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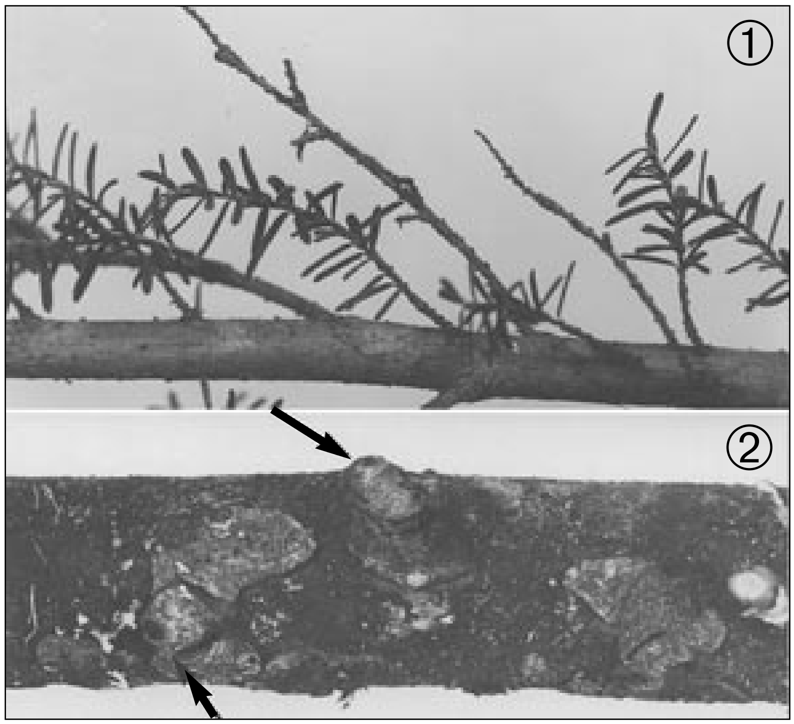
True heart-rots of the Pacific region

By R.S. Hunt and D.E. Etheridge

Introduction

Decay caused by root-, butt- and trunk-rotting fungi (Basidiomycetes) is responsible for an estimated annual loss of timber in British Columbia that exceeds 10 million cubic metres (14). Obviously, accumulated decay volumes are staggering. The bulk of this volume loss is due to heart-rot in trunks of living trees.

Among the most destructive of the heart-rots in British Columbia forests are those caused by true heart-rotting fungi. These are so-named because the characteristic decay is usually confined to the true heartwood. They are the only species that consistently produce fruiting bodies on living trees. They may also produce sterile structures known as “punk knots” or “swollen knots.” Unlike other heart-rotting fungi, these species never occur as primary invaders of slash and dead material, or cause damage to timber in service, although they may continue to develop in freshly cut logs in the forest for varying periods. They also differ in their mode of attack, since mechanical injuries do not appear to be the principal infection courts for these species. Control measures designed to reduce wounding of trees, or as protective treatments to scars, are therefore unlikely to prevent infection by these fungi.



Figs. 1 and 2. Potential infection courts of *Echinodontium tinctorium* on living branches of western hemlock. Fig. 1. Recently dead, adaxial branchlets, about 1 mm in diameter, on a 10-year-old branch. Fig. 2. Stubs of branchlets on a 50-year-old branch (see above), recently broken off close to the basal callus (arrows), provide actual entry points.

Only the true heart-rots will be dealt with in this leaflet. There are four species of true heart-rotting fungi in British Columbia: the Indian paint fungus (*Echinodontium tinctorium* (Ell. & Ev.) Ell. & Ev.) and the ring scale fungus (*Phellinus pini* (Thore: Fr.) A. Ames) on conifers, the false tinder fungi (*P. tremulae* (Bond.) Bond. & Poriss. in Bond.) on aspen, and *P. igniarius* (L.:Fr.) Quél. on other hardwoods.

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Hosts and distribution

Echinodontium tinctorium, confined to western North America, is common on true firs (*Abies* spp.) and hemlock (*Tsuga* spp.), and occasionally occurs on Douglas-fir [*Pseudotsuga menziesii* (Mirb.) Franco], western redcedar (*Thuja plicata* D. Don), and spruce (*Picea* spp.). True firs are highly susceptible throughout most of their range in British Columbia, while western hemlock [*Tsuga heterophylla* (Raf.) Sarg.] suffers moderate to severe levels of attack in specific habitats, principally in interior forests, at higher elevations on the coast (18), and on below-average sites (9). It has not been reported on the Queen Charlotte Islands (8).

