Hardwood Log Grading in the United States—Part III: An Assessment of the Current Status of Log Grading in the Hardwood Industry

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Abstract

This article documents how the hardwood industry, in the absence of a standardized, industry-wide log grading system, has gone about grading and scaling hardwood logs by surveying mills, primarily in the Appalachian region. In total, 135 surveys were completed by respondents and returned via mail, with only 110 of those surveys considered usable for further analysis, after a thorough review of the individual surveys. Survey responses were grouped around annual production level, with three defined levels; ≤2.5 million board feet (MMBF), >2.5 and ≤8.0 MMBF, and >8.0 MMBF. Responding mills used some variation of a log grading system based on the number of clear faces on the log and the small end diameter of the log. The most common log rule used by mills in this study was the Doyle log rule, with over 75 percent using Doyle for scaling logs. Nearly 90 percent of all mills sampled graded logs without rolling the log to examine all four sides/faces. Half of all the sawmills surveyed pay the same price per thousand board feet (MBF) for butt logs and uppers. When asked if they would support the development of a standard log grading system, about two-thirds of the respondents (66%) indicated they would indeed support a standardized system for Appalachian hardwoods. These findings can help guide the development of a set of log grading standards for buyers and sellers in the Appalachian region and other parts of the world where hardwood lumber is produced.

Hassler et al. (2019a) provided a historical perspective of the development of hardwood log grading in the United States in Part I of this series, and in Part II, Hassler et al. (2019b) summarized how the development of the US Department of Agriculture Forest Service (USDAFS) hardwood log grading system was received by the hardwood industry and reasons why it never gained any significant traction (Vaughan et al. 1966).

The USDAFS system has remained relatively unchanged since its introduction in 1949, in part because there has been no industry impetus to drive the process toward another system, and because the USDAFS has not considered it necessary to alter or change their system, since it meets the internal needs of the Agency. Although some competing systems were developed during the timeframe in which the USDAFS system was developed, those competitors showed no long-term sustainability. There is no evidence that any of these systems survived or are in use today. The only formally developed log grading system that remains is the USDAFS system.

The USDAFS system primarily flourished within the Forest Service, particularly with its use in some Forest Inventory Analysis work and in Forest Service and university research. Whenever log grades are an important consideration in research work, USDAFS grades are used, as documented in both past and current literature. Finally, log grading workshops, even now, typically present only the USDAFS log grading system to their audiences.

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However, from a hardwood industry perspective, there has never been a broad acceptance of the USDAFS Hardwood Log Grading system or the grades defined in the system. Rast and Baumgras (1997) provided an internal, unpublished report after visiting 38 sawmills in 1997 throughout the Appalachian region and concluded that ''practically no two plants are similar in the way that they grade, if they grade at all.'' Their report noted that many of the mills used some aspect of grading that incorporated the number of clear faces on the log as an indicator of quality or grade. And as recently as 2012, McConnell (2012) stated that no set standards exist for grading hardwood logs and trees. He suggested that, even though the USDAFS produced a comprehensive rule for hardwood log grading, other more simplified grading systems are used more commonly by the industry than the USDAFS system. However, very little literature is available to support his assertions or, more important, to describe these other systems.

Scaling of hardwood logs is arguably just as important as grading, since log pricing is based on only two factors; grade and scaled log volume. And only two measurements are required to determine log volume: *scaling diameter* and *length*. Diameter for hardwood logs is determined by measuring the diameter inside the bark (DIB) at the small end of the log. The total length of the log is measured in feet. Once these two measurements have been determined, the total volume, in board feet, can be calculated using an established log rule.

Three log rules consistently used by the hardwood industry include the Scribner, Doyle, and International 1/4-inch log rules. And while there is much known about the origins of these log rules, very little information is available detailing which of these three log rules is used most often by the hardwood industry.

The Scribner log rule was developed by J. M. Scribner in 1846 and is based around diagrams of logs with different diameters, drawn to scale, showing the number of 1-inch boards, with saw kerf included, that could be sawn from that log. At a later point, the log rule was modified and renamed the Scribner Decimal C log rule, where the original volumes were rounded off to the nearest 10 board feet and the last zero dropped. This was intended to help log scalers and graders when large volumes of logs had to be inventoried (Avery and Burkhart 1983).

The Doyle log rule, developed by Edward Doyle in 1825, uses an algebraic equation for determining volume, as detailed below:

$$\text{bd ft} = \left((D-4)/4\right)^2 L$$

It accounts for 4 inches of slab allowance and 5/16 inches of saw kerf. This log rule underestimates log volume for smaller logs, approaches the true volume once log diameter reaches about 24 to 28 inches DIB, and then overestimates volume for larger diameter logs (Avery and Burkhart 1983).

The International log rule was created in 1906 by Judson Clark and is considered to be the most accurate of the currently used log rules. The International log rule is equation based and takes taper into account with a fixed allowance of 1/2 inch per 4 feet of log length. This log rule has two different kerf allowance specifications: 1/8 inch and 1/4 inch. The 1/8-inch kerf version was developed for use in bandsaw head rig mills, and 1/4-inch kerf is for use in circular saw type milling operations (Avery and Burkhart 1983).

While log scaling systems used by Appalachian mills are generally limited to one of the three systems discussed above, the methods used by sawmills to account for defects present in the log are generally considered to be significantly more variable. For a standardized scaling and grading system, any scaling deduction must be in the form of a rule of thumb that can be applied quickly and efficiently in a production setting to adjust either grade or scale.

The US Forest Service log grading system used relatively complicated formulas, rather than rules of thumb, for calculating percentage deductions for the various scaling defects, which was not conducive to production settings and was a significant drawback to the adoption of the Forest Service rules. The rules developed and used by mills in Appalachia for dealing with log defects are not well defined or available for review but have certainly evolved into easily used rules of thumb that can be applied quickly in a production setting.

