SALVAGING TIMBER; SCUTTLING FORESTS
The Ecological Effects of Post-Fire Salvage Logging

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INTRODUCTION

Most native species of plants and animals inhabiting forest ecosystems evolved with natural adaptations to the patterns and processes of fire disturbance and recovery.[1] One of the effects of fire disturbances is the creation of dead trees, both standing "snags" and downed logs. Fire-killed snags and logs serve vital roles in the structure and function of healthy forest ecosystems in general, and are especially important for natural recovery processes following fire events. [2] They provide food and shelter to wildlife, fish, and numerous insects, microbes, and fungi that are vital to post-fire recovery and long-term site productivity, they help retard surface water runoff and help retain and build soil, they help cycle nutrients and water to plants and soil, and snags that fall across streams provide links between terrestrial and aquatic ecosystems. [3] Indeed, a forest ecologist could argue that for the sake of healthy wildlife and plant populations, fertile soil, and clean water, large-diameter snags and logs are some of the most valuable trees in the forest.

The vital ecological importance of snags and logs and other "course woody debris" (tree trunks and branches greater than three inches in diameter) has only been recognized since the late 1970s. [4] Scientists have learned the vital uses of snags and logs for terrestrial and aquatic species. Unfortunately, the dominant view of forest managers since the 1930s has been that fire-killed trees are a wasted resource unless they are quickly "salvage" logged to extract their economic value for wood products. For decades the U.S. Forest Service and Bureau of Land Management have routinely salvage logged fire-killed trees using predominantly economic arguments, coupled with the assumption that the impacts of salvage logging were less harmful than "green tree" logging because the background effects of forest fires made the impacts of salvage logging relatively insignificant. However, this assumption that post-fire salvage logging causes "no significant effects" should be challenged by the growing weight of scientific evidence that demonstrates that salvage logging exacerbates the short-term adverse effects of fire, causes significant long-term environmental damage and ecological degradation of burned watersheds. [5]

Given that controversy over salvage logging has been growing since the big fires of the late 1980s, [6] some forest managers and elected officials have raised a new justification for salvage logging that capitalizes on the public's socially-conditioned fear of forest fires: the claim that fire-killed trees must be removed quickly before they fuel a future catastrophic wildfire. This is the so-called "reburn hypothesis" and it assumes that fire-killed trees pose an extreme fuel hazard and fire risk; therefore, by removing dead and dying trees, salvage logging can reduce the probability of a future high-intensity wildfire. Unfortunately for the proponents of the reburn hypothesis, there is no support in the scientific literature demonstrating that the probability for high-intensity fires is greater for areas of abundant fire-killed snags and logs compared to salvage logged areas. [7] The fact is, there simply is not a strong scientific or ecological basis for using post-fire salvage logging as a tool for wildfire prevention, post-fire "recovery" objectives, or ecosystem restoration objectives. [8]

On the contrary, a review of the effects of wildfire and salvage (Beschta et al. 1995) came to the conclusion that,

"Human intervention on the post-fire landscape may substantially or completely delay recovery, remove the elements of recovery, or accentuate the damage…In this light, there is little reason to believe that post-fire salvage logging has any positive ecological benefits, particularly for aquatic ecosystems. There is considerable evidence that persistent, significant adverse environmental impacts are likely to result from salvage logging." [9]

They further indicated that, *"There is no ecological need for immediate intervention on the post-fire landscape,"* and advocated that *"Human intervention should not be permitted unless and until it is determined that natural recovery processes are not occurring."* [10]

The following provides scientific evidence indicating that post-fire salvage logging, far from being an environmentally benign or beneficial management activity, can have significant adverse impacts upon a wide range of forest resources and ecosystem components.

SALVAGE LOGGING CAUSES SIGNIFICANT EFFECTS ON FOREST SOILS

Fires can cause short-term adverse effects on soils such as increasing erosion from removal of vegetative cover that exposes soils to rain and snowfall and subsequent runoff. These impacts vary depending on a number of environmental factors, including the severity of the fire, the steepness of slopes, natural erodibility of soil parent material, precipitation events, and other factors, but in general, burned soils are highly vulnerable to additional disturbance. [11] One of the natural recovery processes initiated by fires is that when large-diameter snags fall to the ground across the slope contour, they serve as natural check-dams that slow runoff and retain soil, which is especially important on steep slopes. [12] Salvage logging directly displaces soils by felling trees and dragging large-diameter logs across the exposed ground surface. But salvage logging also indirectly facilitates erosion through removal of large snags and logs that would have naturally slowed overland flow and retained soil.

