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A BIOLOGICAL EVALUATION OF FOREST HEALTH IN THE PARADISE MOUNTAINS

USDI BUREAU OF LAND MANAGEMENT
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Biological Evaluation of Forest Health in the Paradise Mountains

Abstract

During the week of May 19, 2008, the USDA Forest Service, Forest Health Protection, Ogden Field Office (FHP-OFO) surveyed pinyon-juniper woodlands and ponderosa pine stands in the Paradise Mountain Project Area to document insect and disease activity and to assess stand and landscape level risk. Ponderosa pine stands primarily occurred on the northerly aspects of drainages in the mountain range. The results of the survey indicated that endemic levels of insect and disease agents were present within the project area. No current bark beetle activity was observed. Both pinyon-juniper and ponderosa pine stands however, had moderate susceptibility to bark beetle infestation. Several ponderosa pine stands burned during the Paradise wildfire in 2007 have high likelihoods of post-fire tree mortality. General recommendations for the Paradise Mountain Project Area include monitoring stands annually for increased insect and disease activity and the development of a vegetation management plan incorporating both long and short-term insect and disease treatment strategies for minimizing adverse impacts and meeting resource objectives.

Background

The Paradise Mountain Project Area is located in the Paradise Mountains in southwestern Utah just north of Uvada along the Nevada border. The Paradise Mountains lie within the Great Basin Physiographic Province and generally run north and south with the highest peaks approaching 8,000 feet in elevation. The climate is typically arid with annual precipitation ranging from eight to eighteen inches.

Singleleaf pinyon pine (*Pinus monophylla* Torr. and Frem.) and Utah juniper (*Juniperous osteosperma* (Torr.) Little) woodlands occur at lower elevations (approximately 5,000 to 7,000 feet) in the project area. Colorado pinyon pine (*Pinus edulis* Engelm.) are scattered throughout these woodlands. With increasing elevation, common associates of pinyon and juniper include curlleaf mountain mahogany (*Cercocarpus ledifolius* Nutt.) and stands of ponderosa pine (*Pinus ponderosa* Dougl. ex Laws) that occur on north-facing aspects. At the uppermost elevations, particularly in more mesic sites, stands may contain minor amounts of Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco.). Small stands of aspen (*Populus tremuloides* Michx.) occur along upper elevation ridgelines.

Thick patches of greenleaf manzanita grow in the understories of ponderosa pine stands on sites characterized by shallow, rocky soils. Other shrub species include serviceberry, Wood's rose, sagebrush, and rabbitbrush. Various species of herbaceous plants and grasses typical of southwestern Utah mountain environments also occur.

The USDI Bureau of Land Management (BLM) administers approximately 40,600 acres in the Paradise Mountains. The Paradise Mountain Project Area comprises approximately 8,850 acres and provides important timber, cultural, archeological, geological, and other ecological values. In July of 2007, the Paradise wildfire burned approximately 6,000 acres of pinyon-juniper woodlands and several stands of ponderosa pine in the vicinity of Pine Creek. Half of the burned acres were located in the northern portion of the project area. Doug Page, Silviculturist, Cedar City Field Office, was concerned that bark beetles (Coleoptera: Curculionidae) may have infested or might infest fire-injured pinyon and ponderosa pines increasing the risk of damaging outbreaks. High levels of tree mortality associated with insects, diseases, animal, and human activities in addition to declining forest health would potentially conflict with important resource values in the project area.

During the week of May 19, 2008, USDA Forest Service, Forest Health Protection, Ogden Field Office (FHP-OFO) staff surveyed pinyon-juniper woodlands and several ponderosa pine stands in burned and unburned portions of the project area to document forest insect and disease activity and to assess stand and landscape level risk to insect outbreak. This biological evaluation describes the methods used to survey forest vegetation within the project area and discusses survey results. Recommendations and management alternatives for reducing potential damage due to insects and diseases and improving forest health in the Paradise Mountains Project Area are also discussed.

Methods

Data Collection

Ortho-photo quads and topographic maps were used to design a strategy for surveying pinyon-juniper woodlands and ponderosa pine stands located in three compartments in the project area. These compartments included PCBAAA, PCZFJC, and PCZFLA. Due to the size of the entire project area insect and disease conditions were assessed by walking or driving through unburned and burned portions of the pinyon-juniper woodlands in each compartment. Trees with evidence of damage caused by insects and diseases were examined to determine the causal agent, extent, and severity of damage. Indicators of damage and poor tree health included discolored foliage, sparse foliage, chewed foliage, webbing, branch dieback, pitch streaming, wood staining, and basal resinosus.

For surveying stands in the ponderosa pine type, sample points were systematically distributed throughout stands in each compartment. These points were spaced at 10 chain (1 chain = 66 feet) intervals along parallel transects located 10 chains apart to ensure sufficient coverage within each stand. From each sample point, a variable radius plot (basal area factor of 20) was established to determine sample trees. All trees greater than five inches diameter at breast height (dbh) were tallied and measured. Tree mensuration data collected included tree species and condition (live, declining, or dead), and dbh. We examined all symptomatic trees in each plot for evidence of insects and diseases and recorded the causal agent and type, extent, and severity of damage. Symptomatic trees

observed between plots were also mapped. Appendix 1 provides a list of potentially damaging agents by host type for pinyon-juniper and ponderosa pine forest types.

Next, all juniper, pinyon pine, and ponderosa pine regeneration less than five inches dbh, and greater than six inches in height was tallied in a 1/300th acre subplot (radius = 6.8') at plot center. Species of shrubs, herbaceous plants, grasses, and other vegetation found within a 1/10th acre subplot established at plot center were recorded. Downed woody fuels were inventoried and litter and duff depths measured to determine surface fuel loads (Brown 1975). In burned ponderosa pine stands, methods described by Hood and others (2006) were used to determine the percentage of crown length scorch and cambium kill ratio of sample trees. From these data, the probability of post-fire ponderosa pine mortality was estimated. Finally, we recorded insects and diseases affecting aspen (*Populas tremuloides* Michx.) in small clones (<10 acres) as they were encountered in surveyed areas.

Data Analyses

All of the insect and disease data collected in the pinyon-juniper woodlands surveyed was summarized by hand. Data collected in ponderosa pine stands was either summarized by hand or by using the Forest Insect and Disease Tally (FINDIT) program (Bentz 2000).

The FINDIT program calculated following summary statistics to determine the risk and susceptibility of stands to damaging agents:

1. Total trees/acre (TPA).
2. Total live and dead basal area (BA ft^2/ac).
3. Live ponderosa pine, quadratic mean diameter (QMD).
4. Live stand density index (SDI).
5. Number of dead and live trees.
6. Percentage of each tree species.
7. Percentage of basal area (BA) comprised of each tree species.
8. Total regeneration/acre of each tree species.
9. Percentage of basal area killed by insects and diseases.

