Evaluation of the Effects of Heart Rot Fungi on Live Tree Structural Stability

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Executive Summary

A project was initiated in 2006 to better understand and predict the effects of the native heart rot fungus *Phellinus pini* infection on tree structural stability (as applicable to hemlocks and true fir species). The project objectives were:

1. to correlate the presence of visible indicators (conks, blind conks) of infection by *P. pini* to tree wood condition (extent of decay, actual stem shell thickness);

2. to verify the criteria and rigour of the "conks indicator thresholds" currently used in the Wildlife Danger Tree Assessor's Course (WDTAC) training program for *P. pini* on hemlocks and true firs; and

3. to provide operational and safety recommendations concerning the assessment and management of trees infected with *P. pini* in forestry operations.

Two study sites were selected on southern Vancouver Island. In total, 14 western hemlock and balsam trees were measured and destructive sampled, providing an overall sample size of n=39 conk and blind conk stem positions for analyses. Project results yielded the following conclusions and recommendations.

The infection of host hemlock or balsam trees in susceptible stands appears to be relatively low and difficult to predict. In general, the occurrence of visible *P. pini* conks on such trees indicates internal heartrot decay, ranging from advanced staining to advanced white pocket rot with soft or brittle fiber and loss of wood strength. However, it is virtually impossible, without performing detailed diagnostic tests (e.g., increment boring, resistograph, tree felling), to predict whether an infected tree showing visible conks actually has sufficient AST (observed *Actual Shell Thickness* measured on the tree stem). Therefore, infected hemlock and balsam trees which show any visible *P. pini* conks should be considered suspect and potentially unsound. Trees with multiple conks spread along the bole, trees with multiple conks spread along the underside of infected limbs, trees with conks and other tree damage (e.g., broken tops, other fungal heartrot pathogens present), and dead trees with conks, will all likely have low AST/RST ratios with advanced decay present.

Trees with blind conks only indicate the early stages of decay (staining) and can be considered sound.

The following recommendations are suggested concerning worker safety and ongoing implementation of the current WDTAC procedures:

1. As per current WDTAC guidelines (WTC 2005), hemlock and balsam trees with any visible *P. pini* fruiting bodies (conks) should receive a default rating of *Dangerous* (D) for level of disturbance (LOD) 2, 3 or 4. This rating can only be overturned by conducting a detailed stem analysis, which is often not possible under operational forestry conditions.

2. Infected hemlock and balsam trees with multiple *P. pini* conks distributed along the bole or along the underside of limbs, or trees with conks AND other tree damage (broken tops, large stem scars or branch wounds), and standing dead trees (snags) with conks, should all be considered very suspect and be assigned a default *Dangerous* (D) rating for LOD 2-4.

Background

The Wildlife/Danger Tree Assessment Course (WDTAC) process recognizes the presence of heart rot as a potential dangerous indicator for trees. For some tree species groups, namely the Douglas-fir, Spruce, Pine and Larch group, the presence of the heart rot fungus *Phellinus pini* on live, undamaged trees does not rate as a high failure potential threat to the structural integrity of the tree. As a result, visual assessment of the trees affected by *P. pini* can be declared safe without performing a detailed stem analysis. However, for other species groups, such as hemlocks and true firs (hembal), the presence of *P. pini* is presumed to be a dangerous default conclusion. In addition, *P. pini* fruiting bodies (conks) are not always located at a height on the tree bole that would allow an assessor to conduct a detailed stem analysis. **Where conks are only evident in the upper stem of an otherwise healthy tree, the WDTAC guidelines currently require assessors to default to a dangerous rating for trees in the hembal group**.

Some preliminary observation of trees within the Hemlock and True Fir species group indicate that when live trees with conks of *Phellinus pini* are drilled or the trees are felled, there is sufficient solid stem thickness to declare the trees safe for retention. If this holds true for all live trees affected by *Phellinus pini*, then the tree assessment process can be modified, allowing assessors to make confident safety decisions based upon visual assessments of live trees. However, there has been very limited empirical data collected in this context, and results from this small sample size (Manning 2001) suggest that affected trees with *P.pini* conks must be live (tree class 2) AND have no other visible stem damage (scars, cracks, broken tops, etc.) in order to have sufficient “actual average stem shell thickness” (AST) and be structurally sound. Thus, new information which correlates the presence of *P. pini* conks with external tree condition and actual internal stem condition (i.e., as measured by average AST), is required for live trees from the hembal species group.