The Appalachian Hardwood Center (AHC) at West Virginia University has, since 2005, conducted over 60 mill studies at sawmills in six states to assist sawmills to better understand their log grades, lumber grade yields, and pricing of hardwood logs. In the course of these studies, the AHC became acutely aware that these mills had created their own de facto systems, unique to each individual mill or company. While these mill-specific systems could vary considerably in how logs were graded/classified, certain commonalities were evident, among these, species, scaling diameter, and number of clear faces. Certain nuances in assigning a grade were applied by mills, with no consistency between mills, and could include such factors as log length, position in the tree (butt or upper log), and log-end conditions.

The purpose of this article is to document how the hardwood industry, in the absence of a standardized, industry-wide log grading system, has gone about grading and scaling hardwood logs through a survey of sawmills, primarily in the Appalachian region. This information can serve to further develop commonalities that could be used in developing and implementing a standardized hardwood log grading and scaling system acceptable to the hardwood industry.

Methods

Primary wood-product producers in the Appalachian region were surveyed to determine how hardwood sawlogs are purchased and to identify grading and scaling measurement protocols that could be used in the development of a regional hardwood log grading and scaling system. The specific issues addressed in the survey include log rules being used, log procurement methods, mill production, log scaling and grading protocols, current grading specifications, production costs, and support for a standardized grading system.

Contact information for prospective mill contacts through the mail was developed from two sources. The first source was the Appalachian Hardwood Manufacturers, Inc. (AHMI). The mission of AHMI is to promote the benefits of logs, lumber, and products sourced from the Appalachian region. AHMI member data included primary wood-product producers from nine states, including Ohio, New York, West Virginia, Pennsylvania, Tennessee, Virginia, North Carolina, Maryland, and Kentucky.

The second source was from state forestry agencies that provided contact information for non-AHMI member companies in the same nine states. These two lists were reviewed to ensure no duplicates were present. The combined nine-state list was finally adjusted to include only those wood-products producers that actively graded hardwood sawlogs. Thus, only primary wood-product producers and log buyers were included in the study. Once the lists were finalized, a total of 1,085 producers from both AHMI (45 records) and non-AHMI member companies (1,040 records) were identified.

The subsequent responses were then grouped around annual production level, so that natural breaks, as defined by the study team, resulted in three separate production level groupings. Groups needed to be relatively even, to avoid skewing the statistical analysis results by potentially overwhelming one or more groupings.

Frequency distributions were developed for each survey response and used to categorize data. This ensured, within the natural breaks, that no more than 25 percent of the cells had fewer than five cell counts. Owing to the nominal structure of the data, where it is categorized by frequency counts, the chi-square test of independence in the form of an $r \times c$ contingency table (Conover 1980) was used for all statistical analyses, where the data were analyzed based on annual mill production (in board feet) and survey responses (R Core Team 2019). The *P* value was set to $\alpha \leq 0.05$ throughout the study.

Once a statistically significant test is produced, the variables can be examined to determine the origin of the significance. The observed categorical variable that contributes significantly to the overall chi-square value can be determined by the cell contributions of the expected values. Tabular presentation of the results will only include those questions where a significant statistical result occurred.

Finally, with each survey, participants were asked to provide specification sheets that described their current log grading and pricing matrix, by log grade and species. The specification sheets provided by the respondents were analyzed by focusing on the highest and second highest log grades, excluding veneer grades. The individual mill log grades were used to populate a matrix based on the number of clear faces and scaling diameter.

The matrix was constructed for five clear face categories (0, 1, 2, 3, and 4) and 11 scaling diameter classes (8 inches to 18+ inches in 1-inch increments). For example, if the highest log grade specified by a mill included four clear faces and a scaling diameter of 17+ inches, then two cells of the matrix received one frequency count (four clear faces with 17 inches scaling diameter and four clear faces with 18+ inches scaling diameter). In this way, the variability in how the two highest log grades were categorized by responding mills could be evaluated.

Results and Discussion

Demographics

The survey was mailed in June 2018 to 1,085 primary product producers, with an expected return date of August 15, 2018. Responses showed that seven mills were no longer in business, and six indicated they were not primary wood-product producers. An additional 111 surveys were returned due to invalid addresses. Based on this information it was estimated that the survey reached 961 mills.

The total number of responses was 135, with only 110 surveys considered usable due to critical omissions in the survey responses. The study response rate was 14.0 percent (135/961), and the total usable valid sample population was 11.4 percent (110/961). There were no follow-up efforts to encourage a greater response. However, the response rate compares favorably to a similar survey of hardwood sawmill log procurement practices, which was 12.4 percent (Andersch et al. 2015).

Pennsylvania had the greatest number of completed surveys (19) and represented 17.3 percent of the total number of responses produced. In total, 14 responses were provided by mills in Virginia, followed closely by Kentucky and West Virginia, with 13 responses each. Mills in these four states provided almost 60 percent of the total survey response (Fig. 1).

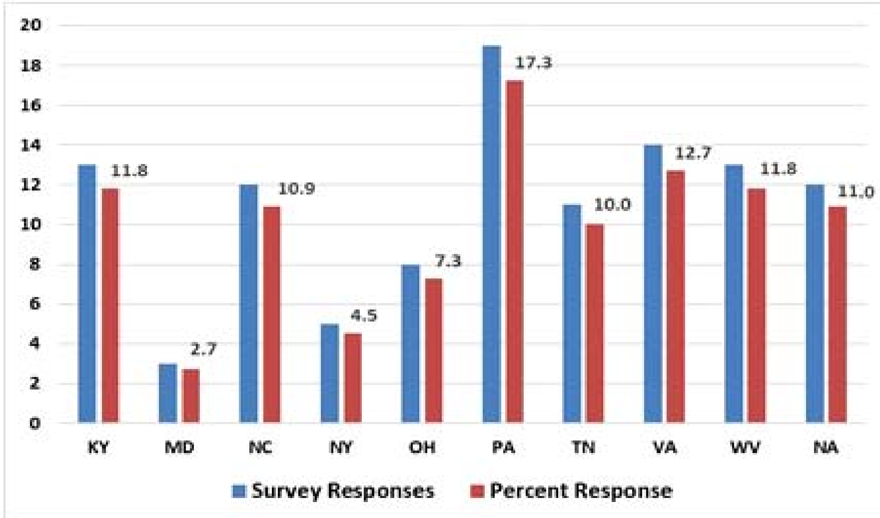
All mills were asked to provide annual production levels in their survey response. Respondent production ranged from 0.04 to 150 million board feet (MMBF) with a mean of 9.9 MMBF of production. Annual production information was classified into three groups based on natural breaks (Table 1), which resulted in a very uniform distribution of responses over the three production levels. These production groupings, where mill size 1 represents all mills with a production level of less than or equal to 2.5 MMBF, mill size 2 represents all mills with a production level greater than 2.5 MMBF but less than or equal to 8.0 MMBF, and mill size 3 represents all mills with a production level greater than 8.0 MMBF, were used for all subsequent analyses.

