Biological Evaluation
RCSC-08-02

Assessment of Recent Bark Beetle Outbreaks on the Shoshone National Forest

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Introduction

Bark beetles are a disturbance process in the forested ecosystem, both endemic and epidemic populations of forest pests are a natural part of an ecosystem. The results of bark beetle epidemics produce changes on the landscape that will last for long periods of time. Beetles do provide important ecosystem functions such as nutrient cycling and successional changes of a forest. With epidemic levels of beetle activity, there is the potential for unintended negative resource consequences. Epidemic beetle populations can reduce the ability to meet desired future conditions and management objectives for the Forest. Losses may include: timber volume and value; potential growth of forest vegetation; native plant species and forage condition; quantity and quality of wildlife habitat; recreation opportunities; visual aesthetics; and changes in fuel conditions.

Forest diversity is a key element in maintaining a forest that is less susceptible to landscape scale bark beetle outbreaks. Forests that have a variety of ages, size classes, species, and stand densities are more resistance to large events than monocultures of size, age, species, and density. Bark beetles have a niche where they are most destructive. Creating a diverse forest reduces the potential areas where insects and diseases can reach epidemic levels that can produce adverse effects to Forest resource objectives.

In forests that have a wide range of diversity, there will be areas that are still highly susceptible to bark beetles, but there should also be those areas where forest susceptibility is reduced. The most significant landscape changes occur when a forest is all in a high state of susceptibility. This condition can lead to changes in forest structure and composition that are contradictory to management objectives.

Recent reports confirm that the level of bark beetle caused mortality is increasing across the entire Rocky Mountains, including the Shoshone National Forest. This assessment documents bark beetle activity on the Shoshone NF over the past 10 years and provides some expectation of what could occur into the future.

Bark Beetles of the Shoshone NF

Spruce Beetle

The most prominent threat to spruce is the spruce beetle. The spruce beetle is a native bark beetle that occurs throughout the range of spruce in North America. The beetle is found at endemic levels in downed trees and large pieces of slash. Epidemic populations most often occur after large disturbances, such as windthrows, affect a large volume of host material. Once populations reach an epidemic stage, all sizes of standing green spruce can be attacked except for reproduction. While all sizes can be attacked, it is most often focused on the larger trees within a stand. Much like mountain pine beetle, it can cause drastic changes in stand structure and composition.

The spruce beetle usually requires two years to complete a generation, in high elevations it can take three years. Adults fly, attack host trees, and lay their eggs in June and July. Larvae develop under the bark and remain there to overwinter. Larval development continues the following spring and summer, with new adults emerging in August. These adults then hibernate beneath the bark until the following June and July.

Spruce stands that are most susceptible to spruce beetle outbreaks generally have the following characteristics (Schmid and Frye 1976):

1. Are located in creek bottoms.
2. Have large diameter host trees.
3. Have high basal areas.
4. Have a large proportion of spruce in the canopy.

Spruce beetle is a concern that should be noted in stands that have large mature and overmature trees. Windthrow events in or near these stands can lead to mortality of standing green trees (Schmid and Hinds 1974).

Spruce beetle, unlike mountain pine beetle, is attracted, and often builds up in damaged trees. Frequently this is in windthrown/blowdown trees, however, fire scorched trees also are susceptible. For example, Rasmussen et al. (1996) found an increased number of spruce beetle in trees that were scorched up to a certain level of damage. Once scorching exceeded 60% of the basal circumference girdled, trees were no longer as suitable for spruce beetle infestation. This is something to be considered when using prescribed fire. Many of the larger spruce may have bark thick enough to survive lighter prescribed burns, however, if they are scorched somewhat, they can be more susceptible to spruce beetle. Stands that contain a large number of larger, partially scorched spruce, could be centers for spruce beetle buildup and epidemics.

Douglas-fir Beetle

The Douglas-fir beetle is the most damaging bark beetle found in Douglas-fir. It occurs in Douglas-fir throughout its range in the west. The Douglas-fir beetle has one generation per year. Adults or larvae overwinter under the bark and in the following summer emerge and attack nearby host trees. The beetle typically kills individual or small pockets of trees, but under the right conditions can reach epidemic levels and kills large pockets of host trees.

Stands that are most susceptible to Douglas-fir beetle outbreaks have the following characteristics (Furniss et al. 1981):

1. Stand density, stands stocked at 80% or more of normal are most susceptible.

2. Stand age, trees 120 years of age and older being the most susceptible.
3. Proportion of Douglas-fir in the canopy.

Douglas-fir beetle is also a concern in areas that have other disturbance events that can leave a large number of damaged host trees available for beetles to build up in, such as windthrow and fire (Furniss 1962, Furniss 1965, Rasmussen et al. 1996). Once populations build up in these damaged trees, infestations can then move into nearby green trees. This is a concern for both natural events and prescribed fires, either of which could damage residual trees enough to start a Douglas-fir beetle epidemic.

Mountain Pine Beetle

The most serious insect pest of pine throughout the west is the mountain pine beetle. This is a native beetle that kills all of the pine species (lodgepole, whitebark, and limber pine) found on the Shoshone NF. The mountain pine beetle can reach epidemic proportions and kill significant amount of susceptible host trees. Although beetle behavior is fairly well understood in lodgepole pine stands, there is less information on their behavior in whitebark and limber pines. In lodgepole pine the beetle generally attacks large diameter, overstory trees, although once an epidemic starts, smaller trees can also be killed (Amman and Cole 1983). The death of overstory trees influences stand structure and composition, and can lead to stand conversion to other species.

The mountain pine beetle generally completes its life cycle in one year in lodgepole pine, although at higher elevations it can take two years (McGregor and Cole 1985). Adults typically emerge sometime in July or August and attack standing green trees. On successfully attacked trees, adults lay eggs and larvae develop under the bark. Immature larvae overwinter under the bark, and then finish feeding in the spring and early summer. The developing larvae feed on the phloem, killing the tree.

