NOTE / NOTE

Revivification of a method for identifying longleaf pine timber and its application to southern pine relicts in southeastern Virginia

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Abstract: Longleaf pine (*Pinus palustris* Mill.) cannot be distinguished from the other southern pines based on wood anatomy alone. A method that involves measuring pith and second annual ring diameters, reported by Arthur Koehler in 1932 (The Southern Lumberman, **145**: 36–37), was revisited as an option for identifying longleaf pine timbers and stumps. Cross-section disks of longleaf, loblolly (*Pinus taeda* L.), and shortleaf (*Pinus echinata* Mill.) pines were measured and the diameters of their piths and second annual rings plotted against each other. From this plot, longleaf pine could be differentiated from the other two southern pine species, demonstrating that a method established with trees harvested more than 70 years ago is still applicable to standing timber of today. No evidence was found to suggest that different growth rates impact method applicability. In those situations where the second annual ring is intact, but not the pith, very large second annual ring diameters (>40 mm) may identify timbers with a lower probability of being longleaf pine. In addition to the identification of very old lightwood stumps as part of a longleaf pine restoration effort, both methods may be applied to timber identification in historic structures and the niche forest products industry involving the recovery and processing of highly prized longleaf pine logs from river bottoms. Measurements from relicts sampled in this study were consistent with the purported range for longleaf pine in Virginia.

Résumé : On ne peut pas distinguer le pin des marais (*Pinus palustris* Mill.) des autres pins du Sud seulement sur la base des caractéristiques anatomiques du bois. Une méthode qui consiste à mesurer les diamètres de la moelle et du deuxième cerne annuel, rapportée par Arthur Koehler en 1932 (The Southern Lumberman, **145**: 36–37), a été réexaminée à titre d'alternative pour identifier le bois et les souches de pin des marais. Des sections radiales de pin des marais, de pin à encens (*Pinus taeda* L.) et de pin à courtes feuilles (*Pinus echinata* Mill.) on été mesurées et les diamètres de la moelle et du deuxième cerne annuel ont été comparés à l'aide d'un graphique. Le pin des marais pouvait être distingué des deux autres espèces de pin du Sud sur ce graphique démontrant qu'une méthode mise au point à partir d'arbres récoltés il y a plus de 70 ans est encore applicable au bois sur pied aujourd'hui. Nous n'avons trouvé aucun indice permettant de croire qu'une différence de taux de croissance a un impact sur l'applicabilité de la méthode. Dans le cas où le deuxième cerne annuel est intact, mais pas la moelle, un deuxième cerne annuel de très grand diamètre (>40 mm) peut indiquer qu'il s'agit de bois qui a une plus faible probabilité d'être du pin des marais. En plus de l'identification de très vieilles souches de bois gras associée à l'effort de restauration du pin des marais, les deux méthodes peuvent être appliquées pour l'identification du bois dans les structures historiques et la niche de l'industrie des produits du bois qui implique la récupération et le traitement des billes très prisées de pin des marais provenant du fond des rivières. Les mesures des reliques échantillonnées dans cette étude correspondent à l'intervalle présumé pour le pin des marais en Virginie.

[Traduit par la Rédaction]

Introduction

Among the southern pines of the southeastern United States, longleaf pine (*Pinus palustris* Mill.) has the richest history for utilization as a prized source of wood products and chemicals. Straight growth and wood that is strong and hard made this pine highly desirable for masts, poles, construction lumber, and flooring. Longleaf pine was also the exclusive source of naval stores until the point at which the supply of timber was depleted (Wahlenberg 1946). Naval stores operations began with the collection of oleoresin in various forms by wounding the trees and continued with the processing of the resin-soaked timbers (Gamble 1921; Butler

