Disease, Insects, and Management in Amphitheater Campground

Review of Surveys, Evaluations, and Management 1991-2018

Technical Report R2-69

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Abstract: Evaluations and management of diseases, insects, and hazard trees in Amphitheater Campground (Ouray District, Uncompahgre National Forest) go back at least 30 years. The earliest survey we have records of is from 1991. The Campground is over 90% white fir, and this is the most important factor leading to insect and disease damage and consequent hazard. Western spruce budworm (*Choristoneura freemani*) has been a more or less chronic defoliator of white fir in recent decades. Annosus root disease (caused by *Heterobasidion occidentale*), which decays roots and leads to substantial risk of green-tree failure, was discovered around the Campground in 1991, and has recently been found throughout most parts of the Campground. Fir engraver (*Scolytus ventralis*) initiated an outbreak on the weakened white fir and began causing substantial mortality in 2012. Douglas-fir beetle (*Dendroctonus pseudotsugae*) is a growing potential threat to Douglas-fir, which is an important source of the limited tree species diversity. A major vegetation management project in 1996 removed over 600 white fir in much of the Campground and, since 2012, roughly 1,450 mature trees were removed due to fir engraver or annosus root disease. It is time now for a major planting and vegetation management project to greatly increase species diversity in the Campground. In the long run, this will substantially reduce insect and disease threats, reduce the expense and time of frequent removals, and increase visitor safety.

1. INTRODUCTION

Amphitheater Campground is a premier campground on the Ouray Ranger District, Uncompahgre National Forest. It is perched on an amphitheater-like bench on the side of a mountain in the northern San Juan Mountains, overlooking a spectacular box canyon with the town of Ouray below. The campground is heavily used and was expanded and upgraded in the 2000s. It now encompasses 35 campsites.

Forest cover is very heavily dominated by white fir. In 1991, 12 plots scattered through the campground captured only white fir (Angwin 1995a). Plots just outside the campground also included a small component of Gambel oak. But in the area, there is also a small amount of Douglas-fir, limber pine, aspen, Rocky Mountain juniper, and patches of Gambel oak and choke cherry. RMRIS indicated that the forest cover was 90% white fir and 10% Douglas-fir and Engelmann spruce (McKenzie 1996). Roughly a dozen or so large container-grown ponderosa pines planted in 1996 survived and are mostly growing well. Ponderosa pine seedlings were planted on the north-facing

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slope south of the campground; these are not growing well. Average stand basal area as of 1996 was 93 sq. ft. per acre, but it ranged from no tree stocking to over 150 sq. ft. per acre (McKenzie 1996).

Diseases and insects have greatly complicated vegetation and hazard tree management in the campground. They threaten the sustainability of the overstory and visitor safety. Western spruce budworm has been active there since at least the 1980s. Severity has varied over time, but it has never quite gone away. Perhaps in part as a result, the canyon and surrounding drainages have sustained a severe and widespread outbreak of fir engraver, which has continued to kill white fir year after year.

A more insidious problem in the campground is annosus root disease (ARD). It decays roots and butts and kills trees, but most often does so by leading to mechanical failure of green, often healthy-looking trees. This poses a risk that must be actively mitigated to maintain a safe campground.

The objectives of this report are to: (1) review forest health issues and management at the campground that we have records for, and; (2) update that record with recent activities; and (3) explore alternatives for vegetation management into the future.

2. FOREST HEALTH: EARLY REPORTS AND RECENT OBSERVATIONS

In the 1980s, entomologist Bernie Raimo of the Gunnison Service Center was tracking western spruce budworm activity. In 1991, Pete Angwin, forest pathologist at Gunnison Service Center, conducted a forest health survey of Amphitheater Campground at the request of Maureen McCormack, forester at the Ouray District (Angwin 1995a).

He found that western spruce budworm (WSB) was an ongoing, chronic problem in all areas of the campground. Some trees had dead tops as a result. Of sampled trees, 92% had evidence of past or current defoliation and 66% of current-year foliage was defoliated. In 1995, the outbreak had declined somewhat. More recently, occasional observations suggest that WSB has been fairly severe.

In his 1991 survey, Pete also discovered annosus root disease on the site, primarily along the eastern edge just outside the campground. A map of the root disease centers was included in the report along with detailed alternatives and recommendations for managing WSB and ARD.