Mountain pine beetle populations in lodgepole pine are in a large part dependent on the conditions present in the forest. In lodgepole pine, susceptibility to mountain pine beetle is based on three factors (Amman et al. 1977):

1. Average tree diameter,
2. Average tree age,
3. Location by latitude and elevation.

Little work has been done on mountain pine beetle behavior in limber or whitebark pine. What is known is that brood production is fairly high in limber pine, indicating that beetles do very well in this species (Cerezke, 1995). A retrospective look at a mountain pine beetle outbreak in the 1930's indicates that tree size (diameter) and stand density are likely important to beetle behavior and outbreaks in these pine systems (Perkins and Roberts, 2003).

In lodgepole pine, the factors that can be managed to reduce stand susceptibility to beetles are reducing average diameter and age. Treating the stands to reduce susceptibility will provide the most effective long-term defense against a mountain pine beetle epidemic. In lodgepole pine, thinning is effective at reducing future losses to the mountain pine beetle (Amman et al. 1988, Cole 1989, Gibson 1989, McGregor et al. 1987). Since beetles are attracted to the largest trees initially, removal of large diameter material is also effective at reducing loss during epidemics (Cahill 1978, Cole et al. 1983, McGregor et al 1987). Obviously, clearcutting lodgepole pine stands removes any risk of beetle infestation.

There has been little work done on silvicultural treatments for reducing beetle damage in whitebark or limber pine. Based on what is known from lodgepole pine and considering the little that is known about potential conditions that increase the likelihood of epidemics in these types, limber and whitebark pine stands could be treated to remove the largest diameter trees and reduce stocking levels.

Work on how fire and fire scarred trees would effect mountain pine beetle populations has shown that this beetle does not search out and infest fire scarred trees (Rasmussen et al. 1996). In other words, the use of prescribed fire and the resulting fire scarred trees would not be any more susceptible to causing beetle population increases.

Current Conditions

Over the past 10 years there has been widespread bark beetle epidemics occurring on the forest. All of the major bark beetles have been in epidemic status on at least parts of the forest during this time. The following charts and maps show the number of acres affected and location of affected acres across the forest by beetle over the past 10 years. It should be noted that even though an acre may be counted as affected, in all cases not every tree on that acre was killed.

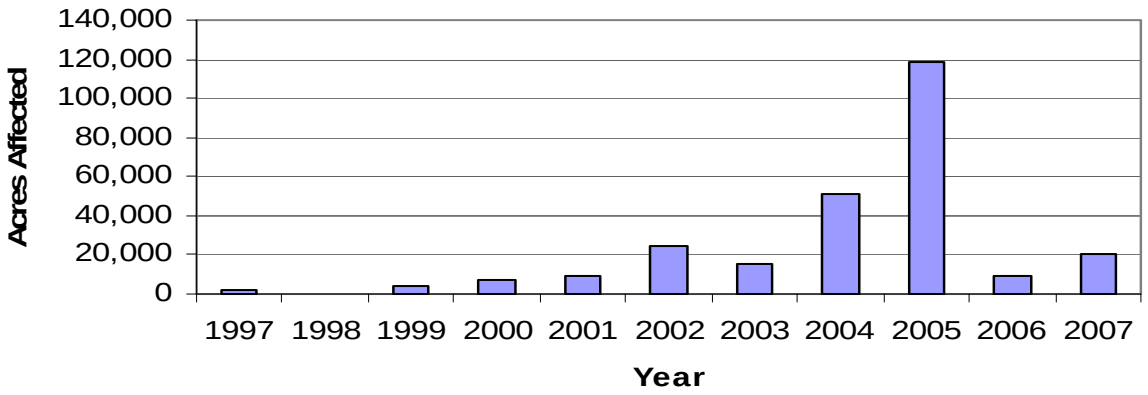
Douglas-fir Beetle

Over the past 10 years, Douglas-fir beetle has been at epidemic proportions in all places where Douglas-fir occurs on the forest. As seen in Figure 1, it was relatively low in the late 1990's and most of this activity was related to populations in the Clarks Fork area that were dying out following the expansion in that area after the Yellowstone Fires of 1988. By 2000, a large and quickly growing beetle epidemic hit the North Fork area. By 2002, most of the Douglas-fir type on the Wind River District was also being affected. By 2006 there was a considerable increase in Douglas-fir beetle activity again in the Clarks Fork area, particularly the Sunlight drainage.

In the North Fork area, by 2004, over 50% of the mature Douglas-fir had been killed and in many of the stands the number was approaching 100% mortality. The results of this mortality included a reduction in stand basal area of over 60% and a decrease in average stand diameter by more than 25% (Allen et al. 2005). This gives an indication of the loss of the mature forest that is occurring across much of the Douglas-fir type.

