Forest Insect & Disease Leaflet 150

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Decays of Engelmann Spruce and Subalpine Fir in the Rocky Mountains

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Engelmann spruce (*Picea engelmannii*) – Rocky Mountain subalpine fir (*Abies bifolia*) forests occur along the Rocky Mountains from central British Columbia and western Alberta southward into Arizona and New Mexico. West of the Rockies, from southwestern Yukon Territory to northern California, *A. bifolia* is replaced by *A. lasiocarpa*. Spruce-fir forests occur at elevations of 2,000 to 7,000 feet in the north and about 8,000 to 12,000 feet in the south. The importance of specific decays varies considerably over the range of the hosts. This leaflet is primarily based on studies of Engelmann spruce and Rocky Mountain subalpine fir in the southern Rocky Mountain ecoregion (northern New Mexico to east-central Wyoming), but the information is generally applicable throughout the Rocky Mountains of the United States.

Wood decay plays a major role in carbon cycling, influencing release or sequestration of carbon in forests. Decay in living trees provides habitat for animals, even after the tree dies and falls to the ground, by softening or hollowing the inner wood, leaving a relatively hard, protective shell. Decay also provides nutrition for fungi, insects, and animals that feed on them. Decay can lead to mechanical failure of live trees, creating hazard to people and property in developed forest areas. Decay diseases, primarily root and butt rots, also cause mortality of standing trees. Finally,

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decay can substantially decrease the value and usable wood volume of trees harvested for wood products. Quantifying this last impact for timber management has been the goal of most studies that have provided detailed information about specific decays, but the results of those studies may be useful in understanding the role of decays in other processes as well.

Engelmann Spruce

Occurrence of Decays

Average defect attributed to decay amounts to 20 percent of the gross merchantable board-foot volume of spruce in Alberta, 12 percent in the Blue Mountains of Oregon and Washington, and 15 percent in Colorado. Estimates of stand defect due to decay in Colorado range from 7 to 26 percent. In spruce, certain tree abnormalities are reliable indicators of stem decay. One means of estimating defect in a stand is based on average stand age and the average amount of cull associated with indicators. Cull deductions as a percentage of gross tree volume for three groups of indicators are available for two age classes (Table 1).

Fungi Involved

Many fungi cause significant decay of mature Engelmann spruce, and there are wide variations in their frequency and volume of decay caused in infected trees (Table 2). The fungi differ also in which of two decay types they cause. In white rot, fungi progressively destroy all wood components, leaving a fibrous or stringy residue. In brown rot, fungi rapidly depolymerize, then gradually consume the cellulose and hemicelluloses, leaving a dry, brown, cubical or crumbly mass of lignin residues. Both types can occur as “pocket rots,” in which the decay occurs primarily in discrete ellipsoidal zones scattered through the wood. Decay results in rapid strength loss of wood in the early stages, particularly in the case of brown rot. Because brown rot results in lignin residues that are recalcitrant to further decomposition, it may contribute to more storage of carbon in the forest floor than does white rot.

Location in the Tree

Stem decays (trunk rots), caused by fungi that decay the inner stem wood of living

Table 1. Average cull deductions of Engelmann spruce trees with indicators as a percentage of gross tree volume (Hinds & Hawksworth 1966).

	Cull deduction (% of gross tree volume in board-feet)	
Indicators and frequency (%) of associated decay[1]	**Under 250 yr**	**Over 250 yr**
Punk knots or conks of *Porodaedalea pini* (100)	68	86
Broken top (75) or dead top with adjacent dead rust brooms (67)	21	25
Basal wounds (37), dead rust brooms (32) or dead leader in living crown (34), frost cracks (32), forks (all types; 23), trees joined at base to one another (47), spike top (30) or trunk wounds (23)	8	11

[1]Number in parentheses is the percentage of occurrences of the indicator that have decay associated with them.

Table 2. Major decay fungi of mature Engelmann spruce and average measurements of associated decay (Hinds & Hawksworth 1966).