For the remainder of this article, the term *total number of responses* will refer to the number of usable responses to the survey question under discussion, not the total number of responses to the survey. While 110 responses were deemed usable, certain questions were not answered by some respondents; therefore, the analyses were performed on the usable responses for those questions. Table 1 contains the breakdown of annual production level by state for survey respondents; Figure 2 illustrates this distribution of mills by size and state.

Scaling protocols

The most common log rule used by mills in this study for scaling was the Doyle log rule, with 83 of 109 mills (76.1%) reporting its use (Table 2). The second most used log rule was International 1/4 log rule (12 responses), followed by Scribner decimal C log rule (11 responses), and finally three respondents indicated that they used some combination of these log rules (three responses). The Doyle log rule was used consistently over all nine states in the sample, with Ohio and West Virginia using it exclusively. The International log rule saw the greatest use in Virginia and North Carolina, while the Scribner Decimal C log rule was used mostly in Pennsylvania and North Carolina.

Mills were asked whether they buy logs of even lengths only or if they also buy odd length logs. A total of 62 (57.9%) mills purchased only even length logs, while the remaining 45 (42.1%) respondents purchased both even and odd length logs. For those only purchasing even length logs, this creates a possible situation where a logger produces a 9-foot log, sells it as an 8-foot log to the mill, and the mill then produces and sells 9-foot boards. The chi-square test of



[1] NA refers to 12 survey responses (10.9 percent) that did not identify a state location.

Figure 1.—Number and percentage of usable survey responses by state.

independence found no statistical difference between level of production and the purchase of only even length logs (8, 10, 12, 14, and 16 feet) or both odd and even lengths (8, 9, 10, 11, 12, 13, 14, 15, and 16).

Mills were asked how they determine scaling diameter of sawlogs, using the small end of the log inside bark for the measurement. Four options were detailed in the survey.

- *Average*—The largest and smallest measurements were taken through the center of the heart added together and divided by two.
- *Short-way only (SWO)*—The shortest measurement of diameter was taken crossing through the center of the heart of the log.
- *Short-way then 90 degrees to that (SW+90)*—The shortest measurement of diameter crossing through the center of the heart of the log and then the measurement 90 degrees to that was taken, and those two measurements were added together, and the sum was divided by two.
- *Other*—Logs were purchased by weight, and just the small end of the log inside bark was measured (with no further explanation).

Of the mills sampled, 45 (42.9%) measured diameter inside bark using the Average option, followed by the (SW+90) option at 33 (31.4%) responses. The least reported was Other option, with 3 (2.9%) responses (Table 3). In general, using the Average option tends to overestimate diameter, while the (SW+90) option is more consistent in estimating the usable amount of wood for lumber production. The chi-square test of independence identified a statistical relationship between the measurement of scaling diameter and size of production (Table 3). More size 1 mills than expected responded SWO and for size 3 mills, more than expected responded Other.

Table 1.—Annual production levels (in million board feet or MMBF) for all usable survey respondents.

Mill size identifier	Production level	Number of producers	% of total
1	>0.0 to $\leq$2.5	35	31.8
2	>2.5 to $\leq$8.0 MMBF	37	33.7
3	>8.0 MMBF	38	34.5
Total		110	100.0

Mills were also asked how they handle fractional inches when measuring the scaling diameter of sawlogs. This is a protocol that falls across a broad spectrum of techniques.

1. If the fractional portion equals 0.5 inches, alternate rounding up and down: The log grader alternately rounds up and down when the diameter falls on 0.5 inches.
2. If the fractional portion is $\geq$0.5 inches, round up: The log diameter is rounded to the next full inch.
3. Round down: The log diameter is rounded down to the lower diameter value in all instances.
4. Round up or down depending on the quality: On good logs round up, and on bad logs round down.
5. Round up if $\geq$0.75 inches: If the diameter is 0.75 inches or greater, the diameter is rounded to the next full inch.
6. Round down if $\leq$0.5 inches: Any fractional proportion of diameter equal to or less than 0.5 inches will be rounded down.

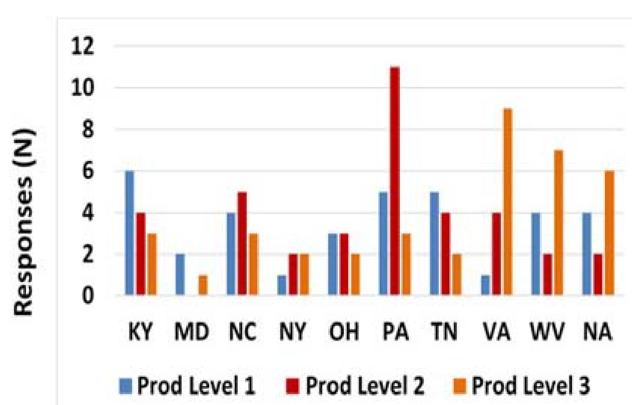


Figure 2.—Distribution of survey responses from sawmills by state and annual production category.

Table 2.—Number of primary wood-product producers by state separated by annual production level and log rule used to determine log volume (109 mills responding).

