2014. Proceedings of the Indiana Academy of Science 123(1):7–13

TREE-RING ANALYSIS IN INDIANA WITH SPECIAL ATTENTION TO DENDROARCHAEOLOGY

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ABSTRACT. Although tree-ring studies have been performed in Indiana since the 1930s, their study in the state has been sporadic, and many gaps in our current understanding of tree growth and forest dynamics exist. Most notably, very little information regarding tree growth prior to the nineteenth century has been made available in the state. The tree rings in timbers of historically erected buildings can be used to build centuries-long chronologies for Indiana and the Mid-Ohio River Valley. Through tree-ring analysis, especially of nineteenth century buildings found throughout the region, study of past growth patterns and dynamics of the old-growth forest that once covered the state is possible.

Keywords: Tree rings, dendrochronology, dendroarchaeology

INTRODUCTION

Tree rings, the annual increments of wood that are deposited around the circumference of woody plants each year, offer a unique opportunity to study growth patterns in trees and forests over extended time periods. Dendrochronology is the science of assigning accurate calendar dates to individual tree rings and using these accurately dated rings to interpret past influences on tree growth. Dendrochronological techniques have been used to examine the influence of various factors on growth rates. For instance, dendrochronological methods have been used to study a wide range of topics including forest fire history, insect outbreaks, ecological phenomena (e.g., disturbance events such as wind storms), and climatic influences on tree growth (Fritts & Swetnam 1989; Schweingruber 1989).

The width of individual tree rings varies from year to year. Tree-ring width in a given year is governed by a suite of biotic and abiotic factors with larger rings being formed during years of favorable growing season conditions and smaller rings in less favorable years. Factors affecting individual tree-ring widths include, but are not limited to, age-related growth trends, climate, and disturbances which originate from within or outside a forested stand. The size of a tree ring is, therefore, an aggregate response to the conditions experienced by a tree in a given year (Cook 1987). The variation in ring width permits dendrochronologists to study long-term growth rates and tease out the influence of different variables on tree growth (e.g., how droughts of varying degrees of severity affect growth in given years).

Additionally, variation in tree-ring widths allows for samples to be crossdated. Crossdating is the process of matching the pattern of small and large tree rings among numerous trees throughout a particular forested stand or geographic region (e.g., Stokes & Smiley 1968; Fritts 1976). Consistent crossdating among tree rings is essential for ensuring that the exact calendar date is assigned to individual tree rings. In Indiana, drought events result in decreases in radial growth rates with the size of individual rings decreasing as stress during a particular year increases. Reliably dated chronologies (i.e., compilation of accurately dated and measured tree rings from a number of trees) can, therefore, be created in a given region. For example, common crossdating signals in southeastern Indiana oak (*Quercus* L.) trees includes very small tree rings (in relation to neighboring tree rings) in 1930, 1936, 1944, and 1984 and smaller than normal rings in 1954, 1970, 1988, 1994, and 2000 (Fig. 1). If the pattern of rings in a putatively dated tree-ring sample crossdates or matches this pattern, the sample is considered to be dated accurately and that the exact year of formation of each tree ring is known. Since droughts affect fairly large areas simultaneously, relatively homogeneous signals throughout an area are created, and crossdating is possible.