Insect and Disease Hazard Ratings

Hazard rating systems such as those in FINDIT are often used by forest health specialists to evaluate stand conditions conducive to the growth and spread of damaging agents. "Hazard" or "susceptibility" is the inherent characteristics or qualities of a stand of trees that affect its likelihood of attack and damage by an insect or disease agent. "Risk" is defined as the short-term expectancy of tree mortality in a stand as a result of a damaging agent. Risk is a function of tree/stand susceptibility and 'pressure' imposed by the damaging agent. Pressure is the magnitude of the damaging agent population affecting a stand as determined by the number of currently infested/infected trees and their proximity to the stand being assessed. Pressure relates to the likelihood of damaging agents entering a given stand. A "high-hazard" stand can exist with little risk when populations

of damaging agents remain low. Conversely, a "low-hazard" stand can have moderate risk when populations of damaging agents are high (Shore et al. 2000, Edmonds et al. 2000).

Numerous insects and diseases damage trees in Southwestern and Intermountain forests. Hazard rating systems do not exist for most of these agents because they cause only minor damage or the factors contributing to stand susceptibility are not well understood. Consequently, stand susceptibility was only determined for those bark beetle species for which reliable systems have been developed.

Bark Beetle Hazard Rating Systems

PONDEROSA PINE. There has been little research conducted in the Southwest regarding stand conditions as they relate to the potential for bark beetle infestation. However, research conducted in western states shows that trees in overstocked stands are more susceptible to bark beetle attack (Fettig et al. 2007). No stand hazard rating models for Southwestern ponderosa pine have been validated for pine engraver beetle species (*Ips* spp.), primarily because beetle populations are often driven by drought and factors leading to large amounts of slash. Stand hazard ratings for *Dendroctonus* bark beetles that infest ponderosa pine typically incorporate measures of tree size, density (BA or SDI), and the percent of host trees within the stand.

In general, even-aged ponderosa pine stands that have an average dbh greater than 12 inches and a stand basal area greater than120ft^2/acre have a high risk to bark beetle attack. Stand basal areas of 80 to120 ft^2/acre have a moderate risk, and stand basal area less than 80ft^2/acre are considered low risk (Schmid and Mata 1992, Schmid et al. 1994, Chojnacky et al. 2000, Negrón et al. 2000). In this survey, hazard rating systems developed by Munson and Anhold (1995) and Steele and others (1996) were used to evaluate stand susceptibility to *Dendroctonus* beetle species in ponderosa pine. The Munson and Anhold system is given in Table 1 (modified from Chojnacky et al., 2000). This system was validated across several sites including the North Kaibab in Arizona.

Outbreak populations of bark beetles will likely infest stands with 'high' susceptibility and moderately susceptible stands as outbreaks intensify. Beetles may infest stands with low susceptibility when populations have reached high levels, or when they have depleted all suitable host type elsewhere.

Because of the more xeric conditions in the southwest compared to other western states, the low risk category may be less than 80ft^2/acre. Also, because pine engraver beetles typically cause the majority of ponderosa pine mortality in the southwest, average stand diameter may not be as important as other areas in the west where *Dendroctonus* beetles cause most of the tree mortality (McMillin, *personal communication*).

Table 1. Hazard rating system developed by Munson and Anhold for mountain pine beetle in ponderosa pine.

% PP	Value	Ave. dbh	Value	B A	Value	Total	HR
>85	3	12	3	>120	3	8-9	High
50-85	2	8-12	2	80-120	2	5-7	Moderate
<50	1	<8	1	<80	1	3-4	Low

PP = ponderosa pine; dbh = diameter at breast height; BA = Mean basal area (ft^2/acre); HR = hazard rating.

PINYON PINE. The pinyon engraver beetle, *Ips confusus*, LeConte (Coleoptera: Curculionidae) is the most important mortality agent of pinyon pine in the Southwest and Intermountain west (Shaw et al. 2005). Historically, outbreaks of the pinyon engraver beetle have been associated with drought, particularly during years with low spring moisture. The greatest amount of tree mortality occurs in dense stands comprised of slow growing trees. In some areas, stand density index is a good predictor of stand susceptibility to infestation by pinyon engraver beetles (Page 2005). Stands with SDI's less than 24 or those with 5-6% of maximum SDI (360 for pure stands of pinyon or juniper, and 415 for mixed stands) have low susceptibility. At the individual tree level, trees with diameters at root collar (drc) greater than about seven inches and/or those heavily infected by dwarf mistletoe are most susceptible to attack (Page 2005). Other factors contributing to outbreaks include disturbances that produce green slash coincident with *Ips* beetle flight.

Defoliators

Although populations of insect defoliators periodically erupt in southwestern and intermountain forests, no systems have been developed to assess stand susceptibility to outbreaks. Most damage however occurs in dense, multi-storied stands where host tree species comprise the majority of stands. Climate also influences population dynamics and the severity of damage.

Mistletoes

With the detection of dwarf mistletoe (*Arceuthobium* spp.), the Hawksworth's 6-class dwarf mistletoe rating system (DMR) (Hawksworth 1977) was used to rate individual pines (both pinyon and ponderosa) and derive an average susceptibility of trees in each survey unit to dwarf mistletoe infection. In this system, the live tree crown is visually divided into thirds (top, middle, and bottom). Each third is rated according to the proportion of crown infected (0 = no infection; 1 = ½ of branches in third infected; 2 = greater than ½ of branches in third infected). The ratings of each third are summed to give a total tree DMR from 0 to 6. A tree with a DMR of three is considered moderately infected. Because the distribution of dwarf mistletoes is patchy, a stand with an average DMR of three is considered heavily infected.

No systems have been developed to assess stand susceptibility to mistletoes in Southwestern and Intermountain forests. Generally, host composition and stand structure

is considered most important for the incidence and spread of dwarf mistletoes (Hawksworth 1996). Multi-storied stands provide the greatest opportunity for dwarf mistletoe spread as dispersing seeds can infect various size classes (Hawksworth 1996). Most growth loss occurs in stands older than 60 years as trees begin to experience age-induced stress (Parmeter 1978). Host tree resistance, ecological, and climatic factors may also limit dwarf mistletoe spread (Conklin 2000).

Site conditions have been associated with the distribution of juniper mistletoe infections (*Phoradendron juniperinum* Engel. ex A. Gray). Greg (1991) found that the most heavily infected sites are those with a dependable moisture supply to maintain the high demand of infected trees. Others have observed that juniper mistletoes more seriously impact female plants than male plants (Gehring and Whitman 1992).

Results

Due to time constraints only pinyon-juniper and ponderosa pine stands in Compartments PBCAAA and PCZFLA were surveyed.

The following section summarizes the results of FINDIT and other analyses used to determine stand susceptibility and risk for those stands surveyed. Bark beetle hazard ratings for stands in Compartment PCZFJC were determined from stand examination data collected on 1/10th acre fixed plots by BLM, Cedar City Office crews in 2007. These results provide useful descriptions of stand conditions. However, standard errors of means were generally high due to the low number of plots sampled in each stand. Therefore, our interpretation of the results, particularly hazard ratings, and recommendations considered this limitation.

Compartment PBCAAA –Ponderosa Type

We first surveyed Stands 1, 2, 3, 4, and 6 in Compartment PBCAAA. All of these stands were located on the east side of Pine Creek and burned during the Paradise wildfire. The amount of fire damage in these stands ranged from moderate to severe. We also surveyed Stands 9, 11, 12, 15, 16, and 17 located on west side of Pine Creek. These stands were not affected by the fire.

