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A BIOLOGICAL EVALUATION OF FOREST HEALTH ON MOQUITH MOUNTAIN

BUREAU OF LAND MANAGEMENT
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Biological Evaluation of Forest Health on Moquith Mountain

Abstract

In July and October of 2006, the USDA Forest Service, Forest Health Protection, Ogden Field Office (FHP-OFO) surveyed approximately 5,000 acres in the Moquith Mountain Wilderness Study Area and Coral Pink Sand Dunes to document current insect and disease activity and to assess stand and landscape level risk. This area was primarily comprised of pinyon-juniper woodlands and stands of ponderosa pine. Individual trees in the Ponderosa Grove Campground and popular dispersed recreation sites were also examined for evidence of insects and diseases and human damage. The results of the survey indicated that endemic levels of insect and disease agents generally occurred within the project area. Juniper gall rust and juniper mistletoe were the most damaging agents detected, although infections caused only minor impacts. No current bark beetle activity was observed. Small patches of ponderosa pine and ponderosa pine stands in the Sand Dune area however, had moderate to high susceptibility to bark beetle infestation. Aspen in the project area exhibited symptoms of decline. A number of insect and disease agents contributed to this damage, but the underlying cause appeared to be stress associated with grazing and plant competition. The trees in recreation sites had injuries typical of those caused by human activity, but this damage had not resulted in tree decline. General recommendations for the Moquith 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 within the Moquith Mountain project area.

Background

Moquith Mountain is a small plateau located near the town of Kanab in southern Utah. The plateau rises approximately 6,000 feet in elevation and lies within the Vermillion Cliffs portion of the Grand Staircase area of the Colorado Plateau Physiographic Province. Pinyon pine (*Pinus edulis*) and juniper (*Juniperous osteosperma* and *J. scopulorum*) woodlands characterize upper plateau sites where shallow, rocky, and sandy soils occur. Islands of ponderosa pine (*Pinus ponderosae*) occupy sites in lower lying draws, swales, and dune areas. Shrub species on the plateau include thick patches of Gambel oak, interspersed with serviceberry, manzanita, sagebrush, and rabbitbrush. Other vegetation includes yucca, various cacti species, herbaceous plants, and grasses typical of southern Utah desert environments. The USDI Bureau of Land Management (BLM) administers approximately 50,632 acres of Moquith Mountain as a Special Recreation Management Area. Of this total, the Moquith Mountain Wilderness Study Area (WSA) comprises 14,830 acres including the northern portion of the Coral Pink Sand Dunes (~ 1,500 acres). These areas provide a wide range of important recreation, scenic, archeological, wildlife, botanical and other ecological values. Declining forest health and high levels of tree mortality associated with insects, diseases, animal, and human activities would potentially conflict with these resources.

At the request of the BLM, Kanab Area Field Office, the USDA Forest Service, Forest Health Protection, Ogden Field Office (FHP-OFO) surveyed approximately 5,000 acres in the Moquith

Mountain WSA and Coral Pink Sand Dunes in 2006 to document current insect and disease activity and to assess stand and landscape level risk. Individual trees in the Ponderosa Grove Campground and popular dispersed recreation sites were also examined for evidence of insects and diseases and human damage.

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 on Moquith Mountain are also discussed.

Methods

Data Collection

An ortho-photoquad and topographic maps were used to subdivide the project area into smaller survey units based upon major forest cover types (either pinyon-juniper woodlands, or ponderosa pine), other vegetative characteristics, and landscape features. This resulted in 17 units ranging from about 138 to 2000 acres in size (Table 1). Survey units A through J were predominantly pinyon-juniper woodlands. Ponderosa pine was the dominant forest cover type comprising survey units K through P and the Sand Dune area.

Table 1. The approximate size of units delimited in the pinyon-juniper and ponderosa pine forest cover types in the Moquith Mountain project area.

Pinyon-Juniper Type		**Ponderosa Pine Type**	
Unit	**Acres**	**Unit**	**Acres**
A	386	K	138
B	207	L	193
C	403	M	165
D	241	N	138
E	361	O	723
F	648	P	331
G	615	SD (sand dunes)	1,983
H	634		
I	303		
J	195		
Total	**3,993**	**Total**	**3,671**

For the purpose of data collection, plots were systematically distributed throughout each survey unit. The large size of the project area, the lack of road access, and time constraints limited the number of plots that could be feasibly inventoried. As a consequence, plots were spaced at 20 chain (1 chain = 66 feet) intervals along parallel transects located 20 chains apart to ensure sufficient coverage within each survey unit.

In the pinyon-juniper type, tree data was collected on fixed radius plots 1/20th acre in size (radius = 26.3'). Variable radius plots (basal area factor of 20) were used to determine sample trees in the ponderosa pine survey units. On each plot, all trees greater than five inches diameter at breast height (dbh) were tallied and measured. The mensurational data collected included tree species and condition (live, declining, or dead), and the dbh of junipers and ponderosa pines, or diameter at root collar (drc) of pinyon pines. Age and height data was also collected for one dominant or codominant ponderosa pine in each ponderosa pine-type plot. All sample trees were examined for evidence of insects, diseases, and other damage, and indicators of poor tree health including discolored foliage, sparse foliage, branch dieback, pitch streaming, and basal resinosus. With the detection of tree damage, the causal agent and type, extent, and severity of damage was recorded. Symptomatic trees in each survey unit observed outside of plots was also recorded and/or mapped. Appendix 2 provides a list of potential damaging agents by host type.

Next, all regeneration (juniper, pinyon pine, ponderosa pine and gambel oak less than five inches dbh, and greater than six inches in height) of each tree species was tallied in a 1/300th acre subplot (radius = 6.8') at plot center. Other data collected on each plot included a list of shrubs, herbaceous plants, grasses, and other vegetation. Finally, the percentage of canopy closure, and percentages of bare ground or rock and live and dead fuels were estimated on each plot to provide some insight into the horizontal fuel continuity. The live fuels included all living (green) grasses, herbaceous plants, shrubs, and regenerating tree species. Dead fuels included downed woody fuels of all size classes, litter, duff, and other dead plant material.

Ground and visual surveys were used to detect insects and diseases affecting aspen (*Populas tremuloides* Michx.) in a small (<10 acres), high value clone located near the junction of Hancock Road and Highway 89.

Data Analyses

Tree Data

Tree and stand data collected in each survey unit was either summarized by hand or by using the **F**orest **I**nsect and **Di**sease **T**ally (FINDIT) program (Bentz 2000). Summary statistics for trees in the pinyon pine and juniper survey units included:

1. Total trees/acre (TPA) of each species.
2. Total mean basal area (BA) of each species.
3. Live quadratic mean diameter (QMD) of juniper and ponderosa pine.
4. Average drc of pinyon pines.
5. Percentage of each tree species per acre.
6. Percentage of BA of each tree species per acre.
7. Total regeneration/acre of each tree species.