Major decay fungi[1]	**Percentage of all decay infections**[2]	**Cull in infected trees (cubic feet)**	**Length of decay column (feet)**
Stem decays			
Porodaedalea pini	34	21.2	35
Stereum sanguinolentum	29	5.9	21
Laurilia sulcata	6.7	15.8	24
Veluticeps abietina/fimbriata	0.7	13.9	30
Amylostereum chailletii	2.4	4.3	19
Butt rots			
Phellopilus nigrolimitatus	3.1	14.7	25
Pholiota alnicola	4.3	3.7	8
Coniophora puteana	4.5	3.3	9
Onnia tomentosa/leporina	4.0	3.5	10
Vesiculomyces citrinus	2.6	3.3	8

[1]*Fungi were included if they caused >0.7% of all decay volume in the study. See Tables 4 and 5 for synonyms and distinguishing features. Less important fungi included: the trunk rotters* Antrodia serialis, Gloeophyllum sepiarium, Peniophora septentrionalis, Sistotrema raduloides, Phellinidium ferrugineofuscum, *and* Fomitopsis rosea; *and the butt rotters* Armillaria solidipes, Coniophora olivacea, C. arida, Fomitopsis pinicola, Pholiota *sp.,* P. squarrosa, Flammulina velutipes, *and* Oligoporus balsameus.

[2]*Percentage of all decay columns from which each fungus was isolated. Total is less than 100% because less important fungi are not included in the table*

trees, account for about three-fourths of decay losses in Engelmann spruce. The two major fungi are *Porodaedalea pini* and *Stereum sanguinolentum*; but *P. pini* is the most common and causes the largest decay columns. The disease is called red ring rot because, at least in pines, there is red staining in the early stages and it tends to develop along the annual rings. Red ring rot is associated with all decay indicators, including those found in the basal portion of a tree. The typical decay is easily recognized by its white pockets and by its association with punk knots and conks (Figure 1), which can be common on trees infected for many years. In spruce, it tends to occur most frequently in the lower stem and may even progress into the roots. *Porodaedalea pini* may actually be a complex of species that will be segregated as we learn more about them.

Although red heart, caused by *S. sanguinolentum*, is not as extensive within individual trees as *P. pini*, it occurs nearly as frequently and is also associated with most decay indicators. The affected wood is firm and reddish brown at first, then turns light brown, dry, and friable in the advanced stage. White mycelial sheets are found in the rotted wood in longitudinal section. The thin, leathery, annual fruiting bodies are seldom found on living trees. Length of rot column and cull caused by *Laurilia sulcata* (Figure 2) are greater than those of *S. sanguinolentum*, but this decay

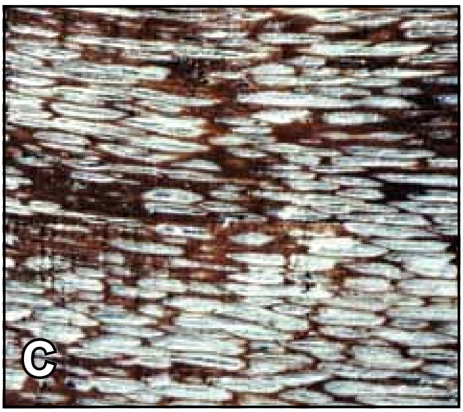

Figure 1. Porodaedalea pini *on Engelmann spruce: (A) conk below branch stub; (B) punk knot with outer surface shaved to reveal golden brown fungal mycelium with embedded resin; (C) advanced white pocket rot in longitudinal section. Punk knots are branch stubs that have become colonized and decayed by the fungus from inside the tree, and often do not callus over as do normal stubs.*

occurs less frequently. The yellowish white pocket rot could be confused with that caused by *P. pini*.

The relatively uncommon brown trunk rots are usually associated with trunk wounds and broken tops. When associated with trunk wounds, they cause smaller losses and are frequently mixed with white rots which progress faster. *Veluticeps abietina*/*fimbriata* causes the largest decay columns among brown-rot fungi in stems. Additional fungi cause less important stem decays in spruce (Table 2, footnote).

Root and butt rots cause less cull than stem decays in spruce, but they more frequently cause mortality, either by: a) killing roots and the root collar; b) causing physiological stress that predisposes the tree to bark beetle attack; or c) causing breakage of the roots or lower stem. For example, *Armillaria solidipes*, which causes little cull, may be the most important and widespread cause of mortality on both species in many spruce-fir forests.