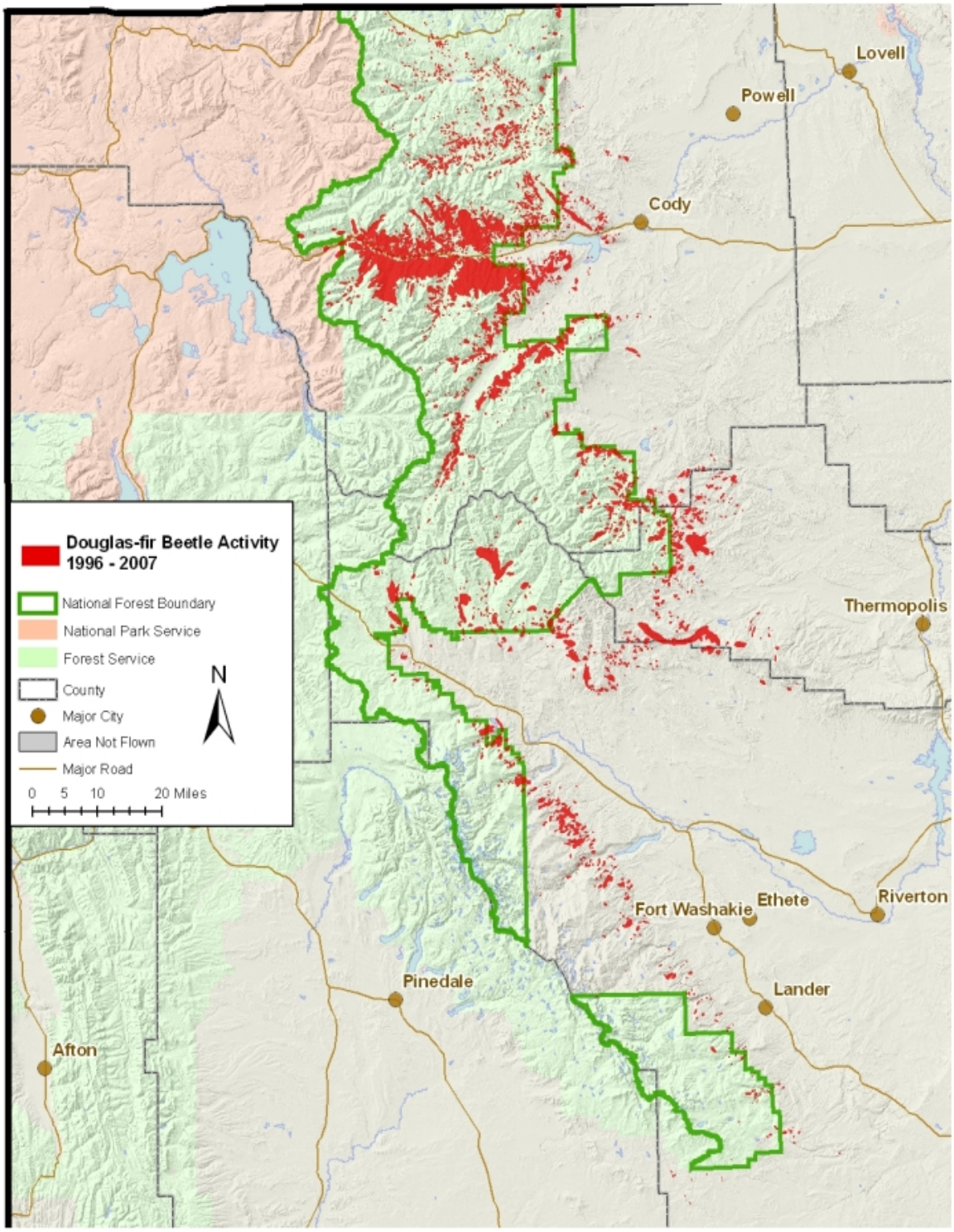
The epidemic that has occurred in the North Fork corridor has gone on for a longer period of time that is typically seen with Douglas-fir beetle in the Rocky Mountains. Typically outbreaks in standing trees last 2 to 4 years, while the epidemic along the North Fork has lasted close to 10 years (Schmitz and Gibson 1996, Allen et al. 2006). As the epidemic along the North Fork continued, even smaller diameter trees, which are typically not attacked by Douglas-fir beetle, were attacked and it appeared that beetles were re-attacking previously killed trees around the root collar by 2006 (Long and Allen 2006).

Figure 1. Acres affected by Douglas-fir beetle by year



As noted in the map below of all Douglas-fir beetle acres that have been affected over the past 10 years, almost all of the cover type has been hit to some degree. The only part that has considerable Douglas-fir cover type and has not been significantly impacted to date is the far southern part of the forest.

Douglas-fir Beetle Activity on the Shoshone National Forest
1996 - 2007



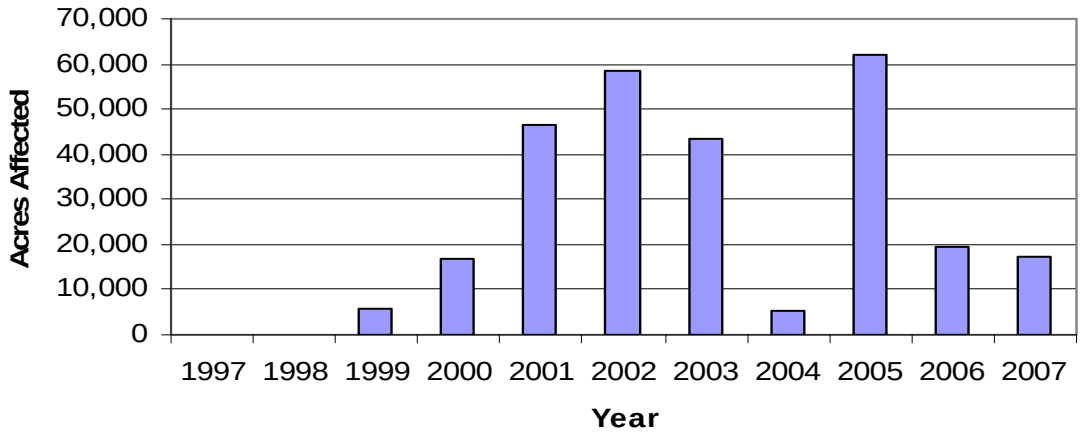
Due to the nature of aerial surveys, the data on this map will only provide rough estimates of location, intensity and the resulting trend information for agents detectable from the air. Many of the most destructive diseases are not represented on this map because these agents are not detectable from aerial surveys. The data presented on this map should only be used as a partial indicator of insect and disease activity, and should be validated on the ground for actual location and casual agent.
Shaded areas show locations where tree mortality or defoliation were apparent from the air. Intensity of damage is variable and not all trees in shaded areas are dead or defoliated.

Spruce Beetle

Spruce beetle activity on the forest was almost non-existent in the late 1990's, as shown in Figure 2. The large upswing in acres affected starting in 2000 is on land around Carter Mountain down toward Wood River and the associated wilderness areas. The more recent activity has been moving north into the Clarks Fork area, with widespread mortality in Sunlight Basin and towards Dead Indian Hill. At this time, there has not been significant spruce beetle activity in the southern part of the forest.

