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Insects and Fungi Found in Fire-Killed Ponderosa Pines and Douglas-firs Within the First Year of Tree Death

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Introduction

Deterioration of fire-killed trees is well documented in the literature (Lowell, et. al. 1992). Insects, fungi, and weather are largely responsible for altering the wood of fire-killed trees (Hadfield and Magelssen 2006). Given sufficient time fire-killed trees will ultimately be completely decomposed and recycled. Almost all published fire deterioration studies began at least one year after the trees were killed. There is ample anecdotal evidence and widespread understanding by foresters, loggers, and sawmill workers who work with fire-killed trees that several changes occur quickly in wood of trees killed by fires. Pines, especially, are known to become bluestained within months of being killed. Insects, especially wood borers and some bark beetles, rapidly infest fire-killed trees. No studies have been made of potential changes that may take place within the first year of trees being killed by wildfires in eastern Washington. The purpose of the study reported here was to document wood changes brought about by insects, fungi, animals, and weather acting on trees killed by a wildfire within the first year of their death.

Study Area

The study was done on the Colville Indian Reservation in eastern Washington. The Manila Creek Fire started on September 10, 2007 and was declared contained on September 24, 2007. The fire covered 26,805 acres. The forest area burned is dominated by ponderosa pine and Douglas-fir forests. Study trees were located in three separate but close locations within the fire. The majority of trees were killed by the fire at each location. All study trees were in areas that had contour falling of snags and staking of logs performed to reduce the potential of erosion and flooding. Salvage logging of fire killed trees began soon after the fire was contained and was completed by the end of April 2008.

Procedures October 4, 2007, about three weeks after the fire was contained, 50 Douglas-fir trees and 50 ponderosa pine trees killed by the Manila Creek fire were selected for study. Study trees were located in contour falling areas to reduce the potential of them being removed by salvage logging. Trees were numbered from 1 to 50 for each species. The selected trees were tagged for subsequent examinations and destructive sampling.

Each of the 100 selected trees was given an initial evaluation at the time of selection that included post-fire observations on bark tightness, insect activity, woodpecker feeding, seepage of resin, burn severity, and cracks. Trees were assigned to three burn severity classes. Light burn severity was defined as having foliage that was scorched but all still remained on the tree. Moderate severity burning was 25% foliage to 90% of foliage

consumed. The high burn severity class trees had at least 90% of the foliage completely consumed.

Study trees were examined on three subsequent dates, April 2008, June 2008, and October 2008.

Standing study trees were examined at each sampling period for insect activity, woodpecker feeding, checking, and bark retention.

Ten study trees of both species were destructively sampled 6 months (April), 9 months (June), and 1 year (October) after being killed by the fire. Sample trees were felled and cut into 16-foot logs to a 4 inch top. Total tree height, height to a 4" top, and bark scorch height were measured. Each 16-foot log was observed for bark scorch, bark tightness, insect activity, woodpecker foraging, cracks, holes in the bark, holes in the wood, wood stain, and wood decay. A one square foot area of bark was removed from the middle of each log to check the underlying wood for insects and insect galleries, cracks, wood stain, and decay (Figure 1). Insects and insect galleries were identified to species or genera when possible.

Figure 1: Peeling the bark to expose beetle, borer and stain activity.

Two inch thick cross-sectional disks were cut and collected for examination at 16 foot intervals. They were cut from the log ends. Disks were examined for bark scorch, bark tightness, and woodpecker feeding. Bark was removed and disks were checked for wood

char, cracks, insect activity, borer holes (including ambrosia beetles), wood stain, and decay. Depth of borer holes into the sapwood was measured. Maximum depth of wood stain was measured on the cross-sectional surface. An attempt was made to identify all insect larvae and adults infesting each of the trees.

Data from the standing tree, log, and disk examinations were used to determine when changes appeared within the first year of death by wildfire. Pictures were taken of the changes observed during the study.

Results

Ponderosa pines

October 4, 2007 (Three weeks after the fire)

Fifty standing fire-killed ponderosa pines were selected on October 4, 2007. Diameters of the study trees ranged from 15 inches to 33 inches. Twenty seven trees were classed as light burn severity, 16 moderate severity, and 7 severe.

Four trees had already been infested by red turpentine beetles, *Dendroctonus valens*, when the trees were examined 3 weeks after they had been killed. The bark was tight on all 50 trees. None of the trees had visible cracks. None of the trees had been foraged on by woodpeckers.

April 2008 (Six months after the fire)

The standing pines were examined again on April 9, 2008. Ten study trees had been removed by salvage logging. Observations were made on the remaining 40 pines. Six trees were found to still be alive. These six trees were examined but they were excluded from being cut and sectioned because they were alive. No pines had been infested by red turpentine beetles between the October 4, 2007 and April 9, 2008 observations. The bark was tight on all trees. No trees had visible cracks. Two trees had been foraged on by woodpeckers. The two trees foraged by woodpeckers were considered to be infested by wood borers.

On April 15 and 16 ten fire-killed pines were cut into 16-foot long logs. Forty four logs were produced and examined. The bark was tight on all logs. No logs had visible cracks. One log had woodpecker feeding. Wood stain and decay were not observed on any logs. One log had red turpentine beetle larvae. No other insect activity was seen in the other 43 logs.

Fifty two disks taken from the ten cut pines were examined. Bark was tight on all disks. No disks had visible cracks. Wood stain was seen on just one disk. No decay was seen in any disks. Two of the 52 disks had bark beetle activity.

June 2008 (Nine months after the fire)

On June 24 and 25 29 standing dead pines were examined for the third time. Red turpentine beetles had infested 16 pines that previously had not been infested. No trees had visible wood cracks. Four trees had been foraged on by woodpeckers between April and June. One dead pine had been infested by ambrosia beetles.

Ten fire-killed pines were cut into 38 logs and examined. The bark was tight on all logs. No logs had visible cracks. No woodpecker feeding was found on the logs. No wood stain or decay was seen. An old sequoia pitch moth attack was seen on one log. Examination of the logs by removing one square foot patches of bark did not reveal the presence of any wood borers. However, wood borer larvae were found on one cross-sectional disk, so one pine was found to be infested by wood borers during the June examination.