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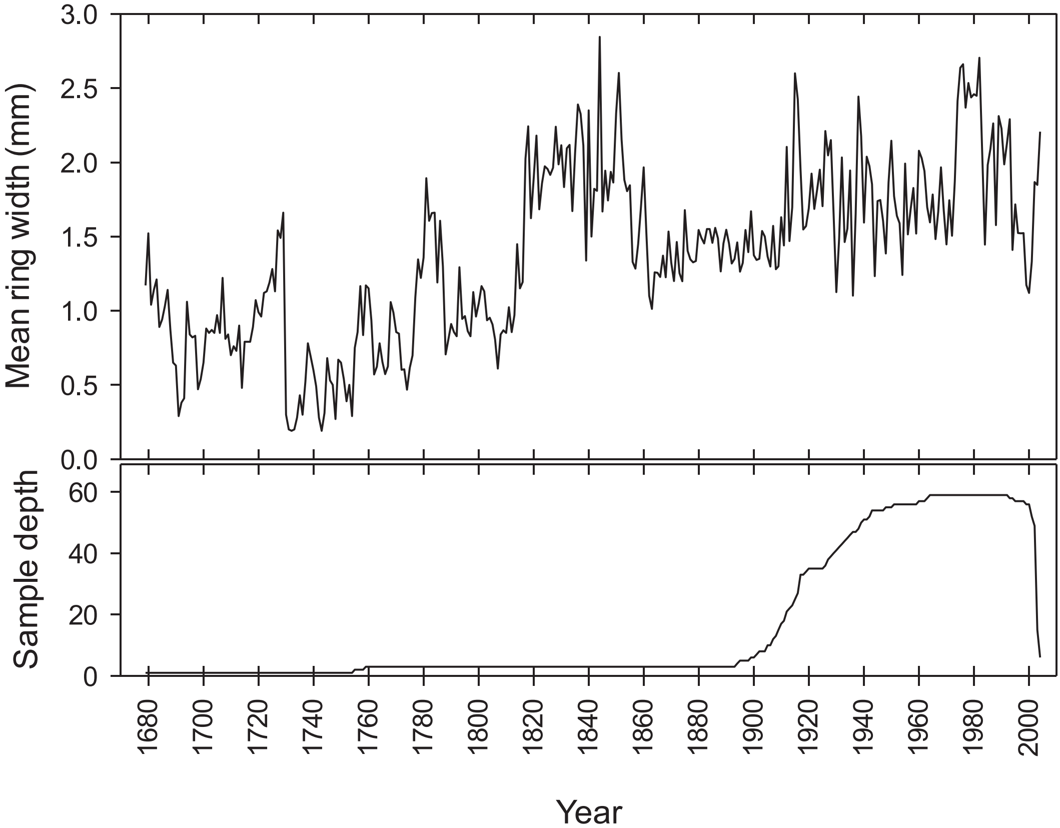

Figure 1.—Mean tree-ring chronology for white oaks (*Quercus* subgenus *Lepidobalanus*) growing in Happy Valley, a forested ravine of Hanover College (Jefferson County, Indiana). Sample depth refers to the number of tree rings dated and measured for a particular year.

Dendrochronology in Indiana.—Tree-ring studies, designed to answer very different questions, have been performed sporadically in Indiana since the 1930s. For example, Edwin Lincoln Moseley identified the pattern of wide and narrow tree rings in oaks throughout several Midwestern states, including Indiana, in the 1930s. Moseley was interested in historic climate cycles/patterns and hoped to create a method of predicting future droughts, Ohio River floods, and lake levels (Moseley 1939; Stuckey 1998). Diller (1935) and Friesner & Friesner (1941) studied the impact of climatic variables including temperature and precipitation on tree growth in the state in the northern half of Indiana and Marshall County, respectively. In 1934, Florence Hawley Senter who was serving as the Director of the Laboratory of Dendrochronology at the University of Chicago (Nash 1999) studied trees from Clinton, Crawford, Knox, Marion, Noble, Owen, and Parke Counties (Hawley 1941). She was working to determine if dendrochronological analysis would be possible in the Midwest United States. If so, chronologies would be created in the hopes of dating Native American ruins in the region. As an example of the different groups interested in tree-ring sciences, the work performed by Hawley and the lab in Chicago was funded by the Indiana Historical Society (Hawley 1941).

More recent studies have focused on stress leading to oak mortality (Pederson 1998); interactive effects of acidic deposition, drought, and insect attack on various oak species (LeBlanc 1998); impact of early season water balance on white oak (*Quercus alba* L.) growth (LeBlanc & Terrell 2001); impact of soil texture on tree growth (Charton & Harman 1973); and the effects of insect outbreaks (Speer et al. 2010) on tree growth. Cook produced an oak chronology for Pulaski Woods in north central

Indiana (International Tree-Ring Data Bank 2013) while creating a continental-wide tree-ring database.