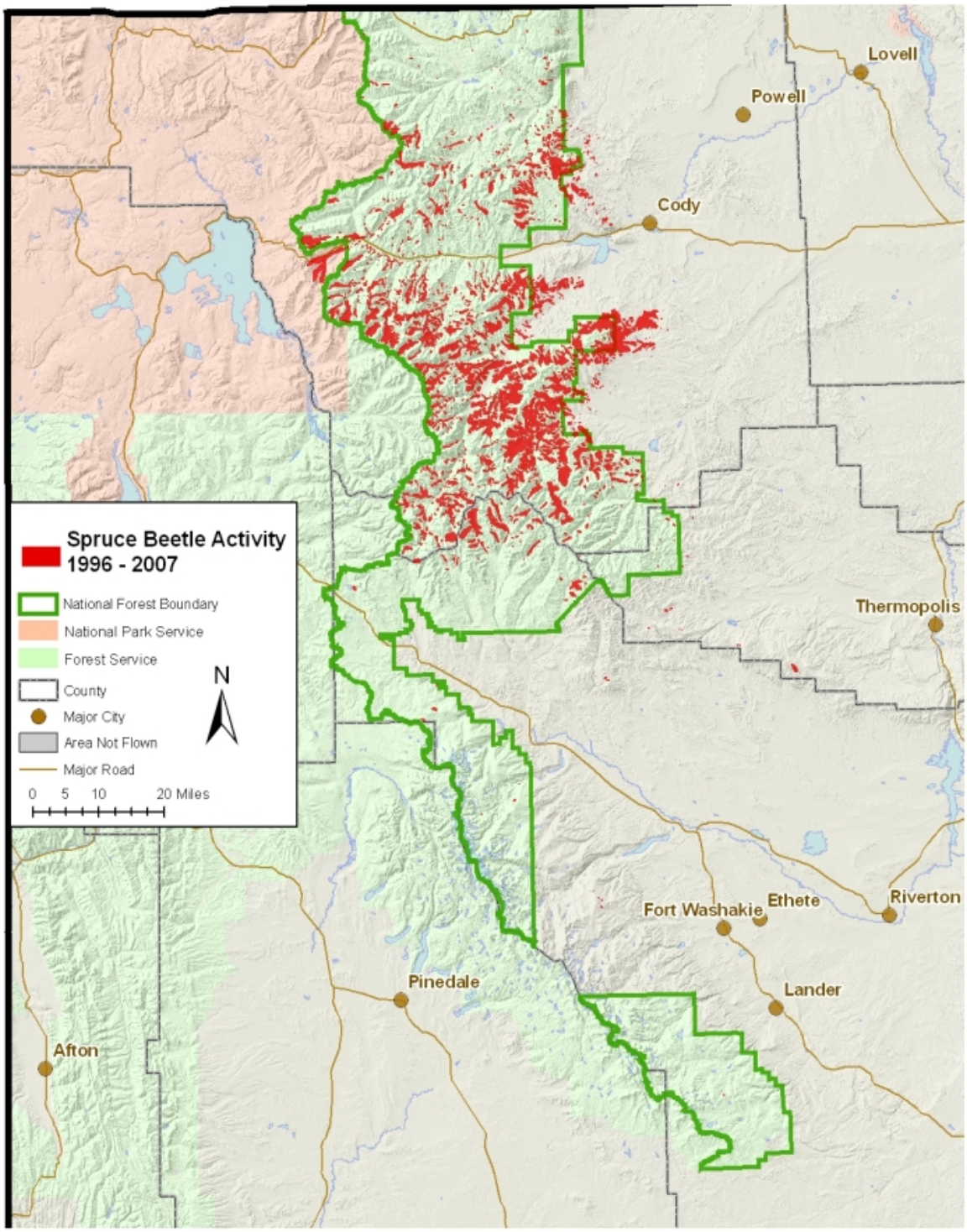
The epidemic that occurred on Carter Mountain killed almost every spruce larger than 5 inches in diameter, leaving a greatly changed landscape (Schaupp 2003). This area is no longer a mature spruce forest and even much of the advanced regeneration is gone. A similar situation is playing out along the Sunlight drainage. Almost all mature spruce have been killed over the past 4 years. Presently, this epidemic is working around Dead Indian Hill and is still increasing in size (Allen et al 2006). Whether or not it will end in killing trees as small as those on Carter Mountain is unknown, but most of the mature overstory will be affected.

Figure 2. Acres affected by spruce beetle by year



As seen on the map below, most of the spruce beetle activity has been located in the central part of the forest. It has not been found extensively in either the far northern or southern parts as of yet.

Spruce Beetle Activity on the Shoshone National Forest
1996 - 2007



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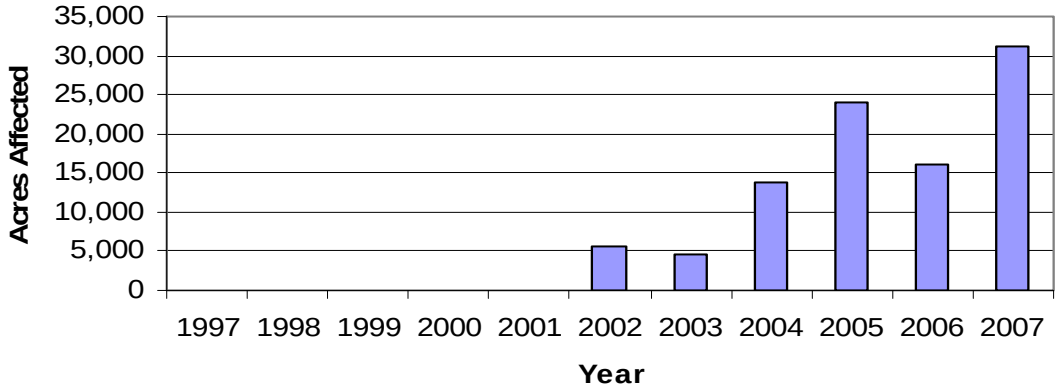
Mountain Pine Beetle

Like spruce beetle, mountain pine beetle activity on the forest was not detected to any extent in the late 1990's. Since 2000, there has been a continual upward trend in the number of acres affected by mountain pine beetle (Figure 3). Figure 3 shows all mountain pine beetle activity, in both lodgepole and the 5-needle pines. The areas where the 5 needle pines are being hit by mountain pine beetle may also have white pine blister rust, an exotic disease, playing a part. In some cases the disease may actually be a more extensive and larger mortality agent than mountain pine beetle, thus causing the relatively high number of acres affected shown on the graph in comparison to the map below.