Phellinus pini is present throughout the entire geographical range of hemlock and true firs in British Columbia, and therefore if new information about the condition of trees with *P.pini* can be elucidated, this may prevent the felling of these trees. Furthermore, reducing the need to fell such trees would benefit wildlife that relies on these trees for habitat.

Project Goal and Objectives

Project Goal

1. to better understand and predict the effects of *Phellinus pini* infection on tree structural stability (as applicable to hemlocks and true fir species).

Project Objectives

1. to correlate the presence of visible indicators (conks, blind conks) of infection by *P. pini* to tree wood condition (extent of decay, actual stem shell thickness (AST));

2. to verify the criteria and rigour of the “conks indicator thresholds” currently used in the WDTAC training program (WTC 2005) for *P. pini* on hemlocks and true firs; and

3. to provide operational and safety recommendations concerning the assessment and management of trees infected with *P. pini* in forestry operations.

Distribution, Host Preference, Ecology and Damage of Phellinus pini

Phellinus pini is a widespread heartwood fungal rot. Its distribution spreads across the north temperate zone, with accounts of occurence noted across North America (Allen et al. 1996; Hunt and Etheridge 1995), and the Old World (e.g., Poland, Germany, Russia, Algeria).

As it occurs across a wide range of habitats, *P. pini* infects a large range of host species. In British Columbia it has been reported on all conifers except yellow cedar (*Chamaecyparis nootkatensis)*, common juniper (*Juniperus scopulorum*) and Pacific Yew (*Taxus brevifolia;* Hunt and Etheridge 1995; Anon. 2006). These three exceptions are recorded as host species elsewhere in its range. *Phellinus pini* most frequently occurs on Douglas-fir (*Pseudotsuga menziesii)*, mature pine (*Pinus* spp.) and spruce (*Picea* spp.), and western larch (*Larix occidentalis*, Boyce 1961); it occurs on hemlocks but less commonly than these previous host species. The true firs are much less susceptible to *P. pini*, though infection does occur (Hunt and Ehteridge 1995, Larsen and Lombard 1979).

Ecology of Phellinus pini

P. pini has many ‘varieties’ adapted to specific host species (i.e., decay dynamics and damage will vary with host species and age; Larsen and Lombard 1979). However, the life-history of *P. pini* has **not been studied extensively**, but is likely similar to that of Indian paint fungus (*Echinodontium tinctorium*; Hunt and Etheridge 1995). *E. tinctorium* infects western hemlock through living branches which provide access to the heartwood

(Etheridge and Craig 1976). Infection through adaxial twigs and branches usually occurs in late fall or early spring (i.e., during wetter cooler seasons). Subsequent infection of the heartwood follows and the fungus remain in the pith until conditions are optimal (**sometimes this process can take over 100 years**). In British Columbia, *P. pini* infections have been reported to occur in Douglas-fir and western hemlock at both branch stubs and wounds such as felling scars (“catfaces”) or broken tops, with branch-stub infections accounting for the majority (Thomas and Thomas 1954, Foster and Foster 1951).

Damage to Trees Caused by Phellinus pini

Phellinus pini causes red ring rot, also known as white pocket rot. The early stage of decay appears as a reddish-purple stain in the heartwood, termed ‘incipient decay’. Later, small spindle-shaped pockets running parallel to the grain are produced, hence the common name “white pocket rot” (Hunt and Etheridge 1995); the surrounding wood tends to be discoloured but still firm. Tests of wood strength suggest no significant weakening during incipient decay (Allen et al. 1996). The wood in advanced stages of decay is soft, light coloured and fibrous (Figure 1). Wood strength loss is considered to be “moderate” for trees with advanced decay. Decay is usually confined to the heartwood of mature trees, either in one continuous column or several discrete columns originating at branch stubs (Zeglen 1997). Typically the most extensive decay occurs in the trunk, but butt rot is common and sometimes the rot extends into the roots (Etheridge 1972).

Damage and decay caused by *Phellinus pini* develops after the fungus causes the springwood to flake. The decay is a white-rot decay (as opposed to brown-rot), and is characterized by the fungi destroying lignin first, and later cellulose (Kimmey 1964). From this stage fruiting bodies may develop at branch stubs, or wound faces and sunken canker faces along the tree bole (Figure 2). The appearance of the fruiting bodies (conks) is somewhat variable, but they are usually brownish, hard, woody, perennial and hoof-shaped; the undersurface is usually a light brown color with a highly porous texture (Figure 2A). The underside of the conks is a lighter brown in colour and porous. Zeglen (1997) noted that in a study of 31 species of wood decay fungi on Sitka spruce, that only *Phellinus pini* consistently produced the conks that indicate internal heartrot decay.