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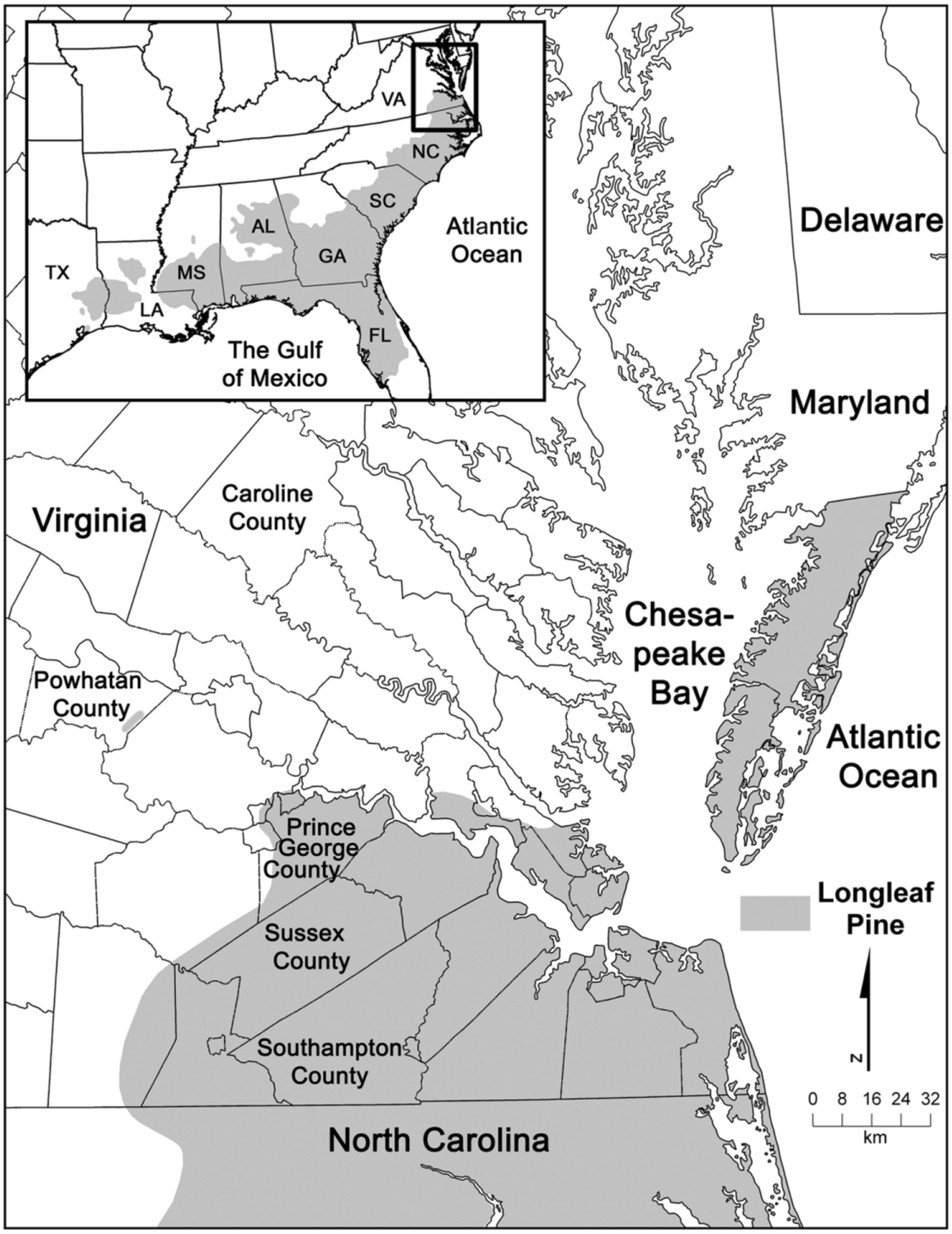
Fig. 1. Map of longleaf pine (*Pinus palustris*) ranges in Virginia and the southeastern United States (inset).



1998; Outland 2004) and, much later, the residual stumps (Gardner 1989).

The range of longleaf pine extends from southeastern Virginia to eastern Texas (Wahlenberg 1946) (Fig. 1). There is evidence that the northern range of longleaf pine may have reached the border with Maryland on the Eastern Shore and the Piedmont Region of Powhatan County west of Richmond (Porcher 1869; Frost and Musselman 1987; Frost 2006). Prior to colonial settlement, longleaf pine was the predominant pine species in the southeastern United States covering over 37 million hectares in pure or mixed forests (Croker 1987; Frost 1993). Current estimates place it at 0.3% of its former range (Frost 1993; Outcalt and Sheffield 1996). In Virginia, of the estimated 607 000 ha of longleaf pine forests estimated to be present prior to colonial settlement, less than 323 ha remain with no more than 2000 native trees (Sheridan et al. 1999; Frost 2006; Bhuta et al. 2008, 2009). Longleaf pines have been reintroduced to its putative range, but not necessarily from seed sources from Virginia (Saucier and Taras 1966).

The current extent of longleaf pine in Virginia, as well as throughout the rest of its range, can be traced back to the naval stores industry, which collapsed in Virginia by 1840 because the longleaf pine stands needed to sustain the industry there were severely depleted (Frost 1993). The devastation was so extensive that William Cullen Bryant, of New York, traveling through southern Virginia in 1843, observed large stands of dead trees stating “We passed through an extensive forest of pines, which had been boxed as it is called for the collection of turpentine...this is a work of destruction; it strips acre after acre of these noble trees, and, if it goes on, the time is not far distant when the longleaved pine will become nearly extinct in this region (Rouse 1988).” Remaining stands of longleaf pine in Virginia were extensively harvested by the Surry Lumber Company, which focused on prime southern yellow pine timber from 1885 to 1927 (Crittenden 1967). After the collapse of the longleaf pine ecosystem in Virginia, these industries moved into the vast longleaf pine forests of the southeastern United States.