In a study that compared five different post-fire salvage logging methods on ponderosa pine sites in eastern Washington, conventional tractor-based systems disturbed nearly 75% of the area, and caused erosion on over 30% of the area, but even helicopter logging caused soil disturbance on 12% of the area. [13] In addition to erosion, salvage logging is also known to cause soil compaction. [14] This also adversely impacts post-fire recovery and long-term site productivity by eliminating pore spaces in soil that retain air, water, and facilitate spread of fine roots. The result of decreased water infiltration and retention is increased surface runoff, sheetwash erosion, and subsequent sedimentation in streams.

Salvage logging also causes nutrient losses not only directly through removal of topsoil, but indirectly through the removal of snags and logs. Although most nutrients are stored in foliage and limbs, large logs also function as an important source of soil organic matter and a long-lasting nutrient reservoir for microorganisms, plants, and animals. [15] In fact, in Douglas-fir ecosystems of the Cascades, up to 30% or more of upper soil layers are composed of old decayed logs. [16] It can take several centuries, even millennia, for forest soil to develop and become productive. Thus, the problem with soil displacement, compaction, and erosion is that once topsoil has been removed from the ecosystem, it constitutes an irreplaceable loss of fertility and productivity, at least in human timescales. [17] Consequently, protection of the topsoil is a primary requisite for aiding post-fire recovery and maintaining long-term forest ecosystem health. [18]

SALVAGE LOGGING CAUSES SIGNIFICANT EFFECTS ON FOREST STREAMS

Fires can affect stream systems through removal of forest litter and duff layers which increases erosion and sedimentation, and through changes in peak flows and water yields. When vegetation is killed, evapotranspiration is halted; thus, instead of plants taking up water through roots and stems, water remains in soil to flow along slope gradients into streams. Consumption of tree canopies by fire can eliminate their ability to intercept rain and snow, causing increased susceptibility to rainsplash and sheetwash erosion, and snowfall accumulations may experience more rapid spring snowmelt. In some instances, high-severity fires create physical and chemical changes that can cause "hydrophobic" soil layers that repel water infiltration, and lead to accelerated overland flow. All of these natural fire-related processes can increase surface water runoff, water yields and peak streamflows, leading to increased potential for erosion, landslides and floods, and subsequent sedimentation of streams. Simple logic as well as empirical research indicates that the net effect of high-severity wildfires is to increase the sensitivity of sites to further soil disturbance. [19]

In the short-term, the adverse effects of high-severity fires--decreased infiltration, increased overland flow, and excess sedimentation in streams--can be greatly exacerbated by the soil disturbance caused by salvage logging. [20] In the long-term, extracting snags that would have become downed logs eliminates their ability to intercept precipitation and retard erosion. Large-diameter logs are also capable of storing vast amounts of water, When logs fall across streams, they trap sediment and form backwater areas and "stair-step" stream profiles that dissipate the energy of flowing water even on high gradient slopes. [21] These check-dams and backwater pools help maintain clean water and create vital resting, feeding, and spawning habitat for aquatic species such as salmon.

Additionally, the interior of large-diameter logs are capable of storing vast amounts of water, releasing water slowly into soil and streams over time, which provides long-lasting, high-moisture microsites that aid forest recovery during drought periods or fires. [22] In a study of downed logs on a dry forest site in the Siskiyou National Forest that did not have any precipitation for 77 days prior to a high-intensity wildfire, so much water was discovered in the interior of sampled logs that the researchers could literally wring the water out of the wood. [23] A study in the Cascades indicated that decayed logs averaged 350% moisture content in the winter, and 250% in the summer. [24] This water in downed wood aids the establishment of pioneering plants following fire, and maintains adjacent vegetation during drought periods when soil moisture would otherwise be low. Removing large snags and logs by salvage logging eliminates these microhabitats on uplands and can adversely affect water quality and aquatic habitats.

