05:1 (Table 7).

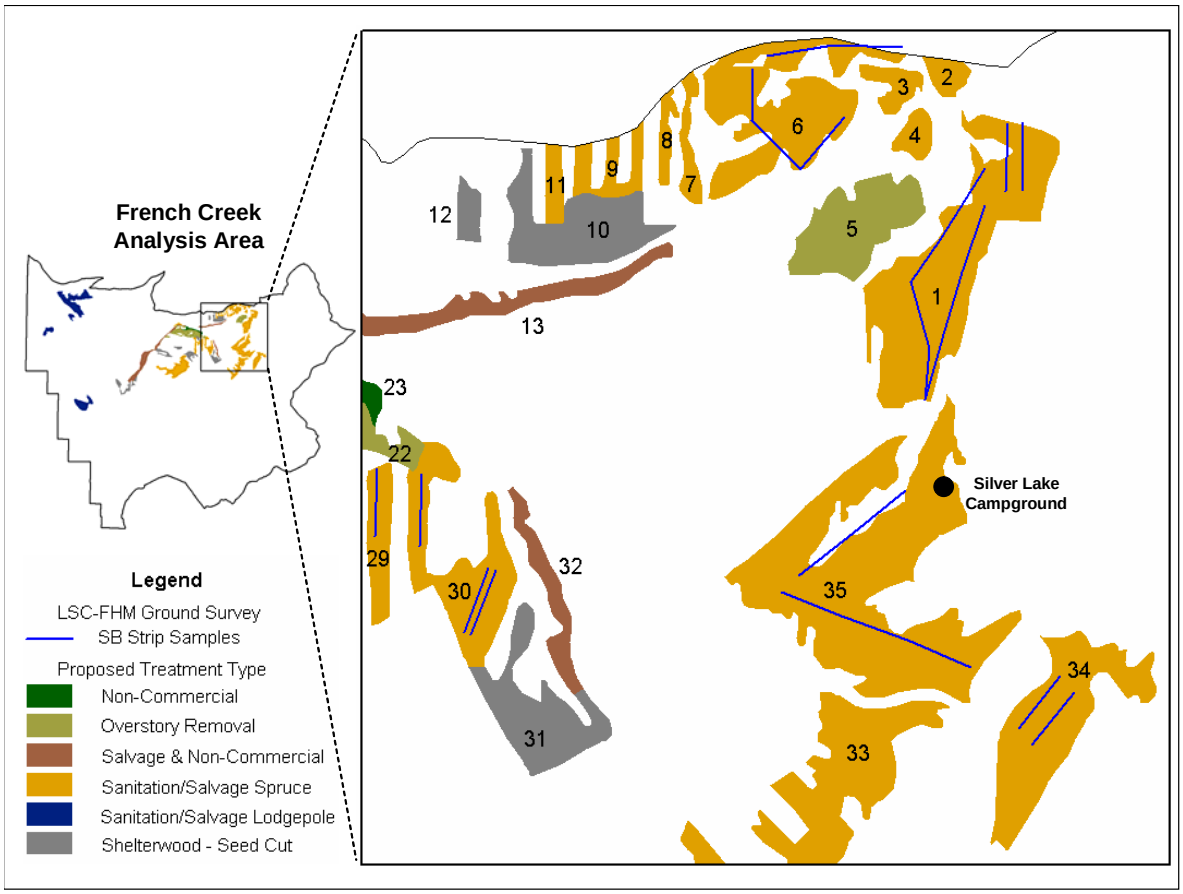

Figure 8. Location of proposed treatment units and LSC-FHM strip survey.

Table 7. Summarized survey results for proposed treatment areas sampled by LSC-FHM personnel (Appendix A).

Unit	Size of Unit	Acres Surveyed	2004 infested trees/ acre	2004:2003 attack ratio
1	189.6	17.5	1.13	9.53:1
6	122.5	10.0	1.10	1.83:1
29	37.2	2	0	0
30	88.6	6.1	1.83	2.75:1
34	115.9	4	0	0
35	305.13	10	1.9	19:1
Overall	858.93	49.6	1.23	4.05:1

Conclusions

Based on the above evaluation there is reasonable evidence available to recommend to the Forest Supervisor that she consider declaring that early-stage epidemics of spruce beetle and mountain pine beetle exist in the French Creek Analysis Area. If she finds that there are threats to ecosystem components then the streamlined NEPA authorities offered by the HFRA are available for her use.