Phellopilus nigrolimitatus is most important as a cause of butt rot. It causes a white pocket rot with unusually large pockets (Figure 3) and decay columns are relatively long. Various trunk wounds can be infected by *P. nigrolimitatus*, and it can cause decay throughout the tree. Two similar species of *Onnia* cause root and butt rot on both spruce and fir: *O. tomentosa* (Figure 4) and *O. leporina*. They cause a white pocket rot preceded by a red stain; the disease is sometimes called

Figure 2. Laurilia sulcata: *(A) frost crack (indicator of decay); (B) decay with diffuse white pocket rot; (C) bottom, conks.*

red root rot. Like *Pholiota alnicola*, which causes a common white stringy rot, they gain entrance through roots. Although they can cause butt rot up to 8 to 10 feet up the stem, their main damage is to the roots, predisposing trees to windthrow. Most basal rot is associated with old basal wounds and frost cracks.

With the exception of *Coniophora puteana* and *Fomitopsis pinicola*, the brown rots seldom cause extensive basal decay. *Coniophora puteana* is most frequently encountered, but *F. pinicola* is equally important in causing cull where it occurs. Because *F. pinicola* usually attacks dead sapwood, it is often associated with large, old, basal wounds. Many other fungi cause less butt rot in spruce (Table 2, footnote).

Subalpine Fir

Occurrence of Decays

Although indicators are useful for detecting and estimating amount of decay in spruce, fir has no consistent

Figure 3. Spruce wood decayed by Phellopilus nigrolimitatus *and subsequently weathered. Note the large, broad pockets separated by relatively undecayed wood.*

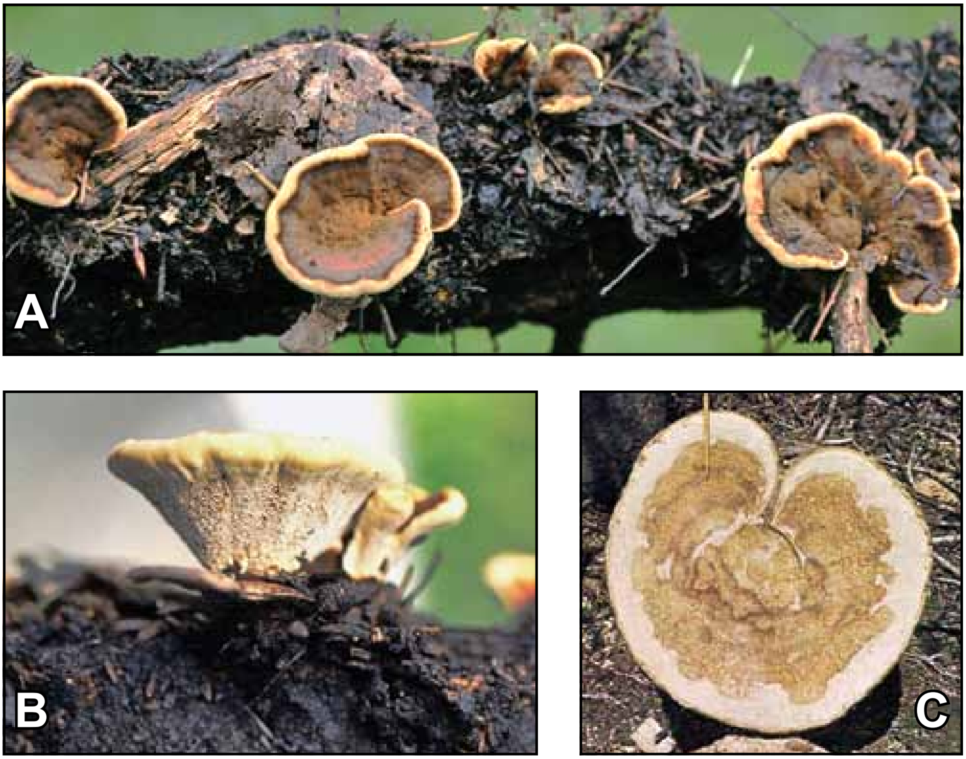

Figure 4. Onnia tomentosa: (A) and (B) mushroom-like conks fruiting from buried roots; (C) cross section with typical decay pattern associated with old basal wound.

external indicators of decay. However, the amount of decay in fir generally increases with age and tree diameter. A major part of the spruce-fir forests in the Rocky Mountains consists of old, uneven-aged stands with large old trees and an understory of younger trees in various degrees of suppression. The dominant and codominant firs in these stands were often suppressed for many years by a spruce overstory which has since died.

Losses from decay range from less than 7 percent (board-foot basis) in trees under 10 inches DBH to more than 40 percent in trees over 20 inches. Decay in trees larger than 9.5 inches DBH averages 35 percent of board-foot volume. Decay in trees younger than 100 years is negligible, but rot increases rapidly with increasing age to 35 percent in the 150 to 199 year age class. The amount of decay is extremely variable in older age classes. While broken tops and trunk wounds are usually indicative of extensive rot, indicators are not consistently useful.