The FINDIT program calculated following summary statistics for trees in the ponderosa pine survey units.

1. Total trees/acre (TPA).
2. Total live and dead basal area (BA ft^2/ac).
3. Live ponderosa pine and juniper 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. Average age of codominant/dominant trees.
9. Total regeneration/acre of each tree species.
10. Percentage of basal area killed by insects and diseases.

Insect and Disease Hazard Ratings

Hazard rating systems 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 (definitions from Shore and Safranyik, 1992, 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 agents where reliable systems have been developed.

<u>Bark Beetles</u>

PONDEROSA PINE. There has been little research conducted in the southwest on how stand conditions relate to the potential for bark beetle infestation. However, other research in the west clearly shows that when trees are stressed from overstocking they are more susceptible to bark beetle attack. No stand hazard rating models have been validated for pine engraver beetle species (*Ips* spp.) attacking ponderosa pine in the southwest, primarily because beetle populations are often driven by drought and factors leading to large amounts of slash. Stand hazard ratings for *Dendroctonus* bark beetles attacking ponderosa pine typically involves measures of tree size, density (BA or SDI), and the percent of host trees within the stand. In general, ponderosa pine stands that have an average dbh greater than 12 inches and a stand basal greater than 120 ft^2/acre are considered at high risk to bark beetle attack, stand basal area of 80 – 120 ft^2/acre are moderate risk, and stand basal area less than 80 ft^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 for *Dendroctonus* beetle species in ponderosa pine. The Munson and Anhold system is given in Table 2 below (modified from Chojnacky et al., 2000). This system was validated across several sites including the North Kaibab in Arizona.

Because of the more xeric conditions in the southwest compared to other western states that have ponderosa pine, the low risk category may be even less than 80 ft^2/acre. Also, because of the large complex of pine engraver beetles that 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 2. 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: Scolytidae, Ipinae)) is the most important mortality agent of pinyon pine in the southwest and intermountain west (Rogers 1993). 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. 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 drcs greater than about 7 inches and/or those heavily infected by dwarf mistletoe are most susceptible to attack. Other factors contributing to outbreaks include disturbances that produce green slash.

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

The Hawksworth's 6-class dwarf mistletoe rating system (DMR) (Hawksworth 1977) was used to evaluate 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 (*Arceuthobium*) (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

All trees in the Ponderosa Grove Campground and the Sand Springs dispersed recreation site were examined for evidence of insect and disease damage. A total of 102 plots were inventoried throughout the remaining Moquith Mountain project area. The number of plots in each unit surveyed ranged from three (Unit K) to 19 in the dune area. Units I, J, and O were not surveyed due to time constraints and limited road access. For these same reasons, some plots in other units were omitted from the survey. Due to the wide spacing of plots in the survey design, small stands (less than five acres) may not have been inventoried.

The following section summarizes the results of FINDIT and other analyses used for the determination of stand susceptibility and risk and developing general recommendations for insect and disease management. A summary of damaging agents recorded in each survey unit is also provided. A map of each survey unit where significant damage was recorded is shown in Appendix 1.

Pinyon-Juniper Type

<u>Stand Summary</u>

Pinyon pine and juniper woodlands characterized upper plateau locations surveyed in the northern portion of the project area (Units A-D) (Table 3). In Unit B, woodlands were sparsely populated with trees, while other units were moderately to well-stocked (77 to 153 tpa). Juniper comprised the greatest percentages (61-100%) of tree species per acre tallied in these woodlands. Approximately 30% of trees were pinyon pine. Juniper diameters were not measured in units A through D. The majority of pinyon pines were relatively small. Due to insufficient diameter data, mean basal areas were not calculated. However, the majority of basal area consisted of juniper.

South of Unit D, the proportion of pinyon pine in woodlands increased, although the total numbers of trees per acre decreased. The fewer number of trees may be attributed to larger tree sizes with pinyon and juniper diameters averaging between 8 and 15 inches. Ponderosa pine also became more abundant and was a major tree component in Units E and H. Stands in these units were not overly dense. Stands in Unit E had the greatest amount of mean basal area (144ft^2/acre). The presence of large ponderosa pine in this unit accounts for most of the basal area.

With the exception of Units G and H, the majority of conifer regeneration in pinyon-juniper woodlands was pinyon pine (Table 4). Varying percentages of Gambel oak regeneration were present in all Units located east of the sand dune area, but percentages dramatically increased more south in Units G and H. Although ponderosa pine was a major tree component in Units E through H, ponderosa pine regeneration was only recorded in Unit F.

Table 3. Summary of tree data for surveyed areas in the pinyon/juniper type.

Area	TPA (%)				BA (%)				drc	dbh		SDI
	P	J	PP	Total	P	J	PP	Total	P	J	PP	
A	50(33)	103(67)	0	153	10	-	0	-	8	-	0	-
B	0	7(100)	0	7	0	-	0	-	0	-	0	-
C	30(39)	47(61)	0	77	13	-	0	-	7	-	0	-
D	44(33)	91(67)	0	135	37	-	0	-	12	-	0	-
E	40(32)	37(29)	49(39)	126	12(8)	29(20)	103(72)	144	8	12	20	210
F	43(54)	25(31)	12(15)	80	29(45)	17(26)	19(29)	65	11	12	17	112
G	67(80)	13(16)	3(4)	83	47(76)	10(16)	5(8)	62	11	12	17	104
H	27(57)	9(19)	11(24)	47	27(32)	11(13)	47(55)	85	14	15	28	121

*TPA(%) = number of trees per acre and percentage of total; BA = basal area per acre and percentage of total; drc = diameter at root collar; dbh = diameter at breast height; P = pinyon pine; J = juniper; PP = ponderosa pine, SDI = stand density index.

Table 4. Regeneration per acre for surveyed areas in the pinyon/juniper type.

Area	P (%)*	J (%)	PP (%)	GO (%)	Total TPA
A	167(84)	33(16)	0	0	200
B	0	0	0	0	0
C	33(66)	0	0	17(34)	50
D	166(59)	97(34)	0	20(7)	283
E	808(46)	38(2)	0	922(52)	1,768
F	192(68)	54(19)	23(8)	15(5)	284
G	200(11)	100(6)	0	1,517(83)	1,817
H	64(5)	55(4)	0	1,209(91)	1,328

*P = pinyon pine; J = juniper; PP = ponderosa pine; GO = Gambel oak.