Suitable stand conditions and the increasing SB populations in a number of units within the French Creek Analysis Area indicate that significant spruce losses are occurring and will increase in future years unless extreme winter weather conditions significantly reduce SB populations. Most of the literature on managing SB deals with direct suppression or protecting individual trees. 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 C. For building SB populations a combination of treatments is more effective than any single treatment. In addition to the proposed silvicultural treatments, the district should continue to use trap trees and cut and peel or remove beetle-infested spruce trees to suppress localized SB infestations. Preventive treatments including the application of insecticides to the boles of high-value, uninfested trees and the deployment of the SB anti-aggregation pheromone, methylcyclohexenone (MCH), to disrupt beetle aggregation on uninfested trees should continue to be used where appropriate. Carbaryl, permethrin and bifenthrin have been shown to be effective insecticides for the protection of uninfested trees from bark beetle attack. Preventive sprays need to cover all bole surfaces from the root collar up to a bole height of 40 – 50 feet. To achieve this coverage the spray pump needs to have a pressure capability of 400 pounds per square inch (psi) and a #8 or #10 nozzle orifice (Munson, personal communication).

There is no literature available that documents either the success or failure of thinning treatments designed to reduce SB susceptibility although studies in Utah

have been established and early results are encouraging (Hebertson, personal commuication). Thinning is done with the long term objective of enhancing structural, age class and species diversity across a landscape to mitigate catastrophic impacts from SB. Within a large landscape, thinning does not "beetle proof" a stand during an epidemic but it can help insure a component of spruce on the landscape following an epidemic. In the face of an advancing outbreak, thinning may be employed to create openings and scarified conditions necessary to establish spruce regeneration before the overstory seed source is killed. Spruce seedlings do not establish well under a mature spruce canopy (Veblen 1986). They require partially shaded mineral soil and do well in gaps and on forest edges (Alexander and Edminster 1980).

Munson (2000) reports that the Uinta National Forest in central Utah has successfully thinned spruce-fir landscapes to reduce stand characteristics susceptible to SB by reducing basal area to below 120 sq. ft. per acre and removing most of the large diameter trees over 16 inches. Spacing between trees is the critical factor for success, rather than just reducing tree density (Lister *et al*. 2002). Munson (2000) stressed that between tree spacing is probably critical to success in sites were a susceptible size class of spruce is left as a residual overstory. Where possible inter-tree spacing should be determined by the diameter of the residual spruce. An example of tree spacing guidelines by diameter for a target basal area of 100 sq. ft. per acre is provided in Appendix D. To reach low hazard status, sites should be thinned to a basal area of 100, average diameter should be reduced to less than 10 inches and spruce species composition to less than 50%.

Residual clumps of spruce-fir should be minimized. Page (2001) warns that partial cutting groups or clumps of trees can create excessive windthrow hazard. Clumps are defined as a small number of trees with interlocking crowns and the main stem or vertical form of the trees may have been affected by adjacent trees. Clumps should not be thinned but should be either taken out as a whole or left for the next cutting cycle. Groups are defined as trees of similar size and age in close proximity; the main stem form and vertical orientation of the trees is not affected by adjacent trees and trees may be easily walked between. Removal of 1/4-1/3 of the basal area can safely be done in most groups; younger groups can be thinned more heavily than older groups. In high windthrow risk areas near saddles, ridges or on the edges of meadows, only individual infested or high risk trees should be removed. Where windfall does occur, it can serve as trap trees. Once infested, down trees should be removed or peeled. Bucking boles into short sections and rolling them to expose the underside to sunlight can also kill a significant number of SB larvae (Schmid 1977).

Thinning efforts to suppress beetle populations may be compromised by adjacent untreated areas where silviculture is not an option, such as in wilderness or roadless areas. Thinning smaller, isolated stands of spruce can be effective in

reducing both short and long term susceptibility to SB if most or all of the spruce component is addressed at one time (Munson 2000).

A supplement to this biological evaluation will be issued once ground surveys for MPB have been completed for lodgepole pine areas recently added to the French Creek Analysis Area. Action alternatives for managing MPB impacts in lodgepole pine stands are provided in Appendix E.