Relicts from the naval stores and logging industries can still be found throughout the southeastern United States and have been used for tree-ring dating and the study of historical land use patterns (Grissino-Mayer et al. 2001; Van De Gevel et al. 2009). Our recent discovery of lightwood and turpentine stumps in central Virginia was of particular interest as possible physical evidence for justifying a northern range extension of longleaf pine. Recent studies have emphasized the relevance of both the historical condition and range of the longleaf pine ecosystem for the purpose of restoration (Van Lear et al. 2005; Predmore et al. 2007). However, the presence of a lightwood stump in itself, even one appearing to show signs of turpentining, does not provide sufficient evidence for longleaf pine. This point is illustrated by an 1884 report indicating that loblolly pine (*Pinus taeda* L.) was turpentined, albeit without commercial success (Wahlenberg 1960). To facilitate our longleaf pine restoration efforts by delimiting its historic range in Virginia, methods were sought to determine the taxon of the above-mentioned stumps.

Southern pine lumber is fairly easy to identify. Along with conspicuous resin canals and abrupt transitions for the rings, the latewood is characteristically wide and comprises a significant proportion (greater than one fifth) of each annual ring (Kubler 1980). Unfortunately, wood anatomy alone does not permit the specific identification of longleaf pine apart from the other southern pines (Panshin and de Zeeuw 1980). Multiple latewood bands sometimes observed in a single annual ring have been suggested as a means to narrow the options down to longleaf and slash (*Pinus elliottii* Engelm.) pines (Kukachka 1960). We found the occasional observation of this feature to be of little consequence. Likewise, attempts to identify stump wood samples by chemotaxonomic and spectroscopic approaches proved to be inconclusive (Eberhardt et al. 2007, 2009*a*). Persistence in this endeavor ultimately led us to a seemingly forgotten method developed by Arthur Koehler (Koehler 1932) whereby longleaf pine can be distinguished from slash, loblolly, and shortleaf pine (*Pinus echinata* Mill.) timbers by measuring the pith and the second annual ring diameters and plotting these data along with a delineating curve (Eberhardt et al. 2009*b*). Data points above the curve correspond to longleaf pine, while data points below the curve correspond to the other southern pines. Irrespective of the diameter of the second annual ring, any pith diameter of less than approximately 2 mm (0.08 in.) would not belong to longleaf pine (Koehler 1932). Since pith size increases with tree vigor, measurement of the second annual ring accounts for the large pith diameters for those slash, loblolly, and shortleaf pines with especially vigorous growth. The method is not flawless, since erroneous measurements classified data points as longleaf for 2.7% of shortleaf, 2% of loblolly, and 3.7% of slash pine specimens. However, only one out of 505 longleaf pine specimens was erroneously assigned as not being longleaf pine, and this was attributed to deformed pith. Koehler (1932) noted that the method is most applicable to forest-grown trees under crowded conditions. It was suggested that larger pith diameters for open-grown slash, loblolly, and shortleaf pines led to the above-mentioned erroneous identifications as longleaf pine.

The successful application of Koehler’s (1932) method to the identification of lightwood/turpentine stumps required that it first be validated with specimens for which the taxa were known. Given the dynamic nature of forest management practices, and the fact that Koehler’s (1932) study used trees harvested more than 70 years ago, it was of particular interest to determine if the method is still applicable to the southern pines from present-day forest resources. While the greatest accuracy was obtained at stump height, Koehler (1932) indicated that even if the stump end was not present, a longleaf pine timber would still provide measurements consistent for longleaf pine. We developed a data set with measurements from loblolly, shortleaf, and longleaf pines taken at stump height and from loblolly and longleaf pines further up the bole to determine if we could validate this method. After validation, we applied this method to unidentified southern pine relicts in an attempt to generate physical evidence that could extend the historical northern limits of longleaf pine in Virginia.

