

Tree Rings

and the Local Environment

By Kevin T. Smith



LEARNING OBJECTIVES

The arborist will be able to

- Define tree rings and describe how they are formed
- Explain the types of information that can be gathered from tree ring records and why they are useful
- Describe the science of dendrochronology and the importance of crossdating in assigning tree ring calendar years

CEUs for this article apply to Certified Arborist, Utility Specialist, Municipal Specialist, Tree/Worker Climber, and the BCMA science category.

The amount of wood produced by a tree each year depends on tree condition, genetic programming, and growing conditions. Wood is mature xylem, the result of inward cell divisions by the vascular cambium, the new cell generator located between the wood and the inner bark (phloem). In temperate climatic zones, where a spring and summer growing season alternates with winter dormancy, the vascular cambium usually produces a single layer or increment of wood each year. Tree rings are annual growth layers seen in cross section. In Mediterranean dry and tropical climates, rings of earlywood are formed when seasonal moisture is available and may not be strictly annual. Tropical trees also produce wood in flushes of growth but usually do not produce rings that can be easily correlated with the calendar. The formation of latewood in tropical species is sometimes associated with environmental changes, such as el Niño and la Niña cycles.

Simple counting of tree rings from the bark to the pith provides a relatively accurate estimate of tree age. Ring counts may, however, be inaccurate because annual boundaries may be hard to identify in particularly narrow rings. Rings may be locally absent from the sample or the sample may contain false rings. An “extra” or false ring occurs from premature deactivation and reactivation of the vascular cambium in a single growing season. A barrier zone produced as part of the tree response to wounding may also be misidentified as a ring boundary, resulting in a false ring.

In addition to tree age, the tree ring record can provide information on environmental processes of forest dynamics as well as disturbance events, such as damage from landscape

equipment, vandalism, fire, storm, and insect outbreak. Tree rings can also record annual variation in temperature and precipitation in addition to documenting the age and provenance of archaeological and cultural objects. Sometimes the tree ring record is easy to interpret, but interpretation often requires a deeper understanding of the interaction of the tree system with the environment.

Distinct growth rings result from the visual contrast between the wood formed late in one growing season and wood formed early in the following growing season (Figure 1). Tree rings are seen in cut stumps or in “cookies” sawed from a stem or branch. Much less destructively, tree rings are observed in cores extracted from trees using an increment borer (Figure 2). For detailed examination, increment cores are usually mounted in grooved wooden blocks to provide support in handling and surfacing.

In many conifers, such as red cedar and spruce, the tree ring boundary is between the thick-walled latewood tracheids, produced late in the growing season, and the thin-walled earlywood tracheids formed early in the following growing season. The visual contrast can also be high in ring-porous hardwoods such as oak, locust, and ash, with wide spring vessels that contrast with the much finer-pored summer vessels that formed late in the previous year.

Ring boundaries can be harder to distinguish in diffuse-porous hardwoods that have narrow vessels scattered across the growth ring. Still, ring boundaries are visible in finely sanded cross sections. Although woodworkers usually use an electric plane along the grain direction, mounted cores can be quickly surfaced for examination with an electric plane across the grain. In roughly sawed disks, a plane can remove saw marks, with the surface finished by fine sanding.

Observations from Single Trees

A single stem disk or core from a forest-grown tree can show periods of growth and release that reflect changes in the stand of trees. Figure 3 illustrates this analysis by use of an increment core from a red spruce (*Picea rubens*). Growth period “A” shows the edge of several relatively wide rings, suggesting that the seedling was established in the full sunlight of an opening or gap in the forest canopy. Such gaps, which promote new seedling and sapling development frequently result from the breakage or uprooting of large trees, facilitated by root and stem decay. After this