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Appendix A

FRENCH CREEK ANALYSIS AREA SB GROUND SURVEY SUMMARY DATA

Page 1

Unit	TRANS/VR PLOT	SURVEYED ACRES	NEW SB HITS/ACRE	OLD SB HITS/ACRE	NEW/OLD	MEAN TOTAL BA	MEAN PICO BA	MEAN PICO DBH	MEAN SPRUCE BA	MEAN SPRUCE DBH	MEAN SUBALPINE FIR BA	MEAN SUBALPINE FIR DBH
French Creek	Summary	49.60	1.23	0.30	4.05	183.91	6.00	16.00	108.00	20.12	62.73	13.49
1	T1/1	2.0	0.00	0.00	0.00	180	0		60	18.4	120	17.4
1	T2/1	2.0	0.00	0.00	0.00	210	0		150	19.9	60	11.9
1	T3/1	2.5	8.00	0.40	20.00	540	0		540	18.4		
1	T3/2	1.5	0.00	0.00	0.00	60	0		30	7.8	30	8.9
1	T4/1	2.0	0.00	0.00	0.00	210	0		180	25.3	30	21.9
1	T4/2	1.5	0.67	0.67	1.00	120	0		120	16.0		
1	T5/1	2.0	0.00	0.00	0.00	210	0		90	15.9	120	11.5
1	T5/2	2.0	0.50	0.00	∞	240	0		240	19.2		
1	T5/3	2.0	1.00	0.00	∞	120	0		90	15.5	30	18.7
1	summary	17.50	1.13	0.12	9.53	231.7	0.00	0.00	166.67	18.79	65.00	14.53
6	T1/1	2.0	0.00	0.00	0.00	240	0		180	21.5	60	10.6
6	T2/1	2.0	3.50	1.00	3.50	120	0		60	22.6	60	17.2
6	T3/1*	2.0	0.50	0.00	∞	0	0		0		0	
6	T4/1*	2.0	1.50	2.00	0.75	0	0		0		0	
6	T4/2	2.0	0.00	0.00	0.00	120	0		60	21.7	60	12.4
6	summary	10.00	1.10	0.60	1.83	160	0.00	0.00	100.00	21.73	60.00	13.37
29	T1/1	2.0	0.00	0.00	0.00	60	0		60	25.7	0	
29	summary	2.0	0.00	0.00	0.00	60	0.00	0.00	60.00	25.65	0.00	0.00
30	T1/1	2.0	0.50	1.00	0.50	150	60	16.5	0		90	8.9
30	T2/1	2.0	5.00	1.00	5.00	240	0		120	27.0	120	12.1
30	T3/1	2.1	0.00	0.00	0.00	270	0		210	21.8	60	15.5
30	summary	6.1	1.83	0.67	2.75	220	20.00	16.45	110.00	23.66	90.00	11.78
34	T1/1	2.0	0.00	1.00	0.00	180	90	15.7	60	14.6	30	14.2
34	T1/1	2.0	0.00	0.00	0.00	180	0		90	21.5	90	10.4
34	summary	4.00	0.00	0.50	0.00	180	45.00	15.70	75.00	18.70	60.00	11.35
35	T1/1	2.0	0.00	0.00	0.00	60	0		30	32.3	30	9.6
35	T1/2	2.0	3.50	0.00	∞	150	0		90	28.6	60	15.0
35	T2/1	2.0	2.50	0.00	∞	270	0		180	15.2	90	13.6
35	T2/2	2.0	1.50	0.00	∞	120	0		30	14.7	90	9.7
35	T2/3	2.0	2.00	0.50	4.00	180	0		30	24.7	150	18.1
35	summary	10.00	1.90	0.10	19.00	156	0.00	0.00	72.00	20.73	84.00	14.29

* No Host Species in VR In Plot

Appendix B

Stand data from stand exams taken in the French Creek Analysis Area 17 – 25 years ago. Data for 21 stand locations representing each of the 35 proposed treatment units in spruce-fir were provided by the Brush Creek Hayden Ranger District. These data average 23 years old and may not reflect increased diameter growth or changes in basal area or percentage of trees due to growth or tree mortality since that time. It is presented only to give an overall view of potential stand conditions.