Phellinus pini has a wide distribution in the North Temperate Zone, and is one of the most common heart-rotting fungi in British Columbia. It is reported on all conifers except *Chamaecyparis nootkatensis* (D. Don) Spach, *Juniperus scopulorum* Sarg. and *Taxus brevifolia* Nutt. (16), but it is noted on these genera elsewhere (7). It occurs frequently on mature pines (*Pinus* spp.), western hemlock, the spruces, western larch [*Larix occidentalis* Nutt.], Douglas-fir, and western redcedar. Generally, true firs are much less susceptible to *Phellinus pini* than other hosts, but amabilis fir in the Kitimat region appears to be an exception (10). *Phellinus pini* probably causes more cull in Yukon spruce than any other agent. No systematic attempt has been made to correlate the occurrence of this fungus with forest type or site. There is evidence, however, of local variations: in British Columbia, infections tend to occur at younger ages more frequently on above-average sites (11).

Phellinus igniarius attacks a variety of broadleaf species throughout the northern hemisphere. In British Columbia, it causes moderate damage to birch (*Betula papyrifera* Marsh.), and has been reported on alder (*Alnus rubra* Bong.), apple (*Malus* sp.), arbutus (*Arbutus menziesii* Pursh), black cottonwood (*Populus trichocarpa* Torr. & Gray), maple (*Acer* spp.), Pacific dogwood (*Cornus nuttalli* Andub.), and willow (*Salix* spp.) (16). *Phellinus tremulae* is a species recently segregated from *P. igniarius*. Its only host in North America is aspen (*P. tremuloides* Michx.), in which it is the most important decay fungus. There have been no systematic studies in this province on site relationships and distribution for these fungi. *Phellinus tremulae* damage can be severe, particularly in stands over 30 years of age. This disease may vary considerably from one stand to another, with decay lowest in more thrifty trees, perhaps as a result of interclonal variations (13, 15, 20).

Life history of the Indian paint fungus

Of the true heart-rotting fungi, only the life history of *Echinodontium tinctorium* has been studied in detail. Enough information about the infection process is now available to question the long-held belief that these fungi enter the heartwood through old, dead branch stubs. For example, in western hemlock, infection courts of the Indian

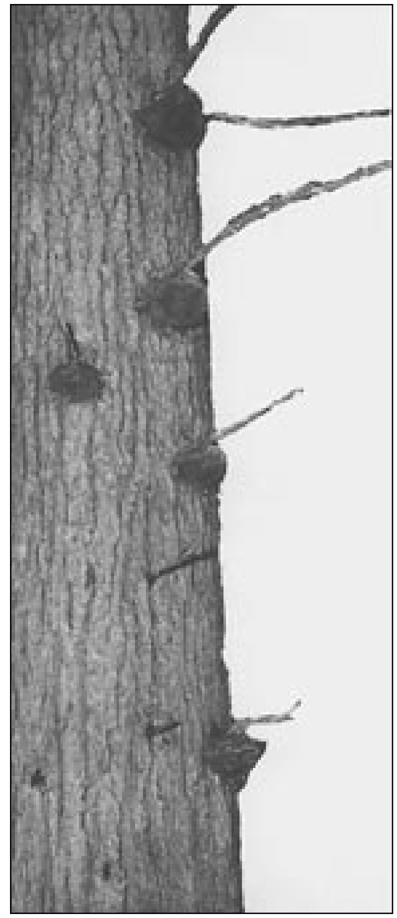

Fig. 3. *Echinodontium tinctorium* fruiting bodies on a living western hemlock tree