In early November 1995, after the report was completed, a large, live white fir fell across the parking spur of site #5 (same site number then and now). It had decay in the roots typical of ARD, and conks of the pathogen in several stumps near the tree (Angwin 1995b). There was no external indicator of decay or root disease on the tree before it fell. Further inspection showed that root disease infection centers were more extensive than found before, also along significant portions of the southern perimeter of the campground (Fig. 1). It was now clear that the root disease was inside at least a small portion of the campground proper (McCormack 1995).

Around 2010, a bark beetle came to the white fir party: the fir engraver. It is more pernicious than WSB – it simply kills firs, especially large ones. It may have been taking advantage of tree stress due to western spruce budworm, root disease, and drought. It has since been active all around Ouray Canyon and extending into side drainages where white fir occurs. Initially it just killed tree tops, then it progressed to killing whole trees. In the last 6 years, about 1,200 white fir were killed and removed in the day-use area and campground.

In early 2017, two large, live, and healthy-appearing white fir fell in the campground close to sites 10 and 15 (Fig. 1, root failures #8 and #13). The first, #13, apparently fell in the winter or spring before the campground was first accessed. The second, #8, fell around May 14 as the campground was being prepared for the season.

Roots of both trees had decay typical of annosus root disease and were near stumps and previous failures with the same decay. We sampled the decay from tree #13, isolated from it in the lab, and obtained a culture that was positively identified as the pathogen that causes ARD.

In late May, silviculturist Todd Gardiner and pathologist Jim Worrall conducted a brief survey of the southern perimeter, where these trees were located, inside and outside the campground. The disease was found in many of the same locations as before, but known locations were extended to the west and to the north, closer to and into the campground (Fig. 1). For the first time the disease was found on the north side (campground side) of the southern loop road.

Then, in early 2018, probably in April, another live white fir fell. It went across the entrance road. The roots were very extensively decayed with ARD (*Figure 2*). The tree was inside the large road switchback leading from the day use area to the campground, and did not threaten any campsites (*Figure 1*).

Examination of that loop on May 1 showed other failures due to the disease had occurred earlier. Stumps with typical pattern of decay associated with the disease, and often with conks, were distributed throughout the inside of the switchback. Further examination across the road, into the campground, revealed infested stumps near campsite #1 and throughout the loop from the overlook through sites 21-27, and one rather isolated adjacent to the tent pad of site 18 (*Figure 1*). On May 4, remaining areas that had not been surveyed in 2017 or 2018 were inspected.

It was apparent that the widespread detection of the disease where it had not been detected previously was due to fir engraver. Fir engraver tends to attack trees that are under stress, including ones that are infected with root disease. The many trees removed as they were killed by fir engraver revealed the typical pattern of decay on some of the stumps. Where the decay was advanced, conks subsequently developed in those stumps.

3. VEGETATION MANAGEMENT SINCE 1990

In February 1992, a Decision Memo was signed for campground renovation based on a categorical exclusion (Free 1992). In addition to constructing a new day-use area outside the campground proper, adding campsites in the former day-use area, campsite renovation, and other improvements, vegetation treatment to address insect and disease was planned. As described in the decision memo:

> *Vegetation treatment to insure continued shade and screening of camp units. An existing spruce-budworm outbreak has inhibited the establishment of new understory conifer trees. Transplants of budworm resistant trees will be planted and placed to provide shade and screening between units. Native species will be used. In addition to the spruce budworm outbreak, a root rot fungus has established itself in the fir trees. Infected trees and root systems will be removed to prevent further spreading. The understory shrub specie [sic], choke cherry is also diseased. Black knot fungus and tent caterpillars have defoliated the plants to prevent adequate screening.*

In late 1995, after the tree failure noted above, plans were initiated for aggressive treatments to address WSB and ARD (Angwin 1995b, McCormack 1995). A report in the Ouray newspaper (Seloheim 1995) discussed the recently fallen tree as well as problems in the campground and plans to address them. A funding proposal was submitted to Forest Health Protection to assist with the project.

In January 1996, Silviculturist Carol McKenzie completed a vegetation prescription for the treatments at Amphitheater (McKenzie 1996). The campground was divided into three areas with different prescriptions.