A host species may create barrier zones of cells in the phloem and xylem to attempt to prevent fungal spread (termed ‘compartmentalization of decay’). *P. pini* may overcome these barriers resulting in canker enlargement (Blanchette 1982). The effects of this on the wood differ by fungus variety. For example, a white rot decay occurred in the heartwood of white fir (*Abies concolor*), but selective delignification occurred in balsam fir (*Abies balsamea;* Blanchette 1982). If the tree is unsuccessful at compartmentalizing the spread of the fungus, decay will spread further into the heartwood. In trees with advanced decay, sporophores (conks) are often seen along the length of the bole (and frequently adjacent to branch stubs and along the underside of limbs).

Overall, *P. pini* is one of the single most damaging/destructive heartrots in North America (Etheridge 1972, Scharpf 1993), especially in old growth forests (Allen et al. 1996). This is likely the result of its wide distribution of host tree species. Bier et al. (1946) estimated the average loss due to *P. pini* decay is about 10% of the volume of interior stands, and less than 5% in stands on Vancouver Island and the Queen Charlotte Islands. In Douglas-fir stands in western Oregon and Washington state, Boyce (1961) estimated that *P. pini* comprises about 15% of the gross volume over the region. *P. pini* can also be found in second growth stands, but this occurrence is more commonly associated with Douglas-fir, spruces and western larch.

Figure 1. Advanced decay caused by *P. pini*. Note very thin, light colored sound stem shell (at arrow and around periphery), and fungal fruiting body (conk) to left of arrow.

Figure 2. Infected hemlock stem showing *Phellinus pini* conks located at an old branch stub and a sunken canker face on the bole.

Figure 2A. Mature *P. pini* conk. Note light brown color and highly porous undersurface.

Methods

In order to gather information about the condition and structural integrity of live (class 2) hemlocks and true firs infected with *P. pini*., and to test the criteria for rating such trees using the WDTAC process, the following approach and methods were employed.

1. Collect qualitative and quantitative data on live trees showing visible *P. pini* conks or blind conks. Data included:
   - tree species
   - tree height (range for stand)
   - diameter at stump height (dsh) – measured 30 cm above ground
   - number of visible conks or blind conks and their relative position (height) on the tree (measured from stump height position)
   - presence of other tree damage or pathogens (e.g., stem scars, broken top, other fungal species)
   - calculation of mean AST/RST ratios[1,2] for comparison to accepted shell thickness failure thresholds. This will also permit comparison with tree condition data collected previously by Manning (2001).

2. Fall and destructively sample trees with conks or blind conks of *P. pini*. **Each sample tree was bucked at the position on the tree where a *P. pini* conk or blind conk was visible**. Measure RST and AST at this point. Record character of decay at this point (e.g., no decay, incipient decay/staining, white pitted rot, brown rot). As needed, the tree can be bucked further along the bole in order to determine the vertical length/extent of the heart rot decay column within the tree bole.

3. Where appropriate, sampled trees were digitally photographed before and after destructive sampling. This provides visual information on external tree defects and internal tree condition, and can be used for training and extension purposes.

[1] RST = *Required Shell Thickness*. Calculated as tree radius at point of measure x 0.30.
[2] AST = observed *Average Shell Thickness*. Calculated as the average of actual stem sound shell width measured at 3 points around the stem at a given height position. This position corresponds to the position of the visible defect indicator (i.e., conk) above stump height.

Study Design

In order to efficiently locate study sites which contained hemlock or balsam trees infected with *P. pini*, the following approach was taken.

- contacted local logging operations (e.g, Lake Cowichan Community Forest) who are harvesting in stands containing mature/old hembal.
- obtained local knowledge of sites with mature/old hembal (local contacts with licensees, woodlot operators, regional MoFR pathologists).
- efforts were made to obtain samples from coastal and interior locations.

Sample Size

The sample design was **NON-RANDOM**. This was necessary because only hembal trees which had visible conks or blind conks of *P.pini* were selected for measurement and destructive sampling. Sampled hemlocks and true firs were pooled in the data analyses in order to increase the sample size. All efforts were made to obtain a minimum overall sample size of N=30.