Fig. 4. Bracket-like fruiting bodies of *Phellinus pini*

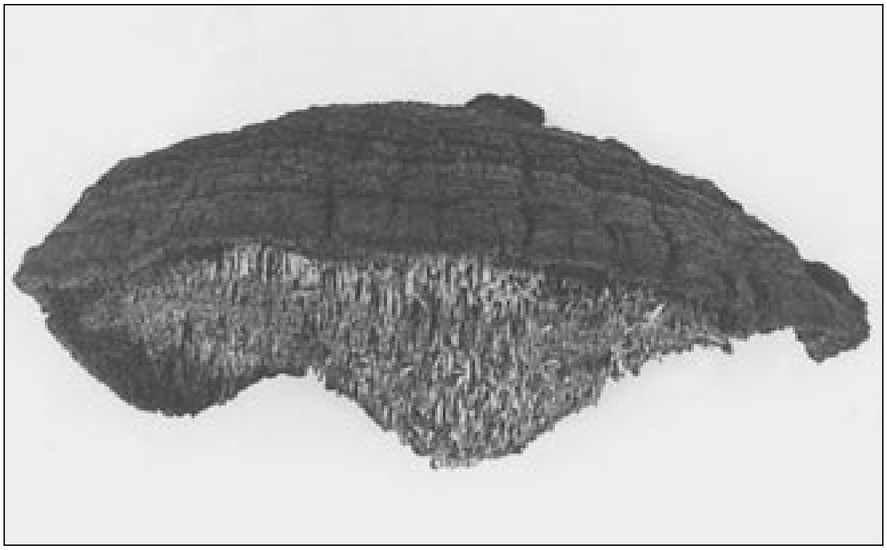

Fig. 5. Perennial hoof-shaped fruiting body of *Echinodontium tinctorium*, showing fissured upper surface and coarsely spined undersurface

paint fungus are almost certainly confined to living branches, which may provide the only route through which infections reach the heartwood (6).

Infection occurs in late fall or early spring when a single spore comes in contact with a suitable infection court. These courts consist of the very small stubs that remain on main branches when dead adaxial twigs[1], about 1 mm in diameter (Figs. 1 and 2), are broken off – usually during winter storms. Larger wounds are unsuitable infection courts. These small wounds heal quickly on vigorously growing trees, and are not available as infection courts during the following fall spore cast. On suppressed trees, however, such wounds may take years to heal, and could be infection courts for many spore casts. Infections enter the heartwood of the main branch through the secondary branch traces, and become localized in tissues around the pith until conditions favour further development. A branch may contain 20 or more of these semi-quiescent infections, which are characterized by large numbers of "resting spores." The quiescent period may last for a considerable time – from the first appearance of infection courts on nonvigorous branches (around 40 years of age) until penetration of the trunk occurs (which may not be for another 100 years). Conditions associated with death and breakage of old, infected branches appear to be the major factor causing reactivation of these infections and penetration of the trunk. The fungus enters the trunk heartwood via the encased branch base, eventually combining with infections from neighboring branches to produce a continuous column of rot.

The typical decay develops when the fungus attacks the spring wood of the annual rings, causing the wood to separate into flakes, and finally producing a yellow or brown stringy mass separated by layers of sound wood. After a variable number of years, during which the mycelium of the fungus exists vegetatively, accompanied by extensive decay development, hyphae concentrate at branch stubs or at wound faces and begin forming fruit bodies. The appearance of fruit bodies at these points is the probable origin of the belief that this fungus infects trees through branch stubs and wounds.

The fruit body, or conk, is perennial, and may function for 12 or more years. One or two spore layers may be formed each year. Basidiospores are released into the air throughout the year during periods of rain, and especially in late fall and early spring when rain follows below-freezing temperatures.

Phellinus pini is believed to have a similar life history (11). Since there is less decay due to *P. tremulae* in aspen when the lower branches of trees are removed (15) and *P. tremulae* can be isolated from small twigs (12), it may have a similar life history also.

Recognition

The fruit body

The most conspicuous and reliable indicators of heart-rot caused by these fungi are the perennial conks, or fruiting bodies, that generally form on the underside of dead branch stubs of living trees (Figs. 3 and 4). Recognition of the common conks is also the best way to identify the causal organisms.

The conks of *E. tinctorium* are hard, woody, hoof-shaped structures, ranging in width from a few centimetres to 30 cm. The upper surface is dull black, rough, and cracked; the undersurface is greyish, and thickly set with hard, course spines (Fig. 5). The interior, or context, is rust-red or brick-red, which is also the color of the advanced stage of decay. The conks are formed on the underside of dead branch stubs and may be quite abundant (Fig. 3), although not every decayed tree bears conks.

