HAZARD TREE ASSESSMENTS: DEVELOPING A SPECIES PROFILE FOR WESTERN HEMLOCK

by Julian A. Dunster

Abstract. Many new housing developments are moving into forests and the public and political pressures to retain trees are high. However, in the absence of good species profiles, hazard tree and tree retention assessments in such forests are fraught with problems. To overcome some of these, species profiles are being developed to assist arborists in knowing what is reasonable to retain and why, and to provide a more defensible basis to justify removal. The hemlock has been evaluated in detail. The findings reveal that external indicators are not sufficient to judge the internal condition of hemlocks. A preliminary species profile has been developed for the western hemlock and is now being refined.

Effective hazard tree assessments require knowledge of failure characteristics for individual tree species. Ideally, a species profile should guide the assessor in a range of conditions, and provide understanding about typical modes of failure, susceptibility to insect and disease attack, and factors that exacerbate stress.

In the Lower Mainland of British Columbia, Canada, much of the tree cover is dominated by second growth conifers. Many new developments are moving into these forest types, and the public and political pressures to retain trees are high. However, in the absence of good species profiles, hazard tree and tree retention assessments in such forests are fraught with problems.

To overcome some of these, species profiles are being developed to assist arborists in deciding what is reasonable to retain and why, and to provide a more defensible basis to justify removal. Western hemlock (*Tsuga heterophylla*) has been evaluated in detail, including the examination of over 500 increment cores and subsequent checking of stumps once hazard trees have been felled. The findings reveal that external indicators are not sufficient to judge the internal condition of hemlock trees. A sampling protocol is recommended to ascertain the presence or absence of decay, following which removal or retention recommendations can be more wisely prescribed.

A preliminary species profile has been developed for the western hemlock and is now being refined. Some of the problems encountered in assessing hemlocks are outlined, along with suggestions for an assessment protocol.

The Need for a Species Profile

Tree retention assessments in an urban setting should consider the species' characteristics, condition, and location. In addition, the potential for long-term healthy survival in modified or an altered setting, as development or redevelopment takes place, must also be considered. Knowing the characteristics of a tree species is especially important in undertaking hazard tree assessments, (5,11,14,19).

In the Lower Mainland of British Columbia, second growth coniferous forest covers a considerable part of the new sites now being developed. Typically, this forest consists of three main conifers species: Western hemlock (*Tsuga heterophylla*), Douglas-fir (*Pseudostuga menziessii* var. menziesii) and Western red cedar (*Thuja plicata*). Of the three, most problems are encountered with western hemlock. This species seems to be predisposed to windthrow and disease, and has proved to be a difficult tree to evaluate, and a dangerous tree to retain (6).

Definitive species profiles, based on empirical data about modes of failure, especially in an urban setting, either do not exist for these species or, are extrapolations from commercial forestry research. These extrapolations typically encompass only a few of the permutations likely to be found in urban settings (1,4,7,10,11,17,19). In the absence of species profiles, most contemporary assessments are based on an analysis of external characteristics: colour of the foliage, growth rate, presence or absence of disease, wounds, damaged branches or structural defects. The assumption in making these external assessments is that internal problems will be manifested as external indicators.

Investigating Western Hemlock

The impetus to develop more refined species profiles came in September 1993, when a severe wind storm provided a unique opportunity to study the condition of windthrown hemlock root mats. Trees that had previously been assessed as suitable for retention, based on thorough assessments of external conditions, were found to have root and butt rots in varying degrees of severity. Although physiologically still quite functional, they were structurally very weak. As a result many blew down or snapped off at points of decay.

Opportunities to simultaneously examine a large sample of trees for root and trunk conditions before and after exposure of the roots are rare. However, a preliminary study was undertaken right after the 1993 windstorm while the fallen trees were still *in situ.* The goal of this study was to see if a single increment core, taken from the root crown area, showed any relationship between the condition of the wood at the base of the tree (the butt) and the condition of the roots.