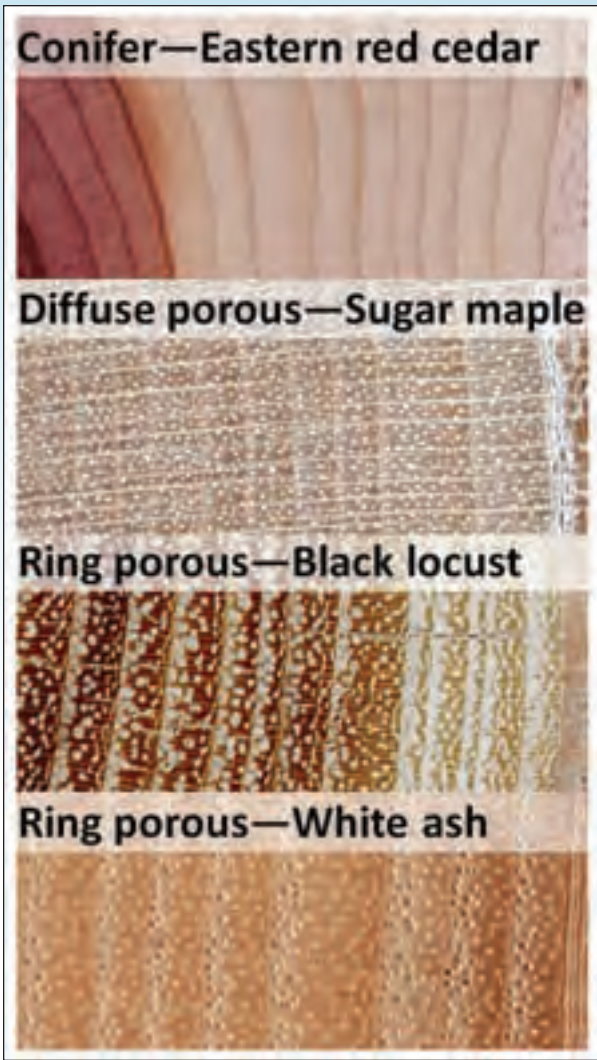


Figure 1. Examples of wood types from northeastern U.S., as seen with a hand lens. Ring growth is from left to right. The vascular cambium and bark are to the right. Photos are of eastern red cedar (*Juniperus virginiana*), sugar maple (*Acer Saccharum*), black locust (*Robinia pseudoacacia*), and white ash (*Fraxinus americana*).

brief initial spurt of growth, ring width continues at a slower rate for a couple of decades (period “B”), as the young trees in the forest gap compete with each other and with older trees for light and other resources. As the forest canopy closed, this shaded tree entered into a period of more than two decades of profound growth suppression (“C”). Identification of ring boundaries and accurate counting becomes especially difficult with narrow, tightly spaced rings. The ability to tolerate growth suppression is a large factor in what makes a tree species “shade tolerant.”

Next, the ring-width record shows that after this period of being in “survival mode” with little radial growth, another disturbance likely occurred and growth was released, allowing



Figure 3. Growth dynamics of a single forest-grown red spruce (*Picea rubens*) from New Hampshire. The letters designate growth periods described in the text.



Figure 2. Collecting a sample of tree rings with an increment borer in southern Siberia.

for more than a half century of moderately rapid growth, punctuated by year-to-year variation in ring width due to variation in temperature or precipitation or to local influences (“D”). That period of relatively rapid growth more or less abruptly slowed as the forest canopy again closed and growth slowed for another couple of decades (“E”). For this spruce, the slow growth was followed by deeper growth suppression for more than a decade (“F”). Again, accurate ring counts are impossible without a close examination of a properly finished surface, perhaps requiring a microscope. It’s difficult to distinguish cause from effect, but such deep growth suppressions are frequently associated with spreading infections of decay fungi in roots and stem, particularly in older trees. Infections by decay fungi persist for decades and increase susceptibility to insect pests and environmental stresses such as heat, cold, and drought, resulting in tree mortality. In the natural and urban forests, this mortality produces a gap in the canopy that promotes new tree establishment. The growth process continues.

A tree formerly in a closed forest and now in an open house lot may show a release or growth stimulation due to selective clearing. Unfortunately, the release may be followed by a growth decline due to construction injury or adverse changes in grade or drainage. Landscape trees that began life in full sunlight as nursery stock or as forest “pioneers” often show very wide rings early in their lives,

followed by an abrupt narrowing due to shade or shock from transplanting. A tree in a closely spaced forest develops with a minimal taper in the stem. When neighboring trees are removed, the “released” tree may develop a crown that is out of balance with what the trunk can structurally support.

