United States
Departmnet of
Agriculture

Forest Service

Pacific Northwest
Research Station

Research Note
PNW-RN-479
January 1989

Effects of Log Defects on Lumber Recovery

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Abstract

The impact of log defects on lumber recovery and the accuracy of cubic log scale deductions were evaluated from log scale and product recovery data for more than 3,000 logs. Lumber tally loss was estimated by comparing the lumber yield of sound logs to that of logs containing defects. The data were collected at several product recovery studies; they represent most of the major commercial softwood species in the Western United States. Defects listed in order of decreasing effect on lumber recovery are: multiple defects, ring shake, soft rot and voids, weather check, firm rot, breakage, crook and sweep, and heart check. The accuracy of cubic log scale deductions was also analyzed. The rules were considered accurate for heart check, breakage, and crook and sweep; they underestimated the impact of ring shake and soft rots and voids on lumber tally, and overestimated the impact of weather checks, firm rot, and multiple defects.

Keywords: Log scaling, cubic log volumes, mensuration, product recovery, softwood lumber.

Introduction

The USDA Forest Service recognizes the need for standardizing measurements taken in different timber management activities. Currently, the International 1/4-inch board-foot log rule, versions of the Scribner Decimal C rule, and several cubic-foot rules are used for estimating volumes of standing trees and cut logs. This mix of systems within and across Forest Service administrative units creates confusion and reduces efficiency. The variety of rules among Federal Agencies in a single area also presents problems for the forest industry.

In 1978, a task force comprised of industry and Forest Service representatives (FI/FS Task Force) evaluated several log scaling systems and concluded that estimating log volumes in cubic feet was superior to the traditional board-foot unit of measure (Cegelka 1985). The task force noted several shortcomings of board-foot scaling systems, including inherent inaccuracies, lack of standardization, and limited ability to predict the total array of products now produced in the forest products industry. The task force is currently testing and refining a scaling system that estimates volume in cubic feet. Eventually, this system will be proposed to the Forest Service and, if accepted, will become a component of a National Forest measurement system.

Estimating defect volumes will be an important part of any new cubic scaling system adopted by the Forest Service. In the past, scaling procedures have required reductions in gross log volumes to account for defects that limit the manufacture of wood products. Examples of common log defects are rot, shake, crook and sweep, and weather checks. The resulting net log volume is one of the most widely used measures in the forest products industry; it is the basis for buying and selling timber, inventory control, long-range planning, and the prediction of product recovery.

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Recognizing the importance of defect estimation, the task force analyzed the impact specific log defects had on product recovery and the accuracy of cubic log scale deductions by the USDA Forest Service (1978) cubic scaling rules. The task force used this information to help refine cubic scaling techniques and to set priorities for future research. This report presents the results of the analysis.

Methods

The general approach used in the analysis was to compare the lumber yield of sound logs to that of defective logs. The average difference in recovery represents the amount of lumber loss caused by specific defects. Lumber yields were empirically determined by several product recovery studies conducted throughout the Western United States.

Data Base

The data used in this analysis were collected during five product recovery studies conducted jointly by the Forest Service, the Bureau of Land Management (U.S. Department of the Interior), and numerous industry cooperators. Species in the studies included western larch {*Larix occidentalis* Nutt.), ponderosa pine {*Pinus ponderosa* Dougl. ex Laws.), coast Douglas-fir {*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii),* western hemlock {*Tsuga heterophylla* (Raf.) Sarg.), California red fir (*Abies magnifica* A. Murr.), Shasta red fir {*A. magnifica* var. *shastensis* Lemm.), grand fir *(A. grandis* (Dougl. ex D. Don) Lindl.), and white fir {*A. concolor* (Gord. & Glend.) Lindl. ex Hildebr.) The following tabulation lists each study:

Study	Species	Study location	Lumber products manufactured	Number of logs
WL-R1	Western larch	Montana	2-inch dimension 1-inch boards	682
PP-R1	Ponderosa pine	Montana	1-inch boards 5/4 shops	662
PP-R3	Ponderosa pine	Arizona	2-inch dimension 5/4 shops	455
DF-R6	Douglas-fir	Oregon	2-inch dimension	964
HF-R6	Hem-fir*	Oregon	2-inch dimension 5/4 shops	677

Trees for the study logs were selected to cover the range of size and quality that exist in a geographic area; these samples would not be representative of the natural frequencies of occurrence of tree size. Also, the incidental defects observed on about half of the study logs were not sampled as representative of the natural occurrence of the types and severity of defects. The intent of the analysis was to refine cubic scaling techniques and to set priorities for future research on log scaling problems.