Forty trees were investigated by examining the upturned root mats for evidence of fungal decay, and then taking a single increment core from the root crown area. The cores were carefully examined to determine if butt rot could be detected, and if the colour of the core exhibited any relationship to the condition of the roots.

The results showed quite conclusively that trees having root rot in any stage from incipient through to advanced, had a corresponding decay pattern in the increment core. The cores varied in colour and texture. The wood of a healthy hemlock with no decay at all has a clear, pale cream colour, the wood is solid and cuts cleanly with the increment bore. Incipient decay seems to be marked by various stages of discolouration, ranging from light to dark brown in colour, and radiating outwards from the centre. The outer part of the increment core is typically cream-coloured, sound wood. The part exhibiting incipient decay tends to have a more fuzzy appearance and does not cut as cleanly. This textural quality ranges from slightly fuzzy through to soft and extremely rough. The wood that is in an advanced stage of decay is very difficult to core effectively, and tends to bunch up in the extractor. In cases where the tree is hollow, only a partial core can be extracted. In all cases, the windthrown trees bore no external indications of internal decay. Foliage was normal in colour, growth rates were average for the previous years, there were no external indications of disease, and no scars or wounds could be correlated with the internal decay.

On the basis of this detailed increment core and root mat examination, it was concluded that an increment core could be used as an indicator of internal condition. Detailed root and butt log analysis revealed that the root rot almost always leads to a progressive column of decay, originating in the larger structural roots, and then extending upwards through the root crown into the bole of the tree (see plate 1). The extent of root and butt rot seemed to be less well related. Extensive rot in the roots did not always occur with extensive and well defined rot in the tree trunk. But, well defined butt rot did seem to be associated with an advanced stage of root rot.

Subsequently, the forest area surrounding the development site was thoroughly investigated. Several hundred standing trees were examined. Every hemlock encountered was assessed using standard visual techniques of investigation. In addition, each hemlock was cored once at the root crown to determine the internal condition.

Of the 173 hemlocks investigated and documented in detail (about 500 were initially analysed but not all were recorded in detail due to time constraints), 46 (27%) were marked for removal. Following removal, the site was revisited and the stumps were examined. Of the 46 trees removed, approximately 50% had pronounced decay (rotten wood) or were hollow, while the other 50% showed signs of incipient decay, either as discoloured wood or as wood that was starting to decay. This was as expected on the basis of the initial increment core analysis.

As shown in Figures 1 and 2, the diameter of the trees investigated bears no obvious relationship to the presence or absence of decay. The distribu-

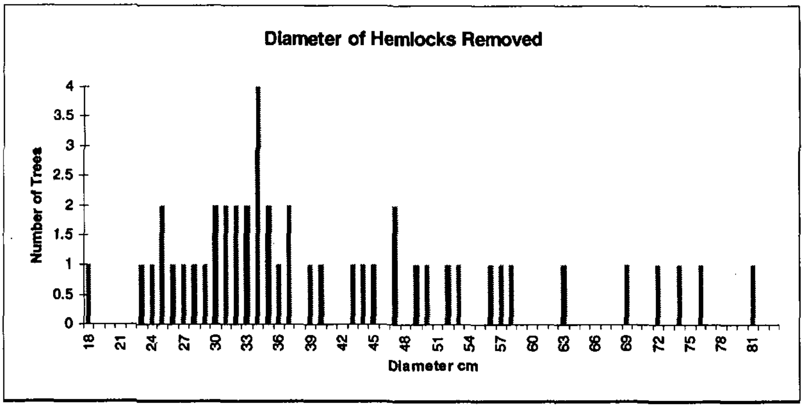

Figure 1.