Tree rings can also record responses to natural mechanical events. The young sapling that produced the stem section in Figure 4 had a pronounced J-shaped bend. The local forester attributed that bend to heavy snows in the 1999–2000 winter season. The tree rings support that explanation. A small scar at the 5 to 6 o’clock position, just outside the 1999 ring, is consistent with the tearing of cambial cells that would result from tension as the stem was bent to the opposite side under the weight of snow. The wide rings of compression wood at the 12 o’clock position corrected the growth back to the upright orientation, as I found it.

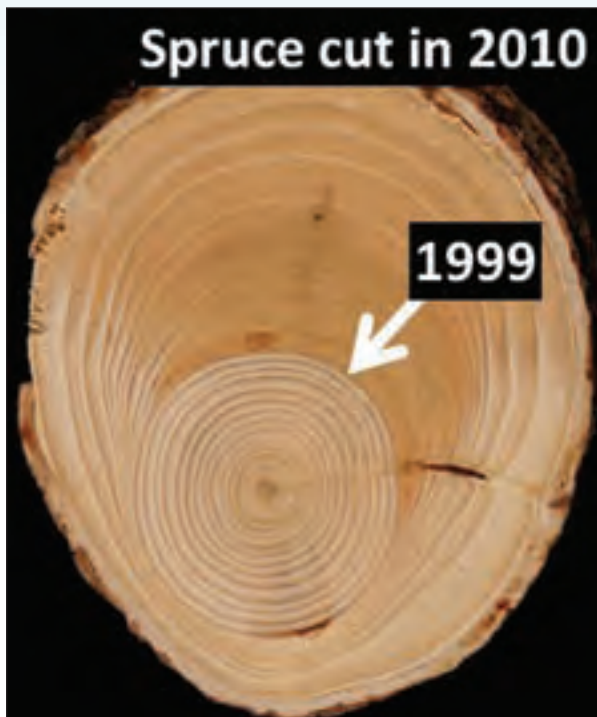


Figure 4. Wide rings of compression wood formed in a bent sapling of European spruce (*Picea abies*) from eastern Finland.

Dendrochronology and Crossdating

The examples presented thus far are based on simple examination and counting of rings. Investigations of more complex environmental questions with the tree ring record requires dendrochronology. Dendrochronology is the art and science of connecting tree ring patterns across many wood samples and with the environment. Patterns in tree rings are often based on characteristics such as ring width, but other features may also be the basis for patterns such as wood density, latewood width, the proportion of latewood to earlywood, chemical characteristics, and anatomical features, such as resin canals and scars. Measurements of such characteristics along a single radius are referred to as a series.

The hallmark of dendrochronology is the accurate and precise assignment of a calendar year of wood formation to each tree ring. This assignment often depends on crossdating, the alignment of multiple series according to common patterns of growth across samples of wood collected from many trees. Marker years, unusual rings found in essentially all trees in a study area or region, aid in crossdating. Marker years enable the alignment of series containing unknown beginning and end dates. Examples include samples from living and dead trees, wooden structures, and archeological samples. Especially narrow rings, due to extreme drought, are most often used as marker years. Exceptionally wide rings may also be useful, particularly for trees in a normally arid environment that infrequently experience a wet year. Depending on the timing, the effect of weather extremes and disturbances on ring width may persist over several years. The listed resource materials describe several good methods for effective crossdating.

Crossdating can identify locally absent rings or false rings that would otherwise result in mistaken assignment of calendar dates. Careful crossdating greatly extends the length of the tree ring record for environmental history beyond the age of the oldest living trees. Series are used to construct annual chronologies of ring characteristics. These chronologies can then be used to position a floating series of unknown dates, perhaps derived from architectural timbers or artifacts. Because even adjacent trees may vary in growth rates, statistical modeling tools are frequently used to reduce the effect of tree-to-tree variation and to maximize the common growth signal in the chronology.

Dating Injury and Pest Outbreaks

In addition to growth, dendrochronology can yield information on the timing of injury or defoliation. Many natural forests depend on recurring disturbances such as fire. Chronologies based on dated series of fire scars can help forest managers understand the natural frequency of fire for a particular landscape. Fire scars result from successful compartmentalization after injury from repeated exposure. This stem section of Figure 5 is from the base of a surviving tree grown in a fire-prone natural landscape. The section shows repeated cycles of cambial mortality followed by woundwood production with a tendency to close over the killed area. Well before wound closure occurred, the cambium was again wounded and killed for a portion of the stem circumference. This single sample shows three separate fires. A fire scar chronology, based on crossdated series including this one, shows that fire sufficient to kill part of the cambium but not severe enough to kill the tree occurred about every 25 years. Once developed, fire scar chronologies can also be used to establish the statistical relationship of forest fire to climate. That statistical relationship may suggest mechanisms linking climate patterns to increased risk of forest fire.