1. **South of the southern loop to the ridge above trail 855.2a**: Very large mature white fir with understory of pole-sized white fir. Occasional Douglas-fir and limber pine. Budworm defoliation moderate, ARD present. Too steep for commercial harvest.
    a. Fell all trees in ARD centers and 30-50 feet beyond. Fell severely defoliated understory trees. Plant created openings with ponderosa pine or limber pine (resistant to both WSB and ARD).
2. **Southern loop and east side of the campground**: 3-storied: large, mature white fir overstory; pole-sized white fir in groups and scattered individually, and; understory of small white fir saplings and some planted ponderosa pine and juniper. Small groups of aspen and some Douglas-fir. Moderate defoliation with some mortality in the understory; ARD present [probably just on the east side as known at that time].
    a. Commercial sanitation harvest. Treat ARD centers as above. Remove hazard trees and smaller trees with heavy defoliation. Plant ponderosa pine, limber pine, or juniper.
3. **Northern loop, picnic area, and main access road**: Mostly single-storied with overstocked, smaller 5-12 inch trees. Some scattered large trees (> 20 inches). Moderate defoliation; no ARD known.
    a. Commercial thinning with average spacing of 25 ft. Leave the largest and most vigorous trees. Discriminate against smaller trees that are overtopped, suppressed, or severely defoliated. Remove hazard trees.

The prescription included these common treatments:

- Sprinkle all freshly cut stumps with borax powder within 24 hours to prevent infection.
- Treat mature, sound residual trees with ace-caps to deter WSB.

Undated notes in Pete Angwin's handwriting on file at Gunnison Service Center were apparently prepared for a 1997 field trip. They indicate that campsites adjoining root disease centers were closed during the 1996 season. News releases and public meetings in Ouray prepared locals for the big changes at the campground. A tri-fold brochure explaining the problems and treatment to the public is also in the file. Ponderosa pine and juniper were planted in some areas before treatment began.

A timber sale occurred in the campground between Oct. 1996 and April 1997. Over 600 trees were marked for removal, and 599 of them were within striking distance of a picnic table or outhouse. A large mature white fir has a truckload of slash on each branch, so a concern was the expense of slash removal. A chipping operation and a Delta Department of Corrections work crew accomplished slash removal. When borax was applied with snow on the ground, deer ate almost all of the borax. The stumps were retreated with a solution of borax and water. The operation was a success, and the campground was opened to the public June 13, 1997.

In 2012 the fir engraver caused significant mortality throughout the campground, trailheads and day-use area. Hazard tree mitigation has occurred each spring from 2012-2017, with approximately 200 trees cut each year. Trees have been removed by a combination of small timber sales and Forest Service crews cutting and stacking wood next to the road for public use firewood. Slash has been treated with a combination of lop and scatter, chipping, and pile burning. Additionally, the Colorado State Forest Service completed hazard tree mitigation in a few small stands along the road up to Amphitheater in 2016.

Concurrent to the hazard tree work has been MCH application to the scattered Douglas-fir surrounding the day-use area, trailheads and campground. There are only about 5-10 Douglas-fir

trees in the developed area, but they are more common in adjacent stands. Douglas-fir beetle activity has been steady across the surrounding landscape, and MCH treatment has been largely successful.

After the two tree failures in early 2017 and the subsequent survey, a decision was quickly made to remove white fir around known occurrences of the pathogen as was done in 1996.

Sites 4,5,6,10, and 15 were closed immediately until the work was completed. Forty-six live trees were removed from in and around the closed sites. Trees within 30 feet of a documented annosus root disease center and within striking distance of a campsite or use area were cut and removed. Slash was chipped. Some logs were removed for firewood and some were left lying on the ground.

Of course, some trees that were cut may not have been infected. To prevent spores of the pathogen from infecting the stump tops, growing into the roots, and potentially attacking living white fir nearby, Cellu-Treat was applied to fresh stump tops. Cellu-Treat is disodium octaborate tetrahydrate. When dissolved in water it hydrolyzes to become sodium borate and boric acid, just as does ordinary borax, sodium tetraborate, which is widely used in detergents and cosmetics.

https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5329558.pdf

http://nisuscorp.com/images/uploads/documents-specimen-labels/label_sds_cellutreat.pdf

In April 2018, Todd Gardiner organized planting of limber pine seedlings in the Campground. Seedlings were containerized and left-over from a shipment designated for the San Juan National Forest (*Figure 3*). Roughly 125 seedlings were planted.

In response to the white fir failure in early 2018, in early May stumps were examined for evidence of ARD in the remainder of the campground that had not been inspected in 2017. Infested stumps were mapped and tallied, and live white fir within 30 feet of them were flagged.