Materials and methods

Specimen collection

Tree cross-section disks used for this study were obtained from several sources. One source was a set of specimens collected from southern pines harvested throughout the southeastern United States as part of a wood quality study. Cross-section disks were cut at approximately 0.5 m above ground level. Loblolly pines were approximately 30 (Texarkana, Arkansas), 13 (Summerville, South Carolina), 29 (Summerville, South Carolina), 29 (Hattiesburg, Mississippi), and 39 (Many, Louisiana) years old at the time of harvest. Shortleaf and longleaf pines, approximately 22 and 55 years old, respectively, were harvested near Hineston, Louisiana. For some of the above-mentioned loblolly pines, disks were also collected at a height of approximately 5 m. Additional longleaf pine cross-section disks were collected at a spacing, pruning, and thinning study site in the Kisatchie National Forest near Alexandria, Louisiana. Twenty 70-year-old longleaf pines were felled and cross-section disks cut at approximately 0.15, 0.75, 6.1, 12.2, and 18.3 m above ground level.

Cross sections from relict lightwood stumps were collected in Sussex, Prince George, Powhatan, and Caroline counties in Virginia. One of the stumps (Caroline County) showed axe cuts and boxing indicative of turpentining and was therefore labeled as a “turpentine stump.” A snag from an old-growth tree struck by lightning was also sampled in Suffolk, Virginia, and provided a sample known to be longleaf pine. Finally, a core was collected from a pine log recovered from the mud of the Blackwater River near Sedley in Southampton County, Virginia. Unique features of the specimen include stampings on the top cross-section cut of the log, holes drilled into the log with broken pegs, striations cut along length of the log, a large percentage of heartwood, a partially healed turpentine scar, and a hinge cut chopped at the base that was seemingly smoothed after felling (Fig. 2).

Fig. 2. Pine log recovered from Blackwater River in Southampton County, Virginia: healed turpentine scar (*a*), striation cuts (*b*), reverse "Z" stamp (*c*), and large-diameter heartwood (*d*).

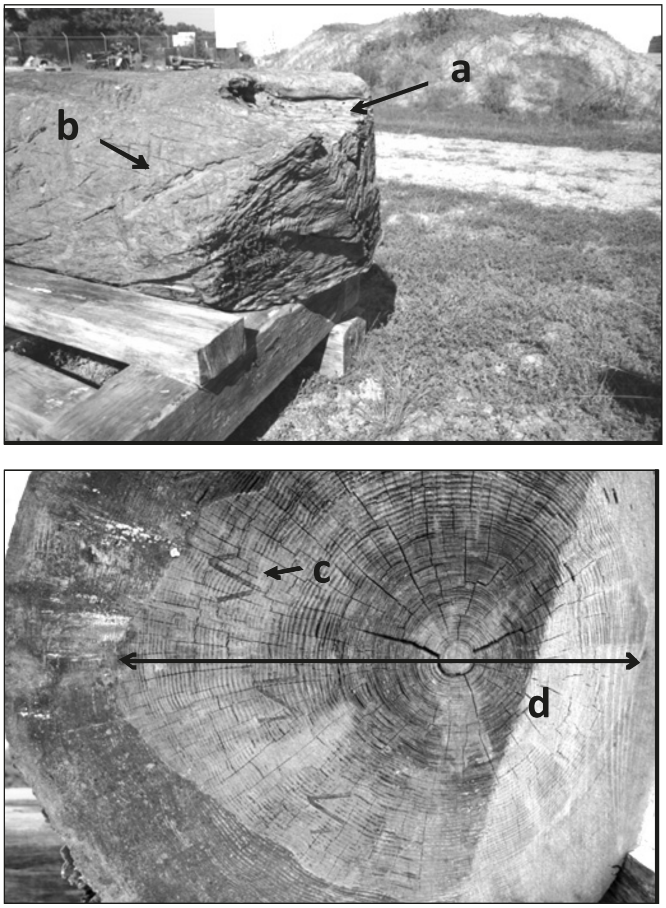
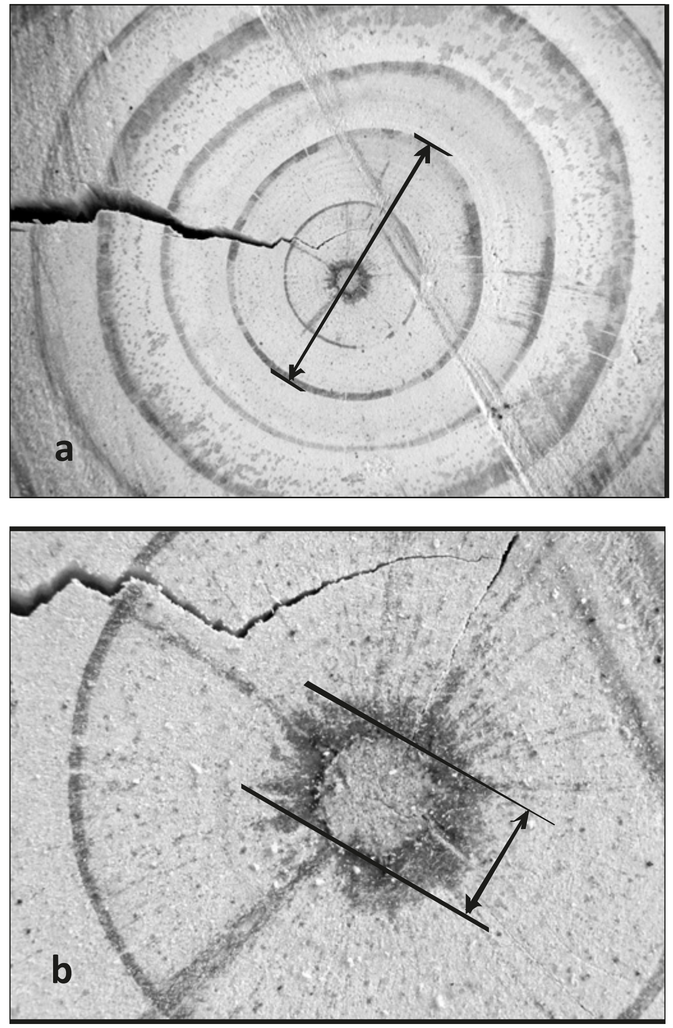