<u>Stand 1:</u> The wildfire killed 100 percent of trees in Stand 1 (Table 2). Only two percent of trees in this stand had been attacked by a single red turpentine beetle (*Dendroctonus valens*, LeConte), and no brood had yet been produced. We removed the outer bark of all dead trees on each plot and observed that wood borers had infested 100% of all burned trees. The majority of these were buprestid beetles a.k.a. flatheaded borers (Coleoptera: Buprestidae).

The crowns of all ponderosa pines we observed were severely scorched (no green needles) or totally consumed by the fire. Most trees had over 90% bole char and in some cases outer bark features were indiscernible. Examination of inner bark tissues revealed

greater than 90% of cambium death. High percentages of cambium death limit suitable bark beetle habitat.

Due to the general lack of woody surface fuels, we did not collect fuels data. We did observe scattered litter but no duff. No snags have fallen since the time of the fire. Some shrub species were beginning to resprout including greenleaf manzanita and Woods rose. We also observed carex species.

Stand 2: The wildfire killed approximately 66% of ponderosa pines in Stand 2 (Table 2). The surviving trees were of average size for this area with diameters ranging from 11 to 17 inches dbh and had experienced 39% crown length scorch on average. Examination of the inner bark indicated that cambial damage varied from 25% to 100%.

With this degree of fire damage we estimated that approximately 74% of surviving ponderosa pines had a 0.10 or less probability of post-fire mortality, 7% of ponderosa pines had 0.20 probability of post fire mortality, and 19% had probabilities of post-fire mortality over 0.60 (Table 2). The highest probabilities of post-fire mortality were estimated for trees in Plot 1.

These results suggest the loss of between four to six additional trees per acre in years following the fire depending on factors such as the level of abiotic stress (i.e. drought) and bark beetle activity. Because the average diameters of surviving trees were within the range of high susceptibility to attack the stand received a moderate rating. However, we did not observe any evidence of bark beetle activity in this stand and buprestid wood borers infested only trees with lowest percentages of crown length scorched.

The total load of downed woody fuels averaged approximately 0.35 tons per acre (Table 3). These fuels were comprised of one hour and ten hour fuels only. Litter depths were just over one half inch on average and no duff was recorded. The wildfire consumed most shrubs and herbaceous plant species in the stand. No tree regeneration was tallied in this stand.

Stand 3: Only one percent of ponderosa pines in Stand 3 were killed by the wildfire. The remaining pines had diameters of 12.3 inches dbh on average with a total basal area of 89 ft^2 per acre leaving this stand moderately susceptible to bark beetle infestation (Table 2).

Most of the pines experienced approximately 34% crown length scorch on average. Examination of the inner bark of sampled trees indicated that the amount of cambial damage varied, but typically 25-100% cambium death was observed. We estimated that approximately 83% of the trees in this stand have 0.10 or less probability of post-fire mortality. Ten percent of the trees in the stand have 0.20 probability of post-fire mortality, and the remaining 7% have 0.60-0.90 probability. Plots 2 and 3 had the highest probabilities due to the highest percentages of crown length scorch and low cambium kill ratio (generally two live cambium samples per tree sampled).

These results suggest the loss of between seven to ten additional trees per acre in years following the fire depending on factors such as the level of abiotic stress (i.e. drought) and bark beetle activity. Again, we did not observe any evidence of bark beetle or wood borer activity in this stand. Approximately five percent of ponderosa pines in these plots were hit by red turpentine beetle with trees having one or two hits.

The total load of downed woody fuels averaged approximately 0.82 tons per acre (Table 3). These fuels were comprised of one hour and ten hour fuels only. Litter depths were just under one half inch on average and no duff was recorded.

There was no regeneration tallied in this stand.

Stand 4: Eighty-seven percent of ponderosa pines survived the wildfire in Stand 4 (Table 2). Residual stand conditions were similar to those of Stand 3 resulting in a moderate susceptibility rating.

Twenty-three percent of ponderosa pines in this stand had fairly high probabilities of post-fire mortality (0.50-0.90). This result was due to high levels of crown length scorch (40% on average) affecting relatively smaller diameter trees. Twenty four percent of trees had 0.20-0.30 probability of post-fire mortality and 18% of trees had 0.10 or less probability.

This result suggests that this stand could lose an additional 16 to 29 pines per acre in years following the fire. However, risk of bark beetle infestation was presently low and we observed only a minor amount of wood borer activity.

We estimated that this stand had approximately 50 ponderosa pine seedlings or saplings per acre. No other regeneration was tallied.

The total load of downed woody fuels averaged approximately 0.60 tons per acre (Table 3). These fuels were comprised of one hour and ten hour fuels only. Litter depths were just under one half inch on average and no duff was recorded.

Stand 6: All of the ponderosa pines in Stand 6 survived the fire (Table 2). This stand also had a moderate susceptibility to bark beetle infestation. Ninety-four percent of trees had over a 0.50 probability of post-fire mortality and six percent of the trees had 0.25 or less probability. This result suggests that an additional 31 to 57 ponderosa pines might die per acre in years following the fire.

We attributed this result to the generally high percentages of crown length scorch (91% on average). These trees were also larger, with thicker outer bark resulting in a higher proportion of live cambium versus dead. Stressed trees with a sufficient amount of suitable habitat are prone to bark beetle attack. Several trees had been hit by red turpentine beetles (one hit only), but we did not observe any other bark beetle activity.

The total load of downed woody fuels averaged approximately 0.193 tons per acre. These fuels were comprised of one hour and ten hour fuels only. Litter depths were just over 1/8 inch on average and no duff was recorded.

No regeneration was tallied in this stand.

Stand 9: Approximately 85% of trees per acre in Stand 9 were ponderosa pine with curlleaf mountain mahogany comprising the remainder of trees (Table 2). The ponderosa pines were relatively large (QMD = 14.7 inches) and the stand was relatively dense (BA = 113ft^2/acre). Consequently, this stand had a moderate susceptibility to bark beetle infestation. However, we did not observe any evidence of insect or disease activity. We tallied approximately 300 pinyon pine regeneration per acre. No other tree regeneration was recorded.

This stand had a total down woody fuel load of 3.3 tons per acre (Table 3). The majority of these fuels were in the 100 and 1,000 hour size classes. This stand also had the deepest litter and duff layers on average when compared to other unburned stands.

Stand 11: Stand 11 had conditions that were fairly typical of the ponderosa pine type in this area (Table 2). These conditions rated low to moderate with respect to bark beetle susceptibility. However, we did not detect any insect or disease activity. No tree regeneration was recorded.

Total fuel loads in this stand were fairly typical of what we recorded for other ponderosa pine stands located on similar slopes and aspects (Table 3). One thousand hour fuels contributed to the majority of fuels. Both litter and duff were approximately 0.66 inches deep on average.

Stand 12: Stand 12 contained a mixture of ponderosa pine, Utah juniper, curlleaf mountain mahogany and singleleaf pinyon. Ponderosa pine had the lowest QMD (10.6 inches) of all stands surveyed, although ponderosa pine basal area was typical (93ft^2/acre) (Table 2). Although trees were relatively smaller in size, stand conditions were within the range of moderate to high susceptibility to bark beetle attack. However, we did not record any insect and disease activity.

We tallied 100 ponderosa pine seedlings and saplings per acre on average. The stand also contained a fairly large proportion (30%) of smaller diameter trees (< 7 inches dbh).