In all, 76 tree remains with evidence of ARD were found. This includes 43 stumps with characteristic decay and no conk, 16 stumps with characteristic decay and conks, and 17 uprooted failures with characteristic decay, one of which had a conk.

The decision was made to remove all live white fir within 30 feet of evidence of ARD that could strike structures or places where people are stationary, such as parking areas and campsites. This totaled almost 200 trees, some of which on the eastern corner of the campground were quite large. Forest Health Protection contributed $20,000 to the effort. Some trees were initially felled by a fire crew doing saw recertifications and the resulting stumps were sprayed immediately with Cellu-Treat. The plan was to do the rest through the Colorado State Forest Service under the Good Neighbor Authority. However, this would have meant closing much of the campground for much of the season. The campground concessionaire insisted they could do it much faster.

By June 7, they had almost all of the trees felled except for three very large ones near the water well facility, and were in the process of cleaning up the logs and slash. The Forest Service followed within a few days to spray stumps with Cellu-Treat.

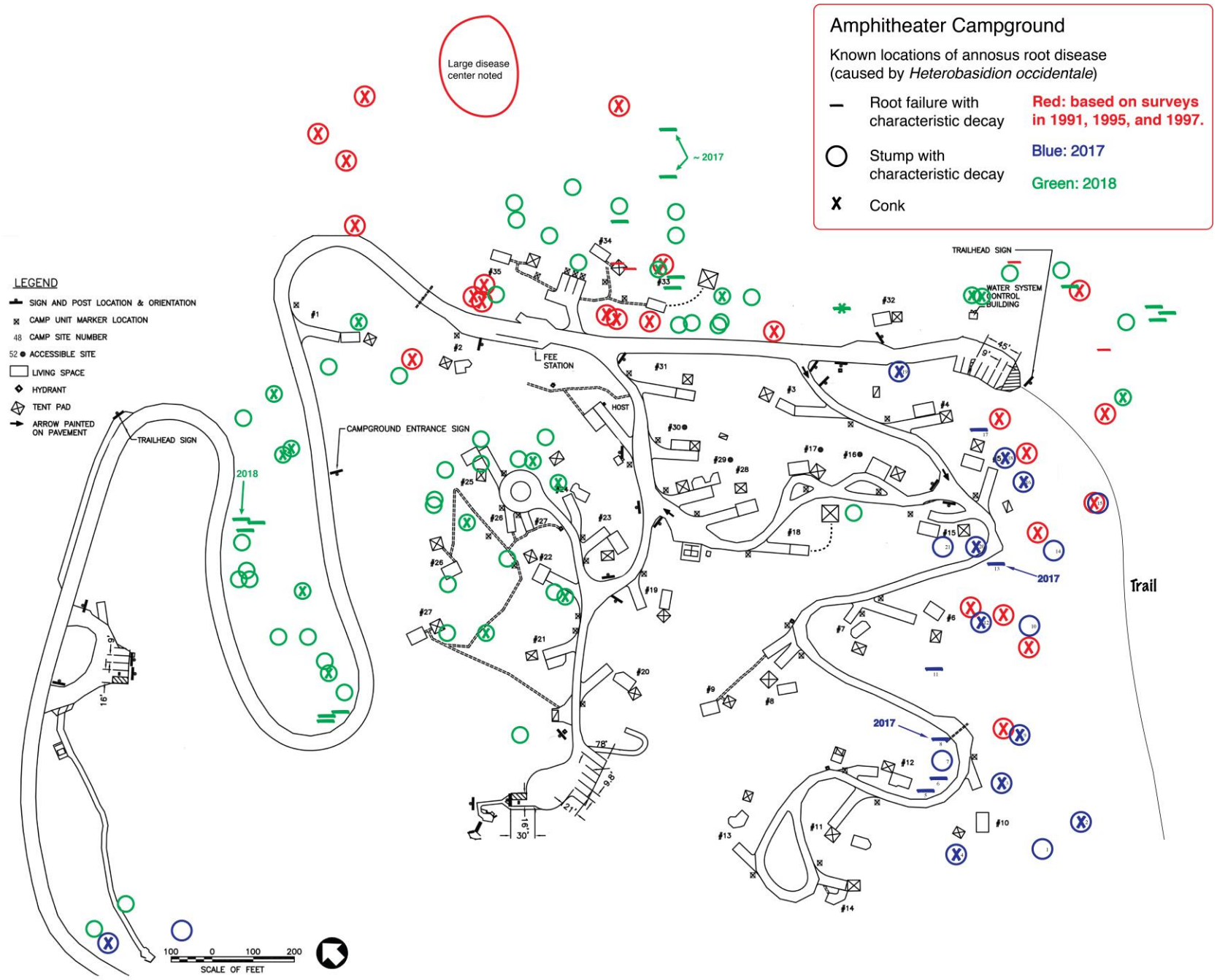

Figure 1. Locations of known annosus root disease in Amphitheater Campground as found in 1991-1997, 2017, and 2018.