	Log rule and production level												
	Doyle			International			Scribner			Combination			
State	1	2	3	1	2	3	1	2	3	1	2	3	Total
Kentucky	5	4	3	1	0	0	0	0	3	0	0	0	16
Maryland	1	0	1	0	0	0	0	0	0	1	0	0	3
North Carolina	3	2	0	0	2	0	0	1	0	0	0	0	8
New York	0	2	1	1	0	0	0	0	0	0	0	1	5
Ohio	3	3	2	0	0	0	0	0	0	0	0	0	8
Pennsylvania	2	6	2	0	1	0	3	3	1	0	1	0	19
Tennessee	5	3	2	0	1	0	0	0	0	0	0	0	11
Virginia	0	4	6	1	0	3	0	0	0	0	0	0	14
West Virginia	4	2	7	0	0	0	0	0	0	0	0	0	13
No state provided	4	1	5	0	1	1	0	0	0	0	0	0	12
Total	27	27	29	3	5	4	3	4	4	1	1	1	109

7. Other: These responses generally implied that when scaling logs, the diameter measurements were not rounded.

Thirty-three (34.0%) respondents handled fractional diameter measurements using option 2. Another 23 companies (23.7%) reported using option 1, while 15 (15.5%) companies used option 6. The most common options and most likely the fairest to both buyers and sellers appeared to be either rounding up or down when the average of two diameter measurements is 0.5 (options 1, 2, and 6). The other techniques generally benefited either the mill or logger in an unfair way. No statistical differences were found between rounding protocols.

Double hearts are prevalent in many hardwood sawing operations and have a negative effect on the value and quality of lumber. Double heart is created when the bole of a tree diverges, forming two forks (Fig. 3).

Mills were asked about how they handle scale deductions for logs with double hearts. Of the mills sampled, 27 (27.8%) indicated they use a length deduction when dealing with double heart. An equal number of mills responded that they typically measure the diameter of the log the short way. No statistical relationship existed between the measurement of double heart and size of mill production. The various methods for handling double hearts are as follows:

- Measure diameter across the bark seam of double heart ($n = 8$ or 8.3%).
- Average of the shortest and longest measurement ($n = 6$ or 6.2%).
- Diameter deduction ($n = 4$ or 4.1%).
- Full scale, no deductions ($n = 7$ or 7.2%).
- Length deduction ($n = 27$ or 27.8%).
- Scale from opposite end (measure diameter of large end) ($n = 5$ or 5.2%).
- Scale one heart ($n = 5$ or 5.2%).
- Short-way only ($n = 27$ or 27.8%).
- Other ($n = 8$ or 8.2%).

Table 3.—How do mills determine scaling diameter, by annual production level in the Appalachian region (105 mills responding)?

	Production level					
	1		2		3	
Response	Observed	Expected	Observed	Expected	Observed	Expected
Average	11	14.6	19	15.4	15	15.0
SWO	14[a]	7.8	6	8.2	4	8.0
SW+90	9	10.7	11	11.3	13	11.0
Other	0	1.0	0	1.0	3[a]	1.0
Total	34		36		35	

[a] Statistically significant at $\alpha = 0.05$.

Traditionally, mills differentiate between butt logs and upper logs when assigning prices, since butt logs typically have fewer knots and produce more clear face lumber when compared with upper logs of the same general dimensions. Of the mills sampled, however, 55 (50.5%) indicated they do not pay differently for butts and upper logs with the same diameter and same number of clear faces, even though butt logs are generally considered more valuable than uppers. Fifty-four respondents (49.5%) indicated they did pay more for butt logs. The chi-square test of independence showed no statistical difference between the purchase of logs based on their position within the tree, based on the level of mill production.

Trim allowance, or the presence of a small amount of extra length beyond the target log length (e.g., 8 feet, 4 inches) on logs, ensures that a mill can saw lumber full length and not be forced to trim lumber back a foot or more. For instance, a 10-foot log with no trim will not usually yield 10 feet of lumber, since there is no room for error during the trimming operation. Once a 10-foot long board is trimmed, it would necessarily be cut back to either an 8-foot or 9-foot length, losing lumber in the process.

Of the 100 mills responding, 26 preferred 4 inches of trim, while 25 respondents reported other preferred lengths of trim ranging from 0 to 12 inches. Twenty-five preferred 6 inches of trim, while 24 respondents preferred a range between 4 and 6 inches. A statistically significant relationship was noted between preferred trim allowance and annual production (Table 4). More size 1 mills than expected preferred other specified lengths of trim.

If the preferred trim allowance was not met, respondents were asked at what minimum trim allowance would the mill initiate a scale-based length deduction. Of the mills sampled, 18 (19.5%) would take a length deduction at 1

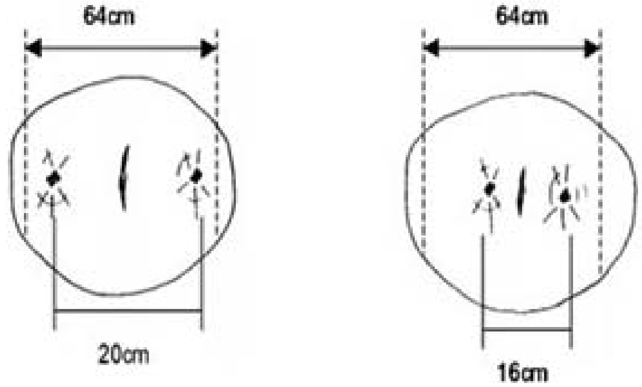


Figure 3.—Double hearts in hardwood logs (Anonymous 2001).

inch of trim, 30 (32.2%) would make a length deduction at 2 inches of trim, 11 (11.8%) at 3 inches, and 15 (16.1%) at 4 inches. Nineteen respondents (20.4%) made deductions based on other criteria, reflecting differing lengths of trim. The chi-square test of independence showed no statistical differences between the deductions based on minimum trim allowance and annual mill production.

Scaling defects

When scaling logs to estimate volume, scaling defects present a range of options for estimating the volume deducted for defects observed in the log. Perhaps the most difficult aspect of log scaling is in dealing with scaling defects in a rational and consistent manner. Determining the most common and practical approaches used by the industry for handling log defects can suggest the best options for a standardized scaling system. Several questions were posed in the survey about scaling defects, specifically sweep, holes, and shake.