Fig. 3. Example of second annual ring (*a*) and pith (*b*) measurement taken during application of Koehler's (1932) method for identifying longleaf pine (*Pinus palustris*) timbers.



Measurements and data assessment

All specimens were air-dried. Pith and second annual ring diameters were measured according to the method described by Koehler (1932), except SI units (millimetres) were used as opposed to Koehler's (1932) use of the English system of measurement (inches). The second annual ring in a southern pine cross section is typically easy to measure, but care must be taken so as to not confuse the resin-soaked wood near the pith as being part of the pith (Fig. 3). Additional images of second annual ring measurements can be found in Koehler (1932). Fine sandpaper was used as necessary to improve the ability to distinguish the pith and second annual ring. Magnification with a hand lens proved to be sufficient for close inspections. Elliptical annual rings were addressed by using an average of the maximum and minimum diameter measurements.

Koehler (1932) provided neither specific data points nor an equation for his delineating curve. The plot provided in the report was enlarged on a photocopier to facilitate the measurement of data points that were then plotted using Microsoft Excel 2007. The best fit obtained for the curve was with a second-order polynomial equation as follows: $y = 0.00183x^2 - 0.0386x + 2.159$ in which y is pith diameter (millimetres) and x is second annual ring diameter (millimetres). The minimum value for the second annual ring diameter on Koehler's (1932) plot is 6.35 mm. Extension below this should be a straight line. Data collected from our sample sets were subsequently plotted along the regenerated version of Koehler's (1932) delineating curve.

Results and discussion

Method validation

Koehler's (1932) method was first validated with longleaf, shortleaf, and loblolly pine specimens, all taken at stump height (approximately 0.5 m). All longleaf pine specimens gave data points that when plotted (Fig. 4) could be readily assigned to longleaf pine. Almost all data points for loblolly and shortleaf pines were indicative of southern pines other than longleaf pine. The exception was a loblolly pine specimen having pith and second annual ring diameters of 2.8 and 26.0 mm, respectively. This observation validated the occasional false positive result observed by Koehler (1932), even when measurements were made at stump height. Results presented here demonstrate that there is no reason to suspect a dramatically different rate of false positives for currently standing timber than the likely very mature timbers available to Koehler (1932) some 70 years ago.

Fig. 4. Plot of pith and second annual ring diameter measurements for longleaf (*Pinus palustris*), shortleaf (*Pinus echinata*), and loblolly pine (*Pinus taeda*) specimens collected in Arkansas, Louisiana, Mississippi, and South Carolina.