<u>Fuels Summary</u>

An average of 42% of the ground in the pinyon and juniper woodlands was bare (Table 5). The highest percentages of bare ground occurred in Units A, B and C, where 55 to 72% of the soil surface was sandy and rocky. The percentages of living and/or dead plant cover were slightly higher in the other units. Generally an average of 30% of living plants and 28% of dead plant material covered the ground surface throughout the area. However, the percentages dead plant material varied much more greatly across units. In Units A, B, C, and D, the coverage of dead plant material was on average about 13 %, while in Units E, F, G, and H the coverage of dead plant material ranged from 33 to 60%. The highest percentages occurred in Units G and H where most of the dead plant material was a relatively thick layer (up to ½ inch) of ponderosa pine needles that covered the ground surface.

Percentages of canopy closure ranged from five percent in Unit B to 39% in Unit E. The most closed canopy conditions were present in the mixed conifer units containing a high proportion of pinyon pine and a major ponderosa pine component.

Table 5. Summary of fuels data in pinyon/juniper surveyed areas.

	% Can. Clos.*	**% Bare**	**% Live Fuels**	**% Dead Fuels**	**Comments**
A	18	55	30	15	
B	5	72	18	10	
C	19	58	20	12	
D	30	37	50	13	
E	39	33	32	35	
F	32	33	33	33	
G	15	20	20	60	Dead = litter
H	26	24	31	45	

*Can. Clos. = canopy closure; Bare = bare ground.

Summary of Insect and Diseases

The most common damaging agents recorded throughout the pinyon and juniper woodlands were the pinyon pitch mass borer (*Dioryctria ponderosae* Dyar (Lepidoptera: Pyralidae), juniper gall rust (*Gymnosporangium nelsonii*), and juniper mistletoe (Table 6). The percentages of pinyon pines infested by the pitch mass borer (PMB) in each unit ranged from 0 to 33%. The most heavily infested stands were those in the northern portion of the survey area. The incidence of PMB decreased in the more southern portions of the pinyon and juniper woodlands surveyed. Attacks were generally light with less than five pitch masses observed per infested tree. Consequently, this agent did not cause significant tree damage.

Both juniper gall rust (GR) and juniper mistletoe (JM) were widely distributed throughout the pinyon and juniper type. From 3 to 54% and 3 to 85% of junipers were infected by GR and JM, respectively. The highest percentages of trees infected by GR were in the southern portions of the woodlands (Units E through H). The level of gall rust infections varied with one to dozens of galls observed in tree crowns. On average less than ⅓ of juniper crowns were infected.

The incidence of JM was also highly variable. The largest numbers of trees with JM infections were recorded in Units C, G, and E (85%, 77%, and 54% of trees, respectively). Infections ranged from light (< 20% of crown infected) to heavy (100% of crown infected) with an average of about 33% crown infection.

Some junipers heavily infected (> 50% of crown affected) by either or both of these agents had branch dieback or exhibited symptoms of decline (sparse, and /or discolored foliage). Heavy infections perhaps in combination with other stressors (damaging agents, drought, etc.) likely contributed to this damage. Adverse impacts associated with these agents, however, was generally minor.

No active populations of pinyon engraver beetles or other bark beetles were detected throughout the pinyon-juniper type. The susceptibility of stands to engraver beetle infestation in Units A, B, C, and D was low. Most stands in Units E, F, G, and H had moderate to high susceptibility. About 30 to 85% of trees in these units were comprised of susceptible trees (average drcs > 7 inches) with total stand density indices ranging between 104 and 210. No other predisposing agents such as pinyon dwarf mistletoe were observed.

Trees (all conifer species) with sapsucker damage were scattered throughout the surveyed area. Most of the other agents causing low percentages (< 5%) of damage were observed in Unit F. These agents primarily affected ponderosa pine and included heartrot caused by decay fungi, limb rust (*Peridermium filamentosum* A. & K.), sapsucker, and fire damage. An average of two pinyon pines per acre had evidence of old engraver beetle attacks. Significant levels of fire-damaged trees were also recorded in Unit H. Large fire scars were present on about 17% per acre of the ponderosa pine component.

Table 6. Insects and diseases found in pinyon/juniper areas surveyed and the number of trees affected per acre by species.

Area	P*			J				PP			Comments
	PMB	TM	BB	GR	M†	DT	HR	FS	L	Total	
A	7	0	0	13	23	0	0	0	0	43	Sapsucker damage and limb rust in PP off plot; numerous dead juniper off plot
B	-	-	-	-	-	-	-	-	-	-	Sapsucker damage in PP off plot
C	10	3	0	3	40	0	0	0	0	56	
D	13	0	0	3	3	0	3	0	0	22	
E	3	0	0	18	20	0	0	0	0	41	
F	0	0	2	8	3	0	3	2	2	20	Sapsucker damage on one juniper; bark beetle damage old strip attack
G	7	0	0	7	10	0	0	0	0	24	
H	0	0	0	3	3	3	0	8	0	17	

*P = pinyon pine; J = juniper; PP = ponderosa pine; PMB = pitch mass borer; TM = tip moth; BB = bark beetles; GR = juniper gall rust; M = juniper mistletoe; DT = dead top; HR = heartrot; FS = fire scar; L = lightning scar.
† Mistletoes infections were light to moderate affecting on average 16% to 50% of individual tree crowns.

Ponderosa Pine Type

Stand Summary

Although scattered ponderosa pines occurred throughout the survey area, the largest most homogenous groups were present in the sand dune area and in lower lying draws and swales. Large ponderosa pine comprised 99% of trees within the sand dune area (Table 7). These trees grew in relatively dense (mean BA 116ft^2/acre) patches that were 1 acre to about 50 acres in size. Scattered (~ one tpa), large diameter junipers were also encountered in the sand dune area.

Ponderosa pine represented the majority of tree species in Units K, L, M, N, and P, although juniper was also a major tree component. Pinyon pine was only a minor component with some

trees inventoried in Units L and M. The number of trees per acre and patch densities in these units was much lower than in the sand dune area. As few as nine ponderosa pines per acre occurred in Unit N and total mean basal areas ranged from 20 to 64ft^2/acre. The size of ponderosa pines was comparable to that of trees in the sand dune area however, with diameters averaging about 19 inches. The exception was Unit K where the ponderosa pine component was slightly smaller. The juniper and pinyon were relatively large trees (11 to 22 inches).
The average ages of ponderosa pine throughout the survey area ranged from 62 to 180 years suggesting several periods of ponderosa pine establishment in different areas on Moquith Mountain (Table 7). The youngest ponderosa pines were present in Units K and M. Not surprisingly, ponderosa pines in these units also had the smallest average diameters. The oldest ponderosa pine occurred in Unit L. This unit also had the second highest total number of trees per acre, the second highest number of ponderosa pine per acre and the greatest number of both pinyon pines and junipers in the ponderosa pine type.