Data analyses included simple descriptive statistics (totals, averages, ranges, standard error, Zar 1974).

Results

In order to reduce search time for hemlock/balsam trees potentially containing *P. pini*, correspondence with local logging contractors and regional Ministry of Forests and Range staff was entailed in October 2006 and March 2007 (as per *Study Design* above) on Vancouver Island (CWH biogeoclimatic zone) and in the Vernon-Revelstoke area of the south-central interior (ICH biogeoclimatic zone).

Despite at least 3 extensive field searches in potential candidate old hemlock stands in the south-central interior, no hemlock or balsam trees containing *P. pini* were discovered. Follow-up conversations with Kamloops Region forest pathologists (H. Merler *per. comm*.) suggested that the incidence of P. pini on hemlock in the southern interior of B.C. is very limited.

Stands of mature or old hembal were pre-identified in locations on Vancouver Island. Field reconnaissance resulted in the confirmation of the presence of *P. pini* at two locations in the Cowichan Lake Community Forest and TFL 46 on southwest Vancouver Island (Mt. Bolduc area west of Lake Cowichan, and Granite Creek Main area east of Port Renfrew, respectively). Field sampling was conducted at these locations during early October 2006 and May 2007. Extreme winter winds and higher than average snowpacks precluded access into any field sites between November 2006 – April 2007.

Both of the above locations were located in the CWHvm2 (very wet maritime) biogeoclimatic subzone, between 650-900 m elevation. Stands consisted of a mix of old growth (>240 years age) western hemlock (*Tsuga heterophylla*), amabilis fir (*Abies amabilis*), western redcedar (*Thuja plicata*), with minor components of yellow cedar.

In total, 14 trees (12 hemlock, 2 amabilis fir) were measured and destructively sampled at the Mt. Bolduc (8 trees) and Granite Creek (6 trees) sites. All trees but two were live (class 2) with few other visible defects. One hemlock (tree #14) had a broken top; two other hemlocks (tree #2, #12) were dead class 4 trees (these were included in the sample in order to increase the total sample size). For the purpose of analyses, this yielded a **total sample size (N) of 39 data points** (i.e., 14 trees contained a total of 39 conk, blind conk or near-conk positions where the tree bole was bucked and destructively sampled).

All sampled trees were bucked and sectioned at the position of the visible conk(s) or blind conks on the bole. In some cases trees were also bucked above and below the conk(s) in order to evaluate AST at these positions, thereby providing an indication of the length of longitudinal spread of the fungal decay column (this ranged from 1-4 m above or below the conk).

An overview of the sampling results is as follows:

- Mean tree diameter at stump height (n=14) 73.7 cm
- Mean trunk diameter at conk positions (n=39) 58.6 cm
- Tree height (as a range) 28 – 35 m
- Mean linear distance of conks from stump height 8.8 m (range 1.0 – 18.5 m)
- Mean AST (n=39) 13.8 cm (± SE 1.78)
- Mean RST (n=39) 8.8 cm (± SE 0.50)
- Overall Mean AST/RST ratio (n=39, 14 trees) 1.52 (± SE 0.16)
- Mean AST/RST ratio of trees with blind conks (n=6) 2.71
- Mean AST/RST ratio of trees with multiple conks (n=21) 1.09 cm (± SE 0.15)
- Mean AST/RST ratio of class 4 trees (n=2) 0.36
- Mean AST/RST for trees bucked above/below visible conks (from 1-4 m above/below conk, n=5) 2.29

Six trees contained blind conks, which are pronounced dark swellings containing masses of fungal mycelium, usually found around branch knots. Blinds conks are common in trees infected with *P. pini*, and represent early or abortive stages in the development of the fruiting body (Allen et al. 1996). Blind conks can be difficult to identify because they often become overgrown with new wood, leaving only a 'bulge or punk knot' visible on the tree stem. This is evidenced by the mean AST/RST ratio for these trees which was 2.71, indicative of AST values almost 3x greater than the required shell thickness for the affected stem at that position (i.e., the tree has ample sound stem wood)[3].

Trees with multiple conks (2-5 conks, n=21) showed a very marginal mean AST/RST ratio of 1.09.

While only a sample of n=2, the two class 4 hemlocks had a very low mean AST/RST ratio (0.36), which indicates they had insufficient sound stem wall thickness to meet minimum acceptable shell thickness requirements for tree columnar strength and integrity (WTC 2005).

