Do You Hear What I Hear?
Part I: Introduction to Sounding

By Christopher J. Luley and Mike Ellison

Sounding trees with a mallet or hammer is one of the most valuable and easily applied field skills arborists can learn and use for the purpose of assessing trees for decay and defects. Some arborists resist learning sounding, possibly because they believe it appears "unprofessional" or doesn't really work. Clients may also wonder, "Just what are you doing to my tree?"

Sounding, however, is a recommended technique for decay and defect evaluation within the ANSI Standard as it applies to risk assessment (ANSI 2017), as well as Best Management Practices for tree risk assessment (Smiley et al. 2017) within a Level 2 or Basic tassessment (Figure 1). Sounding has applications in many other work contexts where arborists inspect trees for structural stability. It is also an important starting point for evaluating the need and location for additional advanced assessment of a tree's structure using tools such as resistance drilling or sonic tomography (Figure 2).

Figure 1. Sounding with a mallet or hammer can be part of a Level 2 or Basic tree risk assessment scope of work. Sounding also can be used in many other work contexts where structural assessment is valuable.

Sounding is used to inform judgment about the presence, location, and severity of wood decay and other potential defects, and ultimately tree stability. Tapping or knocking, as it is sometimes called, has long been used in traditional forestry (Boyce 1961), is also employed to assess wood in service for decay (Zabel and Morrell 1992), and is used in other diagnostics or evaluative settings, such as human medicine. The value of sounding rests in the fact that the human ear and brain can effectively detect subtle differences in resonance when an object or structure is tapped. Most arborists, once trained, can often discern differences in tonal qualities resulting from decay, hollowing, loose bark, cracks, or other features that might be present in trees (Figure 3).

Sounding is an important skill because it is easy to learn, only requires simple hand tools, is quick, and can provide reliable basic information on structural changes in the trunk, root collar, and branches. In virtually all tree applications, sounding is used in conjunction with visual assessment for a variety of purposes such as decay or defect assessment in a basic risk inspection, confirming structural stability in a pre-climb inspection, or quick evaluation of decay indicators (Luley 2012) in tree inventories or sales calls. This makes it an important skill for any arborist as it has uses in many different work contexts.

This article will explore the basic physics of sounding, its application, and its limitations for diagnostics in the field. In a future article, the discussion will explore field application and limitations of the method.

Basic Physics of Sounding

Sounding is relatively simple in terms of the physics of the process. The theoretical basis for sounding is built on the principles of vibration wave propagation and psychoacoustic research as described by Mucciardi et al. (2011). When a hammer strikes the trunk of the tree, a stress wave is generated that propagates through the wood matrix at a velocity proportional to the square root of Young's modulus (an indicator of stiffness of a material). The stress wave moves through the wood by alternating pulses of pressure waves that travel parallel to the trunk surface. The wavelength is determined by the wave's velocity, and internal discontinuities and density of the wood alter the velocity and amplitude of the wave. When the wave reaches the trunk surface, it causes the surface to vibrate, and the vibrations generate pressure waves in the surrounding air. These airborne waves are perceived as sound when they strike an eardrum.

The perceived pitch of these sounds depends on the trunk reverberations, and thus, by its internal condition. Due to the mass of the trunk, the frequency of the pitch falls in the normal audible range (approximately 50 to 4,000 Hz). Most people report that solid wood with intact bark has a relatively high, sharp, or "clean" pitch when struck with a hammer or other solid instrument when compared to decayed wood. This high, sharp pitch, which can vary considerably between tree species, changes depending on the amount, density and distribution of the wood, as well as with growth patterns, decay, hollows, cracking, and bark characteristics.

Mucciardi et al. (2011) reported that the psychoacoustic research does not specifically discuss wood decay. However, research in other fields has clearly shown that the human brain can distinguish complex natural sounds such as footfalls, slamming doors, clapping hands, and breaking bottles. Similar to what arborists encounter with decayed trees, Lufti (2001) found that listeners can develop strategies for distinguishing solid and hollow metal and wooden bars. Mucciardi et al. (2011) believed that the results considered in these psychoacoustic studies contained sufficient information to allow identification of complex source attributes (analogous to different amounts of decay), and that listeners are capable of performing these identifications with limited variation in other source attributes (analogous to diameter and species).

There are many everyday examples of how we use sounding that rely on the same basic principles. Remember Burt Reynolds in *Smokey and the Bandit* (1977)? In the road-haulage industry, the "tire thumper" or baseball bat is often used to assess tire pressure from the note emitted when the tire is struck. This very simple assessment can quickly identify where tire pressure is low, but could prove a difficult visual observation in cases where a truck's flat tire is being supported by a fully inflated tire.

In the railway industry, wheel-tappers have been employed by train operators for around two centuries (Figure 4) and can still be found in eastern Europe and in Asia. These professionals are well aware that a cracked train wheel could have disastrous consequences, so they tap the wheels of a train and listen for anomalies that might indicate a wheel is compromised.

There are other examples, too, such as a doctor tapping on someone's chest with his or her fingers to evaluate how much air or fluid is in it. This is called percussion, and it is analogous to sounding trees for decay and structural anomalies.

Figure 2. Sounding may identify the need for further advanced decay or risk assessment. A tomograph analysis was performed on this red oak (*Quercus rubra*) because sounding indicated the presence of significant internal decay.

Figure 3. Sounding is used in conjunction with visual assessment to assess internal defects such as decay, hollowing, or cracks, or to identify other conditions, such as loose bark. With training, most anyone can become proficient in this skill.

Back to trees, Mucciardi et al. (2011) also reported—after accelerometer testing and statistical analysis from decayed and non-decayed trees—that long duration, low-frequency wave forms were the best predictor of the presence of decay in a range of tree species (Figure 5). Accelerometers are like electronic ears (Figure 6), and the long-duration, low-frequency wave forms translate into a low-pitched or dull thud to the human ear. Hence, when

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Figure 4. Wheel-tappers have been employed by train operators for around two centuries, and they can still be found in eastern Europe and in Asia. This photo comes from a collection of British Railways cigarette cards (1938). The original caption reads: "On arrival of a train at an important station one may see a man on the off-side with a long-handed hammer tapping each wheel as he passes. The sound of that tap tells him if the wheel is faulty. The same process is carried out on engines during the daily examination, and this photograph shows the examiner tapping the giant driving wheel of the Duchess of Kent, one of the L.M.S. Princess Royal type."

Figure 5. Psychoacoustic studies have shown that the human ear can detect subtle differences in resonance characteristics, once trained. Significant internal decay in trees, where cavities have left a thin shell of decayed wood, are a good starting point for training arborists on the use of sounding.

Figure 6. Accelerometer testing by Mucciardi et al. (2011) indicated that long duration, low-frequency wave forms were the best predictor of the presence of decay in a range of tree species. To the human ear this corresponds to a low, dull thud.

sounding trees, the arborist can detect the difference between the high pitched, short-duration sound of solid wood, and the long-duration, low-frequency thud when decay is present. In common terms, hollow trees, when struck with a mallet or hammer, might sound "as hollow as a drum."

Part II of this article will cover the recommended tools for sounding, how to sound, and the limitations in its application.

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