Tree regeneration in the ponderosa pine units was generally low (Table 8). No conifer regeneration was recorded in Units K and P, although about 300 Gambel oak suckers per acre were present in Unit K. All regeneration in Units L and N were pinyon pines and junipers totaling from 100-120 trees per acre, respectively. The highest amount of ponderosa pine regeneration occurred in the sand dune area with about 442 trees per acre. Unit M was the only other unit with ponderosa pine seedlings and saplings (43 trees per acre).

Table 7. Summary of tree data for surveyed areas in the ponderosa pine type.

Area	Age†	TPA (%)*				Mean BA (%)				drc	dbh	
		P	J	PP	Total	P	J	PP	Total	P	J	PP
K	64	0	3(14)	16(86)	19	0	7(33)	13(67)	20	0	22	13
L	180	9(9)	37(37)	56(54)	102	7(8)	30(38)	47(54)	26	15	14	18
M	62	6(17)	14(36)	18(47)	38	3(8)	14(38)	20(54)	37	9	16	16
N	113	0	26(80)	9(20)	35	0	12(50)	16(50)	28	0	11	21
P	130	0	23(37)	40(63)	63	0	17(26)	47(74)	64	0	12	19
SD	95	0	1(1)	119(99)	120	0	3(3)	113(97)	116	0	21	19
All	116	4(4)	19(20)	73(76)	96	3(3)	15(16)	74(81)	92	12	15	18

*TPA(%) = number of trees per acre and percentage of total; BA = basal area per acre and percentage of total; drc = diameter at root collar; dbh = diameter at breast height; P = pinyon pine; J = juniper; PP = ponderosa pine.
†Mean age of ponderosa pine only.

Table 8. Tree species regeneration per acre for surveyed areas in the ponderosa pine type.

Area	P*	J	PP	GO	Total
K	0	0	0	300	300
L	50	50	0	0	100
M	0	0	43	0	43
N	60	60	0	0	120
P	0	0	0	0	0
SD	0	0	442	0	442

*P = pinyon pine; J = juniper; PP = ponderosa pine; GO = Gambel oak.

Fuels Summary

An average of 52% of ground in the ponderosa pine type was bare (Table 9). The highest percentages of bare ground occurred in Units K and N (72% to 60%, respectively). Generally an average of 30% of living plants covered the ground surface throughout the area. The percentages dead plant material was highly variable in the different units ranging from 5 to 43%. Units K and N has the lowest percentages of ground covered by dead plant material. The highest percentage occurred in the sand dune area where most of the dead plant material was a relatively thick layer (up to ½ inch) of ponderosa pine needles that covered the ground surface.
Except in Units K and the sand dune area the percentages of canopy closure were fairly consistent throughout the ponderosa pine type averaging about 14%. The relatively open canopy conditions in Unit K (7% canopy closure) probably resulted from the sparse distribution of trees.

Table 9. Summary of fuels data in ponderosa pine surveyed areas.

	% Can. Clos.*	**% Bare**	**% Live Fuels**	**% Dead Fuels**	**Comments**
K	7	72	23	5	
L	11	50	36	14	
M	16	47	30	23	
N	12	60	31	9	
P	18	47	33	20	
SD	36	34	23	43	Litter

*Can. Clos. = canopy closure; Bare = bare ground.

More ponderosa pine in the Sand Dune area probably contributed to greater canopy closure (36% canopy closure).

Insect and Disease Summary

Juniper mistletoe was the only damaging agent of any real consequence in the ponderosa pine units surveyed (Table 10). On average, 60% of junipers were infected by light to moderate amounts of mistletoe. Juniper gall rust was only recorded in Unit M where about one half of the trees were infected. Low levels of other agents were detected in the ponderosa pine type.

Throughout the project area, bark beetles had recently attacked five ponderosa pines. All of these trees occurred outside of those plots inventoried. One older attacked (more than three years ago) ponderosa pine was recorded in Unit M. Although groups of ponderosa pine in all units contained large diameter trees, the susceptibility of these groups to bark beetle infestation was generally low. The exceptions were Units M and the Sand Dune area with moderate and high susceptibility ratings, respectively.

Table 10. Insects and diseases found in ponderosa pine areas surveyed and the number of trees affected per acre by species.

Area	**J***		**PP**			**Comments**
	GR	**M**	**DT**	**HR**	**BB (Haz)**	
K	0	3	0	0	0(L)	Mistletoe infections heavy
L	0	31	0	3	0(L)	
M	8	3	0	0	0(L)	Mistletoe infections light
N	0	14	0	0	0(L)	Mistletoe infections light

P	0	0	1	0	1(M)	Older dead bark beetle attack
SD	0	1	0	0	0(H)	
* J = juniper; PP = ponderosa pine; BB = bark beetles; GR = juniper gall rust; M = juniper mistletoe; DT = dead top; HR = heartrot; Haz = bark beetle hazard rating; L = low; M = moderate; H = high.						

Ponderosa Group Site

The Ponderosa Group Site has a unique character due the presence of large, stately ponderosa pines adjacent to picnic tables and campsites. With the exception of trees in central island area, ponderosa pine diameters averaged about 28 inches. The majority of these trees were located in sites 1, 2, 3, and 4 on the north side of the site. Most ponderosa pine regeneration was located near these sites as well. Junipers mixed with scattered pinyon pines primarily occurred on the southern side of the site. A mixture of small ponderosa pines, junipers, cottonwoods, and serviceberry grew within the central tree island.

All of the ponderosa pines in the site looked healthy with no visible evidence of damage or decline. A couple of pitch tubes resulting from fairly recent bark beetles attacks were observed on the boles of two trees. However, there was no indication that the attacks resulted in any adverse impacts. Several trees had lower branches removed some time in the past. The pruning scars appeared to be sealing properly.

As elsewhere on Moquith Mountain, juniper gall rust and mistletoe were the most significant damaging agents of junipers affecting 80% and 26% of the trees examined. The pinyon pitch mass borer had attacked a few (< 5 trees) small pinyon pines in the vicinity of Site 6. Sapsucker feeding on one cottonwood was the only damage detected.

Table 11. Summary of tree data for the Ponderosa Group Site.

Species	PP*			P			J			CW		
Site	#T	dbh	# R	#T	drc	# R	#T	dbh†	# R	#T	dbh	# R
1&2	6	23	33	0	0	4	6	-	1	0	0	0
3	1	35	0	1	13	0	10	-	0	0	0	0
4	7	27	3	0	0	0	7	-	3	0	0	0
5	0	0	0	1	11	0	14	-	0	0	0	0
6	0	0	0	0	0	10	16	-	0	0	0	0
7	4	7	0	2	15	14	26	-	6	0	0	0
8	0	0	0	0	0	2	12	-	4	0	0	0
Center	7	8	23	0	0	0	5	-	4	2	10	1
Total	25	23	59	4	13	30	96	-	18	2	10	1

*PP = ponderosa pine; P = pinyon pine; J = juniper; CW = cottonwood; #T = total number of trees; dbh = mean diameter at breast height; drc = mean diameter at root collar; #R = total number of regeneration.
†juniper diameters were not measured.