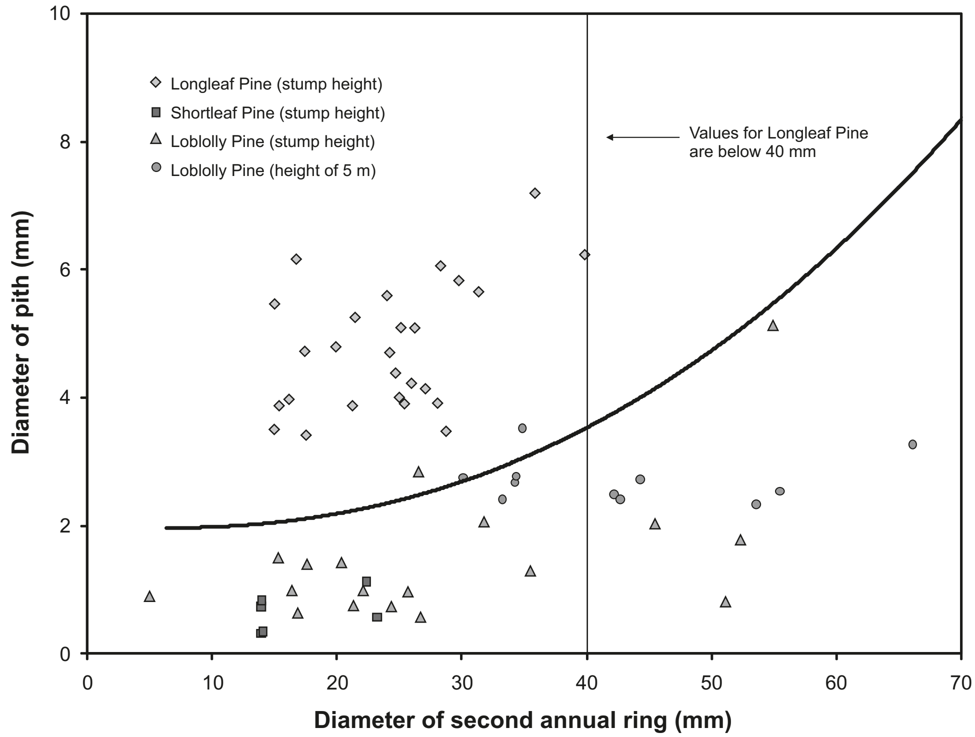
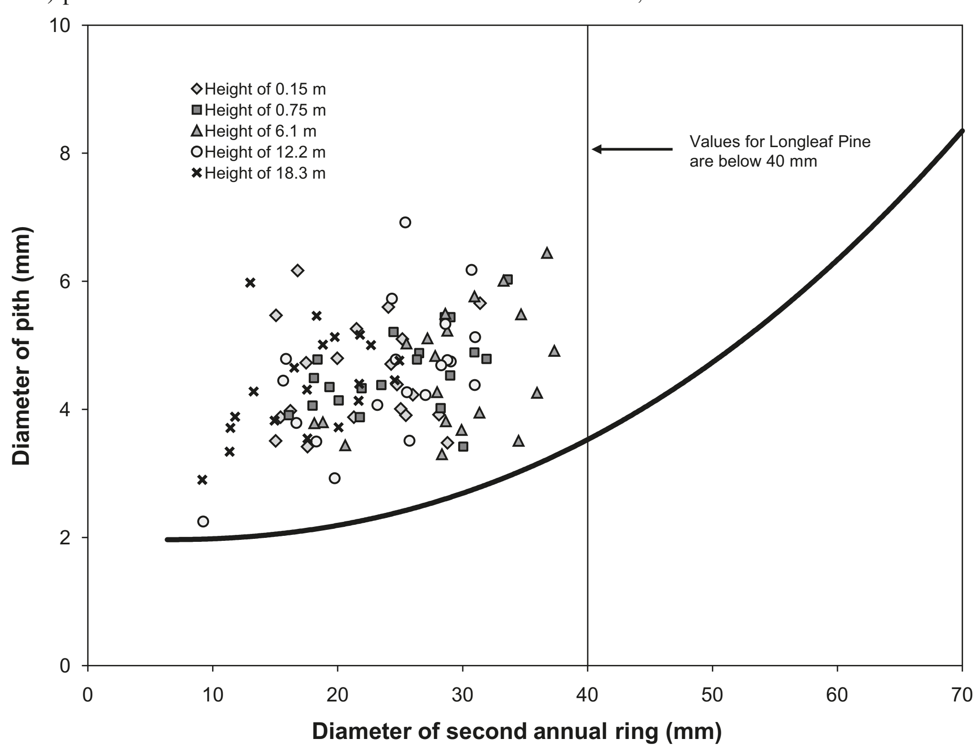
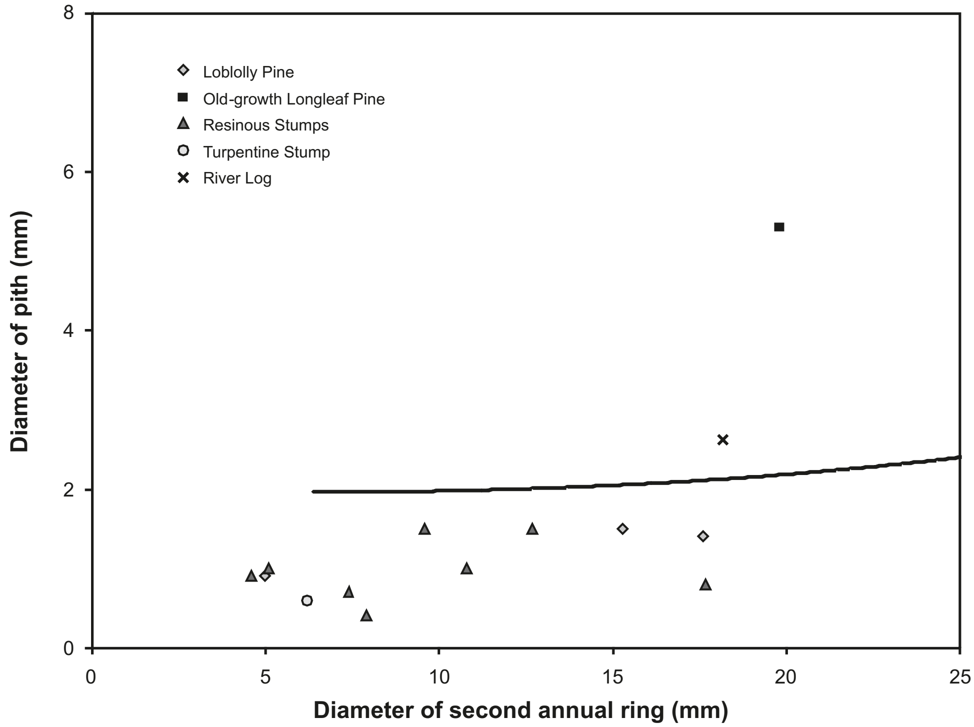