Stand 12 had unusually high total fuel loads compared to other ponderosa pine stands in the area (Table 3). The total down woody fuel load was 13.2 tons per acre with one hour fuels comprising about 60%. We attributed this result to the abundance of curlleaf mountain mahogany and other shrub species that was scattered throughout the stand.

Stand 15: Stand 15 was also mixed being comprised of approximately half ponderosa pine and half curlleaf mountain mahogany. The ponderosa pines were of typical size for the area having QMDs of about 13 inches (Table 2). However, this stand had the highest

mean basal of all stands surveyed (153 ft^2 per acre). With these conditions the stand had a moderate to high susceptibility to bark beetle infestation although the risk was low.

Stand 15 also had a relatively high total down woody fuel load (5.38 tons/acre) compared to other ponderosa pine stands in this area (Table 3). Approximately 44% of fuels were comprised of 1000 hour fuels. Fine fuel loads totaled 3.03 tons per acre with most being comprised of 100 hour fuels. Litter and duff depths averaged 0.66 and 1 inch, respectively.

Stand 16: Stand 16 was fairly open with an average of only 40 ponderosa pines per acre (Table 2). We tallied only ponderosa pine in Stand 16 although curlleaf mountain mahogany was common throughout the stand (Table 2). The ponderosa pine component was typical of the area with trees having QMDs of about 13 inches. However, this stand had relatively low mean basal area compared to other ponderosa pine stands surveyed (40ft^2 per acre). With ponderosa pine diameters averaging over 10 inches dbh, this stand still had a moderate susceptibility to bark beetle infestation.

Fuels were fairly sparse in Stand 16 (Table 3). The total downed woody fuel load was 0.58 tons per acre and comprised entirely of one hour fuels. There was 0.5 inches average litter depth and no duff measured.

Stand 17: The ponderosa pine component in Stand 17 was very open with an average of approximately 30 trees per acre. These trees however were generally larger than those measured in Stand 16 (QMD = 16.2 inches). Curlleaf mountain mahogany were also scattered throughout the stand. Due to the large tree size, this stand had a moderate susceptibility to bark beetle infestation.

Fuels were fairly sparse in Stand 16 as well (Table 3). The total downed woody fuel load was 0.25 tons per acre and comprised entirely of one hour fuels. There was 0.63 inches average litter depth and 0.63 inches average duff depth measured.

Table 2. Summary of FINDIT results for ponderosa pine stands surveyed in Compartment PCBAAA including stand susceptibility to bark beetle infestation and percentages of trees in stands with various probabilities of post-fire mortality.

Stand	*TPA(%)	%Live	QMD(in)	BA(ft^2)	HR	%CLS	PM(%)		
Burned									
1	91(100)	0	NA	NA	NA	100	NA		
2	74(100)	34	15	27	M	39	<0.1(74)	0.2(7)	>0.6(19)
3	157(100)	99	12.3	89	MH	34	<0.1(83)	0.2(10)	>0.6(7)
4	163(100)	87	12.0	70	M	40	<0.1(18)	0.2-.3(24)	>0.5(23)
6	67(100)	100	15	67	M	91	-	<0.25(6)	>0.5(94)
Unburned									
9	112(85)	100	14.7	107	M	NA			
11	116(77)	100	13.3	65	LM	NA			
12	164(100)	100	10.6	93	MH	NA			
15	141(51)	100	13.8	127	MH	NA			
16	40(100)	100	13.5	40	M	NA			
17	28(100)	100	16.2	40	M	NA			

*TPA(%) = mean number of ponderosa pine per and percent of stand; %Live = percentage of living ponderosa pine in stand; QMD = quadratic mean diameter in inches; BA(ft^2) = mean basal area of ponderosa pine in ft^2 per acre; HR = hazard rating; M = moderate; MH= moderate to high; LM = low to moderate; %CLS = mean percentage of crown length scorch; PM(%) = probability of post fire mortality and percentage of trees in stand

Table 3. Fine and course downed woody fuel loads (tons per acre) in ponderosa pine stands located in Compartment PCBAAA.

Stand	**1 hr**	**10 hr**	**100 hr**	**1000 hr**	**Total**	**Ave. LD(in)***	**Ave. DD (in)**
Burned							
1	NA						
2	0.21	0.14	0	0	0.35	0.56	0
3	0.04	0.82	0	0	0.86	0.43	0
4	0.18	0.42	0	0	0.60	0.44	0
6	0.003	0.19	0	0	0.193	0.17	0
Unburned							
9	0.08	0.50	1.38	1.32	3.28	1.40	0.25
11	0.35	0.35	0	1.32	2.02	0.60	0.60
12	0.43	1.82	8.6	2.35	13.2	0.66	0
15	0.81	1.2	1.02	2.35	5.38	0.66	1.0
16	0.58	0	0	0	0.58	0.5	0
17	0.25	0	0	0	0.25	0.63	0.63

*Ave. LD = Average litter depth in inches; Ave. DD = Average duff depth in inches

Compartment PCZFLA

All of these stands burned during the Paradise wildfire with damage ranging from moderate to severe. Due to time constraints we only walked through Stand 1 and the uppermost portion of Stand 2. Both of these stands experienced severe levels of damage

during the fire. We examined ponderosa pine trees as they were encountered and recorded any insect and disease activity that was detected. We also inspected aspen in one small clone located near Stand 1 along the ridgeline that had survived the fire. We observed canker diseases typical of aspen but no other serious damage. This clone was also well-stocked with aspen suckers.

Stand 1: In Stand 1, only small groups (< 20 trees) of ponderosa pine or individual trees had green or lightly scorched crowns. These groups were located in upper slope positions and along ridgelines. Both dead and scorched trees had similar levels of wood borer and red turpentine beetle activity as we observed in Compartment PBCAAA. No other bark beetle species were observed.

Stand 2: We observed similar levels of fire damage in Stand 2.

Compartment PZCFJC – Mixed Type

We reviewed summaries of stand examination data collected from seven stands in Compartment PZCFJC and rated the susceptibility of ponderosa pines in each stand to bark beetle infestation. In general, stands had low susceptibility. We attributed this result to high percentages of curlleaf mountain mahogany (over 60% of trees per acre in some stands) and Utah juniper present in the majority of stands. The exception was Stand 1 where the large size of ponderosa pines (QMD = 16.1 inches) resulted in moderate susceptibility ratings.

Although ponderosa pine was not a primary component of many stands, individual trees typically had diameters within the range of high susceptibility to bark beetle attack (QMDs > 10 inches). In the event of an outbreak, stands could experience some loss of mature ponderosa pine.

Pinyon-Juniper Type

No active populations of pinyon engraver beetles or other insects were detected throughout the pinyon-juniper type. The susceptibility of stands to engraver beetle infestation however was generally moderate with stands comprised of over 50% susceptible trees (average drcs > 7 inches) and total stand density indices ranging between 104 and 210. No other predisposing agents such as pinyon dwarf mistletoe were observed.