Fungi Involved

Many of the fungi important in subalpine fir also occur on spruce, but their relative importance varies and some species are different (Table 3).

Location in the Tree

Stem decays account for about two-thirds of the overall decay in subalpine fir. *Stereum sanguinolentum* (Figure 5) is by far the most important fungus and is responsible for over 75 percent of the stem decay volume. Called “red heart” because of its marked reddish color, the decay can be confused in the field with that caused

Table 3.—Important, identified decay fungi of subalpine fir and associated type of decay, frequency of isolation from decay columns, and average cull (Hinds et al. 1960)

Major decay fungi [1]	Decay type	Frequency of isolation (%) [2]	Cull in infected trees (cubic feet)
Stem decays			
Stereum sanguinolentum	White	37	6.9
Porodaedalea pini	White pocket	7.3	6.9
Amylostereum chailletii	White	6.7	2.5
Veluticeps abietina/fimbriata	Brown pocket	2.4	1.9
Fomitiporia hartigii	White	1.8	2.5
Butt rots			
Coniophora puteana	Brown	7.3	0.8
Armillaria solidipes	White	6.7	0.8
Pholiota squarrosa	White	6.1	0.9
Coniophora olivacea	Brown	4.9	0.8
Onnia tomentosa/leporina	White pocket	3.0	1.1
Phellopilus nigrolimitatus	White pocket	0.6	6.0
Oligoporus balsameus	Brown	0.6	5.8

[1]*Fungi were included if they contributed at least 1% of the total volume of decay by all identified fungi. See Tables 4 and 5 for synonyms and distinguishing features. Less important fungi included the butt rotters* Vesiculomyces citrinus, Helicobasidium corticioides, Pholiota alnicola, Laurilia sulcata *and* Coniophora arida.

[2]*Percentage of all identified decay columns from which each fungus was isolated. Total is less than 100% because less important fungi are not included in the table.*

by *Amylostereum chailletii*. Infection occurs mainly through wounds and broken branches. Multiple trunk infections and extensive mixed decay columns are common. Fruiting bodies of the fungus are seldom found on living trees, more frequently fruiting on downed, dead material. When found, they are usually located on old scars. Fresh fruiting bodies of this fungus redden or “bleed” when wounded—hence the common name, “the bleeding Stereum.”

Porodaedalea pini is the second most important fungus, accounting for about 15 percent of stem decay volume. Incidence of the white stringy trunk rot caused by *A. chailletii* is as common as that of *P. pini*, but losses due to *A. chailletii* are only about 5 percent of the total stem decay caused by all fungi. *Amylostereum chailletii* is a symbiont of woodwasps (*Sirex* species) and is injected into the wood through the ovipositor along with the eggs.

Although many stem-decay fungi can invade the sapwood and even kill cambium at times, *Fomitiporia hartigii* readily does so. Although it causes little cull, this trait may result in some early mortality in subalpine fir stands.

Table 4. Major stem-decay fungi of living spruce and fir, selected synonyms, and some distinctive features.