Forty eight disks taken from the 10 cut trees were examined in June. Bark was tight on all disks and none of them had visible cracks. Three disks from two trees had wood stain that was determined to be associated with pre-fire injuries. None of the disks had stain that could be attributed to post-fire activity. No wood decay was present in any disk. Only 3 disks had insect activity. Two disks had red turpentine beetle larvae and/or galleries and 1 disk had wood borers. Forty five disks had no insect activity. There were no holes in the wood made by borers.

Figure 2: *Cryptoporus volvatus* (pouch fungus) under pine bark, radiating from a beetle gallery.

October 2008 (12 months after the fire)

The fourth and final observation of 18 standing pines was on October 6, 2008. Red turpentine beetles had infested one tree between June and October. The bark was apparently tight on all trees. No trees had visible cracks. Woodpecker feeding was seen

on four trees previously devoid of woodpecker activity. Conks of *Cryptoporus volvatus*, the pouch fungus, were found on three standing pines in the October 2008 examination (Figure 2).

On October 7 and 8, ten standing pines were cut into logs. Thirty nine logs were generated. Bark was tight on 20 logs and loose on 19 logs. Bark was tight on 4 trees and loose on 6 trees. No cracks were visible on any logs. Woodpecker feeding was found on logs from 7 of the 10 cut trees. Ten logs had woodpecker feeding and 29 did not. All cut trees had wood borer and/or bark beetle activity. Wood borer larvae and/or galleries were found in all cut trees and in 24 of the 39 logs. Fifteen logs had holes in the wood made by wood borers. Both *Buprestidae* (flatheaded borers) and *Cerambycidae* (roundheaded borers) were found. Neither of these two families of wood borers seemed to have obvious burn severity or tree position preferences. Ips bark beetle activity was seen in 8 logs and western pine beetle galleries were seen in 6 logs. Nine of the 10 cut trees had logs with wood stain. Twenty nine logs had sapwood stain, 10 logs did not have stain. No wood decay was seen in any logs. Pouch fungus conks were seen on three cut trees, but there was no obvious sapwood decay associated with the conks.

Figure 3: *Ips emarginatus* adult collected from fire-killed ponderosa pine.

Forty nine disks were collected and examined from 10 trees cut in October 2008. Bark was loose on 29 disks but tight on 20 of them. No disks had visible wood cracks. Thirty two disks from 8 trees had stained wood. Seventeen disks had no stain. One tree was

found to have sapwood stain when the bark square was removed from the logs and the underlying wood was examined even though all the disks from that tree did not have stain. The depth of stain penetration on disks with stain ranged from 0.5 inches to 4.0 inches into the sapwood. No disks had sapwood decay. Insect activity was seen on 40 of the 49 pine disks. Wood borer activity was observed in 34 disks. Wood borer activity was seen in disks collected from all heights. Holes made by wood borers ranged from 0.3 inches to 6 inches into the sapwood. Depth of wood borer holes was greater in disks taken from higher tree positions than from lower positions. Wood borers seemed to have a slight preference for moderate and severely burned trees over those lightly burned. Ips beetle larvae and/or galleries were seen on 15 disks. Ips activity was seen on the upper logs, it was never seen in the lowest 16-foot log in any infested tree (Figure 3). Red turpentine beetles were seen in 4 disks. Eighteen disks had holes in the wood made by wood borers.

All ten dead pines cut in October 2008 one year after being killed by fire were infested by multiple species of insects. Wood borers and bark beetles were found in all the trees.

Douglas-firs

October 4, 2007 (Three weeks after the fire)

Fifty standing fire-killed Douglas-firs were selected for study on October 4, 2007. Diameters of the study trees ranged from 13 inches to 37 inches. Thirteen trees were classed as light burn severity, 17 moderate severity, and 20 were severe.

The bark was tight on all trees in October 2007. None of the trees had visible cracks attributable to the fire. One tree had cracks associated with a pre-fire injury. No insect infestations were seen on the trees. There was no woodpecker foraging.

April 2008 (Six months after the fire)

The standing fire-killed firs were examined again on April 9, 2008. Thirteen firs had been removed by salvage logging. Observations were made on 37 firs. Five firs were found to still be alive. They were examined but excluded from being cut because they were alive. The bark was tight on all trees. One tree had visible wood cracks, but they were deemed to be associated with a pre-fire bole injury, 36 trees had no cracks. No insect activity was seen on the standing firs. No woodpecker foraging was detected.

On April 15 and 16, ten fire-killed firs were cut into 44 logs. The bark was tight on all logs. No logs had visible cracks. No logs had woodpecker feeding. Wood stain and decay were not observed on any logs. Wood borers were observed on 3 of the 44 logs. Two wood borer infested logs were from the same tree. The wood borer infestations in the logs had not been detected when the same trees received the standing tree examinations.

Fifty three disks removed from the ten cut firs were collected and examined in April. Bark was tight on all disks. No disks had visible cracks. No stain was seen on any disks. No decay was seen in any of the disks. None of the 53 disks had insect activity.

June 2008 (Nine months after the fire)
The third observation of standing Douglas-firs was on June 24 and 25, 2008. Twenty six trees were examined. Bark was tight on all trees. No trees had visible cracks. None of the trees had woodpecker foraging. Douglas-fir beetle frass was observed on four trees. Ambrosia beetle frass was seen on one standing fir.

Ten fire-killed firs were cut into 47 logs on June 24 and 25. The bark was tight on all logs. No logs had visible cracks. Woodpecker feeding was found on six logs in three cut trees; two logs per tree. Insect activity was seen in logs and disks from 8 trees. Douglas-fir beetle larvae and galleries were seen on logs from 5 cut trees. Eight logs had Douglas-fir beetle infestations. Douglas-fir beetle activity was most frequently seen in the lower log positions, it was not observed in the uppermost logs. Wood borer larvae and galleries were present in four cut trees; two logs for three infested trees and one log from one tree. No holes made by wood borers were seen in any infested logs. Burn severity did not appear to influence insect infestation. One tree had wood stain associated with insect infestation. Two logs in the tree had wood stain. No logs had decay. One log had small holes made by ambrosia beetles.