Most tree-ring studies in the state have focused on oaks (*Quercus* L. spp.) especially those in the "white oak" subgenus [*Quercus* subgenus *Lepidobalanus* including white oak (*Q. alba*), chestnut oak (*Q. prinus* L.), or post oak (*Q. stellata* Wangenh.)]. Species in the white oak group are often chosen for dendrochronological analysis in eastern North America due to their reliable crossdating and consistent response to climatic variables such as temperature, precipitation, and drought indices (e.g., Wedel & Hawley 1941; Sheppard et al. 1988; Rubino & McCarthy 2000). In Indiana, studies on other species have been performed to a lesser degree (Diller 1935; Friesner & Friesner 1941; LeBlanc 1998; Pederson 1998; Sparks & Bishop 2009; Speer et al. 2010). These species include American beech (*Fagus grandifolia* Ehrh.), bitternut hickory (*Carya cordiformis* (Wangenh.) K. Koch), sassafras (*Sassafras albidum* (Nutt.) Nees.), sugar maple (*Acer saccharum* Marshall), tulip poplar (*Liriodendron tulipifera* L.), white ash (*Fraxinus americana* L.), and various oaks in the red/black group (*Quercus* subgenus *Erythrobalanus*) including black (*Q. velutina* Lam.), northern red (*Q. rubra* L.), and pin oak (*Q. palustris* Muenchh.). Taxonomy and nomenclature follow Gleason & Cronquist (1991). The above is not intended to be a thorough historical review of all dendrochronological studies performed in the state but rather a representation of the various types of work that have been done.

Despite the long use of dendrochronology to explore tree growth in the state, many gaps in our knowledge persist. For example, tulip poplar, an important species in many forest types of Indiana, has had only very limited study; from 1930 to 1939 Friesner & Friesner (1941) studied tulip poplar growth in Marshall County in relation to climate. Limited analysis of other widely distributed species such as ash, both white and green (*Fraxinus pennsylvanica* Marshall), has been reported; for example, Speer et al. (2010) created a 74 year-long white ash chronology using 18 trees. Similar voids in dendrochronological study exist for other common trees such as sweet gum (*Liquidambar styraciflua* L.), sugar maple, red maple (*Acer rubrum* L.), beech, elm (*Ulmus* L. spp.), black walnut (*Juglans nigra* L.), and various hickory species (*Carya* Nutt. spp.). A better understanding of forest growth and dynamics will surely require new or additional studies of these and other common species found throughout the state.

Dendroarchaeology in Indiana.—Using standard dendrochronological techniques, the dating of tree rings in living trees is relatively straightforward. Since the year of sampling is known, calendar dates can be given to individual tree rings starting with assignment of the current year to the outermost ring (if the growing season for that year has begun) and assigning the corresponding previous year to each ring until the pith or center of the sample is reached. If the sample crossdates with other samples, confident dates can be given to the individual tree rings in the sample, and it can be included in a regional chronology.

However, date assignment is not always this straightforward. For example, if a sample is obtained from a timber of a structure with an unknown construction date (which is almost always the case), assignment of the dates in which the rings were formed is more complicated. Dating of such a sample could be performed using dendroarchaeological techniques. Dendroarchaeology is a sub-field of dendrochronology that deals specifically with the sampling of historically erected buildings and other wooden objects to tap the tree-ring information found within their timbers. In dendroarchaeological studies, the formation date of an individual tree ring is unknown. The date, however, can be determined by crossdating the pattern of small and large rings in a sample of unknown age with accurately dated chronologies that have been prepared from the same geographic region (Fig. 2).

Crossdating is a highly reliable method for dating wood of unknown age, and dendroarchaeological techniques have proven to be powerful and effective research tools, especially in dry climates such as the American Southwest (Nash 1999). Crossdating and dendroarchaeological techniques also have been used throughout the world in such places as the Mediterranean [work of P.I. Kuniholm's Cornell Lab; Manning & Bruce (2009)], Canada (e.g., Robichaud & Laroque 2008), and Japan (Hoshino et al. 2008), to name a few. Despite the mesic climate of the eastern United States, dendroarchaeological analysis has been successfully performed