Species	Decay type	Host[1]	Fruitbody and decay features
Amylostereum chailletii ≡ *Stereum chailletii*	white	SF	**Fruiting**: Spreading, may have small cap on upper end, up to 1 mm thick, surface smooth to slightly bumpy, waxy, becoming brittle, cinnamon to dark brown, sometimes slightly lilac, with a distinct dark brown margin. **Decay**: stringy.
Fomitiporia hartigii ≡ *Phellinus hartigii* = *Fomes robustus* var. *tsugina* (some authors) ≡ *Poria tsugina*	white	F	**Fruiting**: Fruits on the underside of branches and branch crotches. Perennial, spreading, often with small cap on upper end; cap surface pale yellow-brown; pore surface gray- to purple-brown; tube layers distinctly stratified and old tubes white within. **Decay**: uniform white rot.
Laurilia sulcata ≡ *Echinodontium* (*Stereum*) *sulcatum*	white pocket	S(F)	**Fruiting**: Spreading, often with cap on upper end; cap up to 1.5 cm wide, light brown to black, tomentose; lower surface smooth to bumpy, pinkish-buff to clay, often with cracks. **Decay**: yellowish pocket rot.
Phellinidium ferrugineofuscum ≡ *Phellinus* (*Poria*) *ferrugineofuscus*	white	S	**Fruiting**: Annual or biennial, woody, flat and spreading, about 1 cm thick, margin light-colored and soft; pore surface purplish brown, pores very fine; flesh yellow-brown, tube layer purplish brown. **Decay**: typically laminated and often with small longitudinal pits and fine, transversely oriented, whitish streaks; sometimes with scattered black flecks.
Porodaedalea pini ≡ *Phellinus* (*Fomes*) *pini*	white pocket	SF	**Fruiting**: Perennial, woody conks formed at dead branches but may appear anywhere as sapwood is killed; cap surface reddish-brown to black, rough, with undulating margin; pore surface and interior golden- to reddish-brown. **Decay**: initial purplish stain along annual rings; later stage with more or less distinct white pockets and sometimes numerous zone lines; decay pockets up to 2x10 mm but may coalesce. **Disease name**: red ring rot.
Stereum sanguinolentum ≡ *Haematostereum sanguinolentum* (bleeding Stereum)	white	SF	**Fruiting**: Flat but with cap on upper end, cap projecting up to 15 mm, leathery; surface undulating, finely hairy with yellow to red-brown concentric zones; underside smooth, light brown to gray, bruising red. **Decay**: firm and reddish brown at first, then light brown, dry, and friable with white mycelial sheets in the advanced stage. **Disease name**: red heart (rot).
Veluticeps abietina ≡ *Gloeocystidiellum* (*Stereum*, *Columnocystis*) *abietinum*	brown pocket	SF	**Fruiting**: Annual or rarely perennial, spreading, may have cap on upper end, tough, up to 2 mm thick, lower surface smooth to roughened, often cracked, pale yellowish to brownish orange to grayish, often with violaceous tinges when fresh. Rare compared to *V. fimbriata* in the Rocky Mountains. **Decay**: see *V. fimbriata*.
Veluticeps fimbriata ≡ *Hymenochaete fimbriata* = *Stereum rugisporum*	brown pocket	SF	**Fruiting**: Fruits on scars of living trees but more frequently on dead, downed wood. Usually perennial, pileate, effused-reflexed or resupinate; cap surface dark brown to nearly black; underside smooth to warted, often cracked, gray to light brown; interior brown; spores larger than in *V. abietina*. **Decay**: Incipient stage a wet, brown to black stain in streaks or patches; brown rot develops in pockets surrounded by sound wood; pockets later coalesce; often associated with dark stain, a thin cobweb-like layer of mycelium and odor of apples.

[1]*Letters refer to the usual host: S = spruce; F = fir; host in parentheses indicates occasional occurrence.*

Table 5. Major fungi causing root and butt rot in spruce and fir, selected synonyms, and some distinctive features.