The overall mean AST/RST ratio for trees (n=39 sample positions, 14 trees) with *P. pini* conks or blind conks was 1.52. This ratio meets minimum acceptable standards (i.e., AST/RST >1.0) as defined in the WDTAC (WTC 2005).

A summary of all field sampling data is provided in **Appendix 1** (attached separately).

[3] An AST/RST ratio of 1.00 means that the actual average stem shell thickness is equal to the required minimum shell thickness. Trees with a ratio of 1.00 or greater have sufficient sound stemwood shell to maintain columnar strength and structural stability. Trees (or positions on the bole) where AST/RST <1.00 have relatively thin stem shell walls and therefore have insufficient sound stemwood shell to maintain columnar strength and structural stability.

Other Observations

Three other species of native heart rot fungi were observed on hemlock trees in the Mt. Bolduc and Granite Creek stands. These were Indian Paint Fungus (*Echinodontium tinctorium*), Brown Crumbly Rot (*Fomitopsis pinicola*) and White Trunk Rot of Conifers (*Phellinus hartigii*). All three species were observed more frequently on hembal than *P. pini*. *E. tinctorium* was observed at the higher elevation limits (750m+ elev.). *F. pinicola* was observed primarily on dead stems. *P. hartigii* was observed mainly in association with branch wounds.

Most of the 14 trees infected with *P. pini* occurred in small clusters (i.e., relatively close spatial proximity), as opposed to being evenly distributed throughout the stand.

Discussion

The above results demonstrate some clear trends for hemlock and balsam trees infected with *P. pini*, as follows:

1. Trees showing **blind conks are in the early stages of infection** (termed incipient decay). Infected wood is stained reddish-purple (see Figure 3), but there is ample sound stem shell as evidenced by the high AST/RST ratios. Allen et al. (1996) cited that tests of wood with incipient decay from *P. pini* show "…no significant weakening".

Figure 3. Reddish-purple staining near a blind conk of *P. pini*. This is indicative of early (incipient) decay caused by this fungus.

2. The presence of multiple conks hi-lites the potential columnar weakness and structural instability of trees in this condition (mean AST/RST ratios very close to 1.0). In most cases where trees show **multiple conks spread longitudinally along the bole, decay will be extensive** and AST will usually be less than RST. For example, tree #13 (live class 2 hemlock, 48.0 cm dsh) had 5 visible conks spread along the length of the bole. The mean AST/RST ratio for this tree was 0.61, with a mean sound shell thickness of only 3.5 cm. This condition is indicative of a tree with a very thin stem shell and a high probability of stem failure.

3. Two sampled trees had other visible damage. Tree # 7 (live balsam) had a sound, unbroken dead top; tree #11 (live hemlock) had a broken top with *P. pini* conks clustered 3-5 m below the top. The balsam had a very low AST/RST ratio (0.33), while the hemlock had a marginally sufficient shell thickness ratio (1.42). In the case of the hemlock, proximity to the broken top may have accelerated the decay process and subsequent proliferation of fruiting bodies, in which case the amount of sound shell width will continue to decline over time. Manning (2001) found 4 cases of live hemlock or balsam which had low AST/RST ratios (<1.0) – these trees all exhibited fungal conks AND proximal stem damage (i.e., broken top, stem scar or large branch wound). While it is not possible at this time to state a clear correlation between the amount of AST and the incidence of other tree damage, the **presence of fungal conks and other stem damage should raise a 'flag of caution' concerning the likelihood of more advanced decay in that tree**.

4. While considering the limitations of a small sample (n=2), it is very likely that any **dead trees infected with *P. pini* will have extensive internal decay** with low AST/RST ratios.

5. Based on bucking points from 1-4 m above or below visible conks, it is clear that decay spreads vertically in both directions from the point of infection (which in most cases is a branch stub or broken branch). However, only minor staining was visible at 4.0 m distance, with onset of decay (staining) much reduced beyond 2 m vertical spread. Consequently, **decay columns from *P. pini* appear to be most advanced, with the least amount of sound shell, within 2 m from a visible fruiting body** (conk).