Discussion and Recommendations for Bark Beetle Management

Native insects and diseases naturally occur throughout Intermountain pinyon-juniper woodlands and forest cover types. The level of insect and disease activity fluctuates with the availability of host material, stand conditions, environmental factors, and the abundance of parasites and predators. These agents typically occur at endemic levels within forest ecosystems affecting overmature and weakened trees (Edmonds et al. 2000, Samman and Logan 2000, Goyer et al. 1998). Periodically, populations of insects and

diseases reach outbreak levels and impact healthy trees. Past management practices including fire exclusion, livestock grazing, and timber harvesting have altered some forest types throughout the Intermountain west. As a result, many stands have become overmature, less diverse, and more susceptible to insects and diseases (O'Brien and Pope 1997). With their potential to cause extensive tree mortality, bark beetles pose the greatest threat to important resource values in the Paradise Mountains Project Area.

Bark Beetles Infesting Ponderosa Pine

In ponderosa pine forests of southern Utah, a complex of *Dendroctonus* bark beetles including the mountain pine beetle (*D. ponderosae* Hopkins) (Fig. 1), the roundheaded pine beetle (*D. adjunctus* Blandford), and the western pine beetle (*D. brevicomis* LeConte) typically cause ponderosa pine mortality. Ponderosa pine stands most susceptible to mountain pine and western pine beetle infestation are dense (>120 ft^2/ac), even-aged and comprised of more than 50% pines with average diameters exceeding 10 inches dbh (Steele et al. 1996). Roundheaded pine beetle infestations have been associated with slow tree growth resulting from high stocking conditions and drought (Negrón et al. 2000).

When *Dendroctonus* beetle populations are low, they infest weakened and injured trees. During outbreaks, however, tree mortality can occur over extensive areas. Endemic populations often develop into epidemics in unmanaged forests (McGregor and Cole 1985). During outbreaks, beetles infest the older, large diameter trees first, and eventually kill smaller trees as populations build (McGregor and Cole 1985). Epidemics usually collapse with the loss of all or most large trees.

Species of engraver beetles including *Ips pini* (Say), *Ips lecontei* (Swaine), *Ips knausi* (Swaine) can also cause significant ponderosa pine mortality (Steed 2005). Pine engraver populations may erupt during periods of drought or following stand disturbances such as blowdown, fire, or management activities. These insects are particularly attracted to host volatiles and green slash created during tree removal. Outbreaks of *Ips* bark beetles in standing, healthy trees however are typically sporadic and of short duration. Engraver bark beetles are usually secondary species found in weakened or damaged trees, or associated with tree-killing insect species. Most *Ips* species focus their attacks on smaller diameter pine or the tops of large diameter trees (Furniss and Carolin 1977, Kolb et al. 2006).

The adults of *Dendroctonus* bark beetle species disperse (fly) generally in July-August. Female beetles initiate attacks followed by males and other females. Evidence of successfully attacked trees include pitch tubes mixed with boring dust, and reddish, dry boring dust (similar to fine sawdust) found in bark crevices and at the base of attacked trees (Fig. 2). Mountain pine beetles and roundheaded bark beetles construct characteristic "J-shaped" egg galleries within the phloem (inner bark tissue) of the host tree (Fig. 3). The egg galleries of western pine beetles are typically more serpentine (Fig. 4). Galleries can be over 30" in length and are packed with boring dust. Females deposit eggs in niches along the sides of each gallery. Brood development generally takes one

year to complete. After eggs hatch (September-August), larvae mine horizontally away from the main egg gallery. Older larvae overwinter within the inner bark and resume maturation feeding through the late spring. Pupation occurs in chambers constructed at the end of larval mines. Brood adults feed briefly before tunneling to the bark surface to emerge. The spring following attack, trees will fade to a yellowish color then turn reddish-orange, and eventually reddish-brown. Trees will begin to lose needles the second year following attack. Most trees lose all needles three years after attack (Coulson and Witter 1984).

Figure 1. An adult mountain pine beetle.

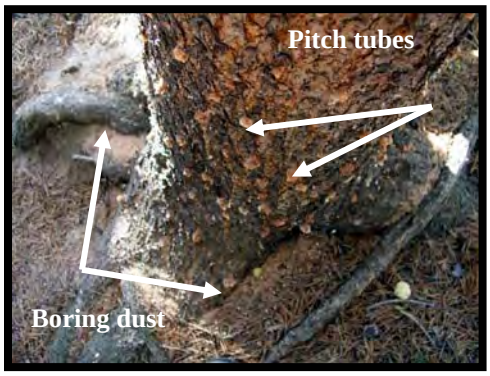

Figure 2. Symptoms of an attacked tree.

Figure 3. Mountain pine beetle galleries.

Figure 4. Western pine beetle galleries.

Like *Dendroctonus* beetles, *Ips* beetles inhabit the inner bark tissues of host trees and cause damage by disrupting the transport of water and nutrients. The life cycles of *Ips* beetles however generally last from six to eight weeks and thus five generations of beetles may be produced in one season depending on the climate, elevation, and species. With more than one population in a given area, the generations may overlap. Consequently, beetles may attack host trees throughout the season. Normally, in Utah, *Ips* beetles will generally begin attacking host trees in mid-April.

Ips beetles are attracted to trees that are under stress. They prefer to attack trunks or branches that are one to four inches in diameter, but might also attack larger diameter material. *Ips* populations often build in fresh green material including pruned branches and wind snapped or downed trees. Populations may also build in groups of small diameter stressed trees. Once populations are sufficiently large, they can attack and kill healthy trees. Beetles will usually initiate attacks at the tops of larger trees or individual branches.

When a beetle chews through the bark it produces red or orange boring dust. Successfully attacked trees will generally have this boring dust in bark crevices and/or around the base of the tree. Needles on branches or trees killed by the beetle will generally turn yellow or light green, in spruce; and yellow to red in pines, within a year of attack.

Bark Beetles Infesting Pinyon Pines[1]

The pinyon engraver beetle is the most important insect mortality agent in pinyon pines in pinyon-juniper woodlands. Endemic levels of pinyon engraver work in association with other insects and diseases serve to remove weakened and stressed trees, thus thinning the forest and reducing competition for light, water, and nutrients. Population levels may build when ample host material is available. This material may consist of freshly dead material including pruned branches and recently broken, uprooted, or downed trees. Outbreaks of pinyon engravers may continue for one to several years killing large groups of trees over the landscape.

Drought, disease or injuries by other insects are often important in weakening a living tree's defense system increasing the potential for successful engraver attacks. Moisture stress may increase tree susceptibility in two ways. The first way is by reducing the production of sap. Vigorous trees can produce enough sap to push or 'pitch' attacking beetles out of entrance holes. Beetles often become trapped in the sap and die. The second way is by increasing the nutritional quality of the tree for the beetles. Moisture stress has been found to increase soluble nitrogenous compounds and sugars in living cells of trees. Both of these substances are important for the development of beetles. Black stain root disease in pinyon pine is often associated with pinyon engraver activity. The beetle also favors pinyons with heavy dwarf mistletoe infections.

[1] Source Keyes and Hebertson, 2003.

Tree damage occurs when adult beetles colonize and reproduce in the conductive tissues of suitable host trees. Conductive tissues transport water and nutrients throughout the tree. Female beetles construct tunnels just under the bark to lay eggs. After the eggs hatch, the larvae feed creating more tunnels that further destroy the conductive tissue. During the initial construction of the egg gallery, the bark beetle often introduces a fungus that invades the wood staining it a bluish color. This 'blue stain' fungus plugs up the conductive tissues of the tree further prohibiting the transport of water and nutrients. Thus, the combined activity of both the beetle and the fungus eventually kills the tree.