Fifty six disks from the ten cut trees were collected and examined. Bark was tight on all disks and none of them had visible cracks. No wood stain or wood decay was present in any disk. Eleven disks had insect activity. Seven disks had Douglas-fir beetle larvae and/or galleries, 3 disks had wood borers, and 1 disk had ambrosia beetle galleries (Figure 4). Forty five disks had no insect activity.

Two firs cut and sampled in June had been infested by bark beetles and wood borers.

Figure 4: Douglas-fir beetle frass and gallery on a disk cut in June, 2008.

October 2008 (12 months after the fire)
The fourth and final observation of standing firs was on October 6, 2008. Sixteen trees were examined. Bark was apparently tight on all trees. No trees had visible cracks. None of the trees appeared to have woodpecker foraging. Seven trees had Douglas-fir beetle frass on the bark and two trees had exit holes made by wood borers. Pouch fungus conks were seen on just one tree.


Figure 5: Round-headed wood borer showing its wood carving mandibles.

On October 7 and 8, 2008 ten firs were cut into logs. Forty one logs were generated and examined. Bark was tight on 35 logs and loose on 6 logs. Bark was tight on 7 trees and loose on 3 trees. No cracks were visible on any logs. Woodpecker feeding was found on 7 of the 10 cut trees. Seventeen logs had woodpecker feeding and 24 did not. Fourteen of the logs with woodpecker feeding had wood borer infestations. All cut trees had wood borer and/or bark beetle activity. Wood borer larvae and/or galleries were found in all cut trees and in 33 of the 41 logs (Figure 5). Twelve logs had holes in the wood made by wood borers. Wood borer activity was observed in all log positions. Both flatheaded and roundheaded wood borers were found in the infested logs. Douglas-fir beetle activity was seen in one log each in four cut trees. Burn severity of the trees did not appear to have an effect on insect activity. All 10 cut trees had logs with wood stain. Twenty two logs had stain, 19 did not have stain. No wood decay was seen in any logs. Pouch

fungus conks were seen on one cut tree, but there was no sapwood decay associated with it.

Fifty one cross-sectional disks were collected from the 10 trees cut in October 2008. Bark was loose on 6 disks but tight on 45 of them. No disks had visible wood cracks. Nine disks from 4 trees had stained wood. Forty two disks had no stain. Stain penetrated a maximum of 1.5 inches into the sapwood. Most stain in the fir disks penetrated only 0.5 inches into the sapwood. One of 53 disks had sapwood decay. Insect activity was seen on 46 of the 51 fir disks. Wood borer activity was observed in 45 disks. All ten trees had at least one disk with wood borer activity. Twenty six disks had holes in the wood made by wood borers. Depth of holes made by wood borers ranged from 0.1 inches to 3.6 inches into the sapwood. Wood borers appeared to penetrate deeper into the wood at mid-bole disk positions than other disk positions. Douglas-fir beetle larvae and/or galleries were seen on 3 disks, 2 of which also had wood borer activity.

Four of the ten Douglas-firs cut and sampled in October were infested by both wood borers and Douglas-fir beetles (Figure 6).