Unit	Acres	Quadratic Mean Dia.[1] (QMD) of Spruce over 10 in. DBH	Average Basal Area (BA) per Acre	% Spruce of total BA[2]	Site Index	Risk Rating Score	Proposed Treatment
1	190	**Conditions similar to Unit 5a**				9	Sanitation/ Salvage
2	11	**Conditions similar to Unit 3**				10	Sanitation/ Salvage
3	15	16.6	173	85	69	10	Sanitation/ Salvage
4	12	23.2	214	81	71	10	Sanitation/ Salvage
5	74	19.5/17.5	123/110	81/73	56/50	9	Overstory Removal
6	123	19.0	184	59	58	9	Sanitation/ Salvage
7	14	**Conditions similar to Unit 9**				7	Sanitation/ Salvage
8	10	**Conditions similar to Unit 9**				7	Sanitation/ Salvage
9	23	18.3	93	55	55	7	Sanitation/ Salvage
10	79	**Conditions similar to Unit 11**				8	Shelterwood-Seed Cut
11	12	19.2	65	89	55	8	Sanitation/ Salvage
12	11	24.4	80	66	48	8	Shelterwood - Seed Cut
13	51	-	191	41	-	-	Salvage, Non-Commercial
14	15	**Conditions similar to Unit 13**				-	Sanitation/ Salvage
15	7	**Conditions similar to Unit 13**				-	Salvage, Non-Commercial
16	279	**Conditions similar to Unit 13**				-	Salvage, Non-Commercial

17	90	18.8	156	31	58	8	Shelterwood - Seed Cut
18	13	19.0	204	71	59	10	Shelterwood - Seed Cut
19	12	11.2	100	36	48	5	Shelterwood - Seed Cut
20	69	14.1	82	96	49	7	Shelterwood - Seed Cut
21	10	**Conditions similar to Unit 22**				-	Overstory Removal
22	250	-	110	27	-	-	Overstory Removal
23	61	**Conditions similar to Unit 13**				-	Non-Commercial
24	24	15.9	72	69	51	8	Shelterwood - Seed Cut
25	339	14.1	185	38	49	7	Sanitation/ Salvage
26	74	13.1	193	54	72	8	Shelterwood - Seed Cut
27	52	**Conditions similar to Unit 28**				10	Sanitation/ Salvage
28	12	16.3	159	92	50	10	Shelterwood - Seed Cut
29	37	**Conditions similar to Unit 28**				10	Sanitation/ Salvage
30	89	**Conditions similar to Unit 31**				8	Shelterwood –Seed Cut
31	74	18.5	66	67	73	8	Shelterwood - Seed Cut
32	29	**Conditions similar to Unit 31**				8	Salvage, Non-Commercial
33	176	15.6	181	41	-	-	Sanitation/ Savage
34	116	18.6/20.1	104/84	42/52	52/53	7	Sanitation/ Salvage
35	305	20.1	84	52	53	7	Sanitation/ Salvage

[1] Percent spruce of total BA is used as an estimate of percent spruce in the canopy.
[2]Data from RMRIS stand summary sheet

Appendix C

ACTION ALTERNATIVES AGAINST SPRUCE BEETLE

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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 sub-alpine 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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Appendix D

Spacing Guidelines for a Target Basal Area of 100 sq. ft. per acre

DBH (inches)	Spacing (feet)	DBH	Spacing
2	3.1	26	40.1
4	6.2	28	43.2
6	9.2	30	46.2
8	12.3	32	49.3
10	15.4	34	52.4
12	18.5	36	55.5
14	21.6	38	58.6
16	24.7	40	61.7
18	27.7	42	64.7
20	30.8	44	67.8
22	33.9	46	70.9
24	37.0	48	74.0

Appendix E

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

USDA Forest Service, Region 2 Forest Health Management

Management Alternatives

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

Alternative 1: No Action

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

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

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

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

Alternative 2: Silvicultural Treatment

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

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

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

Low Windfall Risk Situations

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

Moderate Windfall Risk Situations

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

High Windfall Risk Situations

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

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

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

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

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

Advantages – Silvicultural treatment reduces the susceptibility of trees to MPB attack and has been shown to limit pine mortality from MPB in forest stands (Amman *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 differs from sanitation harvesting (Alternative 3) because it is usually applied on a smaller scale and is often not conducted in conjunction with salvage harvesting.

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

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

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

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

Alternative 5: Protection of High Value Trees

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

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

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

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

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

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