Sand Spring Dispersed Recreation Site

A total of 42 ponderosa pines were examined in the Sand Spring dispersed recreation site. These trees were generally large with diameters averaging 20 inches. Approximately 68 regenerating trees were tallied at Sand Spring. Ninety-nine percent of these were ponderosa pine. The remaining young trees were pinyon pines.

Insect and Disease Summary

All of the mature ponderosa pines examined at Sand Spring had no visible symptoms of decline (i.e. foliar discoloration, sparse foliage, pitch streaming, or basal resinosus). Some lateral roots of six individual ponderosa pines were damaged by motorized recreators traveling through the site. These trees have responded to this damage by hardening the exposed roots. There were no indications that decay causing organisms had infected the roots. The vigor of these trees suggests that other roots have compensated and are providing trees with sufficient amounts of water. There was also no evidence of root system failures.

Ten ponderosa pines (including the six aforementioned trees) had old fire scars. Large callous ridges had formed around the old wound margins indicating that the scars were sealing properly. Although there was no visible evidence of decay, decay fungi commonly infect fire damaged tree tissues. Evidence of wood boring beetles and carpenter ant activity was also minimal.

Other damage recorded at the Sand Spring site included minor amounts of limb rust and sapsucker feeding. Five young ponderosa pines in a seep area had peculiar browning foliage. Although the actual causal agent was not identified, the foliar discoloration may have resulted from stress caused by excessive water, or another abiotic agent including chemicals or vehicle exhaust.

Aspen Clone

Many of the mature aspen in the surveyed clone had signs and symptoms associated with aspen decline including dead branches, discolored foliage and bark, bole wounds, and scars. All the aspen sprouts had signs of severe browsing damage and none were protected from grazing by physical barriers. A number of insect and disease agents contributed to this damage, but the underlying cause appeared to be stress associated with grazing and lack of disturbance.

Discussion

Native insects and diseases naturally occur throughout pinyon-juniper woodlands, ponderosa pine, and other Intermountain forest 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).

The results of this survey indicate that the present level of insects and diseases and associated tree mortality on Moquith Mountain was generally low. Juniper gall rust and juniper mistletoe were the most widespread and damaging agents observed. However, the intensity of individual tree infections was mostly light to moderate (≤ ½ of the crown infected) resulting in minimal tree impacts. Few junipers heavily infected by these agents did experience some branch dieback.

Because impacts due to juniper gall rust and juniper mistletoe were generally inconsequential, they do not warrant immediate management consideration. The exception may be in high value recreation sites where the death of large limbs and the potential loss of high value trees could conflict with scenic and other recreation values. Branches with large, heavy mistletoe brooms over-hanging recreation sites could also pose potential hazards to people and structures.

The most serious agent affecting pinyon pines was the pinyon pitch mass borer. Pitch mass borers had infested trees in several localized pockets throughout the survey area. These pockets were usually small (< 3 trees) and infestation intensities were light with only one or two pitch masses found on attacked trees. Consequently, the attacks resulted in little tree damage.

Endemic populations of insects and diseases were present in the ponderosa pine type and resulted in only minor tree damage. Fire had damaged several ponderosa pines in the Sand Spring dispersed site. Trees in this site and other high use areas also had mechanical injuries. Such injuries may predispose trees to other damaging agents 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.

With no active populations of bark beetles detected in either the pinyon-juniper or ponderosa pine types, the risk of bark beetle outbreaks was low. However, conditions in several pinyon-juniper and ponderosa pine stands were conducive to the development and spread of bark beetle populations. Stands most susceptible to the pinyon engraver beetle were located in Units E, F, G, and H. Ponderosa pine in Unit M and the sand dune area had moderate and high susceptibility ratings, respectively. Outbreaks of bark beetles in these stands could result in extensive tree mortality and threaten many important resource values on Moquith Mountain.

Aspen is an important component of many Intermountain forest ecosystems providing vegetative diversity that benefits both wildlife and humans. The further loss of aspen on Moquith Mountain could result in adverse impacts to important resource values. Historically, lower elevation, drier stands 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 begin to 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). In severely decadent stands such as on Moquith Mountain, aspen may lose their ability to respond following treatment. This necessitates immediate development of management strategies and implementation of treatments to maintain and restore the aspen component.

Recommendations

Insect and disease treatment strategies include prevention, suppression and restoration activities. Prevention strategies often utilize silvicultural practices to modify stand conditions favorable to insect and disease agents and should occur before populations reach unmanageable levels. By enhancing stand diversity and resiliency, prevention strategies can help avoid unacceptable losses of valuable resources, maintain or enhance resource objectives, and maximize revenue in the long term. Suppression strategies are usually implemented with building insect populations. When implemented during the initial stages of an outbreak, suppression activities can reduce population levels and the rate of insect 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. Restoration activities attempt to reestablish vegetation and promote the long-term resiliency of forests to insects and diseases.

I recommend the development of a vegetation management plan incorporating both long and short-term insect and disease treatment strategies to provide guidance for minimizing adverse impacts and meeting resource objectives within the Moquith Mountain project area. 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. The plan should also address hazard tree removal and regular hazard tree inspections in developed and dispersed recreation sites. Insuring tree health is best accomplished by maintaining vigor. Measures should be taken to minimize tree injury from insects, wind, fungi, animals, and humans. Cultural practices including removing infested, dead or severely damaged portions of trees can reduce insect populations and potential hazards. Planting a mixture of non-host tree species will create an environment that supports diversity to reduce insect and disease impacts.

The following section provides specific management recommendations and guidelines for the most damaging insect and disease agents identified in the Moquith Mountain project area.

Juniper Gall Rust

Like other *Gymnosporangium* rusts, juniper gall rust alternates between a broadleaf host plant and juniper to complete its life cycle. Principle broadleaf hosts are in the Rosaceae family and members of the apple genera including *Malus*, *Pyrus*, *Amelanchier*, *Sorbus*, and *Crataegus*. On Moquith Mountain, serviceberry (*Amelanchier alnifolia*) is the broadleaf host.

Juniper gall rust typically forms hard spherical-shaped galls on infected leaves and branches. During rainy periods in early spring (April-May), the galls produce spores in red, orange, to yellow colored gelatinous structures. Spores blown from these structures land on the serviceberry plants. Successful infection of serviceberry plant tissues usually requires cool, wet weather conditions.

Infected serviceberry plants may have discolored and distorted foliage and fruit. Spores are produced in fruiting structures that resemble yellow-orange spots on the undersides of leaves or swollen lesions on twigs and fruits. In mid to late summer these spores are released and blown to the leaves and green shoots of junipers. Galls first appear on infected junipers in about one year with spores produced in the following year.