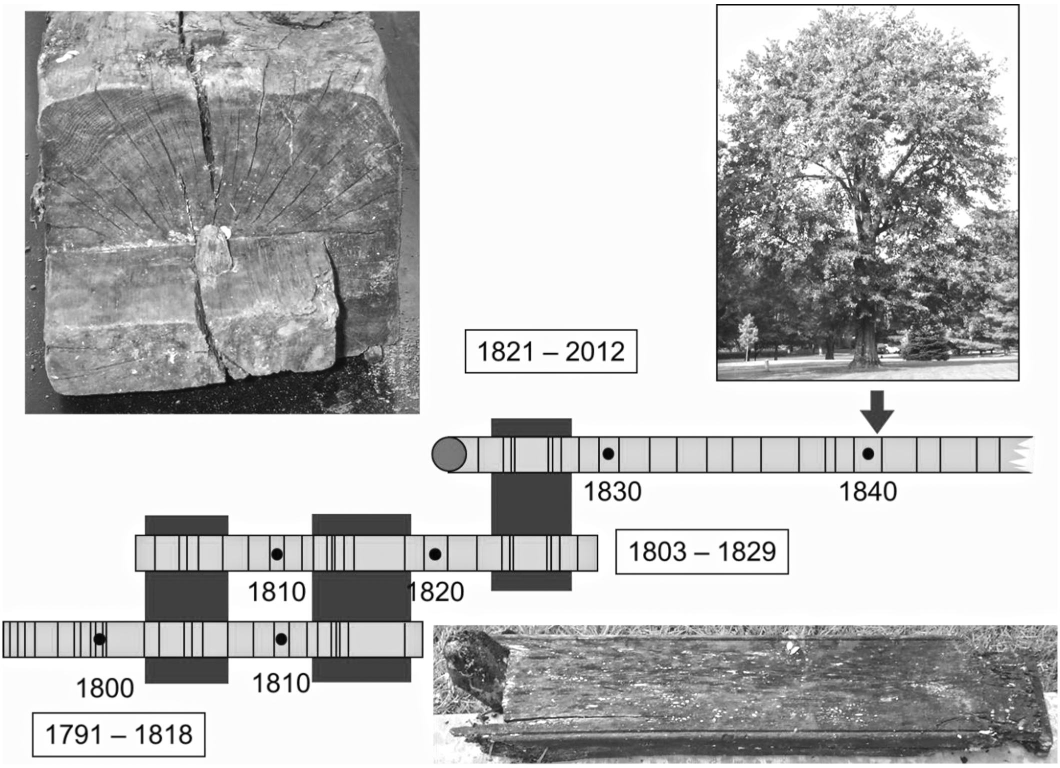

Figure 2.—Dating samples of unknown age (beam and floor joist in this example) are performed by crossdating the tree-ring patterns in the samples with chronologies of dated tree rings. The shaded areas represent unique growth patterns that make pattern matching and crossdating possible. Note: the sample lengths used in this illustration are much shorter than those that are needed to perform an actual analysis.

throughout the region including Michigan (Harley et al. 2011), Georgia (Wight & Grissino-Mayer 2004), Florida (Grissino-Mayer et al. 2010), Virginia (Bortolot et al. 2001), Arkansas (Stahle 1979), and the Southeast [H.D. Grissino-Mayer's University of Tennessee-Knoxville Lab; Grissino-Mayer (2009)].

With European colonization and subsequent settlement of Indiana, few forests were spared the axe. Consequently, the archetypical "virgin" or "old-growth" forested ecosystem is a true rarity in Indiana. The loss of the original forests witnessed by early explorers and settlers was already lamented by Hoosier scientists as early as 1895. A.W. Butler, in his presidential address to the Indiana Academy of Science (Butler 1896) remarked on the loss of "tall trees" and "heavy timber" especially in southern portions of the state. This lack of old trees was also noted by Hawley (1941) in her early work in the Midwest and Indiana in the 1930s (Senter 1938a, b). As a result, most of the chronologies created for the state are relatively short in length, with few extending into and prior to the nineteenth century. Undoubtedly, this problem has been further exasperated in recent decades as many of the remaining old trees have either died or have been cut down.

Studying past forest growth patterns and dynamics, however, is not impossible. Indiana's rich natural (and cultural) past are preserved in the historically erected buildings found throughout the state. Early construction utilized timber standing on site—trees were felled and incorporated into buildings as beams, rafters, floor boards, joists, and braces (Senter 1938a; Hutslar 1992; Roberts 1996). A plethora of nineteenth century Hoosier barns, churches, agricultural outbuildings, homes, and mills can be found in nearly all parts of the state. In these structures we find remnants of the vast, uninterrupted forest seen by the earliest of European settlers and explorers. The tree-ring patterns in these timbers offer a truly unique opportunity to examine the old-growth forests of the state.