1 The hem-fir study includes western hemlock, California red fir, Shasta, red fir, Pacific silver fir, grand fir, white fir, **and noble fir.**

Log Scale Data

Gross and product cubic scale were estimated for each woods-length log by Forest Service and industry check sealers. Gross cubic scale is the log volume in cubic feet estimated from length and diameter measurements. Two cubic-foot formulas were used to estimate gross log volume: Bruce's (1982) formula was applied to the butt logs, and Smalian's (Avery 1967) formula was applied to the upper logs. Product cubic scale is gross scale reduced for all defects expected to affect the yield of solid wood products. The logs were scaled by the scaling systems evaluated; however, we limited the defect analysis to the scale based on the USDA Forest Service (1978) draft cubic scaling rules. Defect volumes were estimated by the 1978 draft rules except for shake in the western larch (WL-R1) study and the ponderosa pine (PP-R1) study. These studies were completed before 1978, and shake volume was estimated from the lineal inches of shake measured on the log ends. The 1978 rules state that shake volumes should be estimated by subtracting the volume of a cylinder inside the shake from the volume of a cylinder outside the shake. Firm rot is not recognized as a scale deduction in the draft handbook (USDA Forest Service 1978); however, it was included in this analysis for general information. The following tabulation shows the gross and product cubic scale for each study:

Study	Gross cubic scale	Product cubic scale	Defect
	(Cubic feet)	(Cubic feet)	(Percent)
WL-R1	18,592	17,411	6
PP-R1	26,703	25,293	5
PP-R3	14,397	13,768	4
DF-R6	63,853	58,140	9
HF-R6	44,114	41,098	7

Individual defects were itemized for each log. Table 1 shows the defects found, the number of logs in each defect category, and the percentage of cubic log volume deducted.

Table 1—Scaling defect and number of logs by defect and study

Study	Heart check	Breakage	Weather check	Crook and sweep	Ring shake	Firm rot	Soft rot and voids	Multiple defects
	Percent (number of logs)							
WL-R1	1.0 (23)	2.8 (66)	76.4 (40)	3.5 (16)	1.2 (32)	5.3 (8)	3.7 (47)	9.7 (138)
PP-R1	1.0 (8)	2.6 (18)	20.3 (28)	4.1 (40)	1.2 (9)	49.8 (8)	2.6 (106)	14.6 (92)
PP-R3	.4 (1)	1.2 (2)	14.8 (2)	5.5 (69)	.3 (2)	3.4 (23)	1.9 (30)	12.9 (87)
DF-R6	1.0 (32)	4.3 (136)	.5 (1)	4.8 (21)	1.6 (35)	45.5 (32)	4.6 (42)	29.6 (139)
HF-R6	1.2 (57)	6.6 (53)	7.6 (25)	5.5 (14)	4.4 (19)	16.1 (7)	10.7 (31)	10.9 (247)
All studies	1.0 (123)	4.4 (275)	23.4 (96)	49.0 (160)	1.9 (97)	33.6 (78)	4.0 (256)	15.9 (703)

Brief definitions of these scaling defects are as follows:

Heart check—an opening or separation across the center of the log at right angles to the annual rings.

Breakage—mechanical damage caused by logging or millyard equipment.

Weather check—splits on the surface of a log caused by loss of moisture.

Crook and sweep—crook is a sudden curve or bend in the log; sweep is a gradual curve in the log.

Ring shake—separations of wood fiber causing openings between annual rings.

Firm rot—decayed wood that will make a solid wood product.

Soft rots and voids—soft rot is unusable rotten wood; voids are portions of the log that are missing.

Multiple defects—logs with more than one of the above-mentioned defects.