The conks of *Phellinus pini* may vary in structure from thin shell-shaped to bracket-like and hoof-shaped (Figs. 4 and 6). They range in width from 2 cm to more than 30 cm. The upper surface is dull, greyish or brownish black, and rough with concentric furrows parallel to the lighter brown margin. Young and actively growing conks are zoned (Fig. 6) with a brownish tinge and a light-brown margin that is velvety and light gold-brown.

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1 adaxial twigs = small secondary branchlets growing from the upper surface of the main branch.

The undersurface is greyish brown or rich brown, with round to irregularly shaped pores. The interior is cinnamon-brown, and has a corky or punky texture. The conks usually issue from knots or branch stubs on living trees; on dead-standing or down trees, they are often crust-like instead of bracket-like, and issue from cracks in the bark. In addition, this fungus commonly produces "punk knots", which contain the same substance as the interior of the conk, at branch stubs.

Phellinus igniarius and *P. tremulae* produce hard, woody, thick conks that may become 20 cm wide, or more. These are usually hoof-shaped (Fig. 7), but may sometimes be shelf-like. These fungi are not easily distinguishable, and were regarded as the same species for many years; but *P. tremulae* is restricted to aspen, while *P. igniarius* attacks many hosts. The upper surface is greyish black to black, dull or shiny, and becomes rough and cracked with age. The undersurface is brown with small, circular pores, giving a velvety appearance. The interior of the conk is rusty-brown with conspicuous white flecks between the old layers of tubes. On living trees, the conks issue from knots or branch stubs, and occasionally from wounds. On dead-standing or down trees, the conks are often crust-like. Typical "punk knots," showing the rusty-brown punky substance characteristic of the interior of the conks, may appear at branch stubs.

Fig. 6. Zoned upper surface of *Phellinus pini* conk

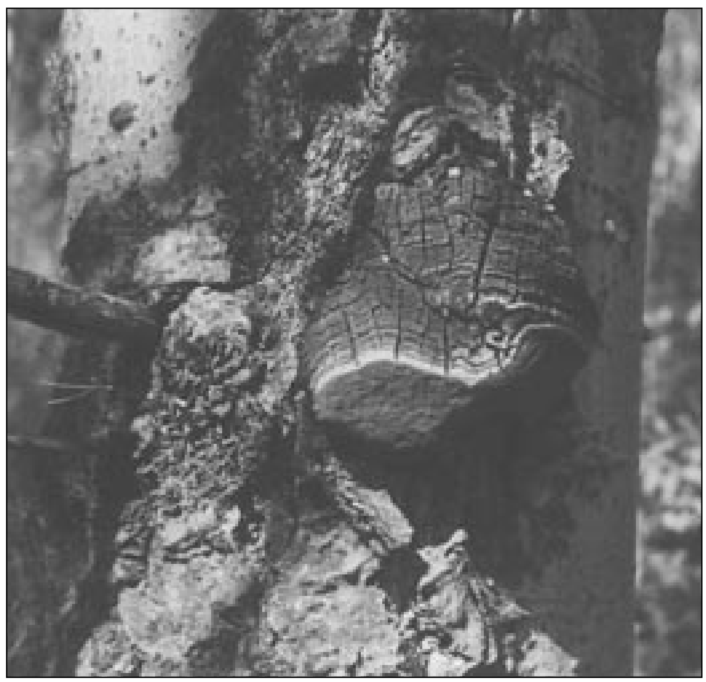

Fig. 7. Hoof-shaped fruiting body of *Phellinus tremulae* on aspen, showing deeply fissured grey-black upper surface

The decay

These causal organisms can also be recognized by the characteristic decay they cause in trees. The following descriptions of the rots are taken from the handbook "Common tree diseases of British Columbia," by Allen, et al.[2], to which the reader is referred for descriptions of other common trunk-rotting fungi:

Echinodontium tinctorium causes a brown stringy rot in both true firs and hemlock. The early stage of decay appears as a light-brown or water-soaked stain in the heartwood. Later, the wood darkens to red-brown or yellow-brown. Small rust-colored flecks and occasionally streaks (Fig. 8), and white channels resembling insect tunnels, may develop. Finally, the wood is reduced to a yellow-brown, fibrous, stringy mass (Fig. 9).