Figure 2. Root system of a white fir that fell across the road in 2018. Almost all the roots had advanced decay.

Figure 3. Containerized limber pine seedlings planted in April 2018.

4. BIOLOGY AND ECOLOGY OF THE AGENTS AND FOREST

4.1 Western Spruce Budworm

Western spruce budworm (*Choristoneura freemani*) is a defoliator of Douglas-fir and white fir, and less notably Engelmann spruce, blue spruce, subalpine fir, and occasionally pines. This insect feeds on the new needles, where dead and dying needles webbed to twigs impart a brown cast to infested trees. Feeding from this insect can cause growth loss, top-killing, and tree mortality, especially on suppressed trees.

Western spruce budworm has one generation per year. The larvae are the only stage of this insect that feeds, and it develops through six instar stages. Eggs are very small (1 mm), green, and normally found on the underside of needles. Eggs will hatch within 10 days, where young larvae seek shelter to overwinter. From early May to late June, the larvae will feed on new foliage, one-year foliage, or within closed buds. After their sixth instar molt (30-40 days to mature), the larvae will pupate. Adult moths emerge after a 10 day pupation. Both male and female moths fly, and emerge from their pupal stage from late July to August.

Larvae prefer new foliage and buds, but will feed on old foliage if all the new foliage is destroyed. Defoliation occurs especially at tops of trees and outer branches. The larvae spin silken threads to float from the top-down to continue to feed. Understory trees are the most severely damaged. Severe defoliation over several years can decrease growth, cause top-kill or tree mortality, or render the trees severely weakened and more susceptible to bark beetle attack (specifically fir engraver in Ouray).

4.2 Annosus Root Disease

Annosus root disease in white fir is caused by the fungus *Heterobasidion occidentale*. The disease name is in flux; it has also been "annosum root disease" and "Heterobasidion root disease". *Heterobasidion occidentale* is one of several host-specialized species that have been recognized within the *H. annosum* complex (Otrosina & Garbelotto 2010). Hosts include true firs, Douglas-fir and spruces. However, in Colorado, it is almost exclusively found on white fir (Worrall *et al.* 2010, who refer to it as *H. parviporum*). Subalpine fir appears to be a rare host in our area, and Engelmann spruce has only rarely been found infected where it occurs with infected white fir.

4.2.1 Disease cycle

Like most wood-decay fungi, *Heterobasidion* spp. spread long distances via wind-blown spores. The ideal place for a spore to land is a fresh stump top, but they can also infect relatively fresh stem wounds. Spores germinate and the filamentous hyphae of the fungus grow through and begin to consume the wood. Hyphae from compatible mating types fuse and exchange nuclei.

In addition to wind-blown spores, *Heterobasidion* spp. have a second, local way of spreading. Where roots of an infested stump or tree make contacts or grafts, the pathogen can grow into a neighboring tree. In this way it creates gradually expanding root disease centers, with older mortality, downed trees, and stumps in the middle and newly infected trees at the margin.

Most growth in roots and butts of white fir tends to be in the internal wood, or between the sapwood and heartwood. Sapwood is alive, and has effective, active defenses, while heartwood is often occupied by wetwood that is inimical to decay (Worrall & Parmeter 1983). Decay structurally weakens the tree and often leads to mechanical failure while trees are still alive and apparently healthy. If trees don't fall over green, they are eventually killed standing.

The pathogen can survive for many years, perhaps 50 or more, in large stumps and roots. It remains capable of infecting roots that come into contact with it. It bridges generations, infecting each generation in turn. For practical purposes then, root disease centers can be considered perpetual as long as the host is present.

Conks (fruiting bodies) are usually produced inside hollow cavities in stumps or other hidden, moist places. Spores produced from these conks are windborne, closing the cycle.

Figure 4. Galleries of fir engraver in a dead white fir. Parent galleries are horizontal; larval galleries vertical. Note the beetle on the right side of the gallery left of center.