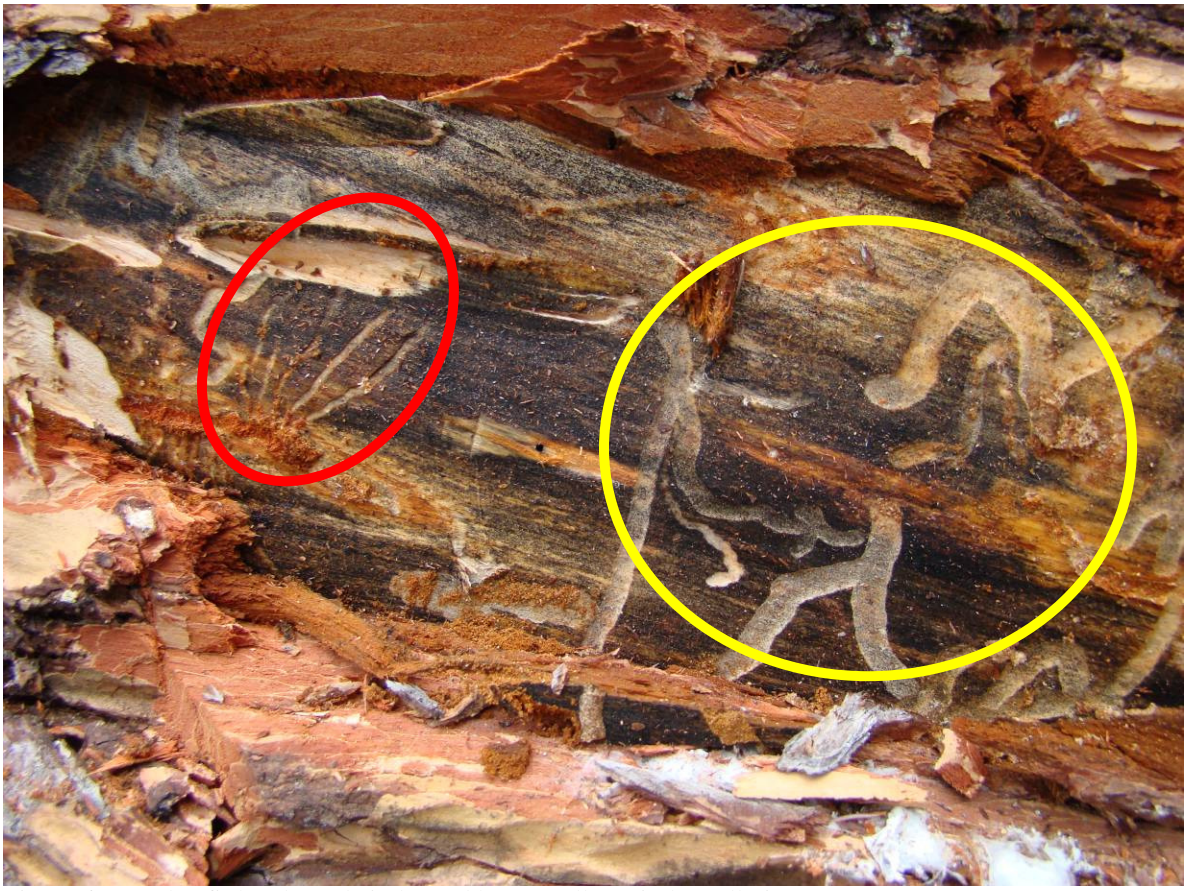

Figure 6: Douglas-fir beetle (red circle) and borer (yellow circle) galleries

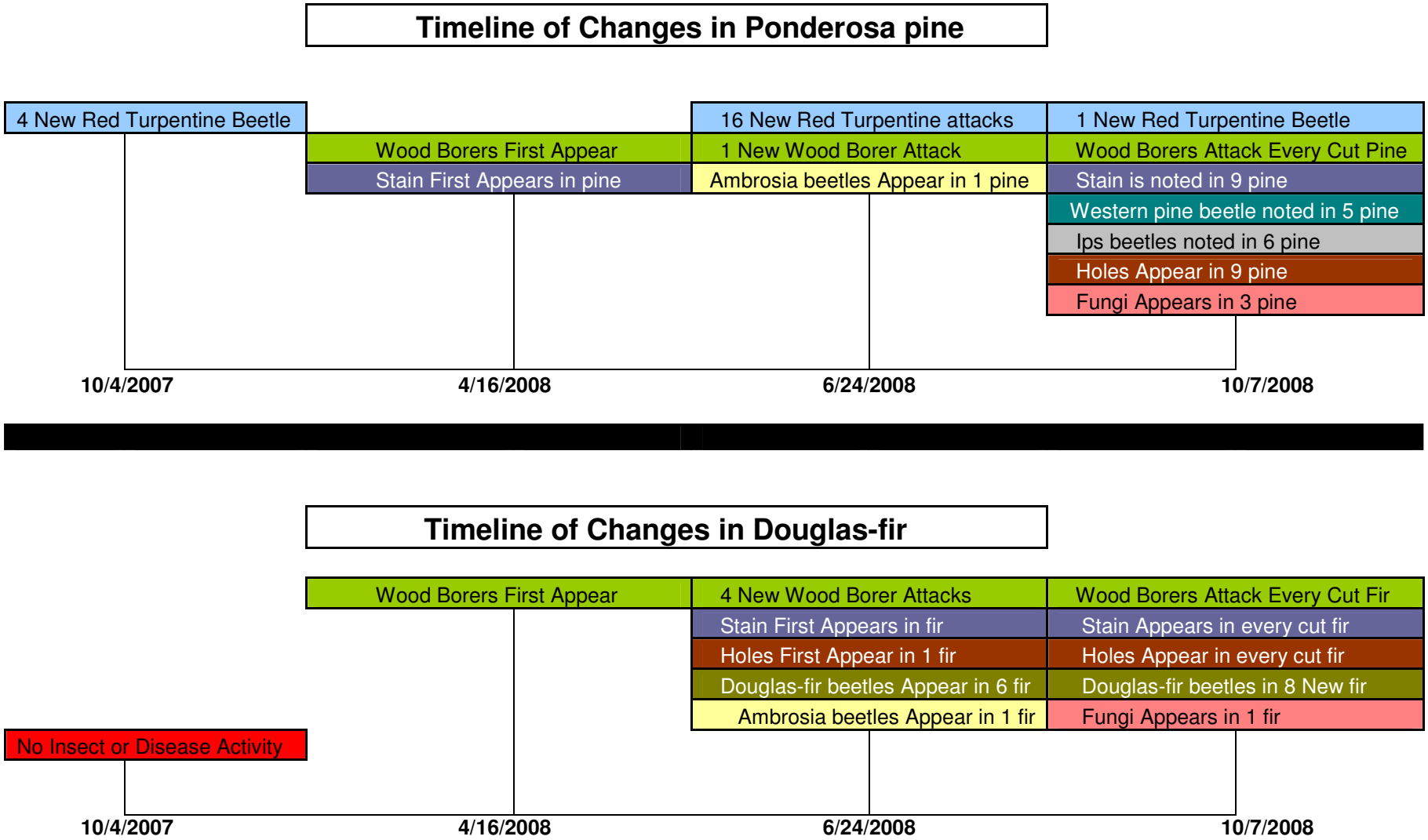

Chart 1: Timeline of damaging agents in fire killed ponderosa pine and Douglas fir trees over one year.