Fig. 5. Plot of pith and second annual ring diameter measurements, at five different heights, for specimens collected from a 70-year-old longleaf pine (*Pinus palustris*) plantation in the Kisatchie National Forest near Alexandria, Louisiana.



A higher rate of false-positive assignments was suggested for samples taken at positions other than stump height (Koehler 1932). In the present study, out of 11 loblolly pine specimens taken at a height of 5 m, one gave a data point near the delineating curve, while another was well above it. Interestingly, these two data points, and that for the above-mentioned false positive at stump height (0.5 m), occurred at a relatively intermediate position along the curve. Since Koehler (1932) did not provide any data in his report, there is no way of knowing if this intermediate position was also problematic

Fig. 6. Plot of pith and second annual ring diameter measurements for loblolly pine (*Pinus taeda*) tree and southern pine relict specimens collected in southeastern Virginia.



for him. Data presented here substantiate the claim that false-positive determinations far outweigh the chance of false-negative determinations. These results also show that erroneous data points are likely to fall at an intermediate position along the curve.

Method application and adaptation

Unfortunately, the lack of actual data points in the original report (Koehler 1932) eliminates comparison with future studies. In the present study, upon observing the actual data points, it becomes readily apparent that there may be another differentiating feature that could be used to identify a specimen as a southern pine other than longleaf pine, that feature being the diameter of the second annual ring alone. Whereas the very rapid growth of loblolly pine is manifest in the measurements of second annual ring diameters reaching 54.88 mm, the largest value for longleaf pine was 40 mm (Fig. 4). To put this to the test, another set of specimens was collected from a 70-year-old stand of longleaf pine. Measurements taken at stump height and further up the bole (Fig. 5) gave results that were very similar to the first set of measurements (Fig. 4), the latter only taken at stump height. Whereas comparison of pith diameter measurements for all five sampling heights by analysis of variance showed no significant difference ($P = 0.931$), there was a significant difference for the second annual ring diameter measurements ($P = 1.22 \times 10^{-7}$). The greatest average second annual ring diameter was 29.26 ± 5.52 mm at a height of 6.1 m. Values further down the bole (0.15 m, 21.97 ± 5.03 mm; 0.75 m, 24.79 ± 5.33 mm) and further up the bole (12.2 m, 23.94 ± 6.10; 18.3 m, 17.54 ± 4.71 mm) were lower. The highest single value for second annual ring diameter for this data set was 37.35 mm. Given that the corresponding values at 0.15 and 0.75 m were lower (31.39 and 30.94 mm, respectively), it would appear that stump specimens having second annual ring diameters greater than the proposed cutoff of 40 mm would have a low probability of being longleaf pine. Identification and measurement of second annual ring diameters may at the very least provide tentative evidence for taxa other than longleaf pine in situations where the pith is missing or decayed away.