SALVAGE LOGGING CAUSES SIGNIFICANT EFFECTS ON FOREST VEGETATION

Salvage logging can decrease natural plant regeneration, both by mechanical damage from felling and dragging logs across the ground surface, and by changing the microclimate through removing protective shade. [25] The primary effects of removing shade-producing large snags and logs are increased solar radiation causing higher site temperatures and lower relative humidities during daytime, increased heat loss during night, and more extreme temperature fluctuations overall. [26] Soils and vegetation are also more exposed to the drying effects of increased surface winds.

Even though high-intensity fire may consume tree crowns, the residual shade provided by large-diameter snags and logs is often vital for retaining soil moisture for vulnerable tree seedlings, and for moderating temperature increases in streams for sensitive fish species. [27] For example, on a hypothetical south-facing 50% gradient slope located at 45 degrees latitude, 100 trees averaging 150 feet tall and 24 inches wide would provide 6,900 square feet of shade, or 14% of the slope surface during the course of a day. [28] In an empirical study of headwaters burned by high-intensity wildfire during the 1987 Silver Fire, researchers discovered that dead trees provided 57% of the shade for streams; this was three times more shade than derived by the surrounding topography, and twice as much shade as produced by the remaining live vegetation. [29] In addition to aiding survival of vegetation and fish, the microclimatic effects of shade-producing snags and logs also help mitigate fire hazard. [30] These ecological benefits of fire-killed snags and logs on moderating the microclimate are sacrificed by salvage timber extraction.

SALVAGE LOGGING CAUSES SIGNIFICANT EFFECTS ON WILDLIFE

Although fires can cause mortality of individual animals, in general, wildlife populations often respond positively to fires and in fact are attracted to burns for the flush of nutrients and new vegetation, and the pulse of new snags and logs, that result from fires. [31] Cavity-nesting species are prime beneficiaries of fires, and 62 species of birds and mammals use snags, broken-topped, diseased or otherwise "defective" trees for roosting, denning, foraging, or other life functions. [32] In the Douglas-fir region of western Oregon, approximately 20% (34 species) of all bird species depend on snags for nesting for foraging. [33] In bird studies conducted in the Foothills and Star Gulch Fires, 87 bird species were recorded in the burns, 43 species built nests, and 67% of those species were neotropical migrants. [34] In another field study, 96% of all dead trees within monitoring plots showed evidence of foraging by woodpeckers within one year after the fire. [35] Woodpeckers are an especially important species, since they excavate cavities essential for non-excavating species such as bats and squirrels. Recent studies indicate that current management guidelines for maintaining snag density may be too low to provide for desired population levels of woodpeckers because the guidelines only focus on their nesting requirements. [36]

Relatively large diameter trees (e.g. greater than 20 inches DBH) are not only more utilized by cavity-nesting wildlife, but they also stand longer and have greater longevity as downed logs than smaller-diameter trees. [37] Large-diameter trees enable bigger cavities for larger-sized animals, and the deep furrows of their bark provide greater food supply of insects. [38] In addition to snags, large-diameter logs are utilized for feeding, shelter, and reproduction by a number of mammals, reptiles, amphibians, and insects. [39] The density and distribution of snags and logs in Douglas-fir forest ecosystems greatly influences the density and distribution of snag/log-dependent wildlife. [40] Empirical studies have found that the range of snag diameters, and average length and frequency of downed logs in streams was greatest in unmanaged old-growth stands compared to salvage-logged areas. [41] In fact, forest managers are finding it difficult to meet the number, density, size, and condition of snags required by their Forest Plans due to past salvage logging and old-growth clearcutting that removed snags. [42]

Far from being a "wasted resource," large-diameter snags and logs play critical structural and functional roles in maintaining healthy, diverse wildlife populations. [43] Indeed, an ecologist could argue that a dead tree sustains more wildlife than a live tree. However, salvage logging primarily targets larger-diameter trees because they typically represent a relatively high commercial value.

SALVAGE LOGGING CAN INCREASE FIRE RISKS AND FUEL HAZARDS

Salvage logging proponents may acknowledge the essential ecological roles and values that snags and logs provide for soils, streams, vegetation, and wildlife, but these values may be negated because of a desire to reduce fire risks and fuel hazards. However, as previously noted, there are no scientific studies demonstrating that large-diameter fire-killed snags pose an increased risk of high-intensity reburns, or that salvage logging effectively reduces fire risk. [44] On the contrary, there is growing scientific evidence that large-diameter snags and logs have naturally low flammability while post-fire salvage logging itself may actually increase the rate of spread, intensity, and severity of fires.

