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Decays of White, Grand, and Red Firs

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White fir (*Abies concolor*), grand fir (*Abies grandis*), and red fir (California and Shasta red fir, *Abies magnifica* and *Abies magnifica* var. *shastensis*) are ecologically and economically important conifer species in moist forests in many areas of western North America. White fir is the most widespread of the three species. Two varieties of white fir are recognized: Rocky Mountain white fir (*Abies concolor* var. *concolor*) in southeastern Idaho through central Colorado to northern Mexico, and California white fir (*Abies concolor* var. *lowiana*) in western Oregon and northwestern California, central Oregon, and the Sierra Nevada. Grand fir inhabits stream bottoms, valleys, and lower-elevation mountain slopes in the Pacific Northwest, and northern Idaho and Montana west of the Continental Divide. Red fir dominates large areas of cool, moist forest above 5000 feet in the Sierra Nevada of California. Shasta red fir occurs in similar environments in the northwestern Coast Ranges of California and the southern Cascade Mountains in California and Oregon.

Figure 1. Fallen grand fir exposing rust-red stringy rot and hollow caused by Indian paint fungus.

Many fungi invade and decompose wood in tree stems (Figure 1). Some species are restricted to either heartwood or sapwood, while some species decay both heartwood and sapwood. True heart-rot fungi infect only living trees and are confined to the heartwood. They do not need natural openings or wounds to penetrate the bark, but can infect through living, undamaged branches and stems. True heart-rot fungi are not primary colonizers of dead wood, although some species continue to

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develop in the wood for a short time after trees die. Many decay fungi require openings in the bark for entry. True firs do not have a primary resin system, so exposed wood is highly susceptible to fungal infection. Openings can result from wounds caused by fire, weather, animals, humans, or from natural causes such as branch stubs, open knots, dwarf mistletoe cankers, and dead branches. Wounds can also exacerbate dormant infections. Decay fungi that commonly occur only in the base and roots of trees are known as butt rots. Some of these fungi also cause root diseases. Still other fungi primarily decay wood in dead trees or in dead portions of living trees. Some species continue to decay logs and lumber in service. Some also decay wood and roots on the forest floor and in the soil.

Vegetation Dynamics and Ecological Role

In general, decay is most prevalent in older, larger trees, due at least in part to accumulation of wounds and an increase in the proportion of heartwood over time. Decay fungi that become abundant in old forests may be important as disturbance agents that initiate and sustain small canopy gaps. This is especially true in areas where large-scale disturbances such as windstorms or fires are infrequent. In these situations, breakage associated with decay may be one of the main means by which large trees are brought down, creating small gaps. In these gaps regeneration of shade-tolerant tree species can occur, and shrub and herbaceous vegetation can develop. Structural complexity of the forest is increased by the presence of down wood, tree regeneration, and understory vegetation. Decayed wood added to the forest floor contributes to the physical structure, nutrient composition, and moisture-holding capacity of the soil. It provides food and micro-habitats for a myriad of decomposer organisms.

Figure 2. Bushy-tailed woodrat in a hollow grand fir.

Hollows in trees and logs resulting from the action of certain decay fungi are critical components of habitat for many wildlife species. Woodpeckers, black bears, American martens, Vaux's swifts, bats, flying squirrels, and bushy-tailed woodrats are among the species using hollow trees for dens, roosts, nests, and foraging sites (Figure 2). Fungi that decay heartwood in living trees are very important in the formation of hollow trees and logs. Such decay is compartmentalized within the cylinder of heartwood that was present when the tree was wounded. Hollows occur in the advanced stages of decay when the cylinder of heartwood is weakened to the point that it collapses inside the tree. White, grand, and red firs are important contributors to hollow-tree habitat caused by decay fungi. Hollow chambers in large-diameter trees are most useful to wildlife. Because it takes many decades for large trees with advanced decay to develop,

large hollow trees are found primarily in late-successional and old-growth stands.