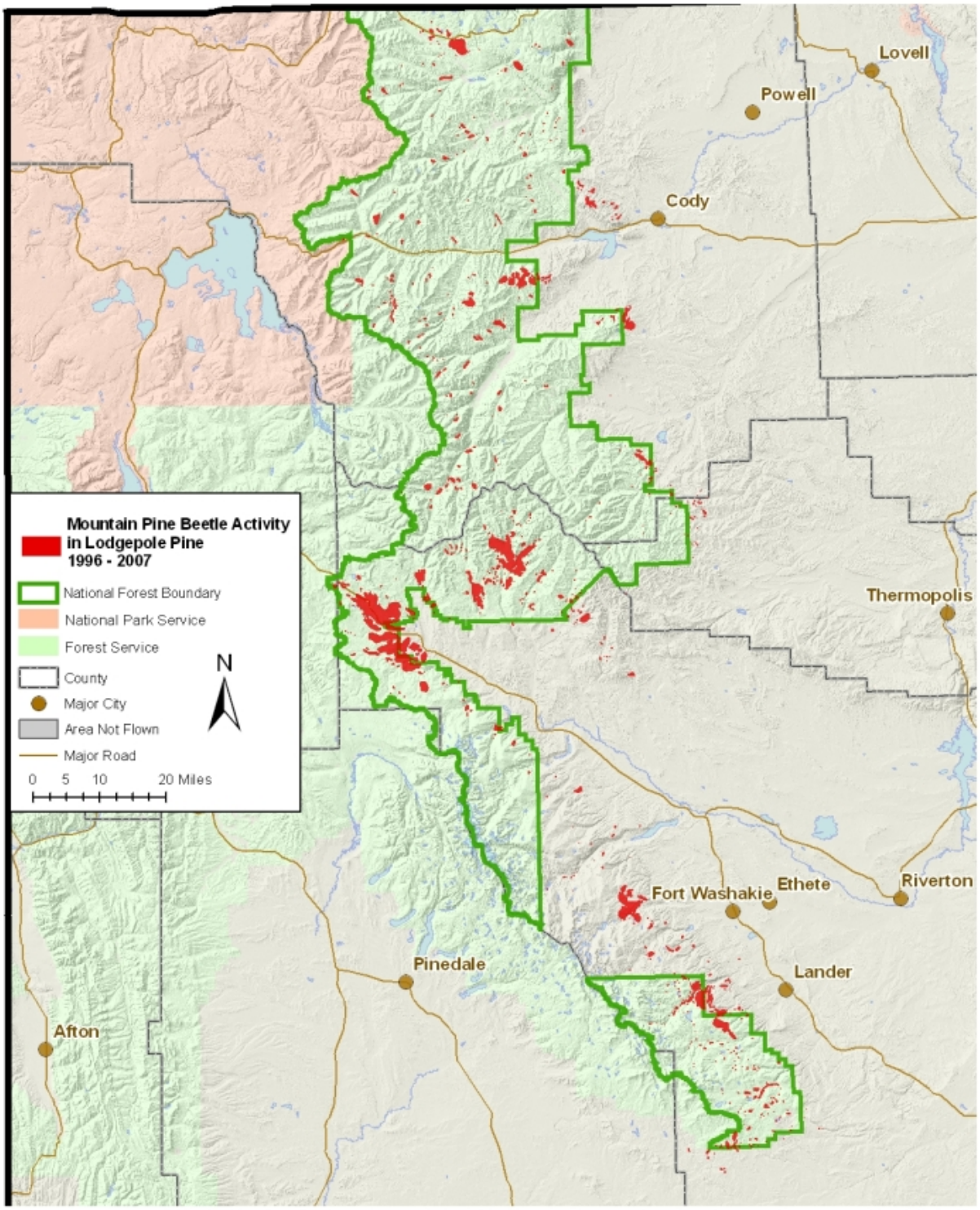
What is known is that there is a significant beetle epidemic occurring in the Wind River area. Both the 5 needle pines and lodgepole pines are suffering large areas of mortality (Allen 2005). Entire drainages are being killed in this current outbreak, which started in about 2001.

Figure 3. Acres affected by mountain pine beetle by year (lodgepole pine)



The map below shows where mountain pine beetle mortality is occurring in lodgepole pine. As noted above, 5 needle pine mortality is not included on this map. There have been large acreages of 5 needle pines affected over the past 10 years, a large portion of this is mountain pine beetle caused mortality, however, there is also a significant part of it that is more due to white pine blister rust. At this time, the largest extent of both lodgepole and 5 needle pine mortality has been occurring in the Wind River area, however, it should be noted the smaller areas showing up in the North Fork and Clarks Fork areas. These are very recent occurrences and that have just started over the past couple years. All of these areas are in lodgepole pine. This could be the start of a mountain pine beetle epidemic in these areas. In these northern areas, there is a considerable amount of susceptible cover type available to carry such an epidemic.

Mountain Pine Beetle Activity in Lodgepole Pine on the Shoshone National Forest 1996 - 2007



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Shaded areas show locations where tree mortality or defoliation were apparent from the air. Intensity of damage is variable and not all trees in shaded areas are dead or defoliated.

Future Potential Bark Beetle Activity

To get an estimate of future beetle caused mortality, first we should consider what has occurred to date.

On the forest there is approximately 373,000 acres of Douglas-fir. As of now, about 193,000 acres have been affected to some degree by Douglas-fir beetle. This is 51% of the Douglas-fir acreage that has already been affected. Not every tree on every acre has been killed, but there are certainly large expanses of Douglas-fir where there is 80-90% mortality already. Some areas, such as the Clarks Fork area have a large area of mature Douglas-fir that has not been heavily impacted. At this time there are growing levels of Douglas-fir beetle in this area and a continued outbreak and above average levels of tree mortality is expected in this area. Whether the Clarks Fork area will experience the same high levels of mortality as seen in other places, such as the North Fork in the next 10 years is unknown for sure, but the forest conditions are such that it could occur. What is clear is that considering the large component of mature Douglas-fir in this area, there will be a large scale change at some point in the future, and with a high level of beetles in the area already, there will likely be continued above average levels of tree mortality occurring in the near future. Overall, Douglas-fir beetle activity, in acres affected should decrease in the next 10 years, however, there will still be some areas that experience high levels mortality over this time period.