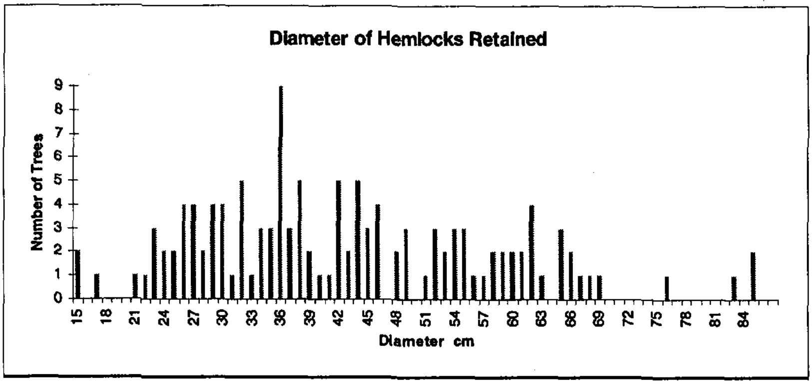

Figure 2.

tion of diameters has a typical bell curve, reflecting the gradual recovery and reforestation of a heavily disturbed site, in this case, logging and burning around the turn of the century. Note that the distribution of trees with decay encompasses all sizes, and by extension, all ages. However, caution must be exercised in using diameter as a surrogate indicator of age. Some of the smaller diameter trees are quite old, but of small diameter due to heavy suppression; others are young and developing in previously formed canopy gaps. Nonetheless, analysis so far suggests that all age classes are susceptible.

Other Problems Associated With Hemlocks

During the course of this intensive investigation, several other previously unsuspected factors emerged. Hemlock in this part of the world is known to be susceptible to the traditional root rots such as Armillaria (*Armillaria ostoyae*), Phellinus (*Phellinus weirii*), and Annosus (*Heterobasidion annosum*) (1,2,7,13,16,17). It is also known that diagnosis of root rots is difficult without careful investigation of the below ground components of the tree. Diagnosis is complicated by the slow development of decays, and the great variability with which trees manifest external signs of internal decay damage (16,17). Dwarf mistletoe (*Arceuthobium tsugense*) is also common and causes varying degrees of damage, ranging from reduced growth and loss of vigour, to top kill, and mortality. The dead tissues resulting from mistletoe infestations are known to be points of entry for other diseases. Mistletoe infestations can be fairly well assessed and classified to give some management direction (12,18).

The root samples sent off to Natural Resources Canada for identification also revealed the widespread presence of yellow root rot (*Perreniporia subacida*); a fungal disease once thought to have fairly insignificant importance in commercial timber management operations, but becoming increasingly evident in many different sites (4,9,15). Yellow root rot affects both roots and the butt of the tree (13,17). The conk is typically a blanket or sheet of yellow to white mycelium wrapped around the underside of roots. In its advanced stages, the decaying wood delaminates, which can lead the observer to diagnose laminated root rot (*Phellinus weirii*). The absence of clearly visible conks, even with root examination, makes the disease especially difficult to diagnose until it is well advanced. The onset of yellow root rot, like many of the other diseases, seriously weakens the tree, thus predisposing it to windthrow, or trunk failure.

Another interesting defect is that hemlock is able to rapidly callus over wounds, completely covering them to the extent that they are not easily noticed. Several trees were found having slightly flattened areas on the trunk. Only when they were tapped was it possible to notice that the hollow beneath the bark. Removal of the bark at these points reveals a more typical wound surface underneath, complete with callus roll and decaying wood. The only other indication of the old wound is a slight slime flux in some cases, usually a blackish secretion at some point on the edge of the wound area, or cracks in the outer bark, varying in size and extent. Neither sympton was found consistently.

Hemlock is known to be very susceptible to wounding on the roots and tree trunk, and research has shown that trunk wounds and branch scars are a very significant point of entry for disease (4,9,13). In particular, freshly exposed wounds on hemlock are readily colonised by primary and secondary "wound parasites" (9) and other diseases such as the Indian paint fungus *Echinodontium tinctorium*, and the red ring rot *fomes pini*, leading to significant volume losses due to trunk rots and breakage at points of decay. This has significant implications for tree retention activities where site clearing activities, or past logging and other site disturbances, have created large trunk wounds. Extrapolating the evidence from analyses of wounds in industrial forestry, suggests that such wounds will lead to structural failures in later years.