Severe outbreaks of insect pests are also recorded in tree rings. All the ring-width series in a collection from living red spruce in a Maine forest stand show the drastic reduction of growth beginning 1914 (Figure 6), known by independent observation as the time of a regional outbreak of

spruce budworm. This collapse was followed by recovery in growth later in 1920. Although the recovery was strong, keep in mind that as the sample cores were only collected from living trees, those that were killed were not included in the sample. Where independent observations of forest health are not available, insect outbreaks are sometimes identified in chronologies by comparison with chronologies constructed from non-host trees in the same forest stands. The high degree of year-to-year variation in growth and the trends of growth increase and decline highlight the need to identify the growth signal of interest, whether for modeling annual variation in weather, trends in forest stand dynamics, or episodic outbreaks of fire, pest, or storm injury.

Applying dendrochronology to regional and global environmental processes requires extensive sampling and usually the manipulation of tree rings with sophisticated statistical and modeling techniques. But simple observations of a well-prepared tree ring sample can reveal a lot about the life history of a particular tree or small group of trees.

Additional Reading

Smith, Kevin, T. 2008. An organismal view of dendrochronology. *Dendrochronologia* 26:185-193. <nrs.fs.fed.us/pubs/9076>

Speer, James, H. 2010. *Fundamentals of Tree Ring Research*. University of Arizona Press, Tucson. 333 pp.

The Ultimate Tree Ring Web Pages. <web.utk.edu/~grissino/>

The Tree Ring Society <www.treeringsociety.org/>

The Association of Tree Ring Research <www.tree-ring.org>

Acknowledgments: Wood samples collected by the author and photographed by Kenneth R. Dudzik, USDA Forest Service, Northern Research Station.

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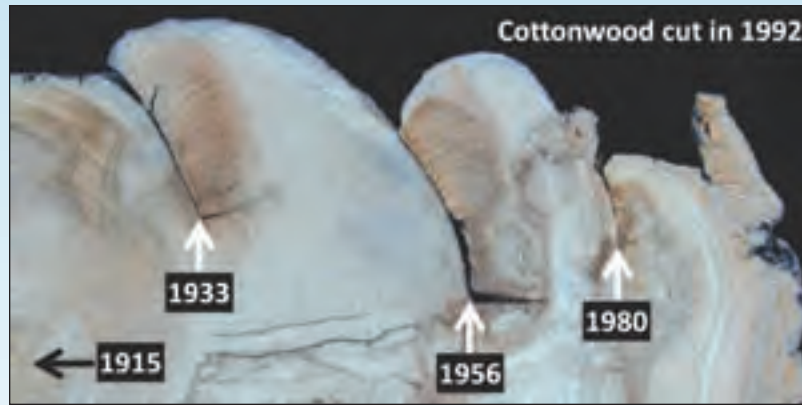


Figure 5. Dated fire scars in Fremont cottonwood (*Populus fremontii*) record fire frequency in the Colorado Front Range.

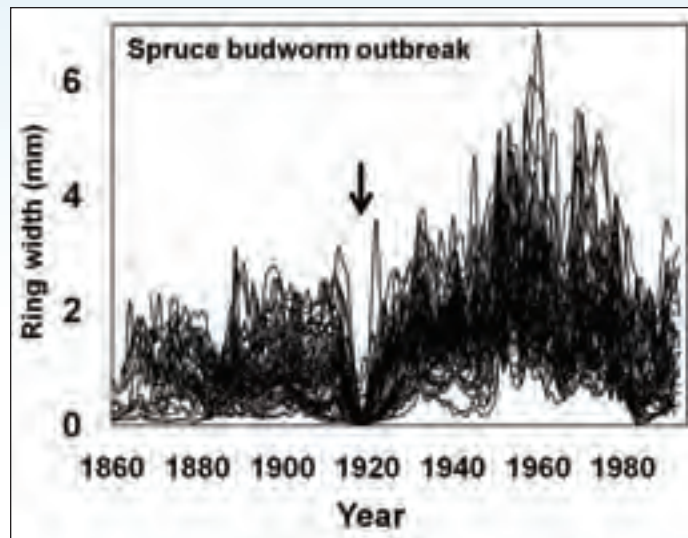


Figure 6. Sixty-eight-ring width series from 34 red spruces in a forest stand in northern Maine. The arrow marks the midpoint of growth suppression due to an outbreak of an insect pest.