Juniper gall rust seldom causes serious damage to infected plants and generally does not warrant management action. In the Ponderosa Grove Group Site and other recreation sites, several management options may be used to minimize any adverse impacts associated with this disease. In areas with few, lightly infected junipers, pruning out galls while the fungus is dormant (fall) can improve tree vigor and may decrease the incidence of the disease. Removing all serviceberry within ¼ mile of the site may decrease rates of juniper infection. Planting more resistant junipers or non-host plants can also mitigate disease impacts. Although available, the use of fungicides is typically not economical or environmentally feasible except for treating very high value trees.

Juniper Mistletoe

Juniper mistletoe is a flowering, parasitic plant that only survives on living hosts. Mistletoe plants grow from infected branches and form characteristic bunches of olive-green shoots that can be seen throughout the tree crown (Fig. 1). Mistletoes have both male and female flowers that are produced on separate plants. Small pinkish berries develop on the female plants that contain seeds. Birds spread mistletoe seeds after feeding on the berries.

Once adhered to juniper stems and branches, the seeds take root and send sinkers down into the host plant tissues to absorb water and nutrients. Heavy infections of juniper mistletoe can increase host-plant water stress, reduce host vigor, cause branch dieback, and result in host tree mortality. Mistletoe damage however is generally of little consequence in juniper stands. Mistletoes plants have high nutritional value as animal forage and birds often consume the berries.

Mistletoe infections seldom cause sufficient damage to warrant management action. High levels of individual tree damage can pose serious concerns in some recreation and high-value sites. Thinning stands in these locations can improve tree vigor and tolerance to mistletoe infection. Pruning infected branches can increase individual tree vigor and reduce incidence of the mistletoe. The removal of aerial mistletoe shoots does not eliminate the disease, but does decrease reproductive capacity of the plant and the potential for seed dispersal by birds.

Pitch Mass Borer

Dioryctria species are found throughout most woodlands where pinyon occurs. In the larval stage, pitch mass borers bore into the cambium of the trunk and branches to feed causing wounds (Fig. 2). The tree produces large masses of pitch in response to the feeding. The boring injury can weaken the tree and kill branches. In recent years, this injury coupled with prolonged drought, weakened pinyon trees in many intermountain woodlands predisposing them to attack by pinyon engraver beetles. Pitch mass borers may also attack ponderosa pine.

Pitch mass borer and tip moth populations currently remain at endemic levels on Moquith Mountain. Because these insects tend to attack stressed and wounded trees, measures should be taken to minimize tree damage in the campground. Monitor the campground annually for new attacks. Where new attacks are noted, remove pitch and try killing the larvae with a sharp probe. If high-value trees become infested with pitch mass borers you should remove the heavily infested branches. There is no registered chemical control for the pitch mass borers, although chemical trials have been somewhat effective in controlling related insects. The insects may be attracted to fresh wounds on the trees. Therefore, any pruning work in the campground should be done in the late summer/early fall to avoid the insect's active period.

Figure 1. Juniper mistletoe.

Figure 2. Pinyon pitch mass borer.

Limb Rust

Limb rust occurs throughout the ponderosa pine type in southern Utah affecting all age classes of trees. This fungus infects trees through needle-bearing branches and spreads through the sapwood to other branches (Fig. 3). The disease often results in the death of branches associated with infected sapwood leaving large gaps in the crown. Infected trees may also experience top kill. Extensive branch dieback can result in growth loss and even tree mortality. Stem cankers may form on sapling stems, but are rarely observed on mature trees.

In the Intermountain region, limb rust infections range from light to locally severe in some locations. The incidence of this disease in the Moquith Mountain project area is presently low. A limited number of treatment options exist for limb rust. The removal of infected trees during stand management activities can decrease the incidence of the disease.

Figure 3. Branch infected with limb rust.

Damaging Agents of Aspen

The most serious insect affecting aspen is the aspen borer (*Saperda calcarata* Say, Coleoptera: Cerambycidae) a roundheaded, longhorn beetle (Fig. 4). This beetle typically attacks trees stressed by disease, drought and other damaging agents. Females lay eggs in bark crevices during the early summer. Once the eggs hatch, developing larvae feed first in the inner bark then move into the sapwood. Numerous larval tunnels can weaken tree trunks making them susceptible to snow and wind breakage. Woodpecker excavations and decay fungi further weaken trees (Solomon 1995, Karen 1986).

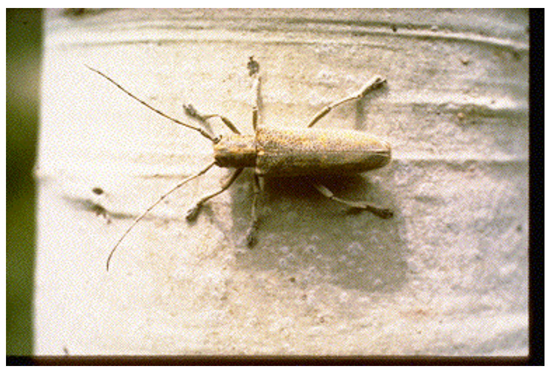

Figure 4. Adult poplar borer.

The bronze poplar borer (*Agrilus granulatus liragus* Barter and Brown, Coleoptera: Buprestidae), a flatheaded, metallic beetle can also infest aspen. Damaged trees, and those attacked by aspen borers are most susceptible to attack. The larvae of this beetle initially feed in the cambium creating shallow, long-winding tunnels that can girdle the branches and trunks of infested trees. Up to 75% of aspen with only a few attacks can experience mortality as a result of this larval feeding. The larvae then bore into the sapwood and heartwood to complete their development. This activity weakens the tree structurally and allows for the introduction of decay fungi. In recreation sites, affected trees can present a hazard (Solomon 1995, Karen 1986).

Several important diseases commonly infect aspen in the Intermountion region. Aspen leaf spot (*Marssonina populi*) is the most common foliar disease infecting aspen (Baker et al. ND) (Fig. 5). This disease causes dry, brownish lesions with yellowish borders. The most serious infections generally occur during exceptionally wet springs and result in extensive defoliation (French 1991). Wood boring insects and wounding often predispose trees to a number of serious canker diseases. Sooty-bark canker (*Encoelia pruinosa*) (Fig. 6), Cryptosphaeria canker (*Cryptosphaeria populina*), black canker (*Ceratocystis fimbriata*). and Cytospora canker

(*Cytospora chrysosperma*) commonly infect aspen in Intermountain forests. Some canker diseases are lethal to healthy trees, while others kill stressed trees. Cankers can also create infection sites for decay fungi (Johnson et al. 1995, French 1991, Baker et al. ND).

Figure 5. Aspen leaf spot.