For all of the 70-year-old longleaf pines, the data points were well above the delineating curve (Fig. 5). This result is consistent with Koehler's (1932) observation that even if the stump end was not present, a longleaf pine timber would still provide measurements consistent for longleaf pine. Thus, for timber identification in historic structures, or the niche forest products industry involving the recovery and processing of highly prized longleaf pine logs from river bottoms, the probability of identifying a longleaf timber as belonging to one of the other southern pines is very low. The caveat here is the greater chance of a false positive with the identification of a timber as belonging to longleaf pine when in actuality it belongs to one of the other southern pines.

The 70-year-old longleaf pines that we sampled had widely variable growth rates as evidenced by values for diameter at breast height ranging from 14 to 48 cm. The positive identification of all of these trees as longleaf pine demonstrates the robustness of the method. Scatterplots of the pith diameter measurements against the corresponding second annual ring diameter measurements showed no correlation at either the low (0.15m) or high (0.75m) stump heights, with R^2 values of 0.001 and 0.231, respectively. Since higher pith diameter measurements corresponded to higher second annual ring measurements in our loblolly pines, it would appear that the delineating curve was based more on the data points collected from the other southern pines than the more tightly grouped data points for longleaf pine. Finally, these data again demonstrate that a method established with trees harvested more than 70 years ago still applies to standing timber growing today and, ironically, to longleaf pine trees planted 70 years ago.

Measurements from relicts

In addition to current-growth southern pines, we were fortunate to gain access to an old-growth longleaf pine near Suffolk, Virginia, that had been killed by lighting. This sample provided a connection for our data to those likely collected by Koehler (1932). The measurements from this tree were well within the limits for longleaf pine (Fig. 6). At this point, we turned our attention to accessible lightwood stumps located within (Powhatan, Prince George, and Sussex counties) and outside (Caroline County) the purported range of longleaf pine in Virginia. One of the stumps in Caroline County that we were able to sample showed scarring and was therefore of particular interest. Turpentine scars were suggested as an indicator of longleaf pine (Koehler 1932). It should be noted that although slash pine was also widely turpentined, it did not grow anywhere near Virginia. Results for lightwood stumps for which the pith was sufficiently intact were also plotted (Fig. 6). In all cases, the results suggested that these relicts did not belong to longleaf pine. A few loblolly pine trees in Virginia were also sampled and gave similar results. The revelation that the apparent turpentine stump in Caroline County did not belong to longleaf pine was particularly intriguing. Again, loblolly pine was suggested to have been subjected to turpentining operations, but without commercial success (Wahlenberg 1960). The above observation would appear to substantiate that historical report.

Finally, we were afforded a rare opportunity to collect and measure a core from a pine log recovered from the mud of the Blackwater River near Sedley in Southampton County, Virginia, in 2010. Unique features of the specimen include reverse “Z” stampings on the top, holes drilled with occasional remaining broken dowels, striation cuts along length of the log, a partially healed turpentine scar, a large proportion of heartwood, and a hinge cut chopped at the base that was seemingly smoothed after felling. Compared with the longleaf pine results (Figs. 4 and 5), the second annual ring diameter of 18.18 mm is on the lower end of the range and suggests more moderated growth as would be expected from an old-growth forest. The data point is above the delineating curve (Fig. 6), and thus, this log has a very high probability of belonging to longleaf pine. This conclusion is further supported by the large proportion of heartwood (over 60% of the diameter). Old-growth longleaf pine has a high percentage of heartwood volume compared with loblolly, shortleaf, and slash pines (Koch 1972). Moreover, turpentining limits growth, thereby resulting in 5%–12% greater volume of heartwood in longleaf pine (Wahlenberg 1946). The cumulative evidence (diameter measurements, large proportion of heartwood, turpentine scar) strongly supports our determination that this specimen is longleaf pine. The exact origin of the tree from which this log was cut is unknown. There is no record, to our knowledge, of a timber industry floating logs downstream on the Blackwater River. Further investigation of historical records, and the Blackwater River itself, is warranted to investigate this possibility. However, the final resting place of this log was well within the purported range for longleaf pine in Virginia.

Conclusions

While the longleaf pine timber resource of today may differ from that on which the method was developed, the delineating Koehler (1932) plot still provides a definitive tool for differentiating longleaf pine timbers from those of the other southern pines. No evidence was found to suggest that growth rate differences impact method applicability. In those situations where the second annual ring is intact, but not the pith, very large second annual ring diameters (>40 mm) may provide an adaptation to the method to identify timbers with a lower probability of being longleaf pine. To date, measurements from pine timbers and stumps yielded results consistent with the purported range for longleaf pine in Virginia.

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