In the case of spruce beetle, there are about 348,000 acres of spruce-fir cover type identified on the forest. Over the past 10 years 208,000 acres have been impacted to some extent by spruce beetle on the forest. This is roughly 60% of the spruce-fir type that has been affected over the past 10 years. A large portion of this acreage is from the years 2001-2003 and centered around the massive outbreak surrounding Carter Mountain. In this area, basically all spruce larger than 6 inches in diameter were killed and so as far as mature stands of spruce are concerned, the effect is almost complete removal of the spruce forest. More recent activity has been occurring in the scattered spruce along the North Fork and then a more recent jump in beetle activity in the Sunlight drainage and around Dead Indian Hill. The spruce along the North Fork and in Sunlight was again affected almost 100%. The outbreak on Dead Indian Hill is relatively young and so the amount of beetle caused mortality is lower at this time. The main concern with spruce beetle is once an outbreak starts, they will often run through and kill all susceptible stands over large (forest-wide) landscapes. Over the next 10 years, all the spruce stands in the Clarks Fork area on the northern end of the forest are at high risk and will likely be affected by spruce beetle, especially the stands with older and larger trees. To this point, there has not been a high level of spruce beetle activity on the southern end of the forest and barring any other environmental damage, such as more fires or windthrow, the spruce on that end of the forest should be fairly safe in the near future.

For mountain pine beetle in lodgepole pine over the past 10 years there have been 72,000 acres affected out of about 294,000 acres of lodgepole on the forest (24% of the lodgepole acreage affected). In the southern part of the forest, where the effect is close to 100% mortality in susceptible lodgepole stands, with some scattered light mortality in smaller size class stands. Mountain pine beetle mortality has also heavily affected lodgepole stands along the North Fork, with many of these areas experiencing greater than 50% mortality already and the levels are still increasing. Most of the mature lodgepole along the North Fork will be killed in the next 10 years. There is also growing mountain pine beetle mortality in the Clarks Fork area. There are large areas of susceptible host in this area also, so there is a good chance that beetle mortality will continue to increase and expand in the Clarks Fork area over the coming 10 years.

Mountain pine beetle activity in the 5 needle pines is less clear. Over the past 10 years there has been over 100,000 acres affected to some level by both mountain pine beetle and white pine blister rust. How much of the mortality is caused the beetle or how much is caused by blister rust is hard to distinguish. There is a large amount of beetle caused mortality occurring in 5 needle pines on the southern end of the forest at this time. In most of the areas, beetles are causing close to 100% mortality in these stands. This is expected to continue, with most of the 5 needle pine stands on the southern end of the forest being affected. Right now, there has not been as much activity in this cover type on the northern end of the forest, however, as the beetle outbreak grows in lodgepole in the Clarks Fork area, certainly many of the whitebark and limber stands nearby will be affected.

Bark Beetle Activity in the Context of Historic Range of Variability

Whether the current Douglas-fir beetle epidemic is within the historic range of variability is debatable. As noted above, the current epidemic is certainly one that has significantly changed the landscape for a long time to come. The beetles have also been behaving outside of their typical range in overall length of epidemic and size of trees being affected. A large part of this behavior is explained by the forest conditions that existed at the time the epidemic started. A majority of the stands were dense, older aged stands and covered a large part of the landscape. There were few stands in younger age classes or in more open grown condition. Having a forest that is mostly in high susceptibility creates a scenario that will lead to landscape level changes caused by the beetle.

Much as with the Douglas-fir beetle, it is hard to say spruce beetle is outside of historic range of variability. The amount of small diameter trees that were killed on Carter Mountain is certainly uncharacteristic of spruce beetle, the rapid increase in tree mortality and continued spread to other spruce areas on the forest seem fairly typical with large scale spruce beetle epidemics. What is occurring with spruce beetle is probably within historic range as far as the amount of acres affected, as this insect is typically a change agent on a large landscape scale. The part that bothers me concerning the current spruce beetle

outbreak is the size of trees being attacked. Typically spruce beetle won't attack trees much below 16 inches in diameter. In this current outbreak, we are seeing whole stands of 6-8 inch trees being liquidated. Not only is the overstory being destroyed, an entire age class of advanced regeneration is also going by the way. This is certainly not typical, whether it actually falls outside of the historic range is questionable.

At this time, mountain pine beetle is would probably not be considered outside of the range of historic variability. The large scale outbreaks in lodgepole pine have occurred in the past when stand conditions reach a high susceptibility across large areas. This is the current condition in much of the lodgepole on the forest. There may be some questions about the amount of acres and relative speed this beetle has affected at higher elevations in the 5 needle pines at this time, but outbreaks have occurred in this environment in the past also.

The combination of all the major bark beetles being in outbreak status at once may or may not be outside of the HRV, however, much of this is likely related to the current stand conditions that were present at the beginning of the outbreaks. Considering the factors involved, the current situation is probably not outside the HRV, it is more an extremely infrequent event that is going to change the overall forest landscape for a long period of time.

Bark Beetle Effects on Other Resource Areas

Management area prescriptions will influence the occurrence of bark beetle activity and what, if any, actions are taken to minimize beetle impacts.

Natural disturbance events will continue to operate, however the scale upon which natural processes operate as the primary agents of change will vary depending on how areas are assigned to different management objectives. Where natural processes are the predominant process, the management of bark beetles is unlikely. Since beetle risk is medium or high on much of the forest and there are ongoing, large beetle populations present, many of these acres at risk of beetle damage will be attacked within the next 10-20 years. The potential exists for large areas of the forest to be subject to landscape sized events when these conditions occur.