Sweep is a scaling defect that occurs when significant deflection is present in a log (Fig. 4). Sweep is often more prevalent in upper logs but can also exist in butt logs.

Of the 90 responses to these questions, 33 (36.7%) of the responding mills indicated that they use both a diameter and length deduction when handling sweep, followed by 30 mills (33.3%) indicating the use of a diameter deduction. Sixteen (17.8%) respondents indicated they use a length deduction only, and 11 (12.2 %) indicated they did not use any kind of diameter or length deduction. The chi-square test of independence showed no statistical differences between the different deduction methods and annual mill production levels.

Table 4.—Preferred trim allowance specified by mills categorized by annual production level in the Appalachian region (100 mills responding).

Production level	Trim 4 in.	4–6 in.	6 in.	Other	N
1					
Observed	6	5	6	14[a]	31
Expected	8.1	7.4	7.8	7.8	
2					
Observed	13	8	7	7	35
Expected	9.1	8.4	8.8	8.8	
3					
Observed	7	11	12	4	34
Expected	8.8	8.2	8.5	8.5	
Total	26	24	25	25	100

[a] Statistically significant at $\alpha = 0.05$.

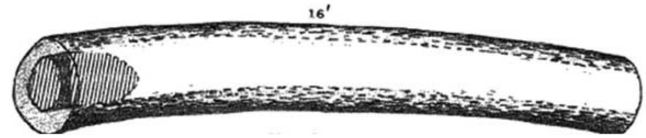


Figure 4.—A diagram of sweep and holes in hardwood logs (Rast et al. 1973).

Holes are scaling defects that occur due to heart rot, which affects the section of the log where the cant is generally located. Holes are an end defect and can range in severity based on how far the hole extends into the log. From a visual perspective, it is difficult to assess the potential impact of a hole, with its associated decay (termed dote), on lumber recovery and quality. These end features can have varying effects on the value of certain logs—all related to the severity of the decay. Figure 5 provides an illustration of a hole defect in a hardwood log.

Of the responding mills, 34 (36.9%) indicated that they account for holes or interior defects during the scaling process using both diameter and length deductions, while 25 (27.2%) use only a length deduction. Twenty-three (25.0%) were using diameter only, and 10 (10.9%) indicated they did not use any kind of diameter or length deduction. The chi-square test of independence showed no statistical differences between the deductions based on holes and annual mill production.

Ring shake, like sweep and holes, directly impacts the volume of sawn material (Fig. 5). A total of 35 (38.9%) respondents used both diameter and length when making deductions for shake, followed by 24 (26.7%) that used a

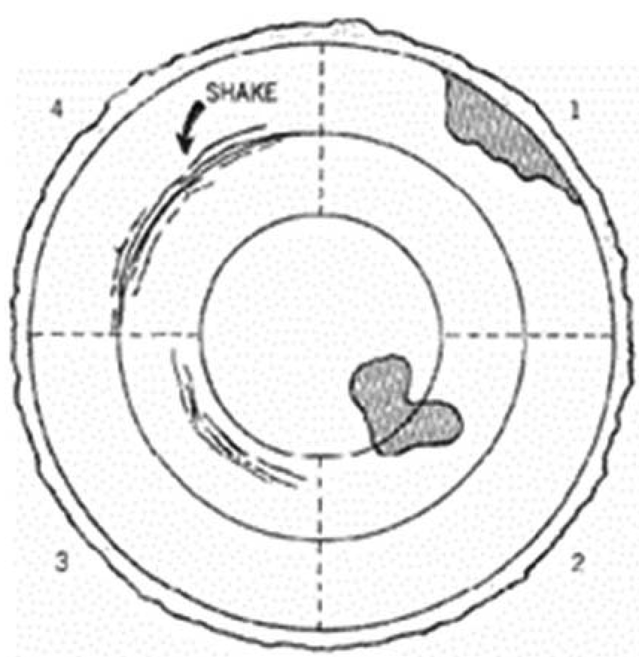


Figure 5.—A diagram of shake and holes in hardwood logs (Rast, et al. 1973).

length deduction. Nineteen respondents (21.1%) used only a diameter deduction, and 12 (13.3%) indicated they did not use any kind of diameter or length deduction. Other types of deductions were made from visual assessments of the loss of board footage caused by the defect. No statistical differences were noted between the deductions based on shake and annual mill production.

Grading protocols

Grading hardwood logs is a process that uses the exterior features of logs to estimate their quality. Generally, the log is visually divided into four quadrants or faces (Fig. 6) and these faces are evaluated independently to determine the presence or absence of defects. The grade is then based on the number of clear (i.e., defect free) faces. Several questions were asked of respondents regarding their grading procedures.

Of the responding mills, 95 of 107 (88.8%) graded logs without rolling the log to examine all four sides/faces, while 12 (11.2%) indicated they did roll logs. Rolling logs is a common practice in the purchase of veneer logs, but according to respondents, this is not the case with sawlogs. While the survey did not question why logs were not rolled, one would assume that mills are attempting to save time in a production setting, where it is often critical to grade logs as quickly as possible. The chi-square test of independence showed no significant statistical relationship between level of production and grading logs as they lay.

The respondents who answered that they do not roll logs were further asked about the assumptions made regarding the downside (hidden) face of the log. Thirty-four (42.5%) assumed the downside of the log was ''similar to other 3 sides,'' followed by 27 (33.8%) responses where the face was assumed to be clear. Assuming the downside face is ''clear'' is often a false assumption that unfairly boosts the quality of a log. ''Other'' responses (19 or 23.7%) suggested that the downward face has at least one defect or more or half of the logs have defects on the downward face. No significant statistical relationship was noted based on a chi-square test of independence.