Not all of the windthrown hemlock trees assessed had root rot or other structural defects. Many were healthy and would quite rightly have been retained on the basis of external examinations. Windthrow is a common problem in most west coast forests, and our knowledge of factors contributing to windthrow is fairly recent, and as yet only partially developed (3). Certainly we know that second growth trees that have been isolated from their original stand, and new edge trees created from within the stand, are unstable and not well adapted to edge conditions. Typically, they will have very high crowns with few if any lower branches. This places all of the wind stress at the highest point on the tree, where effective leverage is greatest. Under strong wind conditions even healthy trees will blow down; defective trees blow down sooner. Given the tall, very spindly nature of many second growth trees, they are seldom able to adapt to the new wind patterns; removal and replanting is a much more effective and safer long-term solution (6).

Root Mat Morphology

Examination of root mat morphology revealed that hemlock is consistently shallow rooted, regardless of soil type. The root system typically comprises many radial roots of approximately equal size. The roots form a dense interlaced mat penetrating the soil to as much as 50 or 60 centimeters for a tree 80 to 90 centimeters in diameter, and occasionally deeper for the larger and older trees.

Hemlocks are shade tolerant, and prefer to grow in damp areas. These areas are often zones of poor drainage, typically with shallow soil above a hardpan or impervious stratum. As a result, many of the root mats examined resembled a pancake of roots that has penetrated to their maximum depth and then grown outwards. Under conditions of high water table and strong winds, the structural capability of the soils was diminished enough to permit windthrow. Many windthrown hemlocks reveal a yellow felt mat completely engulfing one or more roots, which is characteristic of the yellow root rot.

The correlation between root mat diameter and drip line distance was very strong, and confirms that setback distances in development sites should be at least equal to the drip line distance to avoid root damage. The well defined edge of most root mats was very similar in extent to the drip line, although many smaller roots, typically several centimeters in diameter, were found extending several meters beyond the drip line distance.

A Preliminary Species Profile

In the intervening two years since these problems first came to light, a species profile for western hemlock has been built up using the results of these investigations. The following factors should be considered when assessing western hemlocks.

1. They are always a shallow rooted species, regardless of soil conditions, and tend to have many similar sized radial roots, rather than a few large roots. The drip line is a minimum distance for set back protection during development. They are very susceptible to windthrow, especially when they have been isolated from their original second growth stand conditions.
2. They are susceptible to a range of fungal root diseases, including Armillaria, Phellinus, annosus, and yellow. External indications of decay in the roots and butt are not always present, at any time of the year. Fungal decay at points up the trunk is virtually impossible to detect with an external examination until it is very well advanced.
3. Trees that are physiologically functional, and have apparently healthy foliage of normal colour and growth rate, can still have very advanced stages of internal decay. If this decay is in the form of a root rot, or a butt rot, the tree should be classed as a high hazard and considered for removal if targets are within striking distance.
4. Hemlock is predisposed to breakage of the main trunk at any point along its length. Decay problems readily occur at points of branch breakage or pruning, in crotches between twin leaders, or at other points of wounding. Decay is not solely restricted to the roots or butt of the tree trunk.
5. Given the species' predilection for decay at wound sites, great care should be taken to ensure that trees previously wounded are thoroughly assessed, and new wounds are carefully avoided.
6. Hemlock trees or stands infested with mistletoe should be carefully assessed to determine the level of infestation. Heavy infestation levels equate to structurally weak trees which should be marked for removal.

Overall, it has to be concluded that mature or even semi-mature western hemlock is seldom an easy tree to retain in urban developments. This is especially true when the trees are remnants of a second growth forest. Any hazard tree assessment involving western hemlocks must exercise extreme caution.

Developing an Assessment Protocol

In view of the high incidence of root and butt rot encountered on all sites throughout the Lower Mainland of British Columbia, the following assessment protocol is recommended for western hemlock.