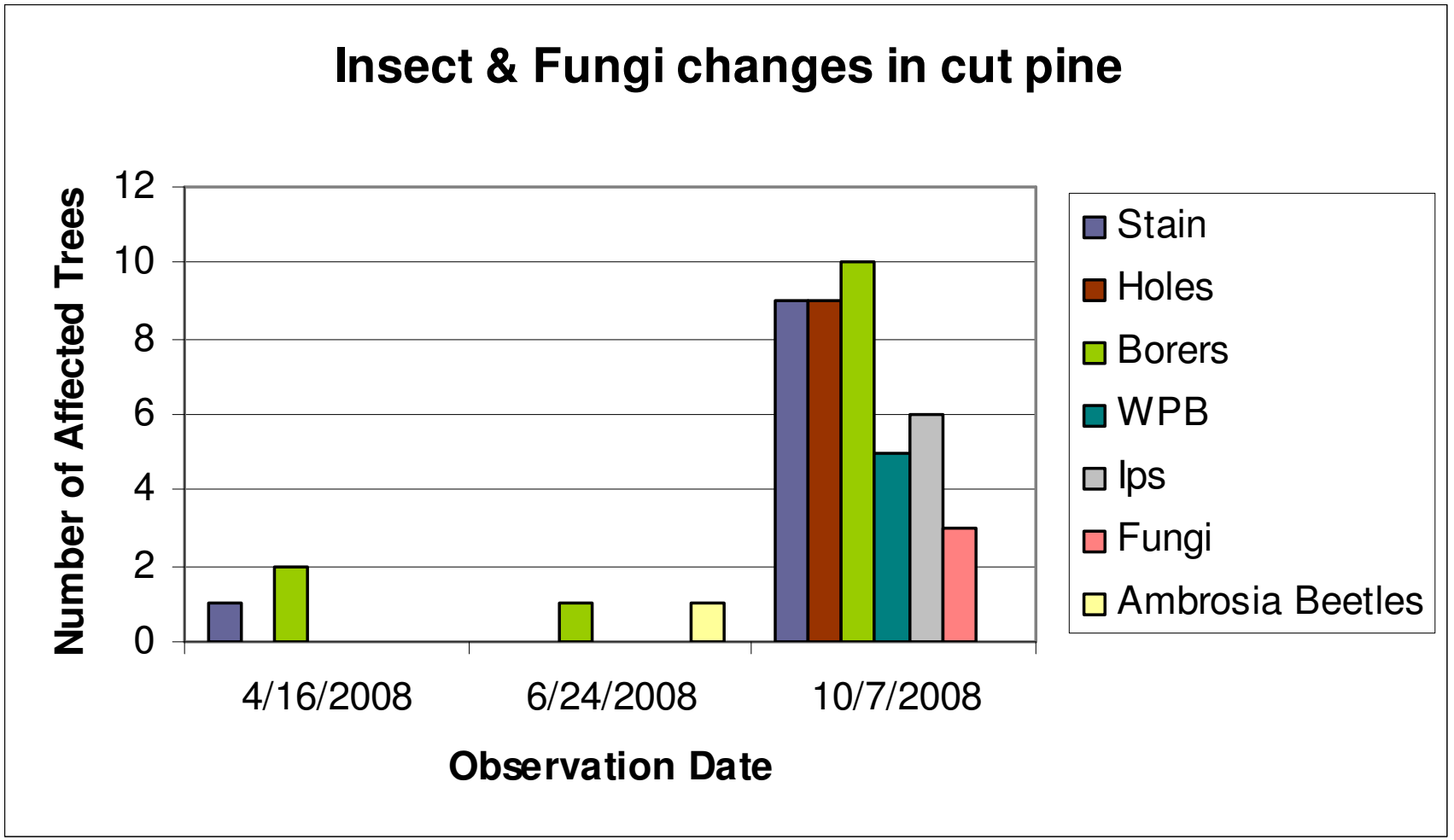

Chart 2: Insect and fungi changes in cut ponderosa pine trees.

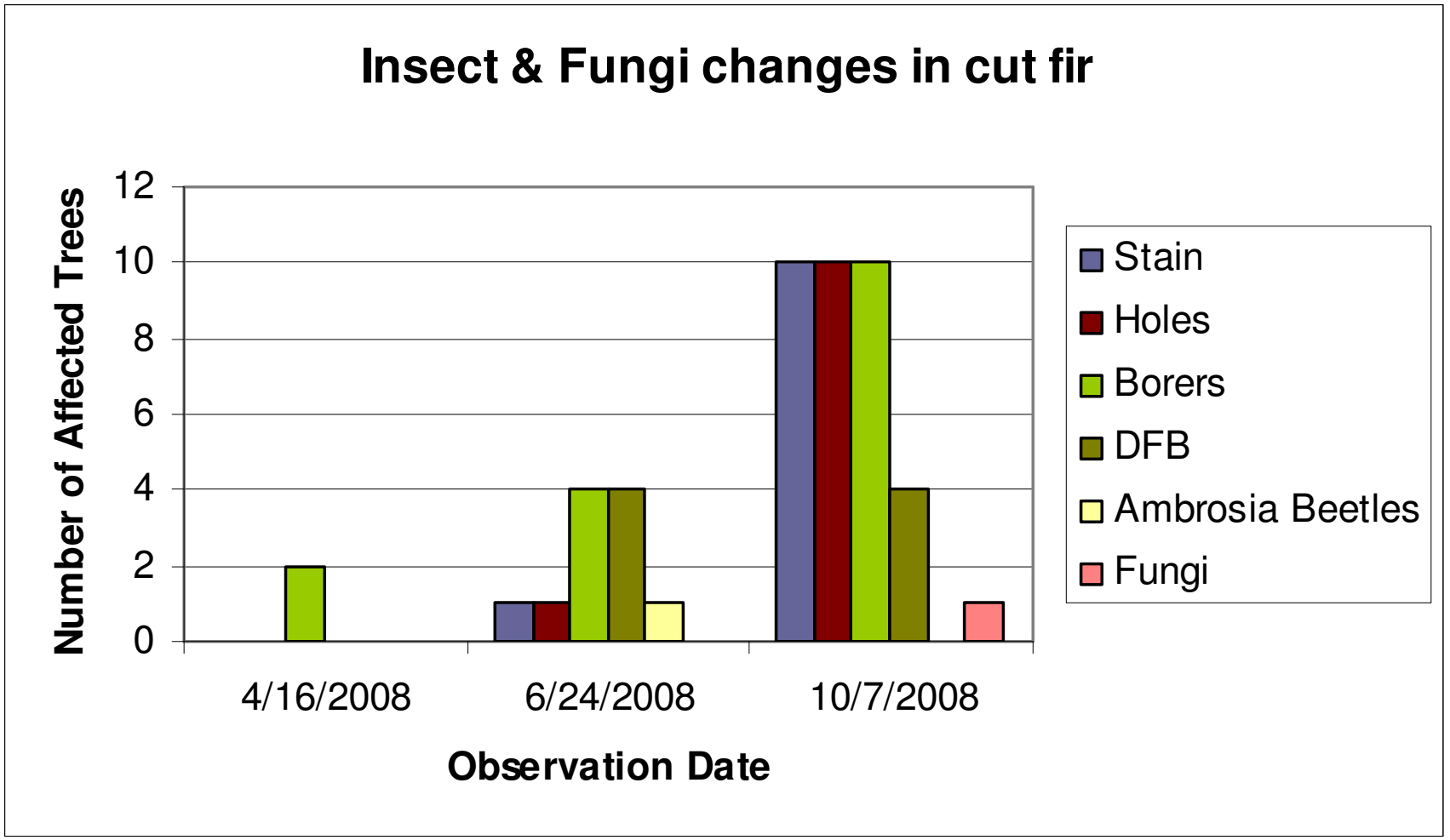

Chart 3: Insect and fungi changes in cut Douglas-fir trees.