4.3 Fir Engraver

Fir engraver (*Scolytus ventralis*) is an important killer of true firs. In the Rocky Mountains, this insect is most commonly found in white fir, but can be found attacking grand fir, California red fir, and rarely Douglas-fir in the Pacific Northwest and California.

The fir engraver has a one-year life cycle, and has a long flight period, from early spring until early fall. This insect is monogamous (other engravers such as *Ips* are polygamous), and females initiate the attacks on trees. The male and female work to create a nuptial chamber, and create unique

galleries that run horizontal across the bole of the tree. Eggs are laid on both sides along this latitudinal gallery, and the larvae develop longitudinally. The beetles transport a brown-staining fungus that helps the larvae successfully develop by providing additional nutrition. This scoring of the wood by both adults and larvae facilitate girdling of the tree, eventually leading to the tree's demise.

Trees that are stressed by drought, western spruce budworm, or root disease are more susceptible to fir engraver attack. The fir engraver attacks trees, branches, slash piles, and windthrown trees of 4 inches in diameter or larger. Trees can be killed the first year, or after several years of repeated attacks.

4.4 Douglas-Fir Beetle

Douglas-fir beetle (*Dendroctonus pseudotsugae*) is a common bark beetle that kills Douglas-fir trees (Allen *et al.* 2010). The town of Ouray and Amphitheater Campground have yet to experience a Douglas-fir beetle outbreak, but populations of Douglas-fir beetle are active around Ouray and building to the east along highway 145 towards Telluride.

This beetle has a one-year life cycle, and adults emerge in early or late spring. Distinctive vertical egg galleries are constructed by the female in the phloem layer, and are anywhere from 5 to 12 inches long (Allen *et al.* 2010). Eggs are laid in alternating groups along the side of the parent gallery. These beetles overwinter as adults or larvae.

Douglas-fir beetles usually attack trees that have been weakened by defoliation, fire, or disease. When beetle populations are low, they can kill small groups of stressed trees. During an outbreak, thousands of trees can be killed.

Douglas-fir beetle uses a pheromone (an aggregant) to communicate to other Douglas-fir beetles to help attack trees and overcome their defenses. When a tree has been successfully attacked, the beetles release another pheromone (an anti-aggregant) to tell their counterparts that this tree is "full", and to fly to a different tree. This anti-aggregant pheromone is MCH, which has been synthetically produced and is now a tool land managers can use to protect their valuable Douglas-fir trees. MCH bubbles can be stapled to individual trees, and protects stands by preventing beetles from initiating new attacks. MCH has been deployed in Amphitheater from 2016 to present. Although populations are low, the site has been at risk from nearby populations that are building.

4.5 Ecology

4.5.1 Forest history

Pre-settlement forest conditions on this site are not known. However, two human influences suggest that the stands may have been more diverse before the settlement and mining era.

Logging. Because white fir wood in service is more susceptible to decay than most other species, and less strong, mining-era loggers likely avoided white fir. If pines and Douglas-firs were more numerous then than now, it is likely they were selectively logged, leaving white fir behind. White fir is shade-tolerant and can replace itself in a continuous canopy, but the pines and Douglas-fir are less shade-tolerant. White fir reproduces more prolifically and regularly than associated species.

Fire exclusion. White fir is much more easily damaged by fire at the base than the other species, and once there is a fire scar, decay fungi infect readily and the tree dies or falls over in short order. Again, we don't know the fire regime in pre-settlement forests here, but any fire would tend to

maintain diversity by killing white fir and favoring Douglas-fir and pines. To the extent fire exclusion has limited fire in such stands, white fir is greatly favored by its fecundity and shade tolerance.

The increase in abundance and purity of true fir species has been documented in many parts of the west since European settlement and attributed as outlined above. For example, as described by Romme et al. (2009) for southwestern Colorado, including the Uncompahgre National Forest:

> *The combination of fire exclusion, selective logging, and favorable climatic conditions for young tree establishment in the early 20th century, has created an unusual stand structure in many warm-dry mixed conifer forests today. The large, old ponderosa pine and Douglas-fir trees that formerly dominated the canopy are gone, and the stands now are dominated by smaller, young individuals of pine, Douglas-fir, and white fir.* ***White fir especially has increased in density during the long fire-free period of the 20th century, and establishment of new ponderosa pine and Douglas-fir individuals has tapered off or stopped in many stands, probably because of the dense stand conditions.***