6. While the overall mean AST/RST ratio of 1.52 for all trees included in the sample meets acceptable minimum stem shell thickness criteria (WTC 2005), in fact13/39 (33%) of the total sample failed the shell thickness criteria (i.e., AST/RST ratios <1.0). An additional 8 trees only had marginally acceptable ratios between 1.06-1.42. Consequently, while the presence of a single *P. pini* conk does not always indicate insufficient sound shell thickness, **trees with conks will in the very least have advanced staining and/or some measure of advanced decay** (white pocket rot).

7. While not quantifiable, field observations obtained during sampling suggest the following patterns associated with the incidence and tree damage caused by *P. pini*:

   - No clear differences in the extent of decay on hemlock versus balsam.

   - Where *P. pini* conks occur along the length of a limb (Figure 4), the extent of decay in the adjoining trunk appears to be advanced.

Figure 4. Numerous *P. pini* conks distributed along the underside of an infected hemlock limb. Note that advanced decay has extended into what was the heartwood of the tree stem (left side of photo).

- In all cases, the observed infection courts (i.e., point of entrance) for *P. pini* into host trees was through **branch ends and broken branch stubs**.

- **The decay dynamics of *P. pini* appears to be very slow**. From the time of initial infection, through incipient decay (staining), to advanced decay (white pocket rot, delignification and eventual breakdown of cellulose, softness, brittleness, and loss of wood strength), **can often take well over 100 years** (Figure 5).

Figure 5. Cross-section of infected hemlock stem showing barrier zone line (hi-lited black). This indicates the outer extent that decay would likely have progressed within the heartwood of this tree. By counting annual rings, there are approximately 130 years (double arrow) between the time of initial infection (black zone line) and the current date. Again note the infection court through the broken branch stub.

- **Trees are infected through completely stochastic (random) events**. In most cases this is the result of branches broken during wind or snow events during the autumn when *P. pini* sporophores (conks) on other trees are coincidentally releasing airborne spores. By chance these spores must land on a freshly wounded tree host and begin the infection process. Most of the sampled trees occurred in small clusters in the stand, and in the case of the Granite Creek site, infected trees were all within the same elevation band and aspect (SE exposure to prevailing winds) on the slope. This suggests that *P. pini* infection of some of these trees may have occurred as a result of the SAME stand damaging event (i.e., a fall or early winter storm which broke branches). However, the amount of decay currently present in any of these trees is variable. In other words some trees had sufficient AST/RST ratios, while others did not.

  Again, the advancement and amount of decay is a function of the diameter (amount of current heartwood) and vigor of any individual tree. Some trees will be more successful in compartmentalizing the infecting pathogen and restricting decay to the diameter of the heartwood at the time of infection (as per the '*Compartmentalization of Decay in Trees*'(or CODIT) theory, Shigo 1991, see Figure 6). If incremental tree growth is relatively good, the tree has no other injuries or stressors (e.g., stem damage, climate factors, other pathogen attack), and the tree is able to put on new annual wood at a faster rate than the generally slow decaying *P. pini* fungus, then trees with visible conks can still have sufficient sound stem shell (AST/RST will be > 1.0) and be relatively structurally sound (Figure 7).

- The presence and frequency of hemlock and balsam trees infected with *P. pini* is generally low, random and poorly predictable. This is due to the random nature of the host infection process as well as the general "preference" of *P. pini* for other coniferous species (especially Douglas-fir, spruces, pines and western larch).