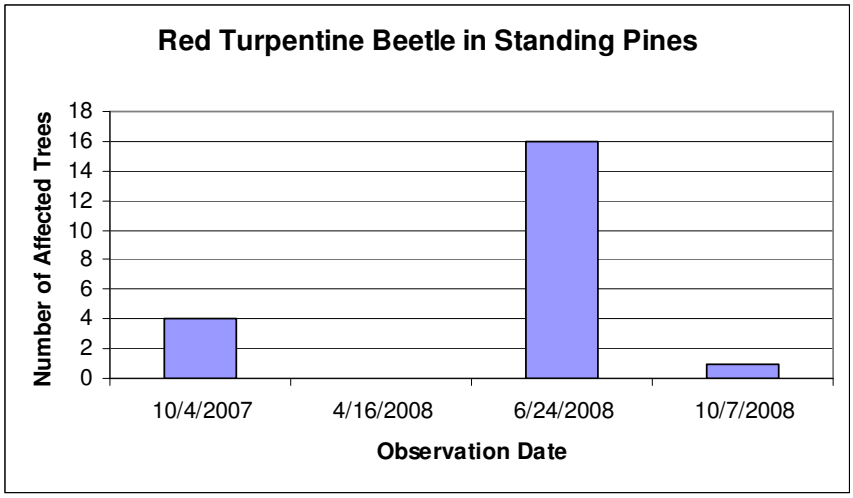

Chart 4: Red turpentine beetle observations in standing pines.

Discussion

Ponderosa pines and Douglas-firs killed by a September 2007 wildfire experienced several changes in stem wood characteristics within the first year of their death (Charts 1, 2, and 3). There were few changes in the first six months after the trees were killed but numerous changes in the next six months. Insects were responsible for most of the changes in the wood of the fire-killed trees. Changes induced by fungi, specifically sapwood staining, were initiated by insects infesting the dead trees. Changes brought about by weather were not apparent in the study trees. Changes did differ between ponderosa pine and Douglas-fir.

The 2007 Manila Creek fire is considered to be a late season wildfire in that it burned in the last half of September. Most large wildfires in eastern Washington burn in the months of July and August. The lateness of the Manila Creek fire undoubtedly had a significant influence on living post-fire change agents, especially insects. With the notable exception of red turpentine beetles, adults of bark beetles that infest ponderosa pine and Douglas-fir are active in late spring and summer. Adult bark beetles seldom attack trees in September and October in eastern Washington. Bark beetle attacks on trees affected by late season fires typically commence 8 to 10 months after the fires. Trees killed by early season and mid-summer wildfires are likely to be infested by bark beetles within days or weeks of the fires, because adult beetles are actively seeking trees to infest then. Wood borer adults seem to be active from early summer through fall.

Some observations made on the standing fire-killed trees were determined to be unreliable in detecting changes. When the trees were cut, bucked into logs, and cross-sectional disks were collected the trees were examined closely. Wood borer infestations and infestations of bark beetles other than red turpentine beetles were seldom detected by examining the standing trees, but they were detected in the logs and disks. Woodpecker foraging was missed on several standing trees but detected when the trees were cut and bucked into logs. The bark on a few trees was found to be loose when they were cut into logs and disks in the October 2008 examination, whereas the observations on standing trees indicated the bark was tight on all.

Fire-killed ponderosa pines were being infested by red turpentine beetles within three weeks of tree death by fire (Chart 4). Four study trees were determined to be infested by red turpentine beetles when they were selected on October 4, 2007. The presence of large pink globs of fresh pitch close to the ground was evidence of red turpentine beetle infestations. Red turpentine beetles can vector bluestain fungi on their bodies and inoculate trees, ultimately resulting in stained sapwood (Figure 7).

Figure 7: Red turpentine beetle gallery and bluestaining fungi brought in by adult beetles.

There were almost no changes in the fire-killed pines and Douglas-firs from their examination on October 4, 2007 to the next observations of standing trees on April 9, 2008 and examination of logs and disks from cut trees on April 14 and 15, 2008. Six months passed between the first and second examinations. Temperatures were cold during the fall and winter months. Precipitation was primarily in the form of snow. Insects, being poikilothermous (cold-blooded), were not active for most of the time between the first and second examinations. Two Douglas-firs cut in April had wood borer larvae under the bark. It was not possible to determine if wood borer eggs or the larvae had overwintered in the trees or the infestations began in the spring. Only two of the 44 Douglas-fir logs examined in April had wood borers.

The fire-killed trees did not appear to have experienced changes brought about by weather between the first examination in October 2007 and the next exam in April 2008. There was no obvious cracking of stems and no obvious loss of bark or branches from snow, ice, and wind. Weather checks were never detected in any pines and firs observed in the first year.

The third examination of study trees took place in June 2008, almost nine months after they had been killed by fire and two months after the April exam. Temperatures warmed and occasional rainstorms contributed moisture. The only changes detected in the fire-killed trees were associated with insects. Insect infestation of the fire-killed trees increased substantially between the April exam and the June exam.

Infestations of Douglas-fir beetles were seen for the first time in firs cut during the June 2008 sampling, nine months after the trees had been killed. Douglas-fir beetle adults typically become active in the study area in May and early June when the air temperature reaches 60 degrees. Douglas-fir beetles and/or galleries were found in almost 50% of the firs cut in June; none of the firs cut in April had Douglas-fir beetles or their galleries (Figure 8). There was only a trace of wood stain in fir logs and disks examined in June. Wood stain was found in two logs when the one square foot patch of bark was removed. No stain was seen on any of the 56 disks examined. Douglas-fir beetles can vector spores of stain fungi on their bodies and inoculate them into trees. The very small amount of wood stain seen in Douglas-firs examined in June suggests the Douglas-fir beetle attacks were quite recent and only small numbers of Douglas-fir beetles had infested the study trees. The large size of the fire and abundance of fire-killed and injured Douglas-firs provided huge numbers of trees for the beetles to infest.

Figure 8: Douglas-fir beetle collected on 10/7/2008 12 months after the Manila Creek fire.

There was a small increase in the number of firs infested by wood borers between the six month and nine moth examinations. Still, only four of the firs cut in June had wood borers detected in logs and/or disks.