Adult beetles generally overwinter in groups at the base of infested trees. Adults emerge in the spring to infest suitable host material often re-attacking uninfested portions of the same tree or attack another susceptible host tree. In Utah, pinyon engravers normally begin flight in mid-April. A male beetle locates and attacks host material emitting a pheromone that attracts females and other males. The male and female mate in the nuptial chamber in the tree phloem before the female constructs a gallery to lay her eggs. This egg gallery generally follows the grain of the wood with eggs laid singly along both gallery walls. These eggs hatch into small larvae and create larval galleries extending perpendicular to the egg gallery. Larvae eventually pupate and transform into new adults. The life cycle of pinyon engraver beetles generally lasts from 6 - 8 weeks with up to 5 generations produced in one season depending on climate and elevation. With multiple generations produced every year infested trees may contain beetle of various life stages.

Foliar symptoms provide initial evidence of engraver beetle attack. Pinyon pine needles on branches or trees killed by the beetle will generally turn yellow (fade) to orange/red within a few days or weeks. Before long, the needles begin to fall. Successfully attacked trees will also have red or orange boring dust (frass) in bark crevices and/or around the base of the tree. Boring dust is produced when beetle chews through the bark. Small, inconspicuous tubes of pitch containing boring dust may also be visible on the bark surface around entrance holes.

Water stress, diseases and the presence of other insects are good predictors of a tree's susceptibility to pinyon engravers. The probability of beetle attack also increases with increasing pinyon density even when pinyon represents a minor portion of the stand (Negrón and Wilson 2003). The most susceptible trees are relatively old with average root collar diameters (drc) between 7 and 11 inches. The beetle also favors pinyons with heavy dwarf mistletoe infections (Wilson and Tkacz 1992; Negron and Wilson 2003). During intense drought years pinyon pines may be susceptible to attack even at low densities and small diameter (two inches drc).

Forest Health Monitoring typically does not aerially survey pinyon-juniper woodlands and forests on BLM administered lands in southwestern Utah. Review of 2007 and 2008 aerial survey maps for locations closest to the Paradise Mountains (Bull Mountains and Pine Valley Mountains to the south) showed only low levels of ponderosa pine and pinyon pine mortality attributed to bark beetles.

We did not detect any active populations of bark beetles in either the pinyon-juniper or ponderosa pine types in the Paradise Mountain Project Area in our survey. Therefore the risk of bark beetle outbreaks is presently low. However, the pinyon-juniper woodlands and ponderosa pine stands we surveyed had structures and compositions conducive to the development and spread of bark beetle populations. The portions of pinyon-juniper woodlands we walked through were dense and comprised of high percentages of relatively large pinyon pine trees, particularly stands at lower elevations.

All of the ponderosa pine stands in Compartments PCBAAA and PCZFLA had moderate susceptibility to bark beetle infestation, except Stands 3, 12, and 15 where susceptibility rated moderate to high. In the event of an outbreak, bark beetles may infest these stands as population levels intensify.

The BLM data indicated that ponderosa pine stands in Compartment PCZFJC had low susceptibility to bark beetle infestation. However, we observed that the conditions in these stands were very similar to those in the compartments we surveyed. Moderate ratings may have been obtained for these stands if FHP and BLM data collection methods had been similar.

The probabilities of post-fire tree mortality in burned ponderosa pine stands indicate that Stands 4 and 6 in Compartment PCBAAA have the greatest overall likelihood of experiencing further ponderosa pine loss. However, there was a high likelihood that individual large diameter (>20 dbh) ponderosa pines with more than 50% crown scorch and < 50% cambial death in any fire-damaged stand may die.

Pinyon engraver beetles have been observed to attack pinyon pines in burned stands even though fire damage to individual trees was not apparent (Steed *pers comm*.). However, the direct contribution of bark beetles to post-fire tree mortality remains uncertain. This is because interactions between the physiological condition of host trees pre- and post-fire, the season of burn, the amount and severity of damage, bark beetle risk, weather and climate, and other biotic and abiotic factors make accurate predictions of post-fire tree mortality difficult (Jenkins et al. 2007).

In burned areas, fire damage may also predispose surviving to other damaging agents such as root diseases and/or slowly weaken them over time. Although not presently apparent, deleterious impacts could become evident as trees age or are subject to prolonged stress.

Bark Beetle Prevention Strategies

Based on the results of this survey, I recommend developing a vegetation management plan for the Paradise Mountains Project Area that incorporates both long and short-term bark beetle strategies to provide guidance for minimizing adverse impacts associated with outbreaks and meeting resource objectives. A single treatment strategy generally does not address all resource values within a susceptible and/or infested landscape. Therefore,

the selection of ecologically appropriate and economically feasible treatments should consider resource management priorities.

Further loss of trees due to bark beetles may conflict with critical resource values in the Paradise Mountain Project Area such as timber, pine nut production, recreation, and providing ecological diversity. While bark beetle risk remains low, I recommend developing and implementing treatments to minimize the potential for outbreaks. Prevention strategies offer the greatest likelihood of reducing the long-term susceptibility of stands to bark beetle infestation by creating a mosaic of structures, age classes, and species mixtures.

Traditionally, thinning (density management) has been the preferred strategy for bark beetle management in western forests (Goyer et al. 1998). Thinning is the selective removal of trees to benefit the quality of the stand (Daniel et al. 1979). Thinning effectively reduces a particular host resource base that supports bark beetle populations, reduces competition for water and nutrients, and disrupts the effectiveness of pheromone communication. The higher temperatures in thinned stands also reduce beetle survival and alter attack behavior of the insect (Schowalter et al. 1992, Amman et al. 1988, Schmid and Frye 1977, Sartwell and Stevens 1975).

Ponderosa Pine

Ponderosa pine stands to prioritize for thinning in those unburned portions of the project area surveyed are Stands 12 and 15 in Compartment PCBAAA. Thinning treatments should reduce stand densities to less than 80ft^2/acre while maintaining inner-tree spacing and reducing average stand diameters to eight inches dbh. As density increases above 100ft^2/acre, bark beetle susceptibility generally increases. In portions of project area not surveyed, stands with an excess of 120ft^2/acre mean basal area and average tree diameters of eight inches or larger are susceptible to bark beetle population increases. Thinning treatments should include these stands as well.

In uneven-aged stands, susceptibility also will increase as ponderosa pine dbh reaches eight inches or larger. Smaller diameter trees will be attacked when mixed with larger trees. Inter-tree spacing guidelines should be employed to reduce susceptibility. In sites where resource objectives rely on the clumpiness of ponderosa pine, inter-tree spacing guidelines should be implemented between clumps with age-class diversity emphasized to reduce losses if an outbreak does occur. In mixed conifer stands, when the ponderosa pine component exceeds 50 percent and ponderosa pine dbh averages $\geq$8 inches with BA's >100, susceptibility to mountain pine beetle will increase (DeMars and Roettgering 1982, Amman and Logan 1998, Feeney et al.1998, Kolb et al.1998).