Effects of fire and fuels management

The effects of large, destructive wildfires on bark beetles would be to reduce those that exist in areas where extremely hot fires burn over. Fires can also reduce stand density and make stands more resistant to attack. However, lower burning intensities associated with parts of wildfires and prescribed fires can weaken trees and make them more susceptible to some bark beetles by damaging root systems and cambial tissues. This can in turn lead to increasing populations and subsequent outbreaks of some beetles.

Major bark beetle epidemics can also change the fuel conditions in the forest. As

beetle epidemics occur, forests will go from areas of standing green trees, to trees that have been killed and will retain dry, red needles for 1-2 years, to standing dead with no needles and finally, over time, to increases in large woody debris on the forest floor as dead trees fall down. The rate at which beetle killed trees will fall will vary with tree species, tree size and the local climatic conditions.

Effects of timber management

Timber harvesting and timber stand improvement provides an opportunity to prevent or reduce bark beetle outbreaks. Harvesting trees provides an opportunity to remove diseased and high-risk trees and reduce overall stand susceptibility. Clearcuts and other final harvest methods provide long-term protection against bark beetles, as these stands are replaced by regeneration that is too small to be attractive to beetles. In stands scheduled for overstory removal, shelterwood, or uneven-aged management, individual suppressed or dying tees can be removed, increasing the overall growth and vigor of remaining trees. In commercial and precommerical thinning operations, susceptibility to bark beetles will be decreased by increasing the growth and vigor of the remaining trees through lowering overall stand density.

Actions that increase the amount, extent, or density of mature and over mature stands will generally increase the risk of bark beetle epidemics. Large scale disturbances caused by bark beetles can change stand structure, effect species changes or changes successional trends. Large disturbances can also have the effect of regenerating expansive areas to basically a single age class, reducing diversity.

Sanitation cuts to harvest infested timber and to attempt to slow infestations from spreading can be used to some degree of success, however, it is not as effective as preventative treatments. The degree to which these harvests are undertaken will largely depend upon the risks associated with the potential infestation spread into healthy stands, public safety, the presence of high value resources, and the resource emphasis of the infected or adjoining area.

Alternatives with the greatest allocation to Management Areas that allow active forest management will have the least amount of area left at high risk to insect and disease outbreaks.

Effects from recreation and travel management

In developed and dispersed sites, where trees are often stressed by camping activities and overall vigor are reduced by soil compaction from recreational uses, bark beetle activity can be increased. Beetle management activities would be intensified to protect developed recreation sites, including the use of sanitation and salvage of infested or dead trees and the use of pesticides or pheromones for tree protection. Costs may be higher than for general forest to ensure that vegetation in and around developed recreation areas is not degraded, causing safety hazards due to bark beetles.

Emphasis of more natural settings and older stands for recreation opportunities would result in forest conditions that are generally more susceptible to bark beetles. Management areas that emphasize wilderness, backcountry, and non-motorized recreation would have little or no management activity for prevention or reduction of bark beetles.

Effects from scenic resource management

Generally, the more restrictive the Scenic Integrity Objective, the greater the potential for beetles to be present at potentially damaging levels. Objectives that limit the amount of forest management practices will lead to denser stands and increased likelihood of bark beetle infestations.

Effects from wildlife habitat management and old growth

In general, favoring older age classes and denser stands of trees tend to favor buildup of bark beetles. Those that favor a wide range of age classes, greater stand diversity and greater species diversity tend to reduce the effects of beetles. Thermal cover for big game is generally very susceptible to beetle outbreaks.

Trees that are left behind after treatment as replacement snags will generally continue to increase in susceptibility due to size and age, although if the overall stand density is reduced, beetle susceptibility will be reduced. Clumps of trees left after harvest will have the same response only stronger due to the increased clump density that is left.

Areas left as old growth will generally be highly susceptible to bark beetle outbreaks. Typically these are stands with larger trees and closed canopies that are highly favored by bark beetles. Trying to maintain a stand as old growth will often require more intensive management than other stands. When designating old growth stands, there needs to be the understanding that these stands will change, often very suddenly, and this consideration needs to be planned for.

Effects from threatened, endangered and sensitive species

The concern for protection of threatened, endangered, and sensitive plant and animal species will result in specific requirements being met for these species. Concern about these species may result in limited or no actions taking place regarding management for beetles. Actions could be delayed beyond the appropriate biological window for treating beetles depending on TES species present and their needs.

In general, those alternatives that have reduced levels of management activity and may be more beneficial to mature forest stands, also tend to create stand conditions that are more susceptible to beetles.

Cumulative Effects

Forest stand density, age and size have increased and are causing an increased risk of bark beetle epidemics on a greater number of acres.

Silvicultural treatments can offset these effects. Changes to vegetation structural stage from silvicultural treatments can create forests that are more resistant to large scale outbreaks on the forest. Salvage and sanitation operations can occur in management areas where timber production is emphasized or where needed to reduce hazards in high use recreation areas.

As forest stands age, they pass through different stages of susceptibility to insects and diseases. Generally, mature forest stands are at the highest risk of bark beetle activity where impact may exceed management objectives. As the forest ages, the susceptibility to beetles continues to increase. We have seen the effects of this scenario already in many parts of the forest, which are landscape level changes caused by bark beetles.

One of the biggest considerations is how much of the forest land should be left in prescriptions that are ruled by natural processes. Some of these are relatively straight forward, for instance, wilderness is treated with a hands off approach. Whether the forest is truly in a natural state or functioning in a natural state now is debatable. Many years of fire suppression and allowing continued growth of the overstory has left a forest that is largely a mature, dense forest that is highly susceptible to bark beetles and is due for change. Bark beetles can cause large scale changes in a relatively short time. Reducing the potential impacts of bark beetles will require a similar large scale look at the land. There have already been significant changes in the forest due to bark beetles. These changes should be expected to continue in the future.

Literature Cited:

Allen, K.K. 2005. Evaluation of mountain pine beetle activity on the Wind River Ranger District of the Shoshone National Forest. USDA Forest Service, Rocky Mountain Region, Biological Evaluation, R2-05-10, 7 pp.