Impact and Identification

Fungi cause significant amounts of decay in white, grand, and red firs, resulting in loss of merchantable timber, reduction in wood quality, windthrow, and breakage. Decay is generally more extensive in white fir and grand fir than in red fir. Trees with decay in recreation areas and other developed sites can be extremely dangerous as they are more prone to failure than sound trees. Decay fungi play very important roles in the ecosystem by creating structural diversity, returning nutrients to the soil, and providing crucial wildlife habitat. Young, uninjured fir trees are normally free from decay, but wounded fir trees and fir trees over 140 years old often have significant decay.

Decay can be difficult to identify in the early stages. Incipient decay caused by some fungi may cause color changes in wood, but other changes are more cryptic. Fruiting bodies (conks) are usually good indicators of decay, but frequently are not present. Conks vary from fleshy mushrooms to woody shelf-like structures. They can be annual or perennial. Some decay fungi continue to produce conks on down trees or stored logs. Table 1 summarizes the physical characteristics of the common decay fungi affecting white, grand, and red firs. *Armillaria* species and *Heterobasidion occidentale*, fungi that cause root disease in true firs as well as butt rot, are covered in Forest Insect and Disease Leaflet (FIDL) 78, *Armillaria Root Disease,* and FIDL 172, *Annosus Root Disease of Western Conifers*.

Decay fungi also differ according to the type of rot they cause: either white rot or brown rot. Distinguishing between white and brown rot can aid in identifying the causal fungus and the effects of decay on wood structure and use. White rots are caused by fungi that produce enzymes that decay both the cellulose and lignin in wood. The decayed material may form pockets and is often pulpy, fibrous, laminated, or stringy. It is usually white, tan, or brownish. In advanced stages the wood may be completely destroyed, leaving a hollow tree or log. Pulp yields from wood containing white rot are reduced, but pulp quality is not greatly affected. Most of the common decay fungi affecting white, grand, and red firs are white rots. Brown rots destroy cellulose and leave the lignin, resulting in a column filled with a dry, brown, crumbly mass. The decayed material is fragile and often disintegrates into small cubes (Figure 3). Wood colonized by brown-rot fungi, even in the earliest visible stages of decay, is greatly reduced in strength and of little use in service. Since the cellulose fibers are destroyed, wood affected by brown rot has little value for pulp.

Figure 3. Advanced brown cubical decay caused by velvet-top fungus.

In the absence of fruiting bodies or visible decay in true firs, symptoms such as fire scars, wounds, dead tops, broken or bayonet tops, dwarf

Table 1. Characteristics of common decay fungi affecting white, grand, and red firs