In burned ponderosa pine stands (Stands 1-6 in Compartment PCBAAA, and Stands 1 and 2 in Compartment PCZFLA), I recommend implementing a combination of sanitation and salvage treatments in ponderosa pine stands to remove 1) merchantable trees killed by the wildfire, 2) remove fire-damaged ponderosa pines with high

probabilities of post-fire mortality (dbh > 20 inches; > 50% crown length scorch, < 50% cambial death), and 3) any ponderosa pine currently infested by bark beetles.

Pinyon Pine

Page (2005) recommended that to reduce the long-term susceptibility of stands to the pinyon engraver beetle, thin the pinyon component to an SDI of 20 or less (~6% of maximum SDI; 360 for pure stands (pinyon or juniper) and 415 for mixed stands). Where stands are composed of mixed pinyon and juniper, a total SDI of 24 may be appropriate and will approximate the same competitive conditions.

Table 4. TPA*, BA and spacing between trees based on SDI and diameter in inches (Stand SDI = 24 or 5.6% of maximum SDI) (After Page 2005)

SDI	DRC	TPA	BA	Spacing
24	6	54	10.7	28.3
24	8	34	12.0	35.6
24	10	24	13.1	42.6
24	12	18	14.1	49.3
24	14	14	15.0	55.8
24	16	11	15.8	62.0
24	18	9	16.6	68.2
24	20	8	17.3	74.2
24	22	7	17.9	80.1

*TPA = trees per acre; BA = basal area; SDI = stand density index; DRC = diameter at root collar.

Table 5. Target after-treatment stand (at 5.6% of max SDI) (After Page 2005)

Size Class	SDI*	TPA	BA	Spacing
Regen (<3”)	6.5	45	2.2	31.2
Small (3-6”)	6.5	15	2.9	54.4
Mid (6-9”)	6.5	8	3.4	75.2
Large (>9”)	6.5	14	15.0	55.8
Total	26	82	23.5	--

*TPA = trees per acre; BA = basal area; SDI = stand density index.

Traditional measures of stand density for an SDI of 24 for given size classes is shown in Table 4. Multi-aged/sized stands should have the total SDI apportioned among size classes (Table 5).

Various factors should be taken into account in the selection of trees to retain on the site ("leave trees"). Damaging agents, such as disease or physical damage (including logging damage), can weaken and stress trees, making them more susceptible to pinyon engraver. Leave trees should be those that appear the healthiest trees with the least damage. If

dwarf mistletoe (a parasitic plant species) is present on individual trees, these trees should not be favored for leave trees over adjacent uninfected and otherwise healthy trees.

Pinyon engraver beetles prefer trees with somewhat reduced crown ratios. Pinyon leave trees should be those with the higher percentage of crown-to-height ratio. The beetles also prefer larger diameter pinyon trees, thus it may be desirable to retain older juniper "legacy" trees and remove any older/larger pinyon trees that show signs of declining vigor.

Stand susceptibility to pinyon engravers is also influenced by stand composition, and those stands with a higher percentage of pinyon-to-juniper tend to be more susceptible to beetle-caused mortality. Thus it is desirable to maintain a good mix of species. Additionally, treatments may vary by size of pinyon leave trees and percentage of pinyon-to-juniper leave trees.

Trees in thinned, vigorous stands are infrequently colonized by engraver beetles. Generally engraver beetles have presented problems in sites where a natural disturbance has occurred (windthrow, fire, etc.) or slash has been produced by stand management activities, road building, etc. In areas where there is a history of engraver beetle problems, slash should only be produced during late summer to early winter. This usually will allow the slash to dry out such that brood sites become unsuitable for engravers. Slash created in late winter through early summer provides ideal breeding habitat for this insect.

Other management practices that can be used to minimize impacts are: 1) Prompt slash disposal (burning, chipping, trampling, etc). 2) If slash disposal is not feasible, lop into smaller pieces and scatter slash in openings to promote drying. 3) Green chains providing slash throughout the flight period. Large piles of slash produced in the spring will also concentrate beetle populations (piles should be 20 feet wide and 10 feet deep, distributed throughout the area treated or disturbed). During logging, directional felling to avoid wounding residual trees and using designated skid trails will reduce susceptibility of remaining trees. Trees with disturbed roots or those wounded during logging should be removed (Steed 2005).

Bark Beetle Suppression Strategies

In addition to developing prevention strategies, I recommend monitoring ponderosa pine stands and pinyon juniper woodlands annually for the early detection of bark beetle outbreaks. In the event of an outbreak, suppression strategies are usually implemented to reduce bark beetle population levels and rates of spread. Treatment alternatives associated with suppression, however, are usually limited often occurring at small scales. Because treatments may not sufficiently modify stand conditions, the benefits are often short term.

SANITATION. Sanitation treatments may reduce local bark beetle levels in stands with low, but building populations and decrease stand susceptibility. Sanitation treatments

involve the removal of infested and susceptible host trees. The removal of large diameter trees reduces stand densities and alters residual stand structure. To minimize the probability of re-infestation, particularly where risk remains high, sanitation treatments would need to address the entire susceptible host component. Created openings may promote some age class diversity in treated sites. Stands to consider for sanitation treatment would include infested stands with a susceptible host component that remains at risk to bark beetle attacks.

Benefits of this treatment would include deriving some commercial value from harvested timber and creating greater species and structural diversity while treating fewer acres. By reducing local susceptibility, this treatment would also offer long-term management for bark beetles and provide the greatest opportunity for maintaining mature trees within various sites. This treatment would require access to susceptible and infested trees increasing short-term site impacts. However, the necessity for stand re-entry would decrease. Other undesirable consequences of this treatment would include loss of large diameter trees, probable damage to residual trees and increased potential for windthrow.

Treatment success decreases with rapidly expanding bark beetle populations. Openings created in stands could predispose trees to blowdown. This treatment would not reduce the susceptibility of stands to subsequent bark beetle attacks and may require additional entries to treat or remove downed host material, or newly infested standing trees.

Restoration

The majority of ponderosa pine stands we surveyed were fairly even-aged and lacked sufficient regeneration (no ponderosa pine seedlings tallied in most stands) and younger age classes of trees for maintaining desirable stocking levels and a mature tree component over the long-term. A comprehensive vegetation management plan should include guidelines for enhancing ponderosa pine age-class and structural diversity. Consider planting a mixture of non-host tree species to create an environment that supports diversity and reduces long-term insect and disease impacts.

Aspen is an important component of many Intermountain forest ecosystems providing vegetative diversity that benefits both wildlife and humans. Because aspen comprises a minor component in the project area any losses due to insects and diseases could result in adverse impacts to important resource values.

Historically, lower elevation aspen stands, particularly those on drier sites, tended to burn more frequently serving to rejuvenate aspen and reduce the incidence and extent of fungal diseases, wood borers, and other damaging agents throughout the type (Bartos 2001). In the absence of fire or management, aspen stands deteriorate after about 100 years with aspen heart rot, cankers, root disease, and poplar borers contributing to decline (Solomon 1995, Karen 1986, Hiratsuka and Loman 1984, Ostry and Walters 1983, Schier 1975).