Finally, mills were asked if they would support the development of a standard log grading system. Of the mills that responded, 58 (65.9 %) indicated they would support an industry standard log grading system (30, or 34.1%, said they would not support an industry standard). The chi-square test of independence showed no statistical relationship between the level of support for an industry standard log grading system and annual mill production. In other words, mill size does not seem to play a role in whether a mill would support the introduction of a standardized log grading system.

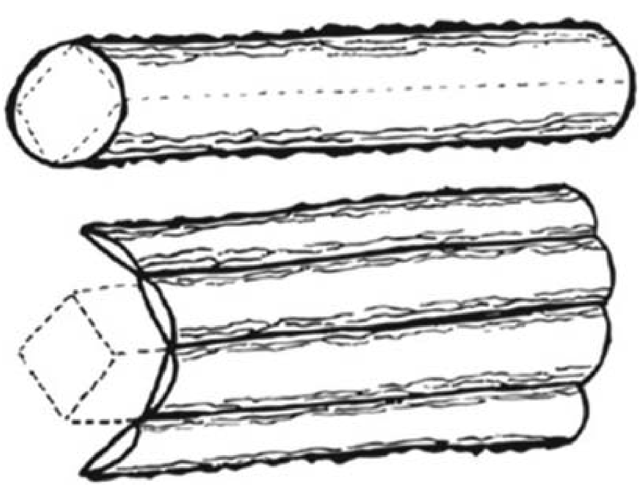


Figure 6.—Obtaining the four, equally sized grading faces when grading a log.

Factors influencing production

Mills were asked if they purchase gate wood, where gate wood is defined as raw material (logs) purchased at the mill from an independent logger or landowner where the seller is responsible for the logging and transportation of the logs to the mill. Of the 108 responding mills, 94 or (87%) indicated that gate wood purchase is a normal log acquisition process across all production level classes. A chi-square test of independence showed a statistical relationship between the purchase of gate wood and annual mill production. That is, more size 1 mills than expected responded they did not purchase gatewood (Table 5).

To further understand the level at which mills consume gate wood, responding mills were asked to detail how much of their total annual raw material supply is acquired through the purchase of gate wood. From the results, 44 percent of the responding mills reported they acquired under 25 percent of their annual raw material supply as gate wood. In contrast, 56 percent stated that they acquired between 25 and 100 percent of their annual raw material supply as gate wood. No significant statistical relationship existed between the amount of gate wood purchased and annual production levels.

Mills were asked if they grade logs from tracts they purchased or owned. The results showed that 64 of the 108 (59.3%) mills did grade logs from purchased tracts, while 44 (40.7%) indicated they did not. The chi-square test of independence between grading stumpage and level of production showed no significant statistical relationship.

In some cases, the mill desires to control the merchandising of logs, so they will purchase raw material as tree length stems. In this type of procurement action, the logs are hauled as tree length pieces (usually to a top diameter that reflects the minimum diameter accepted by the mill for sawing) and then bucked and merchandised at the mill. Of the mills responding, 86 of 108 (79.6%) indicated they did not purchase tree length stems.

Table 5.—Number of respondents that purchase gate wood by production level in the Appalachian region (108 respondents).

Production level	No	Yes	Total
1			
Observed	10[a]	23	33
Expected	4.3	28.7	
2			
Observed	3	34	37
Expected	4.8	32.2	
3			
Observed	1	37	38
Expected	4.9	33.1	
Total	14	94	108

[a] Statistically significant at $\alpha = 0.05$.

Of the 22 mills that reported the purchase of tree length stems, a total of 13 were from Pennsylvania, Ohio, and West Virginia. Pennsylvania had six mills that purchased tree length stems, while Ohio had four, and West Virginia had three. A statistical relationship was noted between the purchase of tree length stems and annual mill production, with more than expected size 3 mills purchasing tree length stems (Table 6).

When mills were asked if they had difficulty getting longer length (14 feet to 16 feet in length) logs, 82 (76.6%) of the 107 responding mills reported having no issues getting long logs, whereas 25 (23.4%) did have issues. No statistical differences existed between mills having difficulty getting longer length logs and level of annual production.

The respondents were asked to indicate whether they were paying any type of premium for long length logs. Of the 78 responding mills, 48 (61.5%) indicated that no premiums were being paid for long length logs, while 30 (38.5%) reported that they did pay premiums for long lengths. No statistical relationship was noted between mills paying premiums for longer length logs and level of annual production.

Straight-through pricing is a purchasing strategy used by mills providing a set price per thousand board feet (MBF) for logs delivered to the mill, based on a minimum scaling diameter and a minimum number of clear faces. For instance, the mill would pay the same price per MBF for logs 12 inches DIB and up and having at least two clear faces. The mills were asked to indicate whether they offer straight-through pricing to loggers, and of the 107 responding mills, 57 (53.3%) indicated they did not, while 50 (46.7%) did provide straight-through pricing. No statistical differences existed between mills providing straight-through pricing and level of annual production.

Since the price of raw material has consistently increased, it is critical for mills to understand the real cost of operating. When respondents were asked if they knew the cost to operate their mill per hour, 79 of the 105 (75.2%) reported they did. No statistical relationship was noted between mills knowing the cost to run the mill per hour and level of annual production.

To further investigate the understanding of the real cost of production, respondents were asked if they knew the sawing cost per MBF by species. Of the 103 responding mills, 67 (65%) responded they did know the sawing cost per MBF by species. No statistical relationship was noted between mills knowing the sawing cost per MBF by species and level of annual production.

The relationship between knowing the cost per hour to operate the mill and sawing cost per species by MBF was explored further based on the responses to these two questions. Of the responding mills, 61 of 103 (59.2%) indicated they know the cost of both, while 19 (18.5%) did not know the cost of either. Six (5.8%) knew only the cost per hour, and 17 (16.5%) knew just the cost per MBF.