NAME OF ROT	CAUSAL FUNGUS *Current name* *(Proposed name)* Common name	PART OF TREE DECAYED	FIELD ID	DECAY TYPE	DECAY	FRUITING BODY
Rust-Red Stringy Rot	*Echinodontium tinctorium* Indian paint fungus	Heartwood, middle to upper stem	Conks, rusty knots, older trees	White	Rusty red, soft and stringy, separates at annual rings	Perennial conk, often under tree limbs; top black, rough, cracked; bottom toothed, gray; interior bright brick-red
Red Ring Rot, or White Speck	*Phellinus pini* *(Porodaedalea pini)* Ring scale fungus	Heartwood, throughout stem	Conks, punk knots, swollen knots	White	Pocket rot, spindle shaped pockets, firm wood in between	Perennial conk; top dark brown to black, concentrically furrowed, scalloped margin; bottom brown, irregular pores
Red Ring Rot Canker	*Phellinus cancriformans* *(Porodaedalea cancriformans)* Butterfly conk	Heartwood, lower to middle stem	Conks, sunken cankers	White	Pocket rot, spindle shaped pockets, firm wood in between	Perennial conk; top dark brown to black; bottom brown, irregular pores, occur in dense clusters in sunken cankers
Schweinitzii Root and Butt Rot, or Brown Cubical Butt Rot	*Phaeolus schweinitzii* Velvet top or Cow-pie fungus	Heartwood, roots and butt	Conks at tree base or on ground near base, swollen butts	Brown	Light to dark brown cubes with resinous white fungal tissue in cracks	Annual but persistent conk, round with sunken center, short stalk; top velvety, yellow to reddish-brown when new, brittle, dark brown when old; bottom green to brown pores
Mottled Rot	*Pholiota adiposa and Pholiota limonella* Yellow cap fungus and lemon cap fungus	Heartwood, lower to middle stem	Mushrooms, hollow stems	White	Honey colored with brown streaks, wood separates at annual rings	Gilled mushroom, appears in fall in groups from common base on trees and stumps, short-lived, fleshy, sticky when wet; top and stem yellow; bottom yellow to brownish gills
Brown Cubical Rot	*Laetiporus sulphureus* *(Laetiporus conifericola)* Sulfur fungus or Chicken-of-the-woods	Heartwood, occasionally sapwood, lower stem and butt	Conks on wounds in live trees, stumps, snags, downed wood	Brown	Medium sized reddish brown cubes, cracks often filled with mats of white fungal tissue	Annual conk, shelving, overlapping; top bright flame orange; bottom sulfur yellow; fade to chalky white; falls from tree; rarely found on live trees
Yellow Pitted Rot	*Hericium abietis* Coral fungus	Heartwood, lower stem and butt	Fruiting bodies	White	Pocket rot, firm wood between. Pits with blunt ends, honeycomb appearance at log ends	Conspicuous fruiting body, soft, creamy, coral-like with downward pointing teeth, infrequent, short-lived
Brown top rot	*Fomitopsis cajanderi* Rose-colored conk	Heartwood, broken tops < 6" in diameter, branch stubs	Conks, old broken tops or bayonet tops	Brown	Yellow to reddish-brown, soft, irregular cubes, thin mats of white to rose-colored fungal tissue in cracks	Perennial conk, woody, bracket-like, often clustered or stacked, top rough, brown to black; bottom pink to rose-colored
Brown Crumbly Rot	*Fomitopsis pinicola* Red belt fungus	Sapwood first, then heartwood	Conks on dead trees, dead portion of live trees, logs, stumps	Brown	Crumbly, rough small cubes, light reddish brown	Perennial conk, leathery to woody, bracket-shaped, white and round when young; when older, top dark gray to black and bottom creamy with conspicuous red margin
Gray brown sap rot	*Cryptoporus volvatus* Pouch fungus	Sapwood throughout stem	Conks on recently dead trees	Brown	Initially soft, gray to cream color, later light brown, cubical, crumbly	Annual conk, small, round, soft, white when young. Dry and tan when older. May be very numerous on tree