A high incidence of insect and disease activity is not necessarily indicative of poor aspen health. Aspen mortality in stands with sufficient regeneration (> 5000 suckers per acre) for recruitment into the overstory generally signifies the natural 'turn-over' of healthy stands. In decadent stands, aspen may lose their ability to sucker following disturbances. Insufficient regeneration in conjunction with insect and disease mortality, particularly in stands impacted by grazing, will result in the loss of aspen. This necessitates immediate development of a management strategy and implementation of appropriate treatments (prescribed fire or silvicultural treatments) to maintain and restore the aspen component.

We did observe suckers in the aspen stands we walked through, although we did not determine the actual average number of suckers per acre. If aspen regeneration is insufficient to meet resource objectives in the Paradise Mountain Project Area, stands may be rejuvenated using a variety of silvicultural techniques. The use of prescribed fire to stimulate suckering is probably not feasible due to the small size of clones. Regardless of the method selected for aspen management, it is necessary to control the amount of herbivore grazing on the aspen suckers to insure survival of new regeneration (Munson and Guyon 2006). If an aspen clone loses more than one crop of suckers, the rate of sprouting is greatly reduced and the clonal root system can be killed.

Some techniques that can be used to protect regeneration from herbivory include satiating the demand (from herbivores) for sprouts (Crouch 1983), leaving logging lash as a physical barrier to protect sprouts from browsing (Rumble et al. 1996), repellents (Baker et al. 1999), or fencing (Shepperd and Fairweather 1994). Fencing is the only guaranteed means of directly protecting sprouts from browsing animals. Research by Shepperd and Fairweather (1994) has shown that fencing is operationally feasible but must be maintained every 8-10 years (or until dominant stems are ca. 1 inch in diameter) to effectively protect aspen regeneration from animal browsing. Wire fences constructed from two widths of 1 m wide field fencing, or one height of 1.4 m wide fencing with one or two high tensile smooth wires strung above, have been found effective (Shepperd 2001).

If aspen restoration treatments are considered, the following practices can maximize aspen regeneration (Munson and Guyon 2006):

- To stimulate aspen regeneration, the best results are achieved by removing all the aspen overstory.
- Procedures should be implemented to minimize soil compaction in treated areas.
- If treatment of the aspen overstory to stimulate suckering is not an option, removing competing sagebrush and other vegetation may promote aspen release. Again, protecting the developing aspen sprouts from grazing is crucial to achieve aspen regeneration objectives.

Downed Woody Fuels

Providing a comprehensive analysis of fuels complexes and potential fire behavior for the Paradise Mountains Project Area was beyond the scope of this survey. Information on

the composition of plant communities, fuels composition, and fuels continuity however may augment existing fuels data used to help characterize fire regimes.

Conclusions

Based on the results of our survey the incidence of insects and diseases in the Paradise Mountains Project Area was generally low and forests exhibited good health. *Dendrotonus* and *Ips* bark beetle species have the greatest capacity to cause unacceptable levels of pine mortality in the future. Conventional hazard rating systems indicated that both the pinyon-juniper woodlands and ponderosa pine stands survey were moderately susceptible to bark beetle infestation. In the event of an outbreak, stands have structures and compositions conducive to bark beetle spread as population levels intensify. Ponderosa pine stands to prioritize for thinning in unburned portions of the project area surveyed include Stands 12 and 15 in Compartment PCBAAA.

The probabilities of post-fire tree mortality in burned ponderosa pine stands indicate that Stands 4 and 6 in Compartment PCBAAA have the greatest overall likelihood of experiencing further ponderosa pine loss. Bark beetles may contribute these losses. However, the likelihood that individual large diameter (>20 dbh) ponderosa pines with more than 50% crown scorch and < 50% cambial death in any fire-damaged stand may die is high. With increasing risk, pinyon engraver beetles may infest pinyon pines in burned stands even where damage to individual trees was not apparent.

A comprehensive vegetation management plan for the Paradise Mountain Project Area should be developed that provides monitoring guidelines for the early detection of increased levels of insect and disease activity. The plan should also specify appropriate strategies for the prevention and suppression of damaging insects and diseases, particularly bark beetles, and prioritize stands for treatment. The timely implementation of treatments will help minimize the potential for adverse impacts to important resource values.

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APPENDICES

Appendix 1. Potential Insect and Disease Agents of Southwestern Forest Types

Insects				
Tree species	Bark Beetles	Defoliators	Terminal	Borers
Ponderosa Pine	MPB*	Pine sawfly	Shoot borers	Pitch mass borer
	WPB	Pine butterfly	Pine tip moths	
	RPB	Pine tortrix		
	RTB	Gouty pitch midge		
	Pine engravers	Needle miners		
		Weevils		
		Sheath miners		
		Pine needle scale		
Pinyon Pine	Pinyon Ips	Pinyon sawfly	Pitch nodule moth	Pitch mass borer
	Twig beetles	Needle scale		
		Tiger moth		
Juniper	Cedar BB	Spider mites	Twig pruner	Cedar borer
Gambel Oak		Fall cankerworm		
		Tent caterpillar		
		Leaf roller		
		Leaf tier		
		Leaf skeletonizer		
*MPB = mountain pine beetle; WPB = western pine beetle; RPB = roundheaded pine beetle; RTB = red turpentine beetle; BB = bark beetle				

Biotic Diseases				
Tree species	DM/Mistletoe	Rusts/Cankers	Root Disease	Foliar
Ponderosa Pine	Southwest DM*	Limb rust	Armillaria	Needlecasts
		Comandra rust	Schweinitzii	Pine shoot blight
		Atropellis canker		
Pinyon Pine	Pinyon DM	Pinyon blister rust	Black stain	Needle rust
Juniper	Mistletoe	Stem rust	Heartrot	
Gambel Oak				Anthracnose
*DM = dwarf mistletoe				

Abiotic Diseases	
Fire damage	Sunscald
Mechanical Injury	Herbicides
Frost Damage	

Appendix 2. Distinguishing between biotic and abiotic disease agents.

A. SYMPTOMS

Biotic Usually on specific plant parts; environmental conditions or inoculum dispersal factors account for unevenness of symptoms. Example, Canker disease, rain dispersed foliage disease. Occurs as a progressive invasion and symptoms may include dead tissue surrounded by lighter green, yellowing tissue in foliar diseases or callous ridges with stem diseases.

Abiotic Usually uniform in symptom expression, unless portions of plant not exposed - winter dessication is uniform except for branches covered with snow. Not generally a progressive invasion.

B. SIGNS

Biotic Fruiting structures of pathogenic fungi such as conks or mushrooms and the effects of such fungi such as sunken, softer tissues of cankers, rust pustules of rust fungi.

Abiotic No signs of a biotic agent or only signs of non-pathogenic fungi. The latter, in some cases, may only be distinguished after laboratory examination.

C. HOST SPECIFICITY

Biotic Usually host specific or occur on a limited number of related or unrelated hosts.

Abiotic Symptoms may occur on two or more totally unrelated hosts.

D. SPATIAL DISTRIBUTION

Biotic Usually show clumpy type distribution because they are caused by pathogenic agents having a particular pattern of spread. Pattern may be related to favorable conditions for infection.

Abiotic Usually random except when the agent is distributed in a non-random fasion. Example, source pollution patterns are tied to the point source, i.e. factory, etc.