Do You Hear What I Hear?
Part II: Field Application of Sounding

By Christopher J. Luley and Mike Ellison

The Tools

Our experience shows that mallets or hammers in the 10 to 16 ounce weight range, with heads made of nylon or hard plastic, are the most effective for identifying changes when sounding a tree (Figure 1). These tools are often sold as woodworking hammers and may have interchangeable hard rubber and plastic heads. For the field arborist, use of the hard-plastic end produces the best results. Many arborists also use large-faced, rubber mallets, but these are less likely to produce clear and definitive results. However, many variations in types of mallets are in use, and individuals should find the tool they are comfortable with that produces the best results for them.

Figure 1. A 12-ounce woodworking hammer (left) works well for sounding. We recommend the use of the hard plastic (yellow) side of the tool. The "Thor hammer" (right), with a hardened nylon head, is widely used for sounding in the United Kingdom and Australia.

Figure 2. Damage to the outer bark of a red maple (*Acer rubrum*) that was intentionally inflicted from an excessive hammer strike (left). Small, weeping lesions on the roots of a European beech (*Fagus sylvatica*), caused by moderately light tapping with a sounding hammer (right).

How to Sound a Tree

If care is not exercised, sounding can cause damage to the phloem and vascular cambium, as well as to the cortex of thin-barked trees. While *any* hammer can cause damage to a tree if sufficient force is used, an arborist can usually avoid such damage by taking care and by not using heavy, metal hammers and excessive force when striking. Particular caution is advised on thin- or smooth-barked trees, as anecdotal evidence indicates that they are more susceptible to damage from hard strikes (Figure 2), especially in spring when the cambium is active. Some species, such as the Moreton Bay fig (*Ficus macrophylla*), are highly susceptible to damage, and again caution should be exercised.

The force required to strike a tree during sounding is best described as light tapping, as compared to stronger strikes that might be used during hammering, or when driving a nail into wood. Thick-barked trees, or those with denser wood, may require a little more force to be applied. However, a general rule is to use no more force than is required to obtain a diagnostic resonance for any particular situation.

Three steps are typically used in the effective application of sounding. The first is establishing a benchmark for the resonance of non-decayed or non-defective wood in the tree being evaluated. This might be from past experience with the species or via direct testing of the particular tree for the resonance of "normal" wood and intact bark. A standard can almost always be directly determined by sounding known solid, healthy areas of the tree, or of a healthy tree of the same species nearby.

The second step is to start tapping where you expect the tree to be solid and non-decayed. When investigating possible basal decay, this will usually be higher on the trunk or branch. Using light, evenly spaced taps, and work toward the area of concern, listening for changes in resonance, which can often be subtle. Typically, this procedure is repeated several times in the same location to note any changes, and also to focus the tapping where differences in resonance become apparent. This is usually followed by tapping around the circumference of the trunk or branch, using the same procedure. The goal is to locate changes in the thickness of the residual wall of the trunk, root, or branch, and identify other potential defects by observing those often subtle changes in resonance (Figure 3). It is important that sounding be guided by an understanding of tree species and their specific growth and decay patterns.

The third step is to investigate any audible anomalies. This step is also where experience in sounding is beneficial to interpret the importance of any result. It is not unusual to continue sounding as needed to determine the type and extent of any potential defect. Practicing sounding with an experienced instructor is probably the easiest way to become proficient in interpreting results. A detailed visual assessment, probing, or shallow excavation at the root flare with a trowel are all easily and commonly used to supplement sounding results for diagnostic investigations.

Figure 3. Sounding is a learned skill. It is best to establish a baseline resonance where the tree has solid wood and intact bark, from which tapping can assess the resonance, slowly moving toward the area in question.

Application

The most common use of sounding is for decay evaluation. Decay that results in internal hollows, surrounded by a relatively thin cylinder of sound wood, is the easiest to detect with sounding because of the "drum" effect. Sounding can effectively identify the location and relative severity of such hollows in a trunk or stem. Sounding is often used to determine the need for additional, advanced testing, and thus locating the area of the tree or tree part requiring advanced evaluation (Figure 4).

Trees with decay that are not hollow can also be assessed with sounding, but identification requires greater levels of skill and experience to identify the decay presence, and to quantify the extent of decay. Sounding also is effective in identifying areas where bark and cambium have died, but where the bark is still mostly attached to the trunk. Bark or cambium death from cankers or other causes that may be impacting tree health can often be located with sounding—at which point further diagnosis would be required.

Figure 4. Sounding can be used to identify trees that may require advanced assessment techniques, such as tomography.

In practical field application, sounding is an important starting point for further diagnostics. In its most basic use, sounding allows an arborist to classify a tree or a visual defect as requiring additional evaluation, or can provide a level of certainty that a tree or defect is stable in its current state.

Roots are more difficult to evaluate with sounding but can be assessed with practice, to some degree. A normal woody root near the trunk has lots of connection with the ground and with subordinate roots, and typically, there will be little acoustic resonance (providing a solid, high pitch on sounding). If the root has few connections or is perhaps decayed on the underside, it will have reduced connection with the ground and will accordingly have increased acoustic resonance (lower, dull pitch

Figure 5. Sounding of roots near the base of a tree can be more difficult. However, roots with decay or have a poor connection to the soil may produce low, dull resonance on sounding, compared to normal roots with good soil connection. Interpretation of sounding results is more difficult, in general, with roots.

Figure 6. Sounding can help assess trees lacking additional, obvious decay indicators and may have decay in their base. In the case pictured here, decay may have entered the trunk through roots, as was the case with this oak infected with *Grifola frondosa*, which fruits only in autumn.

on sounding) (Figure 5). Soil conditions and other factors that result in normal roots being less connected to the soil, such as soft or waterlogged soil, can also be identified for further investigation as needed.