Figure 6. Sooty bark canker on aspen.

The fruiting bodies on the boles of trees are indicative of infection by aspen trunk rot (*Phellinus tremulae*) (Fig. 7). This fungus infects trees through branch scars and wounds and decays the heartwood. In advanced stages, the central decay column is characterized by soft, yellow-white wood ringed by black zone lines. The fruiting bodies are perennial, woody, hoof-shaped conks often associated with old branch scars. The presence of a single conk usually indicates considerable decay, and aspen with up to two conks have the potential for stem breakage (Ostry and Walters 1983).

Armillaria (*Armillaria* spp.) and Ganoderma (*Ganoderma applanatum*) root diseases also infect aspen, particularly in more mesic sites. Windthrow often occurs with extensive root decay. The root wads of windthrown trees often exhibit a "ball and socket" appearance. Wood tissue at the root collar appears yellowish and stringy, and in some cases, pocketed. Fruiting bodies may occur at the base of diseased trees. Insects also usually attack infected trees.

Figure 7. Fruiting body (conk) of aspen trunk rot.

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. Insufficient regeneration in conjunction with insect and disease mortality, particularly in stands impacted by grazing, will result in the loss of aspen.

The aspen component on Moquith Mountain 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 the clone. 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.

Other Damaging Agents

The trees in recreation sites have injuries typical of those caused by human activity (e.g. ax and vehicle damage). Trees also suffer physical injuries due to animal feeding, chewing, and rubbing. Physical injuries are often associated with heavy resin flow, particularly if trees are wounded in the spring (Hagle et al 2004). A ridge of callus tissue typically develops around wound margins to seal off the injury. Fire-damaged trees have elliptical scars extending upward from the base of trees. Fires scars are often associated with bole char. Frost cracks and lightning cause long, narrow scars that run either vertically, or spiral up tree boles.

Depending on their severity, wounds can seriously stress trees predisposing them to attack by insects and decay fungi. The activity of these agents also structurally weakens wood tissues increasing the likelihood of wind damage. Extensive colonization by wood boring insects can ultimately result in tree mortality (Solomon 1995). Structurally weakened, declining and dead trees also create hazards that pose a threat to recreators.

During a site visit in 2000, FHP staff observed that there were several ponderosa pines in the Ponderosa Group Site with dead branches, evidence of decay, and symptoms of tree decline (Munson 2000). Based on FHP recommendations, trees and branches posing hazards to people and structures were removed. Since that time the remaining trees in the site have incurred little damage.

Because trees in recreation sites are subject to damage and soil compaction from campground users, all trees should be evaluated annually to minimize hazards.

Removing some junipers may increase the vigor of ponderosa pines. In open or partially shaded areas, planting additional ponderosa pine or pinyon pine will encourage both structural and species diversity within the campground. This added diversity will decrease forest insect and disease susceptibility and associated large-scale changes in vegetation caused by a single agent.

As opposed to developed facilities that invite the public in for camping, the user selects dispersed recreation sites. There are a few heavily used dispersed sites under a ponderosa pine canopy where it may be possible to reduce tree hazard following the removal of a few larger dead branches (Munson 2000).

Resting some of these dispersed areas will increase the success of ponderosa pine regeneration similar to that observed on dispersed sites already closed to camping. Some development in these dispersed camping areas will also reduce the likelihood of new or further tree damage in these sites (Munson 2000).

Bark Beetles

Dendroctonus Beetles

In ponderosa pine forests of southern Utah, a complex of *Dendroctonus* bark beetles (Coleopetera: Curculionidae, Scolytinae) including the mountain pine beetle (*D. ponderosae*) (Fig. 8), the roundheaded pine beetle (*D. adjunctus*), and the western pine beetle (*D. brevicomis*) 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 (Negrón et al. 2000).

When bark 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.
The adults of these bark beetle species disperse (fly) generally in July-August. As with other *Dendroctonus* species, 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. 9). Mountain pine beetles and roundheaded bark beetles construct characteristic "J-shaped" egg galleries within the phloem (inner bark tissue) of the host tree (Fig. 10). The egg galleries of western pine beetles are typically more serpentine (Fig. 11). 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 8. An adult mountain pine beetle.

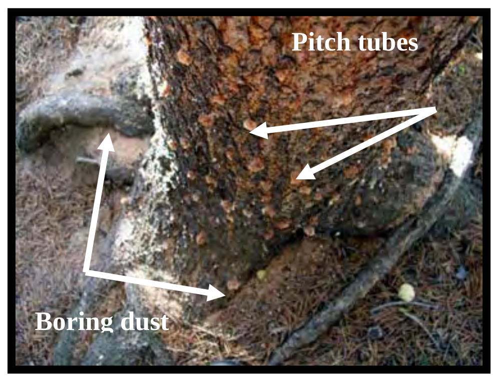

Figure 9. Symptoms of an attacked tree.

Figure 10. Mountain pine beetle galleries.

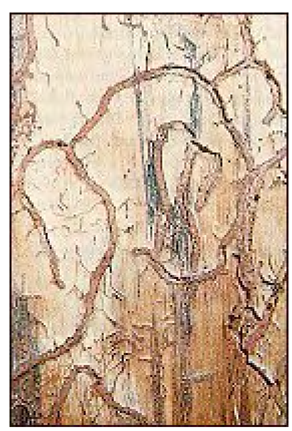

Figure 11. Western pine beetle galleries.

Ips Bark Beetles - Pinyon Engraver[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.

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 emiting a pheromone that attract females and other males. The male and female mate in the nuptial chanber 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 layed 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.

[1] Source Keyes and Hebertson, 2003.

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 or 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 (2 inches drc).

Bark Beetle Management

<u>Prevention</u>

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).

In the Moquith Mountain project area, only ponderosa pine stands in the sand dune area were susceptible to bark beetle infestation. To reduce the susceptibility of these stands, thin to maintain inter-tree spacing and reduce stand densities to less than 80ft^2/acre. As density increases above 100ft^2/acre, bark beetle susceptibility generally increases. Sites in excess of 120ft^2/acre with an average tree diameter of eight inches or larger are susceptible to bark beetle population increases.

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. For mixed conifer stands, if 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).

Thinning offers the best long-term management strategy for the pinyon engraver beetle. To maximize effectiveness, thin the pinyon component to reduce the potential for engraver beetle attack to an SDI of 20 or less (or 5.6% of maximum SDI, 360 for pure stands (pinyon or juniper) and 415 for mixed stands) (Page 2005). Page (2005) recommends that 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 12. TPA, BA, and Spacing Between Trees based on SDI and Diameter (Stand SDI = 24 or 5.6% of maximum SDI)

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

Table 13. Target After-Treatment Stand (at 5.6% of max SDI)

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***	--

Table 12 shows traditional measures of stand density for an SDI of 24 in any one size class. Multi-aged/sized stands should have the total SDI apportioned among size classes (Table 13).