Table 2. Guidelines for estimating decay (cull) in white, grand, and red firs

NAME OF ROT *(Causal fungus)*	California[1]	Pacific Northwest[2]	Western Oregon[3]
Rust Red Stringy Rot (*Echinodontium tinctorium*)	• Single small conk on young tree, deduct 8 ft. above and 8 ft. below conk • Lowest conk 0-32 ft from ground, deduct 12 ft below lowest to 21 ft above highest conk • Lowest conk > 32 ft. from ground **and**: – in bottom ⅓ of tree, cull lower ⅔ of tree – in middle ⅓ of tree, deduct 20 ft. below lowest to 21 ft. above highest conk – in top ⅓ of tree: cull upper ⅔ of tree • 2 or more conks ≥ 25 ft. apart, cull entire tree	Tree dbh: • < 19", deduct 18 ft. above and 13 ft. below • 19.0-26.9", deduct 20 ft. above and 18 ft. below • 27.0-34.9", deduct 20 ft. above and 21 ft. below • ≥ 35.0" , deduct 20 ft. above and 22 ft. below	White and red fir in SW Oregon: • Single small young conk, deduct 8 ft. above and 8 ft. below conk • Lowest conk 0-32 ft from ground, deduct 12 ft. below conk, 21 feet above highest conk • Lowest conk > 32 ft. from ground, deduct 20 ft. below lowest conk, 21 above highest conk • Conks in bottom ⅓ of tree, cull middle and bottom ⅓ • Conks in top ⅓ of tree, cull top and middle ⅓ • 2 or more conks ≥ 25 ft. apart, cull entire tree
Red Ring Rot, or White Speck (*Phellinus pini*)	• Tree age < 150 (or < 24" dbh) – Deduct 8 ft. above and below each conk – Deduct 4 ft. above and below each swollen knot • Tree age ≥ 150 years (or ≥ 24" dbh) – Deduct 16 ft. above and below each conk – Deduct 8 ft. above highest to 8 ft. below lowest swollen knot	Tree age: • < 200 years, deduct 8 ft. above and 8 ft. below • ≥ 200 years, deduct 16 ft. above and 16 ft. below	Tree age > 125 years: • Conks – Deduct 16 ft. for a single conk; – Deduct 16 ft. above and below for a group of conks • Swollen knots – Deduct 8 ft. for a single swollen knot – Deduct 8 ft. above and below for a group of swollen knots
Red Ring Rot Canker (*Phellinus cancriformans*)	Same as Red Ring Rot	Same as Red Ring Rot	White and red fir in SW Oregon, deduct 4 ft. below the bottom of the lowest canker or conk, and 6 ft. above the top of the highest
Schweinitzii Root and Butt Rot, or Brown Cubical Butt Rot (*Phaeolus schweinitzii*)	• Conk on bole of tree, cull butt log • Conk on ground or roots, deduct 8 feet of butt log	• Conk on ground or at base, deduct 8 ft. above; • Conk and basal scar, deduct 2 ft. above top of scar or 8 ft. of butt, whichever is greater	None
Mottled Rot (*Pholiota adiposa and Pholiota limonella*)	None	• Conk, deduct 4 ft. below and above; • Conk and scar, deduct 2 ft. above and below scar, or 4 ft. above and below conk, whichever greater	White and red fir in SW Oregon, deduct 1 ft. below the bottom and 2 ft. above the top of a wound
Brown Cubical Rot (*Laetiporus sulphureus*)	• One conk indicates total cull • Decay visible in basal scar, deduct 4-6 ft. above top of scar	Cull from ground to 8 ft. above highest conk	None
Yellow Pitted Rot (*Hericium abietis*)	None	• Conk, deduct 4 ft. below and above; • Conk and scar, deduct 2 ft. above and below scar, or 4 ft. above and below conk, whichever is greater	White and grand fir in SW Oregon, deduct 1 ft. below the bottom and 2 ft. above the top of a wound
Brown top rot (*Fomitopsis cajanderi*)	Deduct 8 feet above and below each conk or group of conks	Cull from top of tree down to 16 ft. below lowest conk	None
Brown Crumbly Rot (*Fomitopsis pinicola*)	None	Deduct 6 ft. above and 4 ft. below each conk	None
Gray brown sap rot (*Cryptoporus volvatus*)	None	Old conks, 1 to 4 inch diameter reduction to scaling cylinder[4]	None

[1]USDA Forest Service. 2005. Chapter 20- Estimating Tree Volume and Weight. Timber Cruising Handbook. R5 FSH Supp. 2409.12-2005-2. 25 p.
[2]USDA Forest Service. 1986. A Guide to Estimating Decay in the Pacific Northwest. Timber Cruising Handbook. R6 FSH Supp. 1 5/86 Table V. 2 p.
[3]Aho, Paul E. 1982. Indicators of cull in western Oregon conifers. USDA Forest Service, PNW-GTR-144. Portland, OR. 17 p.
[4]Goheen, E.M and E.A. Willhite. 2006. Field Guide to Common Diseases and Insect Pests of Oregon and Washington Conifers. USDA Forest Service R6-NR-FID-PR-01-06, Pacific Northwest Region, Portland, OR. 327 p.

mistletoe stem swellings, or cavities excavated by birds are good indicators that internal decay is present. Frost cracks by themselves do not indicate internal decay, but should be examined closely for additional indicators. It is also common for trees with no visible indicators to have substantial amounts of internal decay. Table 2 summarizes guidelines developed for California, the Pacific Northwest, and western Oregon to estimate the extent of decay in white, grand, and red firs caused by common decay fungi. Estimates for other regions should be based on local surveys as the extent of decay varies from one region to another.