Species	Decay type	Host[1]	Fruitbody and decay features
Armillaria solidipes = *Armillaria ostoyae* = *Armillaria mellea* (in part) (honey mushroom)	white	SF	**Fruiting**: Cap 4-10 cm diam, dark brown with a dense layer of fibrils early, becoming tan to yellowish brown and smooth; gills cream then darkening to rose or burgundy; stem 3-50 mm diam, widening before forming a pointed base. **Decay**: Stringy to spongy, often wet, with occasional zone lines; large mycelial fans under bark and usually fine rhizomorphs attached to roots. **Disease name:** Armillaria root rot.
Coniophora puteana = *C. cerebella*	brown	SF	**Fruiting**: Flat, spreading, 0.5-2 mm thick, surface yellow to brown and smooth or bumpy with a wide, cream-colored margin. **Decay**: thin, pale tan cords and wispy mycelium often scattered in decayed wood. **Other species** of *Coniophora* (*C. olivacea* and *C. arida*) may be involved, but they have thinner fruitbodies (up to 0.3 mm thick); microscopic examination is required to distinguish the species.
Oligoporus balsameus ≡ *Polyporus balsameus* = *P. basilaris*	brown	F(S)	**Fruiting**: Annual, spreading with small cap or more conk-like, about 1 cm thick, whitish becoming pale brown, small pores on underside.
Onnia leporina = *Inonotus* (*Polyporus*) *circinatus* in the sense of earlier authors = *Polyporus dualis*	white pocket	SF	**Fruiting**: Often fruits on butt of recently killed trees; somewhat larger than *O. tomentosa*; delicate and quickly destroyed by insects. Annual, solitary; cap up to 18 cm diam and 11 cm thick, cinnamon to rusty brown, with or without a short lateral stem. **Decay**: similar to *O. tomentosa*. **Disease name**: red root rot. **A similar species**, *O. triqueter*, occurs on *Pinus* and other conifers and has a more southern distribution in North America.
Onnia tomentosa ≡ *Inonotus* (*Polyporus*) *tomentosus*	white pocket	SF	**Fruiting**: Annual in groups, leathery; cap up to 11 cm diam and 7 mm thick, finely hairy, yellowish-brown, usually with a central to lateral stem arising from roots. **Decay**: preceded by reddish stain; pockets may become sharply separated by apparently sound wood, may develop zone lines in later stage. **Disease name**: red root rot or tomentosus root disease.
Phellopilus nigrolimitatus ≡ *Phellinus* (*Fomes*) *nigrolimitatus*	white pocket (large pockets)	S	**Fruiting**: Perennial, spreading, may have small cap; cap surface and margin often soft and spongy, blackish to yellowish brown; pore surface cinnamon; flesh up to 10 mm thick with black lines. **Decay**: initially pale brown ellipsoidal pockets that become large (up to about 10x25 mm), rectangular and white, separated by firm wood. **Disease name:** big white pocket rot
Pholiota alnicola	white	SF	**Fruiting**: Cap up to 6 cm diam, pale yellow-brown, smooth, sometimes slimy; may have fringe of veil remnants; stem up to 1 cm thick, with fine fibrils, pale yellow at top then brown below; gills attached; spore print rust-brown. **Decay**: stringy.
Pholiota squarrosa (scaly Pholiota)	white	F(S)	**Fruiting**: Cap and stem with prominent, erect scales; cap 10 cm diam or larger, pale brownish, may have fringe of veil remnants; stem up to 1.5 cm thick; gills attached, pale yellowish to gray, rarely green-tinged, becoming dark brown; spore print cinnamon brown; odor mild or garlic-like. **Decay**: stringy.
Vesiculomyces citrinus ≡ *Gloeocystidiellum citrinum* = *G.* (*Corticium*) *radiosum*	white	S(F)	**Fruiting**: Flat and spreading, thin, surface smooth, cream to pale brown with a whitish margin with fine cords or fibrils. **Decay**: yellowish, stringy.

1 Letters refer to the usual host: S = spruce; F = fir; host in parentheses indicates occasional occurrence.

Figure 5. Stereum sanguinolentum: *Red heart rot (A) and fruiting bodies (B) on balsam fir.*

Although root and butt rots account for only about one-third of the total decay, they are important in subalpine fir stands because they lead to mortality and wind-throw. Root and butt rots probably cause much greater volume losses by causing trees to fall over than by decay of wood in the butt. Among white-rot fungi, the soft, spongy rot of *Armillaria solidipes*, the white pocket rot of *Onnia tomentosa*, and the white stringy rots of *Pholiota alnicola* and *P. squarrosa* cause about half of the butt-rot volume losses. Their mushroom-like fruiting bodies are found on roots and at tree bases, but are not common enough to be useful indicators of decay. *Vesiculomyces citrinus* is the most common butt-rot fungus in subalpine fir (9.8% of all decay isolations), but its yellow stringy rot causes negligible amounts of cull.

Three species of *Coniophora* are the principal causes of brown cubical butt rot (Figure 6). They gain entrance through basal wounds; however, rot columns seldom extend more than four feet above ground. *Coniophora puteana* is the most common and causes the greatest volume loss. Additional fungi cause less important decays of fir (Table 3, footnote).

Management

Spruce-fir forests are often the most productive forest type in the southern and middle Rocky Mountains. They are

Figure 6. Coniophora puteana: *(A) typical advanced brown cubical rot leading to mechanical failure; (B) effused fruiting body on a piece of slash.*

important for timber, water yields, wildlife habitat, recreation, and scenic value. Where decay in living trees is consistent with management objectives, generally no action is needed. Where management objectives include reducing the amount of decay and promoting tree growth, early removal of spruce with known indicators of decay, and of fir in the older age classes will promote healthy, vigorous trees with a greater growth potential. Decay losses can be minimized by harvesting younger trees: 140 to 150 years for spruce, and 100 to 125 years for fir. Careful marking of individual trees to be cut and close supervision of logging operations to reduce mechanical injuries will minimize points of entry for decay fungi. These sanitation and prevention methods are important because direct control of decays is not possible.

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