In practical field application, sounding is an important starting point for further diagnostics. In its most basic use, sounding allows an arborist to classify a tree or a visual defect as requiring additional evaluation, or can provide a level of certainty that a tree or defect is stable in its current state. These results can inform important conclusions that often cannot be reached with visual evaluation alone or without using valuable time and testing resources needed for advanced assessments.

Sounding is also an important tool used to identify trees with advancing decay that do not have obvious decay indicators. This is most common on trees where root decay has moved into the base of the tree and no wound or other indicator is present on the trunk (Figure 6). These trees might be overlooked or classified as normal, where visual evaluation alone is used. Further, trees with decay in the undersides of buttress roots that do not (visually) appear to be decayed usually have reduced contact with the soil and may produce an altered resonance.

Factors Affecting Sounding (and Other Limitations)

Sounding has a clear human component that cannot be ignored. Training and practice on trees with decay are essential to becoming proficient in the use of this skill. Hearing acuity varies greatly among individuals, and auditory deficiencies in the sound ranges needed could limit the ability of some arborists to apply this method. Our experience shows that arborists are sometimes resistant to learning sounding possibly because it appears too basic, rather than because sounding does not work or is too difficult to learn.

Figure 7. Interpretation of sounding results can be more difficult on trees with thick bark or less dense wood, such as on this older larch, infected with *Phaeolus schweinitzii*.

Several species-related factors also affect one's ability to interpret sounding results. Wood density affects sounding in that tree species with low wood density (such as many conifers, cottonwoods, willows, basswoods, and similar species) produce auditory results that resemble decayed wood even if they are sound. Particularly with early-stage or incipient decay, the difference between trees with decay and those with non-decayed, sound wood may be subtle, and thus difficult or impossible to discern. Conversely, species with very dense wood (such as some oaks, hickory, and sugar maples) can mask decay because of the density of even small amounts of sound wood under the bark.

Bark thickness is a very important factor. Thick bark on some species, particularly older, soft-barked, or other species, can provide a cushioning that limits the effectiveness of sounding for inner decay or defects (Figure 7). This can be an important limitation in some cases, since it is common for larger diameter, older trees to have thicker bark, and larger diameter trees are more likely to have increased amounts of decay.

Sounding may be less effective for evaluating decay caused by some fungi. For example, *Kretzschmaria deusta* and *Ganoderma sessile* are less likely to form internal cavities, particularly where there is rapid progression of decay (Figure 8). Sounding to quantify decay when these fungi are present requires more skill, and is a less effective evaluation method overall.

Sapwood decay patterns, or decay that follows the death of the bark and cambium and progresses from outside the stem inwards, can be identified but usually cannot be effectively quantified using sounding (Figure 9). Sapwood decay presence, which is often overtly evident from visual examination, can be recognized by the dull or soft sound it produces or softness of the wood upon striking. When sapwood decay is present, other methods of testing, such as probing, may be necessary to quantify the extent of decay. Knowing the limitations of sounding is especially important for climbers, considering sapwood decay can greatly impact safe working and ascent practices.

The use of sounding should be part of the process of assessing tree stability and the structural integrity of trunks, roots, and branches. This does not mean that the arborist should tap every accessible part of every tree. When a growth anomaly or feature has been identified as requiring further investigation, the sounding hammer or mallet can be the first stage of a more detailed assessment. This is where arborists use sounding together with a visual assessment, along with their knowledge of decay, to judge the need for additional testing. Without sounding, this decision to obtain information on the presence and severity of decay can be considerably more challenging.

False Negatives and False Positives

Any arborist who relies on sounding should be aware that false negatives (decay is present, but is not detected) or false positives (no decay is present, but is interpreted to be present) are possible.

False negatives usually result when trees are decayed but the decay has not progressed to the point of creating hollows, or where there is a large enough amount of non-decayed sapwood to mask the internal decay. False negatives are often intuitively apparent when trees have conks or visual evidence of decay, but sounding does not produce a definitive result.

False positives are also of concern and can occur due to misinterpretation when species with low-density wood are sounded, or when defects, such as cracks or ring shake (separation of annual rings), are present. In some instances, a false-positive from ring shake (Figure 10) can be convincing enough that action is taken on trees that have no significant internal decay. Advanced testing with resistance drilling or tomography can help identify trees

Figure 8. Decay caused by some fungi, such as *Kretzschmaria deusta* (left) and *Ganoderma sessile* (right), can be more difficult to quantify because their presence is less likely to result in internal cavities. When cavities are not present, the changes in resonance can be very subtle yet still discernable to the trained ear.

Figure 9. Sapwood decay cannot always be adequately quantified using sounding alone, although its presence may be identified.

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with ring shake or internal cracks that might result in false positives.

Summary

Sounding has been used as a tool to evaluate trees for the presence and severity of decay by many generations of arborists and foresters. The practice has application in most work contexts in which arborists assess trees.

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Figure 10. Ring shake can mimic an internal cavity in a tree. The resulting resonance sounds similar to that of a hollow created by decay.

Sounding is a recommended decay-assessment practice within professional tree-risk standards. The process of sounding is a learned skill that has some research support for its potential effectiveness in both the arboricultural and psychoacoustic literature. Arborists who assess the structure and stability of trees for decay and other defects should be familiar with sounding as a tool for the first stages of investigation, and they should be aware of its practical limitations. When potential problems are identified, other means of investigation can be used to confirm or disprove the initial findings.

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