Allen, K.K., A.D. Dymerski and D.M. Hardesty. 2006. Evaluation of bark beetle activity in the Bald Ridge area, Shoshone National Forest, Wyoming. USDA Forest Service, Rocky Mountain Region, Biological Evaluation, R2-06-5, 10 pp.

Allen, K.K., D.F. Long and D.M. Hardesty. 2005. Douglas-fir beetle impacts along the North Fork Corridor, Shoshone National Forest, Wyoming. USDA Forest Service, Rocky Mountain Region, Biological Evaluation, RCSC-05-4, 6 pp.

Allen, K.K., D.F. Long and J. D. McMillin. 2006. Effectiveness of MCH in preventing Douglas-fir beetle attacks during a prolonged outbreak. USDA Forest Service, Rocky Mountain Region, Technical Report, R2-66, 14pp.

Amman, G.D., M.D. McGregor, D.B. Cahill, and W.H. Klein. 1977. Guidelines for reducing stand loss of lodgepole pine to the mountain pine beetle in

unmanaged stands in the Rocky Mountains. USDA Forest Service, Intermountain Forest and Range Experiment Station, General Technical Report INT-36.

Amman, G.D. and W.E. Cole. 1983. Mountain pine beetle dynamics in lodgepole pine forests. Part II: population dynamics. USDA Forest Service, Intermountain Forest and Range Experiment Station, General Technical Report INT-145.

Amman, G.D., G.D. Lessard, L.A. Rasmussen, C.G. O'Neil. 1988. Lodgepole pine vigor, regeneration, and infestation by mountain pine beetle following partial cutting on the Shoshone National Forest, Wyoming. USDA Forest Service, Intermountain Forest and Range Experiment Station, Research Paper INT-396.

Cahill, D.B. 1978. Cutting strategies as control measure of the mountain pine beetle in lodgepole pine in Colorado. In: A.A. Berryman, G.D. Amman and R.W. Stark (eds). Proceedings- Symposium on theory and practice of mountain pine beetle management in lodgepole pine forests. University of Idaho, Forest, Wildlife, and Range Experiment Station.

Cerezke, H.F. 1995. Egg gallery, brood production, and adult characteristics of mountain pine beetle, *Dendroctonus ponderosae* Hopkins (Coleoptera: Scolytidae), in three pine hosts. The Canadian Entomologist 127: 955-965.

Cole, D.M. 1989. Preventive strategies for lodgepole pine/mountain pine beetle problems: Opportunities for immature stands. In: G.D. Amman (ed). Proceedings-Symposium on the management of lodgepole pine to minimize losses to the mountain pine beetle. USDA Forest Service, Intermountain Forest and Range Experiment Station, General Technical Report INT-262.

Cole, W.E., D.B. Cahill, and G.D. Lessard. 1983. Harvesting strategies for management of mountain pine beetle infestations in lodgepole pine: preliminary evaluation, East Long Creek demonstration area, Shoshone National Forest, Wyoming. USDA Forest Service, Intermountain Forest and Range Experiment Station, Research Note INT-333.

Furniss, M.M. 1962. Infestation patterns of Douglas-fir beetle in standing and windthrown trees in southern Idaho. J. Econ. Entomol., 55: 486-491.

Furniss, M.M. 1965. Susceptibility of fire-injured Douglas-fir to bark beetle attack in southern Idaho. J. For., 63: 8-11.

Furniss, M.M., R. L. Livingston and D. M. McGregor. 1981. Development of a stand susceptibility classification for Douglas-fir beetle. In: Symposium Proceedings, Hazard Rating Systems in Forest Pest Management (Univ.

Georgia, Athens, Ga., July 31 - Aug. 1, 1980). USDA For. Serv., Gen. Tech. Rep. WO-27, Washington, D.C., pp. 115-128.

Gibson, K.E. 1989. Partial cutting (sanitation thinning) to reduce mountain pine beetle caused mortality. In: G.D. Amman (ed). Proceedings-Symposium on the management of lodgepole pine to minimize losses to the mountain pine beetle. USDA Forest Service, Intermountain Forest and Range Experiment Station, General Technical Report, INT-262.

Long, D.F. and K.K. Allen. 2006. Conditions of the North Fork campgrounds protected with MCH. USDA Forest Service, Rocky Mountain Region, STR-RCSC-2-07, 6 pp.

McGregor, M.D. and D.M. Cole, eds. 1985. Integrating management strategies for the mountain pine beetle with multiple resource management of lodgepole pine forests. USDA Forest Service, Intermountain Forest and Range Experiment Station, General Technical Report INT-174.

McGregor, M.D., G.D. Amman, R.F. Schmitz, and R.D. Oakes. 1987. Partial cutting lodgepole pine stands to reduce losses to the mountain pine beetle. Can. J. For. Res. 17: 1234-1239.

Perkins, D.L. and D.W. Roberts. 2003. Predictive models of whitebark pine mortality from mountain pine beetle. For. Ecol. and Man.. 174: 495-510.

Rasmussen, L.A., G.D. Amman, J.C. Vandygriff, R.D. Oakes, A.S. Munson, and K.E. Gibson. 1996. Bark beetle and wood borer infestation in the Greater Yellowstone area during four postfire years. USDA Forest Service, Intermountain Research Station, Research Paper INT-RP-487.

Schaupp, W.C. 2003. Evaluation of the spruce, mountain pine and Douglas-fir beetle populations on Carter Mountain, Shoshone National Forest, Wyoming. USDA Forest Service, Rocky Mountain Region, Biological Evaluation, R2-03-09, 26 pp.

Schmid, J.M. and R.H. Frye. 1976. Stand ratings for spruce beetles. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Research Note RM-309.

Schmid, J.M. and T.E. Hinds. 1974. Development of spruce-fir stands following spruce beetle outbreaks. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Research Paper RM-131.

Schmitz, R.F. and K.E. Gibson. 1996. Douglas-fir beetle. USDA Forest Service, Forest Insect and Disease Leaflet 5. 8 p.