Specification sheet analysis

Specification (or ''Spec'') sheets are used by mills to convey how they assess the value of sawlogs. Mills often make specification sheets available to the public, detailing log grades and associated pricing. Respondents were asked if their log specification sheets are publicly available, with the most common response being ''No,'' at 63 (62.4%) of 101 responses. The chi-square test of independence indicated that production level and publicly available specification sheets was significant (Table 7) and that more high-production mills are more likely to have a publicly available written set of log grading standards with associated prices. In total, 26 specification sheets were returned with the survey. These documents generally specified log grade based on clear faces/sides and scaling diameter. An analysis of these specification sheets was undertaken to determine whether any consistency existed among or between the responding mills relative to the actual grading processes defined in each specification sheet. This process was completed for each specification sheet, and the results are presented in Tables 8 and 9. Table 8 illustrates the range of scaling diameters and clear faces for the highest log grade, as defined on the specification sheets.

The highest log grade can start at 12 inches diameter with four clear faces or 14 inches diameter with three clear faces. Thus, any log with a small end diameter greater than 12 inches and four clear faces or 14 inches and three clear faces was valued the same per MBF as a log with a diameter of 18 inches and four clear faces, even though the yield of high quality boards is generally greater in larger diameter classes and with increasing number of clear faces.

The same process was applied to the second highest grade as detailed in the individual mill specification sheets, with the results displayed in Table 9. The most common

Table 6.—Number of producers that buy tree length stems by production level in the Appalachian region (108 respondents).

Production level	No	Yes	Total
1			
Observed	31	3	34
Expected	27.1	6.9	
2			
Observed	31	5	36
Expected	28.7	7.3	
3			
Observed	24	14[a]	38
Expected	30.3	7.7	
Total	86	22	108

[a] Statistically significant at $\alpha = 0.05$.

Table 7.—Number of producers with publicly available log grading standards by annual production level for the Appalachian region (101 respondents).

Production level	No	Yes	Total
1			
Observed	23	8	31
Expected	19.3	11.7	
2			
Observed	25	11	36
Expected	22.5	13.5	
3			
Observed	15	19[a]	34
Expected	22.21	12.79	
Total	63	38	101

[a] Statistically significant at $\alpha = 0.05$.

Table 8.—Distribution of the highest log grade across scaling diameter and clear faces, based on specification sheets provided by survey respondents (26 mills responding).

Diameter (inches)	Clear faces				
	4	3	2	1	0
18+	26	6	0	0	0
17	20	5	0	0	0
16	18	5	0	0	0
15	9	4	0	0	0
14	4	2	0	0	0
13	1	0	0	0	0
12	1	0	0	0	0
11	0	0	0	0	0
10	0	0	0	0	0
9	0	0	0	0	0
8	0	0	0	0	0

combination of diameters and clear faces is 15 inches and four clear faces.

The second highest log grade has a large diameter range and can contain a wide range of clear faces, from two to four. This second highest log grade is quite variable and makes the possibility for fair and consistent pricing impossible due to the variability of the log characteristics that qualify. Where a grade could start at 13 inches in diameter and only have two clear faces, the exact same grade at another mill could apply to a log 17 inches in diameter and four clear faces.

The analysis of these specification sheets revealed a significant degree of variability in how mills categorize their two highest log grades, with significant overlap between those log grades. There are two perspectives to this variability and overlapping grades.

First, from the mill's perspective of maximizing the production of the highest grade lumber (i.e., Selects & Better) at the lowest possible price, it does not make sense to assign their highest grade log (and their highest price per MBF) to smaller diameter logs with four clear faces (12 to 15 inches in Table 8) or logs with three clear faces (14 to 18+ inches in Table 8). Those logs are simply not going to produce the volume of high-grade lumber that large, four clear sided logs will.

Table 9.—Distribution of the second highest log grade across scaling diameter and clear faces, based on specification sheets provide by survey respondents (26 mills responding).

Diameter (inches)	Clear faces				
	4	3	2	1	0
18 +	0	9	3	0	0
17	5	10	2	0	0
16	8	10	2	0	0
15	15	9	1	0	0
14	13	10	1	0	0
13	7	6	1	0	0
12	6	4	0	0	0
11	0	1	0	0	0
10	0	1	0	0	0
9	0	0	0	0	0
8	0	0	0	0	0

From the log supplier perspective, there is an obvious advantage to supplying a mill that will accept a 12-inch log with four clear faces for the same price as an 18+ inch log with four clear faces. On the other hand, the log supplier is at a disadvantage if the mill is buying 17-inch four clear face logs as a second level sawlog and paying the lower price.

This type of variability in defining log grade and subsequently log value inevitably produces uncertainty in developing consistent values for hardwood logs and creates confusion for log sellers as they try to maximize the value of their logs and creates profitability issues for the mill in their quest to maximize production of higher grade lumber.

Conclusions

Grading and scaling

Several conclusions can be drawn from this study. First, each responding mill or yard that purchases logs uses a different approach for grading and scaling, based on their own interests and experience. The analysis of specification sheets illustrates this very well, in that the highest grade log defined by a mill can vary over a wide range of diameters and clear faces. However, some basic commonalities do exist among and between hardwood mills in the Appalachian region. Three basic components serve as the basis for grading and scaling logs (species, scaling diameter, and clear faces) and are applicable over all mill production sizes.

Apart from these basic commonalities, there is very little to suggest any type of standardization. And, while these three components form a solid base for the development of a standard log grading and scaling system, other necessary components (defects, trim, etc.) must be developed from the more common approaches reported in the survey or, where possible, include more than one option for particular components.

Findings that help define the basics of a standardized grading and scaling system

One of the objectives of the study was to determine whether it is possible to solicit input from mills and use that input to develop a standardized scaling and grading system. The authors believe that the results do indicate a reasonable path forward in developing such a system.

In the case of specifying a standard log rule for volume determination, the Doyle log rule was far and away the most common log rule in use. But for a standardized system to attain broad acceptance, all three log rules cited by respondents must be permitted (Doyle, Scribner, and International 1/4 inch). Similarly, the option of buying both even and odd length logs must be included, even though a majority of mills (57.9%) purchased only even length logs.

Further, with respect to log length, the issue of trim allowance again showed significant variation among respondents, with 4 inches or 4–6 inches being the most common responses. Similarly, the minimum trim allowance before applying a deduction was quite variable, from 1 to 4 inches. With such variability, discussion among log grading practitioners would be necessary to reach a consensus about how to handle these important factors in a standardized system.