4.5.2 Effects of change in forest conditions on diseases and insects

If white fir has increased in abundance and other species become less abundant, as suggested by the preceding section, this means current stand conditions may be out of the presettlement range of variability. The current conditions greatly favor the disease and two insects of concern here. These agents, which have dominated recent vegetation management at Amphitheater Campground, are regulated primarily by stand conditions:

Composition. Stands comprised purely of host species ensure that the insect or pathogen can move from tree to tree unimpeded by nonhosts. This also maximizes population growth. Finally, it ensures maximum stand damage by the agents. For all practical purposes the stand occupied by Amphitheater Campground is pure host: white fir.

Maturity. Susceptibility to two of the agents, fir engraver and *H. occidentale*, increases with tree maturity. Trees in the overstory at Amphitheater are over 100 years old. The 1996 RMRIS data indicate the stand was 129 years old (McKenzie 1996).

Structure. One of the agents, WSB, is favored by dense, multi-story stand structure. This is because larvae that sail on threads from an overstory tree, in response to predators or in order to disperse, are likely to land on another tree where they can resume feeding. If they land on the ground, they are likely to be consumed by predators, such as ants and spiders.

In 1996, before the treatment of 1996-1997, three stand structures were present: single, two- and three-storied (McKenzie 1996). No doubt the treatment pushed it toward more single-story, and recent removals have reduced density, but multi-story conditions persist in parts of the campground, and 20 years of growth have closed crowns since then. Spruce budworm has persisted in causing significant damage to trees.

While “thin from below” is a common recommendation for WSB, one result in campgrounds is the persistence of large, mature trees in the overstory. These trees are increasingly susceptible to ARD and stem decays, which create structural defects that are not easy to detect. This can pose a risk to structures and people in a campground.

5. FUTURE MANAGEMENT

Maintaining mostly pure white fir in the campground, often in dense clumps, will result in continued insect and disease losses and continued expense and effort to remove dead and hazardous trees. Annosus root disease will persist, and because we usually cannot detect the disease in standing trees, it may lead to additional tree failures even with the best hazard tree inspection and management procedures.

A stand dominated by a mixture of other species will be healthier and safer in the long run and will require less management and maintenance. Some white fir could remain, especially if it is smaller trees.

We recommend the following actions:

Douglas-fir beetle. Each year, populations should be evaluated. When recommended by the Gunnison Service Center entomologist, MCH should be deployed on Douglas-fir near the campground.

Western spruce budworm. As white fir continue to be removed, stand conditions become less favorable for western spruce budworm. If the composition is further diversified through planting of other species, that will make WSB much less of a threat in the future. If it does remain severe and persistent in the interim, another round of silvicultural treatment could be considered to further thin and reduce the structural diversity in the white fir.

Fir engraver. Observations in the canyon suggest that the fir engraver outbreak may be on the wane. In the Campground, as large, old white fir and those with root disease are removed, the remaining trees will have more resources and be more vigorous. Reduction of WSB defoliation will also help. As with WSB, the long-term solution that is recommended is to push stand composition away from white fir dominance into a more diverse stand.

Direct management of annosus root disease. As soon as access and snow allow in early 2019, the nearly 200 stumps cut in 2018 should be inspected and any remaining live white fir within 30 feet and with targets should be removed. Campsites within striking distance of such trees should remain closed until trees can be removed. This should be done any time white fir stumps are created for any reason. Such stumps should continue to be sprayed promptly with Cellu-Treat.

Develop and implement an aggressive planting program to increase diversity. Species diversity is the long-term solution to almost all of these problems. The planting of ponderosa pine and juniper in the mid-1990s was a small step in the right direction. Although larger trees are mostly growing well, it seems that seedlings planted at that time south of the campground are languishing. The 2018 planting of limber pine seedlings add to this effort.

A more ambitious planting project is needed with a larger number of plants. It could involve a mixture of species and sources of planting material, and structures to protect seedlings from herbivory and trampling. Douglas-fir could be added to the mix, as it is only rarely a host of annosus root disease in Colorado. Ideally transplants could also be done—a transplant machine could be borrowed, rented or hired to transplant small trees from the surrounding forest in the Ouray area or some distance down-valley. This project may require additional white fir removals to create an environment where likelihood of planting survival is increased. White fir removals and planting of other species should especially focus on the parts of the Campground with ARD.

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