1. The tree must be carefully examined for external indicators of defect. Yellowing foliage, the presence of dwarf mistletoe (especially in heavy infestations), the appearance of codominant leaders, old scars, branch wounds, and recent exposure are all important, and may be sufficient reason to justify removal.
2. A single carefully placed increment core should be taken from the root crown area, aiming to extract a core from the edge right through to the centre of the trunk. The presence of advance decay or, advanced stages of incipient decay is an automatic reason for marking the tree for removal. Care should be taken to assess trees at least three tree heights back from the targets, because falling hemlocks, especially the larger trees, have a considerable weight and are capable of knocking down other healthy trees to create a domino effect. Initial stages of incipient decay may indicate the need for additional cores to verify that the decay has not been missed with the first core. Given the species' predilection to

decay and subsequent failure, it is better to err on the side of caution.

3. In the event that butt rot is absent or only slightly present, it may be prudent to take one or more cores from immediately above larger roots, to confirm the presence or absence of root rot. However, each additional core is an additional wound, so a balance is necessary. Remember that the research reported here indicated that root rot can be quite extensive, even when butt rot is absent.
4. The surrounding landscape must be carefully assessed as well as the tree. New edge trees, that were formerly part of a larger stand, will have high crowns, often with sparse branch densities. Such trees are inherently unstable and will be far more likely to blow down than trees that developed in isolated conditions. A branching pattern that extends well down the tree trunk indicates more open grown conditions, and by implication, a higher degree of windfirmness.

Conclusions

While no definitive species profile for western hemlock has previously been developed, I feel confident that the findings reported here are a good basis for better assessments of the western hemlock. Although more data are needed to confirm and refine the initial findings, enough is now known to make defensible recommendations for this species. In the Lower Mainland of British Columbia, the high public and political pressures to retain almost any tree, regardless of health or species characteristics, remain a reality. However, if the certified arborists are to refine their hazard tree assessments, they must have the courage to stand up and recommend removal when it is necessary, and not be pressured into retention of hazardous specimens. Ultimately, our professionalism in hazard tree assessments will be tested in the courts; being able to use the best available information in our decisions will be an important part of our credibility.

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Résumé. Plusieurs nouveaux développements résidentiels se font maintenant en milieu forestier et les pressions publiques et politiques pour préserver les arbres sont fortes. Cependant, faute de bons profils d'espèces, l'évaluation du risque potentiel de chute et de la valeur de conservation des arbres forestiers est pleine de problèmes. Afin de surmonter certains de ces problèmes, des profils d'espèces ont été développés pour aider l'arboriculteur à reconnaître ce qui est raisonnable d'être préservé et pourquoi, et aussi pour pouvoir fournir une meilleure base défendable pour justifier l'abattage. La pruche a été évaluée minutieusement. Les conclusions ont révélées que les signes extérieurs sont insuffisants pour juger de la condition interne des pruches. Un profil d'espèce préliminaire a été développé pour la pruche de l'Ouest et est maintenant en cours de raffinement.

Zusammenfassung. Viele Neubaugebiete werden bis in die benachbarten Waldgbiete hinein erschlossen und der Druck seitens der Politiker und der Bevölkerung diese Wälder zu erhalten, ist groß. Wie auch immer, in der Abwesenheit von guten Artprofilen ist die Überprüfung von anfälligen Bäumen und die Entfernung von Bäumen nicht Problemen behaftet. Um einige dieser Probleme zu bewältigen, wurden Artprofile entwickelt, die die Arboristen in der Entscheidung, was ist schützenswert und was nicht, unterstützen sollen und es soll eine solide Basis geschaffen werden, um Entscheidungen zum Entfernen von Bäumen zu rechtfertigen. Die Hemlockstanne wurde detailiert bewertet. Die Ergebnisse verdeutlichten, das externe Indikatoren nicht ausreichen, um die interne Kondition der Hemlockstanne ausreichend zu bewerten. Für die Hemlockstanne wurde vorab ein Artprofil entwickelt, welches nun verbessert wird.