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1. Tree ring patterns record changes in
 - a. climate
 - b. weather
 - c. insect outbreaks
 - d. all of the above
2. Vascular cambium usually produces a single layer or increment of wood each year
 - a. in dry Mediterranean climates, whether or not there is seasonal moisture
 - b. in temperate zones, where a spring/summer growing season alternates with winter dormancy
 - c. in tropical climates, where tree wood is produced in flushes of growth
 - d. in all climactic conditions
3. Tree ring patterns used for dendrochronology may be based on
 - a. ring width
 - b. ring density
 - c. the proportion of latewood to earlywood
 - d. all of the above
4. Counting tree rings from the bark to the pith
 - a. produces an absolutely reliable tree age
 - b. provides a more or less accurate estimate of the age of that sample
 - c. is the basis for dendrochronology
 - d. permits estimation of future growth
5. Tropical trees continuously produce wood year-round.
 - a. True
 - b. False
6. Which specialized tool can be used to extract tree ring samples from living trees?
 - a. increment borer
 - b. diameter tape
 - c. soil probe
 - d. clinometer
7. Tree ring boundaries are most readily visible in
 - a. palms
 - b. ring-porous hardwoods and conifers
 - c. eucalypts and other diffuse-porous hardwoods
 - d. maple, poplar, and birch
8. Ring boundaries can be more easily seen by
 - a. finely sanding or planing the wood surface
 - b. using sophisticated statistics
 - c. crossdating the samples
 - d. knowing the local weather patterns
9. The ability to tolerate growth suppression is a large factor in what makes a tree species
 - a. hardy
 - b. shade tolerant
 - c. deciduous
 - d. resistant to decay infection
10. Wide rings produced adjacent to the tree pith suggest that the tree
 - a. is shade tolerant
 - b. was established in full sunlight
 - c. was established under a dense forest canopy
 - d. developed from a stump sprout
11. Crossdating tree rings involves
 - a. calculating the average width of each ring around the tree circumference
 - b. aligning or matching patterns of growth across several-to-many tree ring series
 - c. calculating the average width of a tree ring across all trees in a stand
 - d. the relationship of growth to climate
12. The alignment of tree ring series for crossdating is aided by
 - a. marker years
 - b. compression wood
 - c. compartmentalization boundaries
 - d. an increment borer
13. Abrupt narrowing of growth rings can be due to
 - a. insect pest outbreaks
 - b. proper pruning
 - c. proper fertilization
 - d. increased sun exposure
14. Unlike ring counting, dendrochronology relies on
 - a. samples collected with an increment borer
 - b. a single, properly prepared sample
 - c. complete ring series from tree pith to bark
 - d. the precise assignment of calendar year for each ring
15. Dendrochronology is the science of
 - a. tree identification and value
 - b. connections among tree ring patterns and the environment
 - c. wood structure and function
 - d. the timing of growth and dormancy
16. "Floating series" can be aligned to established tree ring chronologies to
 - a. identify marker years
 - b. date wooden artifacts
 - c. date growth suppressions
 - d. determine the severity of insect outbreaks
17. Fire scar chronologies can help demonstrate
 - a. the natural frequency of landscape fire
 - b. the relationship of fire to climate
 - c. the ability of some trees to survive multiple fires
 - d. all of the above
18. Crossdating can identify locally absent rings or false rings that would otherwise result in mistaken assignment of calendar dates.
 - a. True
 - b. False
19. Premature deactivation and reactivation of the vascular cambium in a single growing season can result in
 - a. a missing ring
 - b. disease susceptibility
 - c. a false ring
 - d. woundwood
20. Trees that show very wide rings early in their lives may later show an abrupt narrowing, often due to
 - a. full sunlight exposure
 - b. maturity
 - c. heavy snow
 - d. a closing forest canopy **AN**




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