Red turpentine beetle infestations on pines increased substantially between April and June. Sixteen pines that previously did not have red turpentine beetle pitch tubes were found to be infested in June. No other species of bark beetles were found infesting the pines in June. Western pine beetle adults typically attack pines in July and August in the study area. There were very few pines with wood borer infestations in the June exam. Because few of the pines had been infested by insects, except for red turpentine beetles, there was almost no bluestain of the pine sapwood in June.

The final examination of the fire-killed trees took place in October 2008, one year after they had been killed. Three months had passed from the previous exam. Most of the trees experienced marked changes in the three month period as a result of insect infestations.

Figure 9: Flatheaded wood borer and bluestaining fungi introduced by the adult beetles.

All ten Douglas-fir trees cut one year after the fire had been infested by wood borers. In the exam done 9 months after the fire only four of the ten firs had wood borer activity detected. Thirty three of 41 logs examined in the one year dead firs had wood borer activity and 12 of the infested logs had holes made by borers extending into the sapwood (Figure 9). Wood borer populations increased substantially in the fire-killed firs between the 9 month and 12 month exams All 10 trees had sapwood stain that in all likelihood had been introduced into the trees by borers and Douglas-fir beetles. Bark on the fire-killed trees was loose on 3 of the ten trees, whereas bark was tight on all firs in earlier exams. The bark was loose because of the insect feeding on phloem and cambium tissues.

All ten pines cut one year after being killed by fire were infested by wood borers and bark beetles. Twenty four of 39 logs from the ten trees were infested by borers and 15 of the logs had borer holes extending into the sapwood. The wood borer population in the fire-killed trees increased dramatically between the June and October exams. Ips beetles and/or galleries were seen in 8 logs and in 15 of 49 disks. This group of insects had not been seen in earlier exams. Western pine beetles and/or galleries were found in 6 logs and 3 trees in October. They had not been detected in earlier exams. The warm summer temperatures and emergence of adult Ips and western pine beetles from overwintering sites were the major factors for the large increase in attacks by these bark beetles. Nine of 10 pines sampled in October had bluestained sapwood. The stain fungi were probably carried into the trees by bark beetles and wood borers. Three pines had conks of the pouch fungus but no decay was detected in any of the trees. The bark was loose on 8 of the ten trees sampled in October, whereas it had been tight on all pines in earlier exams. Woodpecker feeding increased between June and October as the birds were finding more wood borer larvae.

There were no apparent associations between bark scorch height and infestation by insects. Bark beetle and wood borer infestations were present under scorched and nonscorched bark on both pines and firs.

Conclusions:
In our judgment, fire-killed ponderosa pines and Douglas-firs experienced almost no loss in monetary value as logs and lumber as a result of post-fire changes six months after tree death. Monetary value losses were probably minor in both tree species nine months after trees were killed. Insects were becoming more abundant in the dead trees but there was minimal sapwood stain and no holes in the wood. The fire-killed, one-year dead pines probably experienced major losses of at least half their potential pre-fire value. Most of the sapwood in the one-year dead pines was blustained. Log purchasers typically assign low value to bluestained pine logs compared to logs without stain. Fire-killed Douglas-firs dead for one year probably experienced moderate monetary loss of value because most trees had been infested by wood borers that were making holes in the wood. Small amounts of the sapwood were stained as a result of Douglas-fir beetle and wood borer infestations.

If a forest landowner's objective is to capture the maximum potential value of fire-killed Douglas-fir and ponderosa pines for logs and lumber the dead trees should be salvaged within 6 months of the fire, or by June of the next year. Major losses of potential economic value as logs and lumber will be sustained if salvage of dead trees is not completed within one year of death by wildfire.

Fire-killed trees do have ecological value. Fire-killed trees are rapidly infested by insects, most of which introduce fungi into the trees. This insect and fungal invasion of fire-killed trees results in the dead trees being recycled. Woodpeckers begin to feed on insects in fire-killed trees within six months of tree death.

This study was done in a late season wildfire area. The low incidence of insects infesting the fire-killed trees for the first six months after the trees were killed is directly related to the timing of the fire. Bark beetle adults, with the exception of red turpentine beetles were not available to infest fire-killed trees in September 2007 when they were killed. Bark beetles and wood borers were in an "overwintering mode" when the fire occurred. Another study of fire-killed trees needs to be conducted using trees killed by mid-summer fires (July and August) to determine the chronology of insects and fungi infesting trees killed by earlier season wildfires.

Appendix

First year Changes Change Agents

Red turpentine beetle, *Dendroctonus valens*, was found in 21 fire-killed ponderosa pines. Adult beetles infest trees throughout the active growing season. Pines killed by the September 2007 fire were being infested within 3 weeks of their death. Red turpentine beetles typically infest the bases or root collar areas of fire-killed pines. Trees responded to the attacks by producing relatively large globs of pink to red pitch on their bases. Even though the trees were killed outright by the fire they still produced large pitch globs when infested by red turpentine beetles. The pitch tubes were right at groundline. Presumably, the root collar and upper roots were still alive and able to produce pitch even though almost all above ground tissues were killed by the fire. Eggs are laid in cavity-shaped galleries about the size of a half dollar. Larvae feed on phloem and cambium tissues in groups. Red turpentine beetles can carry spores and mycelium of bluestain fungi into trees, thereby initiating sapwood staining. However, because most red turpentine beetle attacks on fire-killed trees are close to the ground most effects of their attacks are restricted to stumps heights and do not extend upward into in the lowermost logs. Red turpentine beetles have almost no negative monetary influence on fire-killed pines in the first year of tree death.

Douglas-fir beetles, *Dendroctonus pseudotsugae*, were found in 12 fire-killed Douglas-firs. Attacks were seen for the first time when trees were examined in June, 9 months after the trees had been killed. Almost all Douglas-fir beetle infestation of fire-killed firs happens within the first year of tree death because the larvae require fresh phloem tissues for food. Most Douglas-fir beetle infestations of fire-killed trees in eastern Washington take place in May and June when air temperatures consistently reach at least 60 degrees. Attacks were detected by the presence of characteristic orange colored frass on bark of

standing trees and by adults, larvae, and galleries under the bark. Adults can carry spores and mycelium of stain and wood decay fungi into the trees. Larvae feed on phloem and cambium tissues and loosen the connection of bark to xylem. Attacks occur most abundantly in the larger diameter (>10") portions of the boles. Douglas-fir beetles can have substantial negative monetary influence on fire-killed Douglas-firs by introducing stain and sapwood decay fungi and loosening the bark thereby contributing to weather checking.