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. *Ips* beetles prefer trees with somewhat reduced crown ratios. Pinyon leave trees should be those with the higher percentage of crown-to-height ratio. *Ips* beetles 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 *Ips* is also influenced by stand composition, and those stands with a higher percentage of pinyon-to-juniper tend to be more susceptible to *Ips*-caused mortality. Thus it is desirable to maintain a good mix of species. If research plots are established, it may be desirable to vary the treatments between the densities in the two tables above. Additionally, treatments may vary by size of pinyon leave trees and percentage of pinyon-to-juniper leave trees (Page 2005).

Timing of implementation and treatment of pinyon slash can be critical factors when *Ips* beetles are present in the general area. Green pinyon slash can serve as an attractant to beetles. Beetles can colonize slash during the spring and summer months and maturing beetles can emerge from this slash seeking new hosts, which will tend to be the nearest available suitable pinyon trees. Even chipped pinyon debris can attract beetles during the beetles' flight periods. *Ips* cannot colonize chips but may attack nearby pinyon trees. If chips or slash are to be left on the site, then treatment is best done in late fall, allowing the winter months for material to dry and become less attractive to beetles. Larger green pinyon material that is not chipped should be removed or disposed of before the next beetle flight (March). If green pinyon material greater than 3" in diameter can be removed from the site within four to six weeks of cutting, then operations may be done at any time without risking increasing the incidence of *Ips* beetles. If neither can be practically accomplished, then mitigation for increased beetle activity may be either to leave more juniper and fewer pinyon or to leave more pinyon, realizing that many of these trees may be subsequently killed by *Ips* beetle attack. If retention of pinyon trees on the site is of prime concern, it may be best to delay thinning pinyon stands when *Ips* populations are high in the drainage where the treatment is to take place (Page 2005).

Other species of engraver beetles (*Ips spp*.) also cause significant ponderosa pine mortality (Steed 2005). Trees in thinned, vigorous stands are infrequently colonized by engraver beetles. During drought years, maintaining stand vigor is even more important. 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 sufficiently 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).

<u>Suppression</u>

Several silvicultural treatments can be implemented to suppress bark beetle populations in the event of an outbreak.

SANITATION. 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 either uninfested or infested stands where the stand still has a susceptible host component that is at risk to bark beetle attacks.

SALVAGE. Salvage treatments involve the removal of currently infested and dead trees from the stand. The objectives of this treatment are to suppress local bark beetle populations. Salvage treatments are most effective in stands where infestations remain small and the treatment will remove most, if not all, of the infested trees within the affected landscape. 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.

SANITATION/SALVAGE. A combination of sanitation and salvage treatments is often used to remove currently infested, dead, and susceptible trees. These treatments are designed to reduce bark beetle populations in stands with low, but building populations and decrease stand susceptibility. One strategy for stands where bark beetles pose a threat and susceptible trees comprise less than the desired percentage of species or basal area is the removal of all infested trees. In some stands, host trees may occur in dense patches (densities exceeding 100ft^2). In addition to removing infested trees, selectively cutting susceptible trees to reduce average diameters mean basal areas to desired levels will reduce the susceptibility of patches. Tree selection in patches could also favor non-host species. 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.

Short-Term Bark Beetle Protection Strategies

Should bark beetles begin to initiate tree mortality on Moquith Mountain, Forest Health Protection can help devise short-term suppression strategies to protect high-value trees in high-value sites.

CHEMICALS. Chemical insecticides sprayed on the boles of susceptible trees prior to bark beetle flight can provide effective short-term protection from attack. Any flowable formulation of Carbaryl such as Sevin XLR, or Carbaryl 4L is effective. The insecticide is typically applied to drip up to a bole height of 40-50 feet to maximize its effectiveness. All bole surfaces and the root collar **must** be sprayed completely to ensure thorough coverage of all bark crevices. Chemical treatments are difficult and expensive over large areas and not a recommended strategy for general use. Applications of a chemical insecticide would provide the best protection of high value trees. Re-application would be necessary every two years until bark beetle populations collapse. Better access to trees selected for treatment might require the removal of obstructing vegetation. Pruning the lower branches on larger tree would improve the coverage of spray applications. Restricted access, limitations inherent to treating large trees, and application error may result in some bark beetle attacks and tree mortality. To minimize exposure of chemical residues, 10 mil plastic can be use to cover picnic tables, fire pit grates, and any other nearby facilities before spraying. Washing treated surfaces with a detergent solution will also mitigate chemical exposure to recreation site users. Spray applications should occur during campground closures, and between adult beetle flight.

SEMIOCHEMICALS. Behavior modifying chemicals called semiochemicals have been used to reduce losses to bark beetles. These are combinations of pheromones produced by the beetle and terpenes of the host tree. Pheromones are chemical messengers used by insects for communication. Behavioral responses to semiochemicals include aggregation and anti-aggregation. The anti-aggregation pheromone for mountain pine beetle and western pine beetle (verbenone) may provide another alternative for protecting high value trees, but further research is required to test it's efficacy. Aggregation pheromones have been used effectively to contain small infestations, using baits and traps to stem small developing outbreaks and to manipulate or trap small populations after logging. The aggregation pheromone for *Ips pini* has been identified. Although anti-aggregation compounds have been identified for *Ips pini*, these compounds are still being investigated and are not available for operational use.

Fuels Data

Providing a comprehensive analysis of fuels complexes and potential fire behavior on Moquith Mountain was beyond the scope of this survey. Information on the composition of plant communities, fuels composition, and fuels continuity however may augment existing fuels, climate, and topographic data used to help characterize fire regimes.

Generally less potential for surface fires exist in areas where undergrowth is sparse as a result of high tree densities and/or shallow and rocky soil conditions (Miller and Tausch 2001). Relatively discontinuous surface fuels characterized most areas surveyed on Moquith Mountain. On average, 42% and 52% of ground surface area in the pinyon-juniper and ponderosa pine types, respectively, lacked undercover vegetation. Living plants covered approximately 30% of the ground surface area with the highest percentage of undergrowth occurring in Unit D (50%). The percentages of dead fuel cover were variable (5-60%). The highest percentages occurred in stands of ponderosa pine where needle litter accounted for the majority of dead fuels.

The sparse nature of surface fuels and generally open canopy conditions (on average 20% canopy closure) may suggest that under normal fire weather conditions the susceptibility of the area to fire is low. Valid determination of fire susceptibility however would require more reliable measurements of available fuels. The potential for high intensity crown fires exists irrespective of fuels with extreme fire weather conditions (i.e., hot, dry weather conditions and strong winds) (Miller and Tausch 2001).

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APPENDICES

Appendix 2. 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 3. 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. Ex. 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.