Rust-red Stringy Rot

Rust-red stringy rot, a white rot caused by the Indian paint fungus (*Echinodontium tinctorium*), is a true heart rot that accounts for a major portion of the stem decay in mature grand and white firs in eastern Oregon and Washington, northern Idaho, and western Montana. It is rare in grand firs west of the Cascade crest. It is responsible for most of the heart rot of white firs in Arizona and New Mexico and is also common in white firs in southern Colorado. In California, Indian paint fungus is less common on red and white firs than the yellow cap fungus, but is still responsible for substantial decay. Decay caused by Indian paint fungus is most common in the middle to upper stem. The fungus infects small (less than two millimeter diameter) dead branchlet stubs just before they are overgrown by the branch. The fungus then becomes dormant until the tree is wounded near the infection. Conks of Indian paint fungus are perennial, large, hoof-shaped, and woody. Tops are typically black and cracked, and undersides are gray and toothed (Figure 4). Interiors are a characteristic orange-red color. Advanced decay is reddish-yellow to brown, and fibrous or stringy. This fungus often causes separation between springwood and latewood resulting in a laminated decay.

Figure 4. Conk of Indian paint fungus showing the cracked, black top and gray, toothed underside.

Red Ring Rot

Red ring rot, a white rot caused by the ring-scale fungus (*Phellinus pini*), is another true heart rot that is widespread in western North America. It causes substantial decay in many conifer species, including true firs. Red ring rot can be found throughout the tree stem, but is most common in the middle to upper portion. The fungus is thought to infect trees through live and dead branches and branch stubs, but may also gain entry through wounds. Conks are brownish-black and rough on top. Undersides are cinnamon-brown or gold with irregularly shaped pores (Figure 5). Conks are often formed at old branch stubs and occasionally on branches. Swollen knots filled with fungal tissue called "punk knots" are also common. Advanced decay results in small, spindle-shaped pockets filled with white fibers with firm wood in between. The closely related red ring rot canker fungus

Figure 5. Conk of the ring-scale fungus showing the brownish-black, roughened top and cinnamon-brown underside.

(*Phellinus cancriformans*) is found primarily in southern Oregon and northern California. It affects all true firs including white, grand, and red firs. Red ring rot canker is generally found in the lower stem and sometimes in mid-stem. Conks, known as butterfly conks, are similar in texture and color to ring-scale fungus conks, but are smaller and produced in clusters in sunken areas on the stem (Figure 6). These sunken areas, or cankers, are the result of the fungus invading and killing cambium in a limited area of the stem. The underlying decay is similar to that caused by ring-scale fungus; however, there is less sound wood remaining, hence red ring rot canker is much more commonly associated with stem breakage than red ring rot.

Figure 6. Clusters of butterfly conks in a sunken canker on a white fir stem.

Schweinitzii Root and Butt Rot

Schweinitzii root and butt rot is caused by the velvet-top fungus (*Phaeolus schweinitzii*). This fungus is widespread in conifer forests. It decays heartwood, causing a brown rot in the roots and butts of older conifers including white, grand, and red firs, and often results in breakage near the base. Fine roots are infected by spores that percolate into the soil. Fire scars and other basal wounds probably exacerbate decay in previously infected roots and butts. This fungus produces large annual conks, usually on the ground near the bases of infected trees and occasionally on their stems. The upper surface is velvety in texture and red-brown or yellowish when first produced in autumn. Although produced annually, the old dead conks can persist for years. As they age they become dark brown and brittle, earning the name “cow-pie fungus”. Advanced decay is reddish-brown and cubical with white fungal material in the cracks.

Mottled Rot

Mottled rot, caused by both the yellow cap fungus (*Pholiota adiposa*) and the lemon cap fungus (*Pholiota limonella*), is a major source of white rot in older grand, white, and red firs in eastern and southern Oregon and in California. Both yellow cap and lemon cap fungi are believed to gain entry to the heartwood through fire scars and other wounds. The resulting decay is primarily in the middle and lower stem. Both species produce annual clusters

Figure 7. A cluster of fleshy, yellow, gilled mushrooms of the yellow cap fungus.

of yellow mushrooms with yellowish-brown gills that last only a few weeks, usually after autumn rain (Figure 7). Advanced decay is brown and mottled. It is often associated with wounds, scars, frost cracks, and dwarf mistletoe cankers.