Four techniques were used to estimate the cubic volume of defect:

1 Area deductions—defect volume is estirnated by enclosing the defect in a cylinder or rectangle for the affected length. Area deductions are generally used when the defect occurs on one or both ends of a log. Area deductions are often applied **to,** heart checks, voids, and soft rots.

2. Pie cuts—used for defects that can be confined within a sector of a circle. The defect volume is proportional to the affected portion of the circle. For instance, if 25 percent of the circle is defective for the length of the log, then 25 percent of the gross volume is deducted. Pie cuts are typically used on lightning scars, fire scars, and frost cracks.

3. Length deductions—defect volume is estimated by reducing the log length. The difference in volume based on the total log length and the net log length represents the defect volume. Crook and sweep are examples of defects for which length deductions are used.

4. Diameter deductions—scaling diameters of the log ends are reduced to account for defect. Defect volume is estimated by the difference in volumes based on the gross and net diameters. This method is used for defects that affect the outer portion of the log (weather check).

Lumber Recovery Data

At each of the five product recovery studies, all lumber was identified back to the woods-length log. Lumber was kiln dried and tallied in the surfaced dry condition. Lumber volumes were estimated by applying the rough green lumber dimensions to the surfaced dry tally to reduce variation in recovery caused by mill differences, product mix, and sawing error (Fahey and Woodfin 1976).

Analysis

The objective of the analysis was to estimate the impact each type of defect had on lumber recovery for all five studies and to determine how well the USDA Forest Service (1978) draft rules accounted for the defects. A technique developed by Fahey and others (1981) was used to make this evaluation. This technique was also used to analyze scale deductions for weather checks in dead timber and pecky rot in incense-cedar (Cahill 1983, Cahill and others 1986). In general, the lumber loss is estimated by comparing the recovery of defective logs with sound logs of equivalent volume. The yield of lumber from sound logs was established by regressing lumber volume over gross cubic log scale for each of the five studies. As an example, figure 1 shows the data scatter and the regression line for the sound logs in the Oregon Douglas-fir study (DF-R6).

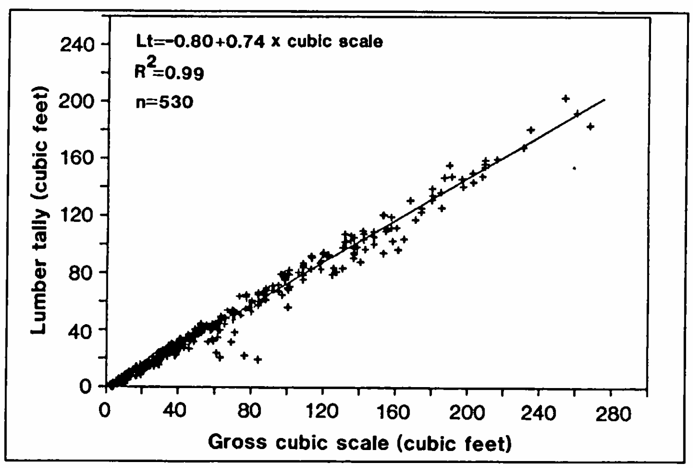

Figure 1-Data scatter and regression line of lumber tally (cubic feet) over gross cubic log scale for sound logs; data from the Oregon Douglas-fir (DF-R6) study.

Using the regression lines for sound logs as a base, we calculated the loss in lumber tally for each log as the actual lumber tally minus the predicted lumber tally using either gross or product scale. The average losses were then calculated for each category of defect, and these averages are called bias:

$$\text{Lumber loss or bias} = (Y_a - Y_p)/N ,$$

where

Y_a is the actual lumber tally from a defective log,
Y_p is the predicted lumber tally from a sound log, and
N is the number of logs in the sample.