Phellinus pini causes red ring rot, also known as white pocket rot. The early stage of decay appears as a red stain and, in cross sections of logs,

[2] Allen, E.A.; Morrison, D.J.; Wallis, G.W. Common tree diseases of British Columbia. Pacific Forestry Centre, Victoria, B.C. Manuscript in preparation

often develops as a well-defined ring, hence the name "red ring rot." Later, small spindle-shaped white pockets (Fig. 10) running parallel to the grain (Fig. 11) are produced, thus the name "white pocket rot."

Phellinus igniarius and *P. tremulae* cause white trunk rot. The early stage of decay appears as a yellow-white stain in the heartwood, usually surrounded by a yellow-green to brown zone. In the advanced stage, the soft, yellow-white wood usually contains fine black zone lines (Fig. 12).

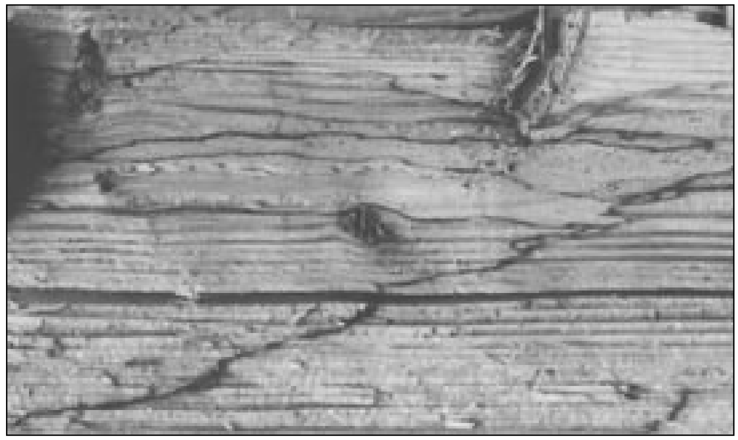

Fig. 8. Western hemlock infected with *Echinodontium tinctorium*, showing the yellow, laminated, advanced decay with red-brown zone lines

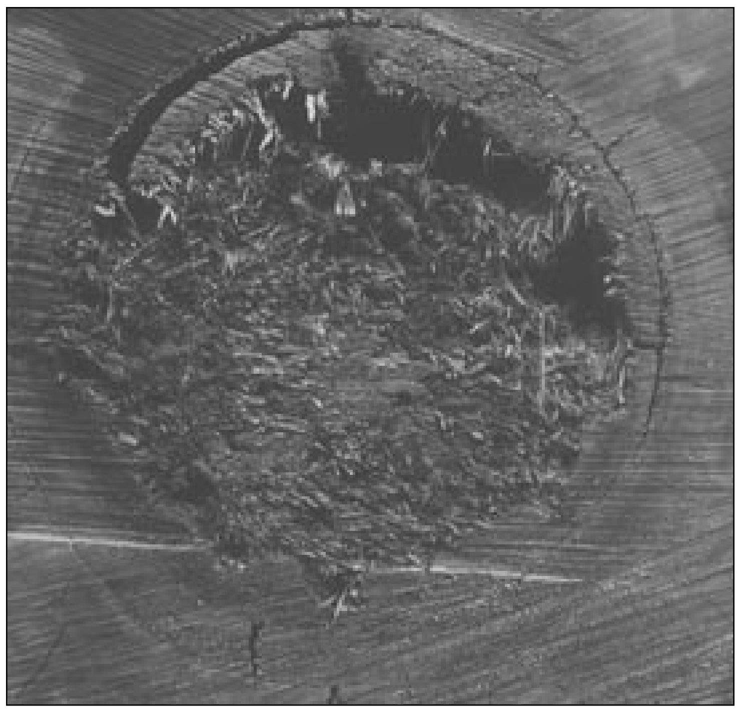

Fig. 9. Yellow-brown, stringy, final decay caused by *Echinodontium tinctorium*

Damage

Losses in interior stands of mature and overmature hemlock caused by the Indian paint fungus (*E. tinctorium*) often amount to 30% or more of the gross volume (9). Losses are generally lower in interior alpine fir (averaging 20%) than in hemlock. Losses in coastal hemlock stands rarely exceed 5%, since these are limited to higher elevations on Vancouver Island and the more northerly areas (5,10). Losses in coastal stands of amabilis fir (averaging 15%), however, are considerably higher than in coastal stands of hemlock (2,4,10). Although decay losses are usually insignificant in trees younger than 150 years (17), such trees are still at risk from decay infections. Heart-rot caused by this fungus has been observed in advanced regeneration of alpine fir as young as 72 years, and less than 5 cm in diameter (17). Younger, or more seriously suppressed trees, may support latent infections that can be activated under suitable conditions. This fungus causes negligible losses in spruce, Douglas-fir, and cedar.