Sapwood stains, caused predominantly by *Ceratocystis* and *Leptographium* fungi were introduced into the fire-killed trees by bark beetles and wood borers. These fungi produce sticky spores that adhere to bodies of insects living under tree bark Bark beetles are more effective vectors of these fungi than wood borers. The fungi that stain sapwood grow most rapidly in the ray cells. The color results from the fungal mycelium. Stain fungi have no significant influence on reducing wood strength. They alter wood appearance. Wood stain was seen as early as April in pine but not until June in the firs. Most wood stain was detected 12 months after the trees had been fire killed. Bluestain of ponderosa pine has a large detrimental influence on monetary value of the trees for lumber. It is common for almost all one-year dead ponderosa pines to have most of their sapwood bluestained. Staining of Douglas-fir sapwood progresses much slower than in pines, therefore the monetary effects are smaller.

The pouch fungus, *Cryptoporus volvatus*, was found on three fire-killed pines and one fir one year after the trees had been killed. This wood decay fungus causes gray brown sap rot. The fungus is inoculated into trees by bark beetles carrying spores and mycelial fragments on their bodies. The fungus grows rapidly in the sugar rich and moist phloem tissues and outermost sapwood cells. Pouch-like, hollow conks are produced in abundance about one year after bark beetles introduce the fungus into trees. Most conks emerge from bark beetle entrance and exit holes. Decay caused by *C. volvatus* is largely limited to sapwood. Almost no sapwood decay from the pouch fungus occurs within the first year of tree death. Large proportions of the sapwood can be decayed between the first and second year of tree death. Large numbers of pouch fungus conks appear on the boles of fire-killed pines and firs one year after bark beetles infest the trees. Trees killed by early and mid-season fires that are subsequently infested by bark beetles carrying the pouch fungus will have numerous conks the following growing season.

Woodpeckers began feeding on wood borers and bark beetles within 6 months of tree death. Woodpecker feeding on fire-killed trees increased markedly between the 9 month and 12 months exams as the wood borer population greatly increased. Woodpeckers primarily were feeding on the large wood borer larvae rather than the tiny bark beetle larvae (Figure 10). Woodpecker foraging on the fire-killed trees exposes sapwood to weather checking and colonization by stain and decay fungi. There is probably minimal reduction in log value associated with woodpecker foraging on fire-killed trees in the first year.


Figure 10: Woodpecker foraging evidence on ponderosa pine bark.

Ips bark beetles of undetermined species were found in six pines at the one year exam. Ips are often called pine engravers. These bark beetles are typically found in the smaller diameter portions of pines. They may have 1 to 3 generations in one year. The Ips species found in the study area probably only have one generation because they were only found in the final 12 month examination. Infestations would only develop in trees dead less than one year from fires Ips beetles introduce stain fungi into the sapwood. Larval feeding on phloem tissues loosens the bark and contributes to weather checking. Because most Ips infestations are in the small diameter portions of trees monetary damage from this group of bark beetles on fire-killed pines is probably small.

Western pine beetles, *Dendroctonus brevicomis* were found on 5 fire-killed pines in the 12 month exam. Most attacks by adults take place in July and August. These insects can introduce stain and wood decay fungi into the trees. Feeding by the larvae can loosen the bark. Large numbers of western pine beetle larvae attract woodpeckers that flake the bark to feed on the insects. Fire-killed pines standing in July and August can experience significant lose of value as logs if they are infested by western pine beetles. Almost all infestations of fire-killed ponderosa pines by western pine beetles takes place on trees dead less than one year

Wood borers in the families *Buprestidae* (flat-headed) and *Cerambycidae* (round-headed) were the most abundant and damaging group of insects infesting the fire-killed trees. Infestations appeared to begin in the spring and increased quite rapidly as the season progressed. All trees cut 12 months after being killed by fire were infested by wood borers. Adult borers seem to be available to infest trees throughout most of the summer and into fall. Eggs are deposited under the bark by females inserting needle-like ovipositors into bark crevices. A small amount of wood stain fungal propagules can be introduced into the trees by the egg laying process. Larvae feed in the phloem tissues for a few weeks to months. The relatively large larvae loosen the bark and attract woodpeckers to feed on them. The large wood borer larvae may exert a substantial degree of control over bark beetles occupying the same space. The wood borer larvae chew their way through bark beetle galleries and consume food before it can be used by bark beetles. Larvae feeding under the bark loosen the connection to the wood, making it prone to weather checking and colonization by fungi. Some larvae burrow into the wood and may penetrate several inches into the wood making large winding holes. Trees infested by wood borers lose a large amount of value for lumber because of the holes in the wood and associated stain and decay. Infestations of fire-killed trees by wood borers begin in the first year the trees are killed and may continue for several years.

Ambrosia beetles are very small wood boring insects that typically infest recently killed trees. They can be found on most conifer species but were only found on one fire-killed pine and one Douglas-fir. Ambrosia beetle infestations are detected by the presence of very fine white frass, or sawdust around basal portions of trees (Figure 11). The adult insects excavate small diameter galleries in the wood and expel the chewed wood outside the holes. They introduce a black stain fungus which they use for food for themselves and the larvae into the galleries. Most ambrosia beetle attacks on dead trees occur in late spring and early summer as the adults emerge from overwintering in duff. Ambrosia beetle galleries can extend several inches into the sapwood. Some ambrosia beetle species excavate branched galleries. The wood with tiny black pinholes experiences little reduction in strength but the appearance is altered. Ambrosia beetle infestations can substantially reduce the value of logs if there are many galleries. Practically all ambrosia beetle infestations of fire-killed trees occur within the first two years of tree death.

Figure 11: Ambrosia beetle (white) and Douglas-fir beetle (reddish) boring dust on a Douglas-fir.

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