The following tabulation shows the computation of bias for a hypothetical Douglas-fir log containing defect:

Log volume	**Actual lumber tally**	**Predicted lumber yield from a sound log**	**Lumber loss or bias**
		(Cubic feet)	
Gross scale (50 cubic feet)	15	36	15-36 = -21
Product scale (30 cubic feet)	15	21	15 -21 = - 6

Based on gross scale, the average bias shows the impact a defect has on lumber tally; the more negative the bias, the greater the lumber tally loss. Bias based on cubic product scale indicates how well the 1978 draft rules for defect deductions work; a bias close to zero indicates that defective logs are being reduced in volume so that the lumber tally is equivalent to sound logs of the same volume; a negative bias indicates underestimation of defect, and a positive bias indicates overestimation of defect.

Bias was also expressed as a percentage of the predicted lumber tally. This was calculated as the average difference in percent for the logs in each defect category. The formula for calculating the percentage is:

$$\text{Percent difference} = (Y_a - Y_p)/Y_p \times 100,$$

where

Y_a is the actual lumber tally from a defective log, and
Y_p is the predicted tally from a sound log,

In the example cited earlier, the difference in percent would be:

Difference (gross) = (15 - 36)/36 = -58 percent.

Difference (product) = (15 -21)/21= -29 percent.

Converting the bias to a percentage is useful because it takes into account the effect of log size. For instance, the average bias for a defect category might be small on a cubic-volume basis, but it could be a large percentage of the total lumber yield if the defect is mainly in small logs. Interpretation for the percentage bias is the same as for volume bias; overdeducting and underdeducting are indicated by the arithmetic sign of the average percentage.

Results and Discussion

The results of the analysis are shown in tables 2 and 3. The average bias and standard deviation are shown in table 2 in cubic feet; in table 3, in percent. Expressed in cubic feet, the defects listed in order of decreasing effect on lumber tally are multiple defects, ring shake, soft rot and voids, weather check, firm rot, breakage, crook and sweep, and heart check. Expressed as a percentage, the ranking of defects changes: multiple defects, crook and sweep, weather check, soft rot and voids, ring shake, breakage, firm rot, and heart checks. The 1978 draft rules appear accurate for breakage, heart check, and crook and sweep; they mostly overestimated for weather check, firm rot, and multiple defects; and they underestimated for ring shake, and soft rot and voids. A discussion of the specific defects follows.

Table2—Average bias in cubic feet of lumber tally and the standard deviation

Scale	Heart checks	Breakage	Weather check	Crook and sweep	Ring shake	Firm rot	Soft rot and voids	Multiple defects
				Cubic feet				
Gross	0	-1.0	-2.1	-0.9	-3.9	-1.8	-3.1	-6.5
Standard deviation	10.8	2.9	4.2	2.9	7.0	5.7	7.2	10.8
Product	+.8	-.1	+3.2	-.4	-2.7	+14.8	-1.5	+2.0
Standard deviation	10.6	2.6	4.4	2.6	6.8	29.4	4.6	17.5

Table 3—Average bias expressed as a percentage of lumber tally and the standard deviation

Scale	Heart checks	Breakage	Weather check	Crook and sweep	Ring shake	Firm rot	Soft rot and voids	Multiple defects
				Percent				
Gross	0	-5.1	-9.9	-10.0	-6.4	-3.8	-8.0	-12.6
Standard deviation	5.0	7.3	12.3	8.9	8.0	9.3	6.3	3.2
Product	+1.0	-.5	+20.9	-3.9	-4.5	+46.7	-4.0	+4.7
Standard deviation	5.0	7.3	11.8	8.9	8.0	11.1	6.4	3.3

Multiple defects—Multiple defects had the greatest impact on lumber tally; on the average, 6.5 cubic feet of lumber was lost or 12.6 percent of the potential lumber tally. This was not surprising because minimizing the effect of two or more defects during sawing is difficult. Scaling rules mostly overestimated the effect multiple defects had on lumber recovery. The average bias and percent bias based on product scale were +2.0 cubic feet and +4.7 percent.

Ring shake—Relative to other defects, ring shake had a large impact on lumber recovery. Most logs with shake were found in three studies; the Douglas-fir (DF-R6), the western larch (WL-R1), and the hem-fir (HF-R6). Minimizing the impact of ring shake on product recovery is complex; the number of rings, their location in the log, and length through the log add to the complexity. The cubic scale rules used in deducting for shake underestimated the effect on lumber yields; thus, additional log volume would have to be deducted to move the bias closer to zero.