In the case of scaling diameter, the number of reported methods does not lead to a consensus among respondents. In this case, a method must be chosen that is relatively common but also does not favor the buyer or seller in any significant way. The best option would appear to be to measure the shortest diameter, rotate 90 degrees, and take the second diameter measurement, and then average them, which was the second most common response (31.4%). The most common response was to measure the smallest diameter then the largest diameter and average them, which would tend to slightly favor the seller of logs, and would not be the best option for an unbiased standardized system.

Handling fractional portions of an average scaling diameter also resulted in a number of options reported by respondents. Perhaps the most logical approach is to simply decide how to handle a 0.5 fraction. For practical purposes, a rule that says round down if the fraction is ≤ 0.5, and round up if the fraction is >0.5 seems reasonable. This approach establishes a level of consistency that does not require remembering to round up or down on the next log or favor the buyer by only rounding up if the fraction is ≥ 0.75 inches.

When it comes to adjusting for defects such as double hearts, sweep, holes, and shake, several options were identified by respondents. In the case of double hearts, nine different methods were reported and varied from a length deduction to adjusting scaling diameter in a number of ways. Since the survey question did not ask about deductions based on the severity of double hearts, it is probably reasonable to consider different adjustments based on the severity. This could range from the least severe, the existence of two distinct hearts, to two distinct hearts containing a bark seam, and at the extreme, to the existence of some portion of the two stems representing the fork of the double heart.

For sweep, holes (interior defects), shake, and other scaling defects (e.g., crook, splits, and spider shake), respondents indicated that a common method for deduction is to take a diameter or length deduction for the log.

This survey was not designed to elicit specific rules of thumb being used by respondents, as that would have unduly complicated the response. The formulation of rules of thumb must necessarily take place apart from the survey results. The most reasonable approach is to analyze the log and lumber yield data in the AHC database in such a way that the selection of a rule of thumb would not significantly alter the overrun/underrun expected from the log in the absence of the scaling defect.

From the grading perspective, a majority of mills do not roll the log when determining grade. Several assumptions about the downside of the log were contained in the responses, ranging from assuming the downside is clear to the downside is not clear and the downside is similar to the other three faces. This is perhaps the primary weakness of current log grading protocols used by the industry. Assumptions about what the log grader cannot see create a situation in which the quality of logs is much too variable, causing problems with how logs are priced and ultimately with mill economics.

The specification sheet analysis illustrates the wide variation in mill assigned log grades and suggests that the variation in how mills grade and scale their highest grade and second highest grade logs is significant. It also indicates a lack of thorough knowledge about the lumber grade yields that a mill can expect to produce from logs of a given size and quality. Furthermore, and most importantly, it effectively illustrates why a standardized system for log grading and scaling is needed. Fortunately, nearly 66% of respondents recognized the need for such a standard when asked about whether they would support an industry standard for log grading and scaling, which sets the stage for the industry to pursue the creation of a standardized log grading and scaling system.

Procurement strategies and milling costs

The other questions in the survey were focused primarily on developing and understanding how logs are procured and to what level the mills understand their cost structure, since sawing costs play a vital role in ultimately determining optimal pricing of logs.

From the procurement perspective, 87 percent of respondents purchased some proportion of their log furnish as gate wood, with the remainder presumably being a combination of controlled stumpage and from log yards. Also, a large proportion (80%) purchase only log length material. The remaining respondents who purchase tree length stems have made the strategic decision to place the bucking of logs for grade in the hands of mill personnel and not loggers in the field. Anecdotal information has traditionally led many to believe that procuring longer length logs is a problem. However, survey respondents (77%) indicated that is not a problem, although 38 percent were paying premiums for longer length logs.

Straight-through pricing was reported by 47 percent of respondents. The advantage of straight-through pricing is that the log inspection process is expedited at the mill and is much easier for a logger to implement. The downside is that pricing the logs is much more difficult because the mill must estimate the proportion of each grade of log (which can vary from tract to tract) and then base pricing on those proportions, which can have negative impacts on mill economics.

Finally, mills were asked about their operating costs per hour and by volume (MBF). Strong majorities said they knew their operating cost per hour (75%) and their cost per MBF (65%). Of great concern is that nearly 20 percent of the surveyed mills stated that they did not know either cost (either hourly or by MBF) and presumably are not currently tracking those costs.

Summary

All of the factors reported and analyzed from this survey, taken together, confirm that the art and science of hardwood log grading and scaling has as many variants as there are mills practicing grading and scaling. This has led sawmills to purchase raw material on a variety of platforms, leaving industry and log suppliers in an environment where it is difficult or nearly impossible to make intelligent economic decisions about where to sell their logs. A cornucopia of grading and scaling protocols among hardwood sawmills is not serving the overall best interests of the hardwood industry.

Based on the results of this study, a standardized hardwood log grading system is sorely needed and is supported by 66 percent of respondents. There is no consistency in the prices received for logs offered to the mill, in part due to a limited understanding of the yield of grade lumber from various sizes and grades of logs by the sawmills buying those logs. Without this information, sawmills cannot define the yield for a specific log and thus cannot ascertain an accurate value or purchase price.

The basic elements of a standardized system are that it must be simple to use in a production setting, that these elements actually mirror as closely as possible what the industry is currently using, and that the system ultimately serves as the basis for efficiently pricing hardwood logs. Log grades must be based on extensive empirical data, which will be collected on a ''per log'' basis. The grades would necessarily be based on lumber yields of National Hardwood Lumber Association lumber grades, which relate back to scaling diameter and number of clear faces. Then, combining log grade with overrun/underrun, sawing costs, and lumber/cant pricing, the pricing of logs can be consistently determined.

Barriers are created when primary wood-product producers are handed a variety of protocols. In that case, it can be difficult to extract the best option for producers, landowners, and contractors. The opinions of all interested stakeholders must be considered in order to ensure actual implementation and continued development of a standardized hardwood log grading system.

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