For estimating damage in individual trees, the presence of a conk on the basal 5 m of the tree indicates that the first two 5 m logs are cull, while a conk higher up means that the main trunk is unmerchantable, and two or more conks some distance apart denote that the entire tree is unmerchantable. In addition, "rusty knots," which are branch stubs containing the rust-colored decay, are useful indicators of decay in the heartwood, especially in felled trees. These are readily exposed with an axe (3).

Losses in British Columbia resulting from red ring rot (*P. pini*) probably exceed those from the other heart-rots in value because of the broader host range of the fungus. With the exception of true firs and cedar, which are attacked only occasionally, the average loss from this decay is about 10% of the volume in interior stands, and less than 5% in stands on Vancouver Island and the Queen Charlotte Islands (1). In Douglas-fir stands in western Oregon and Washington, Boyce (3) estimates that red ring rot comprises about 15% of the gross volume over the region.

Based on the occurrence of conks of this fungus, Boyce (3) gives the following estimates of losses in individual trees: in stands less than

100 years old, heart-rot extends an average of 2.5 m above and below a single conk; in stands between 100 and 200 years old, it extends 7.5 m above and below the highest and lowest conk; it extends 8.1 m in each direction for stands 200 to 300 years old; 9.6 m in each direction for stands 300 to 400 years old; and 12.1 m in each direction for stands over 400 years. For punk knots and swollen knots (which are overgrown punk knots), these distances should be halved.

Boyce (3) indicates that the false tinder fungi (*P. igniarius* and *P. tremulae*) cause more loss, particularly in aspen, than any other wood destroyer of hardwoods. However, in British Columbia this disease is only moderately damaging, with most losses in aspen occurring in the mixed wood forests of the Peace River area (19) and in the central interior region (pers. comm. W. Bradshaw), where it causes losses of about 10% of the volume after trees reach maturity (60 to 100 years). Losses in black cottonwood caused by *P. igniarius* are minor.

In individual aspen trees, rough estimates of volume losses can be made according to the presence of conks and punk knots, which develop in close correlation to the progress of decay (3).

Control

Utilization considerations

Although it is rarely practicable to prevent heart-rot under forest conditions, control of excessive decay losses is often possible by understanding how it occurs. Heart-rot does not normally start until after the heartwood begins to form at 15 to 40 years of age, and the chance of producing suitable avenues of entry increases with the age of the tree. Consequently, the volume of heart-rot increases as the tree grows, and the age at which the volume of heart-rot exceeds the volume of growth determines the “pathological rotation.” In practice, however, the cutting age is determined when the volume of heart-rot becomes so large that trees fail to meet the requirements of the forest industry. This may be well after the actual rotation set by pathological considerations, except in a short-lived species such as aspen, which is often heavily decayed at an early age. Age also determines priority cutting of stands. As a general rule, the older the stand, the more susceptible the trees, and the stand with more conks and defects on trees should be utilized first.

Studies involving the dissection of large numbers of decayed trees have shown that the amount of decay can be correlated with tree age and diameter, provided the species, growing conditions, and external signs of decay are taken into account. By this means,

Fig. 10. Advanced red-brown decay in Douglas-fir, with spindle-shaped white pockets, caused by *Fomes pini*