Soft rot and voids—Logs with voids had the third greatest loss in lumber tally. In our sample, most of the volume loss caused by this defect resulted from rot. Mechanical damage (stump pull, machine damage) occurred frequently; however, the damage was usually minor. Bias was reduced (from -3.08 to -1.47 cubic feet) by the cubic product scale; however, the negative sign associated with the product bias indicates that not enough log volume was deducted.

Weather check—Lumber losses in this defect category were high because most of the logs were from insect- and disease-killed trees. Weather checks in dead timber frequently extend to the pith; sometimes, they spiral. Weather checks that develop in logs cut from live timber are smaller in comparison and have less of an impact on lumber tally. The scaling rules used to deduct for weather checks overestimated their effect on lumber recovery (bias = +3.22). This is consistent with other research (Cahill 1980,1983). Sealers have often commented that it is difficult to quantify all the checks present in a log and to assess their aggregate effect on lumber yield. This becomes more difficult when the checks spiral.

Firm rot—Lumber losses in this category resulted primarily from the chipping of lumber items that contain excessive amounts of firm rot, from trimming of lumber to upgrade it, and from breakage during sawmilling and surfacing operations. Most of the firm rot in our sample came from the the Douglas-fir (DF-R6) and Arizona ponderosa pine studies (PP-R3). Firm rot in Douglas-fir is usually caused by the fungus *Phellinus pini* and is referred to as "white-speck." Firm rot in ponderosa pine is caused by the fungus *Dichomitus squalens* and is commonly called "red-ray-rot." Deductions for firm rot were the most excessive of all defect categories and resulted in large positive biases of 14.77 cubic feet and 46.7 percent.

Breakage—Lumber loss caused by breakage was small (bias = -1.0 cubic foot). The effect of breakage is minimized by trimming lumber back in 2-foot multiples. In some cases, breakage would have no effect on lumber recovery if it were confined to the trim portion of the log. Product scale deductions for breakage were considered accurate. Average bias: based on cubic product scale was only -0.1 cubic foot.

Crook and sweep—Logs with crook lost a relatively small amount of lumber (-0.9 cubic foot); however, when the bias was expressed as a percentage, crook ranked second—behind multiple defects. The percentage was high because, in our sample, crook occurred in small logs where any lumber loss was a high proportion of the total lumber recovery. The product cubic-scale deductions were accurate (bias = -0.4 cubic foot).

Heart check—No appreciable amount of lumber volume was lost because of heart checks (bias based on gross scale = 0.0 cubic feet); thus, the bias increased to 0.8 cubic foot based on cubic product scale. It should be noted that the heart checks in our sample were small; only 1 percent of the total log volume was deducted. Also, we did not have enough information to evaluate the effect of twisting checks on lumber recovery.

We emphasize that, because of sampling limitations, our data do not represent the frequency of occurrence or the amount of defect present in the softwood resource. The averages presented in this paper have limited application beyond this analysis. We do think that the general trends shown are valid. Defects such as shake, soft rots and voids, and combinations of defects will always rank high in effect on lumber recovery because they constrain the efforts of sawyers, edgermen, and trim-saw operators to maximize product recovery.

The Future

The Forest Service and the forest products industry have taken an important step toward developing a measurement system that will provide accurate volume estimates and a degree of national standardization. The Forest Industry/Forest Service Task Force will continue to review, revise, and test a cubic scaling system, but many' issues remain to be settled. Scaling rules used to estimate defect volumes will be studied to determine equitable deductions for timber growers and wood consumers. From these data, the task force has identified some problem areas. Deductions for firm rot, for instance, are clearly not in proportion with the actual impact on lumber recovery; the issues surrounding this deduction need to be addressed.

Finally, the adoption of a new national measurement system will affect many operations that depend on measurement information—timber appraisal, for example. The change will affect the entire forestry community, and much planning must be done to ensure a smooth transition. A new measurement system may look good on paper; but, if it is not implemented with care and a minimum of false starts, some of its benefit to forestry organizations will be lost. Unless people understand, accept, and fully use a system of cubic measure, the system will never achieve its potential.

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