Brown Cubical Rot

Brown cubical rot, caused by the sulfur fungus (*Laetiporus sulphureus*), is a common brown rot in conifers and hardwoods throughout North America. In western forests it is most common in true firs, especially red firs. This fungus also gains entry to the heartwood through fire scars and other basal and stem wounds. Decay is usually limited to the butt and lower stem. Conks appear in late summer or fall and are very conspicuous. They are annual, clustered, shelf-like, soft, and fleshy. Tops are bright orange when fresh (Figure 8). Undersides are sulfur yellow. As they age they become brittle and chalky white. They usually appear on stumps, snags, old wounds, or at the bases of live trees. Advanced decay is reddish-brown and cubical with cracks that are often filled with white fungal material.

Figure 8. Large clusters of fresh conks of the sulfur fungus associated with old wounds on a red fir snag.

Yellow Pitted Rot

Yellow pitted rot is caused by the coral fungus, *Hericium abietis*. It is an important decay organism in living and dead trees, down wood, and logs in the mountains of Oregon, Washington, and northern California. The fungus invades the heartwood through wounds, causing a white rot. There is also some evidence that it may infect through branchlet stubs, similar to the Indian paint fungus. The decay is found in the butt and lower stem of live trees, and also in stumps, snags, and down wood. Fruiting bodies of the coral fungus are produced in autumn, but only infrequently. Their presence indicates extensive decay. The fruiting bodies are large, soft, white to buff-colored, and coral-like with downward-pointing spines or teeth. Advanced decay results in long spindle-shaped pockets separated by firm wood (Figure 9). At the ends of

logs it may resemble honeycombs. Decay will continue to develop in stored logs.

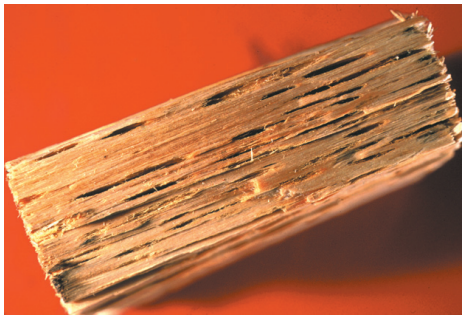

Figure 9. Advanced decay caused by the coral fungus showing the long, spindle-shaped pockets, or pits, with firm wood in between.

Brown Top Rot

Brown top rot, caused by the fungus *Fomitopsis cajanderi*, is a widespread brown rot in conifer forests in western North America. Grand firs are more commonly infected than white firs or red firs, although the fungus and its associated decay are occasionally found in white firs in Arizona and New Mexico, and red firs in California. The fungus primarily infects through wounds caused by broken tops that are less than six inches in diameter, and through branch stubs. Decay develops rapidly, forming soft, irregular yellow to reddish-brown cubes. Conks are perennial, woody, and shelf-like or hoof-shaped. They are brown or black, rough on top, and rose-colored underneath, often appearing in clusters. Decay may continue to develop in piled logs and wood in service. The impact of this fungus is most noticeable on sites where storms cause frequent broken tops.

Brown Crumbly Rot

Brown crumbly rot, caused by the red belt fungus (*Fomitopsis pinicola*), is one of the most common brown rots in western conifer forests. It is abundant in white, grand, and red firs. It most commonly infects and decays dead and down trees, but occasionally causes decay in dead portions of live trees such as those with wounds, broken tops, strip-kill by bark beetles, or stem swellings caused by dwarf mistletoe infection. Conks are perennial, woody, and shelf-like or hoof-shaped. The top is smooth, and gray or black with a wide red margin (Figure 10). The underside is white or yellowish. Decay develops first in sapwood and then progresses into heartwood. Advanced decay is brown and cubical.

Figure 10. Conk of the red belt fungus showing the smooth black top with its wide red margin. The white pore layer underneath is visible along the edge.

Gray-brown Sap Rot

Gray-brown sap rot is caused by the pouch fungus (*Cryptoporus volvatus*). It is a very common brown rot in recently dead conifers throughout western North America, especially those that are insect-infested or fire-killed. Spores of the fungus are introduced into trees by bark beetles and wood borers, making the presence of pouch fungus conks a good indication

that trees were infested by bark beetles or wood borers. Conks develop on tree stems, often in large numbers. Conks usually appear within 12 to 18 months after the death of a tree. They are small, soft, round, and white when fresh, becoming dry and tan with age. Decay develops rapidly, but is normally limited to the outer one-half to two inches of sapwood. Initially the decayed wood becomes soft, and gray or cream-colored. In more advanced stages it is light brown, cubical, and crumbly. The pouch fungus plays an important role in beginning the process of recycling dead wood and contributes to the rapid failure of many beetle-killed trees. It may affect merchantable volume of salvage logs if harvest is delayed, especially in small trees.