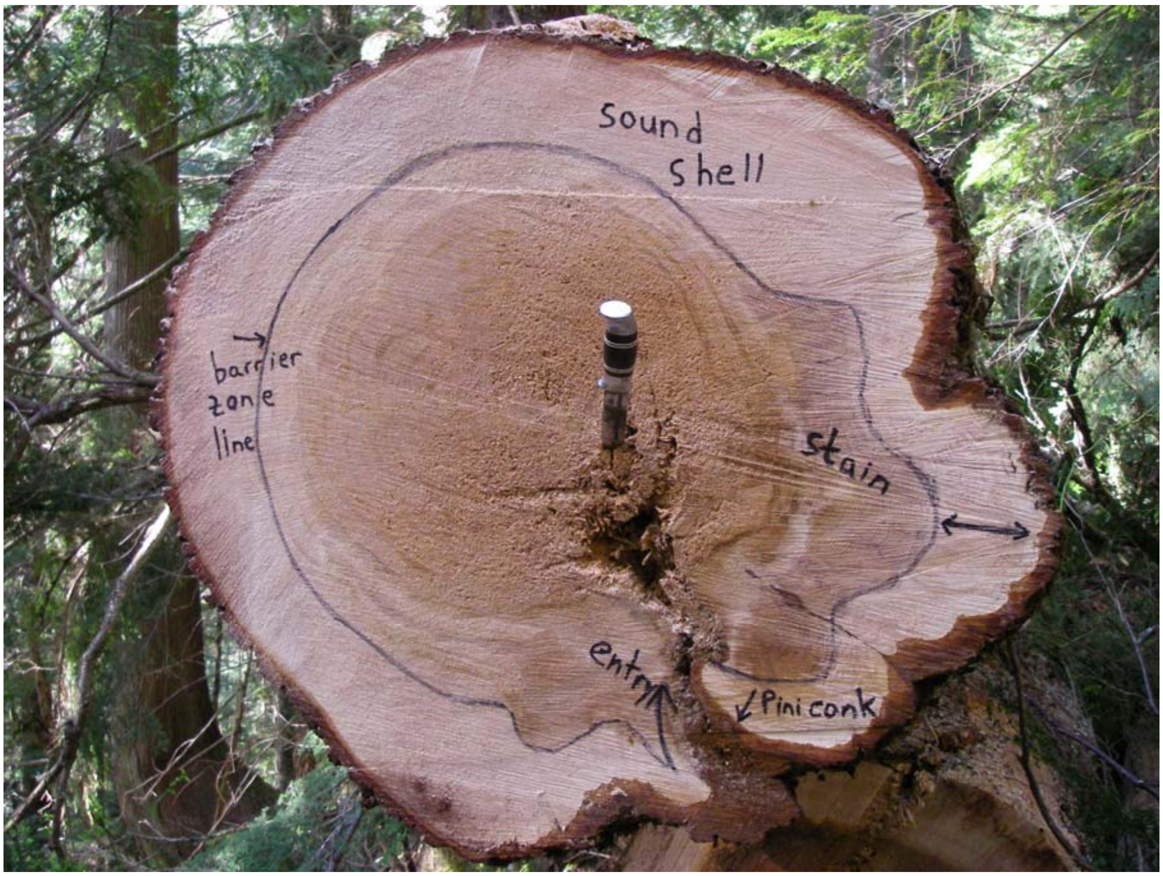

Figure 6. Cross-section of tree stem taken at conk position. Note entry point of fungus at old branch stub, areas of advanced decay (with knife) and staining, and dark barrier zone line which indicates the outer limit that heart rot would have extended in this tree according to the CODIT theory.

Figure 7. Advanced heartrot decay in central section of infected stem. Note that the tree has successfully compartmentalized the invading pathogen (at dark zone line) and there is sufficient sound outer stemwood (AST>RST) to provide columnar strength.

Conclusions and Recommendations

The infection of host hemlock or balsam trees in susceptible stands appears to be relatively low and difficult to predict. In general, the occurrence of visible *P. pini* conks on such trees indicates internal heartrot decay, ranging from advanced staining to advanced white pocket rot with soft or brittle fiber and loss of wood strength. However, it is virtually impossible, without performing detailed diagnostic tests (e.g., increment boring, resistograph, tree felling), to predict whether an infected tree showing visible conks actually has sufficient AST. Therefore, infected hembal trees which show any visible *P. pini* conks should be considered suspect and potentially unsound. Trees with multiple conks spread along the bole, trees with multiple conks spread along the underside of infected limbs, trees with conks and other tree damage (e.g., broken tops, other fungal heartrot pathogens present), and dead trees with conks, will all likely have low AST/RST ratios with advanced decay present.

Trees with blind conks only indicate the early stages of decay (staining) and can be considered sound.

Recommendations

The following recommendations are suggested concerning worker safety and ongoing implementation of the current WDTAC procedures:

1. As per current WDTAC guidelines (WTC 2005), hemlock and balsam trees with any visible *P. pini* fruiting bodies (conks) should receive a default rating of *Dangerous* (D) for level of disturbance (LOD) 2, 3 or 4. This rating can only be overturned by conducting a detailed stem analysis, which is often not possible under operational forestry conditions.

2. Infected hemlock and balsam trees with multiple *P. pini* conks distributed along the bole or along the underside of limbs, or trees with conks AND other tree damage (broken tops, large stem scars or branch wounds), and standing dead trees (snags) with conks, should all be considered very suspect and be assigned a default *Dangerous* (D) rating for LOD 2-4.

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All photographs taken by Todd Manning.

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