Using dendroarchaeological techniques and crossdating structural timbers, one is able to obtain much information from the resulting chronology of accurately dated tree rings. For example, one can determine and/or verify the construction date or modification of buildings (e.g., Stahle 1979; Bortolot et al. 2001; Wight & Grissino-Mayer 2004; Grissino-Mayer et al. 2010; Harley et al. 2011). Additionally, after successfully crossdating a specimen, one is able to investigate plant-environment interactions such as the influence of climate, disturbance events, and human impacts on tree and forest growth by studying long- and short-term growth patterns of previous centuries. Accurately dated tree rings can also prove invaluable as proxy data for studying and recreating climatic regimes of the state and region.

Creation of Hoosier Chronologies.—Despite the loss of old trees from throughout the region, creation of centuries-long, quality tree-ring chronologies is feasible. Over the past decade, the author has developed chronologies from living and recently killed trees. Chronologies from chinquapin oak, (*Quercus muehlenbergii* Engelm.), American beech, tulip poplar, ash, elm, and hickory have been created in southern Indiana. Also during this time the author has sampled scores of nineteenth and early twentieth century buildings throughout the state and the Mid-Ohio River Valley. After a decade of collecting, analyzing, and crossdating hundreds of timbers and tree samples from throughout the region, the creation of replicated and reliably dated multiple centuries-long chronologies for several major forest species has been achieved. These chronologies have been formed by combining tree-ring series from living trees, downed logs, and timbers of historic buildings. In the face of global climate change and various perturbations such as acid deposition and introduction of invasive plants and pests (e.g., emerald ash borer) to local forests, creating such chronologies may be of great importance when investigating past forest growth conditions and responses.

Dendroarchaeological analysis in Indiana is possible and has a great potential to expand tree-ring chronologies in a greatly understudied region of the United States (Senter 1938a, b). Locating potential structures for analysis has been achieved by delivering lectures to civic groups, historical societies, and Historic Landmarks Foundation of Indiana's BarnAgain conferences. Property managers and owners attending these lectures have been pivotal in providing permission or contacts to sample barns, houses, smokehouses, and other types of buildings in the state. Managers are very interested in verifying construction dates of the properties they steward; there is no shortage of potential buildings to date and analyze (Senter 1938a). Dendroarchaeological analysis offers an objective way to date historically erected structures when other lines of evidence (e.g., deed and tax records or oral history) are nonexistent or unreliable.

The goal of this article is to provide a general introduction to both the tree-ring studies that have been performed in Indiana and to the dendroarchaeological analyses that the author has performed in the region over the past decade. Additionally, the author hopes to show the great potential of dendroarchaeology in the Midwest by continuing, 80 years later, the seminal work Florence M. Hawley Senter began in the 1930s when she dated timber from an old Indiana cabin (Senter 1938b). The *Proceedings of the Indiana Academy of Science* is an ideal venue to present the Hoosier history (natural and cultural) that the author has studied and will study using tree-ring analyses. The findings of a dendroarchaeological analysis of a log structure from New Harmony, Indiana are included in this volume of the *Proceedings*. These results represent the first modern contribution of dendroarchaeological analysis to the *Proceedings*. At one time, dendroarchaeology was considered "the greatest single contribution ever made to American archaeology" (Haury 1935). In temperate regions such as Indiana, tree-ring dating of prehistoric archaeological wood objects will likely not be possible because of poor wood preservation. On the other hand, chronologies reaching as early as the 1400s have been created through the study of historic buildings. Dendroarchaeology truly has the potential to enable the study of the once unknown past.

ACKNOWLEDGMENTS

I would like to thank The Faculty Development Committee and The Rivers Institute at Hanover College for generously funding much of this research. Cassie (Morris) Lothery, M.

Ross Alexander, Anna Selby, and Jonathon Ward provided unlimited assistance in the field and lab. Deborah Quinn and Celeste Sutter provided logistic support. I am greatly indebted to individuals that made their structures available for dating analysis or made contact with property owners, especially Stan Totten and Bill Jackson. I would also like to thank Hanover College and especially the Hanover College Biology Department for institutional support.

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Manuscript received 15 October 2013, revised 9 February 2015.