Large snags are important ignition sources during lightning storms, but from the standpoint of the physics of combustion, it is the fine fuels such as grass, needles, and small limbs that carry fire, not large dead woody material. [45] Large-diameter fuels have naturally low flammability because they have a low surface-area-to-volume ratio (SAVR) that limits the amount of oxygen available for combustion. Conversely, smaller fuel particles have higher SAVR values which fuel higher rates of spread and fireline intensity. Consequently, only dead fuels less than three inches in diameter and live fuels less than 1/4 inch in diameter are used in fire spread models because it is these fine fuels that propagate fire; large-diameter fuels (greater than three inches in diameter) are not included in the calculations for fire spread at all. [46] Furthermore, large diameter fuels retain moisture longer and later into the season, further reducing their flammability particularly when wildfire potential is at its greatest. [47]

Large standing tree boles, dead or alive, are typically unavailable for combustion especially when fires have removed underlying ground vegetation and downed fuels. [48] While dead trees may be more flammable for 2-3 years after a fire while their dead needles are retained, after their needles drop to the ground, crown fire hazard essentially drops to zero, and the standing tree boles do not readily ignite. [49] Most larger tree boles are not consumed by fire even if killed, and then they often remain standing for decades, providing biological legacy and ecological values essential for natural post-fire recovery processes. [50] When snags fall to the ground then their relative flammability increases, but it may take as long as 20 years for a pulse of burned ponderosa pine trees 6-9 inches DBH to fall, and recent research suggests that larger ponderosa pine trees can remain standing up to 80 years. [51] Large-diameter downed logs in isolation do not burn well, if at all, unless they are very dry and placed in close proximity to each other (approximately two tree diameters apart). [52] On the other hand, well decayed logs can burn easily via glowing combustion, but this does not cause extreme fire behavior. Decayed logs can smolder for long periods of time, causing high severity, but these effects are localized to underlying and adjacent soil. [53] Snags and logs can emit burning embers that if lofted by wind can cause spotfires, but these embers can only ignite in fine fuels, not other large snags or logs. The low flammability of large-diameter downed logs is further mitigated by their interior water content which increases with the length of time they are on the forest floor and their subsequent stage of decay. [54]

Salvage logging typically removes the larger diameter trees that have the most commercial value but least flammability, but leaves behind the smaller diameter trees and logging slash that have little to no commercial value but are the most flammable fuels. In calculating the fire hazard of slash-laden salvage logging units, they are assigned fuel model 12, one of the highest ratings for rapid fire spread and fireline intensity. [55] Indeed, in a study modeling the effects of various fuels treatments in the Sierra Nevada, lop-and-scatter, group selection (small clearcuts), and salvage logging operations that left the slash and adjacent landscape untreated produced the highest fireline intensity, heat per unit area, rate of spread, area burned, and scorch height of all other fuels method treatments because they increased the flammable surface fuel load. [56] The researcher concluded that salvage logging would make the fire situation more severe because removing only large, standing trees will not reduce fire hazard in Sierra Nevada forest ecosystems. [57] The same principles of fire physics contrasting the flammability of large-diameter logs versus small-diameter salvage logging slash applies to other ecosystems and regions, as well.

CONCLUSION

Fire-created snags and logs serve many vital ecological functions for forest soils, streams, vegetation, and wildlife. Large-diameter snags and logs can also help mitigate conditions that lead to high-intensity fires, and aid post-fire natural recovery processes. Conversely, commercially extracting fire-killed trees via salvage logging causes significant short- and long-term adverse effects on forest ecosystem structures, functions and processes. Considering the wide array of vital ecological services that snags and logs provide, the term "salvage" is appropriate only for logging operations in which the primary management objective is extraction of commodity timber values at the expense of other economic and ecological values. Given these environmental impacts and ecological tradeoffs, the claim that salvage logging is a valid tool for forest recovery, rehabilitation, or restoration must be challenged. The more scientists learn about the ecological values of large fire-killed snags and logs, the more clear it becomes that "salvaging" burned trees is scuttling forest ecosystems.

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