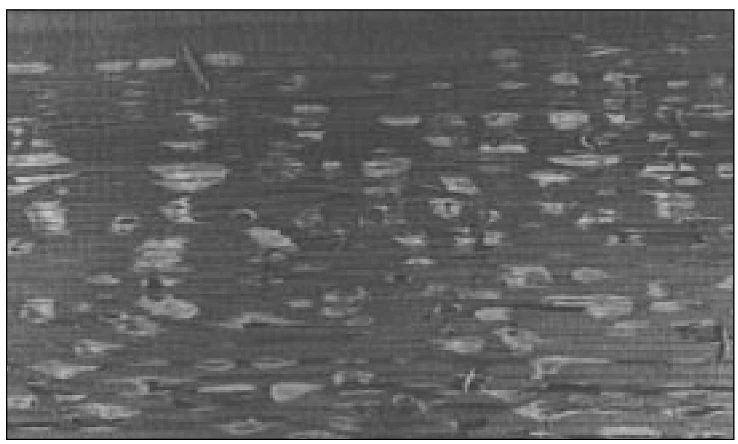

Fig. 11. Section through advanced decay caused by *Fomes pini*, showing white pockets running parallel to the grain

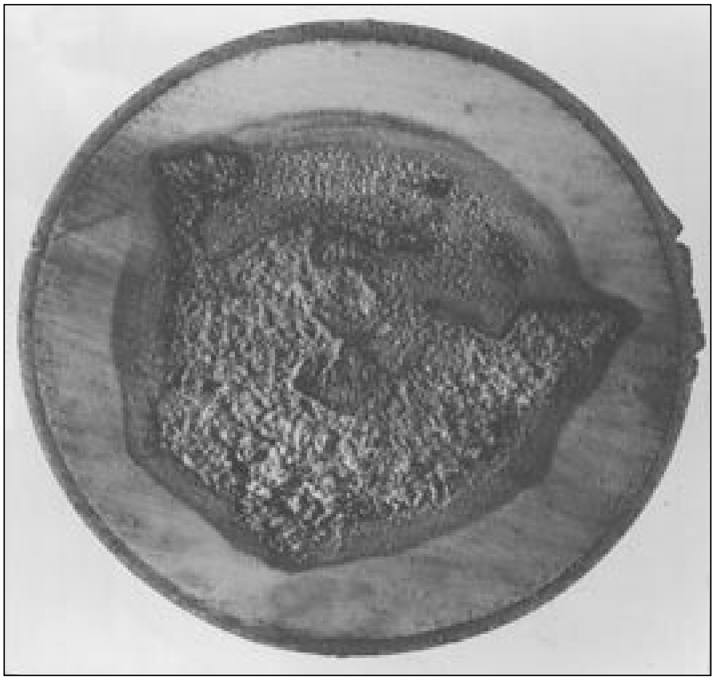

Fig. 12.Yellow-white, stringy, advanced decay in aspen, with black zone lines, caused by *Fomes tremulae*

factors for net volume loss have been developed by the British Columbia Forest Service for all commercial tree species in British Columbia. For greater accuracy, the factors for net volume loss are divided into low-risk and high-risk classes, based on the presence or absence of external signs of decay. High-risk trees bear one or more of the following indicators: conks, trunk infections of mistletoe, frost cracks, forks, scars, and dead or broken tops. Loss factors are further divided into broad age and diameter classes as well as species and geographic zones, in order to arrive at realistic net volumes. Apart from inventory purposes, these loss factors are of considerable value where direct control is impossible, and where it is necessary to reduce financial loss to a minimum by establishing cutting priorities in stands already affected by heart-rot.

Silvicultural considerations

The direct control of decay through special silvicultural and management procedures depends on a sound knowledge of the infection process, and of the factors that affect this process. Of the four fungi discussed here, only the Indian paint fungus has a mode of entry that is understood well enough that control measures based on scientific data can be recommended. Thus, to prevent branch infections in young western hemlock, the aim of silvicultural treatments should be to induce the natural or artificial pruning of branches before suitable points of entry can form on them, i.e., between 35 and 45 years. Also, the vigour should be maintained to promote rapid healing of the small branch stubs, which act as infection courts.

Small, suppressed western hemlock trees that could be released to become a potential crop should be aged to make sure that they are less than 40 years old. If older, these trees are probably already infected with dormant *E. tinctorium*, and should be destroyed so that the site can be planted instead.

If the hypothesis is correct that all four of these fungi initially infect through twigs or twig stubs and then gain access to the stem when the tree grows over branch stubs harbouring these twigs, then pruning should reduce infection by these fungi. Also, the importance of these fungi increases with tree age, and they should therefore be less important in shorter rotations.

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Additional Information

Specimens of conks or advanced decay from living trees may be submitted for identification to:

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Victoria, B.C. V8Z 1M5
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