Management

Management objectives will determine the amount of decay that is acceptable in a given stand. As old-growth stands have been harvested and replaced with more uniform, managed, young-growth stands, the overall amount of stem decay has decreased. In stands where management objectives include enhancing ecological function and providing wildlife habitat, strategies to promote infection by stem-decay fungi and development of decay may be needed. These strategies include retaining existing wounded and hollow trees, promoting the replacement of hollow trees by maintaining advanced true-fir regeneration with indicators of infection, and intentionally wounding selected true firs to encourage infection by stem-decay fungi.

In situations where the management objective is to minimize losses due to decay, stem-decay fungi must be prevented from infecting young trees. The most effective preventive action is to minimize partial cutting in stands with a substantial component of white, grand, or red firs. If intermediate stand treatments are conducted, it is important to avoid injuring residual trees. Basal wounds are the most likely to become infected and are therefore the most critical to prevent. During thinning and other harvest activities the following actions can prevent wounding and associated decay in residual trees:

- Avoid operations during spring and early summer when tree bark is easily damaged.
- Use appropriate size and type of equipment for site and stand conditions.
- Mark leave trees rather than cut trees. This has been shown to significantly decrease damage to residual trees.
- Designate skid trails and skyline corridors in advance. Avoid sharp turns and leave bump trees or cull logs to protect residual trees adjacent to trails.
- Leave low stumps in skid trails (preferably no more than three inches high).
- Use directional felling to reduce the amount of skidder maneuvering and log pivoting.
- Limb and top trees prior to skidding.
- Design contract specifications to ensure the intended results.
- Avoid underburning in true fir stands unless slash, debris, and duff within ten feet of residual trees can be removed beforehand.

Decay caused by Indian paint fungus is a major factor almost everywhere advanced regeneration of true firs is managed. The amount of decay due to this fungus can be minimized by avoiding management of suppressed regeneration that has developed underneath infected overstories. FIDL 93, *Rust-Red Stringy Rot caused by the Indian Paint Fungus*, contains guidelines for assessing advance regeneration for infection potential and decay caused by Indian paint fungus. Advanced regeneration of true firs is at risk of developing severe decay when it has been suppressed for over fifty years, has numerous wounds, is low in vigor due to poor site, or when an infested overstory of true firs is present. If three or more of these conditions exist and significant levels of decay in the mature stand would hinder long-term management objectives, other tree species should be favored or planted. Stands at risk of developing severe decay can also be managed on short rotations so maximum merchantable volume is harvested before decay becomes significant.

A significant number of tree failures in recreation areas and other developed sites are caused by the effects of decay fungi. Trees within falling distance of valuable targets should be examined periodically for external indicators of decay. Sometimes external indicators are not visible or are not sufficient to determine the degree of decay. Questionable trees can be bored with a drill, increment borer, or resistograph tool to assess their structural integrity by determining the thickness of remaining sound wood. If decay is found, probability of failure and potential targets will dictate the appropriate treatment to reduce or eliminate the hazard. In some cases, creative treatments such as topping, leaving high stumps, or falling without removing tree stems may mitigate the hazard while maintaining wildlife habitat. Along roads and in work areas, trees with indicators of decay should be assessed and treated depending on the frequency and duration of human exposure. Favoring a mix of decay-resistant tree species such as pines, larch, incense-cedar, and Douglas-fir over true firs can reduce problems associated with decays and is highly recommended in vegetation management plans for developed sites.

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Assistance

Private landowners can get more information from County Extension Agents, State Forestry Departments, or State Agriculture Departments. Federal resource managers should contact USFS Forest Health Protection (www.fs.fed.us/foresthealth/). This publication and other Forest Insect and Disease Leaflets can be found at www.fs.fed.us/r6/nr/fid/wo-fidls/.

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