Trends in Lumber Processing in the Western United States. Part I: Board Foot Scribner Volume per Cubic Foot of Timber

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Abstract

This article describes trends in board foot Scribner volume per cubic foot of timber for logs processed by sawmills in the western United States. Board foot to cubic foot (BF/CF) ratios for the period from 2000 through 2006 ranged from 3.70 in Montana to 5.71 in the Four Corners Region (Arizona, Colorado, New Mexico, and Utah). Sawmills in the Four Corners Region, Alaska, and California had the highest ratios, with each state's BF/CF ratio greater than 5.0. Among the states using the Eastside Scribner scale, the Four Corners Region had the highest BF/CF ratio (5.71), followed by California (5.03). Among states using primarily the Westside Scribner scale, Alaska had the highest ratio (5.29). All states or regions, with the exception of Alaska, have shown declines in BF/CF ratios over the last three decades. Montana has had the largest estimated decline (29%), followed by Oregon (23%). The increase in Alaska was the smallest change among states (<2%). Two major factors in the western United States appear to have largely influenced BF/CF ratios: changes in log diameter processed by western sawmills and the use of Westside versus Eastside variants of the Scribner Log Rule.

Lumber is the dominant product manufactured from timber in the western United States, with sawmills receiving approximately 75 percent of all harvested timber (Morgan et al. 2004a, 2004b, 2005b; 2006; Brandt et al. 2006, 2009; Smith and Hiserote 2006, 2007; Smith et al. 2008; Spoelma et al. 2008; Halbrook et al. 2009). Estimates of wood usage and trends in the proportion of timber harvested per unit of lumber, as well as patterns and efficiency of utilization, are useful to private and public lands analysts, forest planners, and economic forecasters. Analyses typically require the ability to estimate the total cubic volume of wood fiber contained in the bole of harvested logs. For example, assessing lumber production efficiency or estimating the volume of residual wood fiber available after lumber production for additional products like pulp, composite panels, or energy requires data on the total volume of wood fiber in log inputs. Likewise, supply/demand modeling depends on total wood fiber input and product output data.

The goals of this project were to improve the understanding of changes in volume of timber used to produce a given unit of lumber and changes in production efficiency at western US sawmills over the past four decades. The Scribner Log Rule (SLR) is the most common unit of measure used for reporting timber harvest volume in the western United States; it was originally developed in 1846 (Fonseca 2005) and is now most commonly applied as the Scribner Decimal C Rule. Two difficulties arise when attempting to use the SLR to quantify the total volume of wood harvested and used in lumber production. First, the SLR was not designed to estimate the volume of wood fiber in logs but, rather, to estimate the board foot volume of

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lumber that could be produced from a log based on specified lumber grades and sizes and fixed sawing technology (Fonseca 2005). In addition, two major variants of the SLR are applied in the western United States: Scribner Decimal C Eastside and Westside scales. These two variants provide different board foot estimates, primarily because the Eastside variant is based on a scaling cylinder using 20-foot maximum lengths while the Westside rule uses 40-foot maximum lengths. Further, the SLR is a diagrammatic rule resulting in stepwise changes in volume estimates and a nonlinear relationship between log sizes and board foot volume estimates. Spelter (2004) and Fonseca (2005) provide additional information and references about Scribner and other log scales.

Expressing log volume as a cubic measure avoids the limitations of the SLR and provides a far superior basis for analyzing wood fiber use and production efficiency. Getting away from Scribner requires developing reasonable methods to convert log volumes measured in Scribner board feet to cubic feet. Thus, the specific objectives of this project were to estimate trends for the western US sawmill industry in:

- board foot Scribner volume per cubic foot of timber processed,
- lumber recovery per board foot Scribner and per cubic foot of timber processed.

Analyses and results for sawmills in each of the western states are presented in two articles. This first article describes trends in board foot Scribner volume per cubic foot of timber processed. The second article (Keegan et al. 2010) describes trends in the recovery of lumber per board foot Scribner (i.e., lumber overrun), lumber recovery per cubic foot of log input (i.e., lumber recovery factor), and proportion of timber processed (in cubic feet) that becomes lumber (i.e., cubic lumber recovery).

Four time periods are examined in these analyses: the 1970s, 1980s, 1990s, and from 2000 through 2006. The states included are Alaska, Arizona, California, Colorado, Idaho, Montana, New Mexico, Oregon, Utah, Washington, and Wyoming. Because of the limited number of mills in Arizona, Colorado, New Mexico, and Utah, these states are reported together as the Four Corners Region.

Methods

The primary data sources for this project were periodic forest industry surveys and censuses conducted for or by the Interior West and Pacific Northwest Forest Inventory and Analysis Programs of the USDA Forest Service, the Washington Department of Natural Resources, Washington State University, the University of Washington, and the University of Montana. Results from these surveys and censuses are available in recent publications on the forest products industry (Morgan et al. 2004a, 2004b, 2005b, 2006; Brandt et al. 2006, 2009; Smith et al. 2008; Spoelma et al. 2008; Halbrook et al. 2009) and in approximately 55 additional publications dating back to 1970 (see the Appendix). Other sources (e.g., Brooks and Haynes 1990, 1994; Kilborn 2004) were used for time periods or for states in which mill censuses were not available. With the exception of Colorado in the 1990s and Wyoming in the 1980s and 1990s, at least one mill census or other data source was available in each state during each decade (Table 1).

Table 1.—Number of mill surveys available by state and decade.[a]

State	1970s	1980s	1990s	2000–2006
Alaska	—	—	—	1
Arizona	1	1	1	1
California	1	1	1	1
Colorado	1	1	ND	1
Idaho	1	1	2	1
Montana	1	2	2	1
New Mexico	1	1	1	1
Oregon	2	2	1	1
Utah	1	1	1	1
Washington	2	5	2	3
Wyoming	1	ND	ND	1

[a] — = sources other than mill surveys; ND = no data.

The mill surveys and censuses provided a variety of information (i.e., volume of timber processed, volume and types of lumber manufactured, and quantity and types of wood residue generated) that enabled estimating the total cubic volume of wood fiber contained in each thousand board feet (MBF) Scribner of logs. The following steps outline the assumptions and calculations used.

1. Total cubic volume of wood fiber in logs processed by sawmills was assumed to equal the cubic feet (cft) of finished lumber, plus shrinkage in drying, plus the cubic volume of used and unused mill residue (excluding bark):

$$\text{cft fiber volume} = \text{cft lumber} + \text{shrinkage} + \text{cft residue}$$

2. The average cubic volume of wood fiber in finished lumber was assumed to be 56.5 cft of wood fiber per MBF lumber tally ($MBF_{\text{lumber tally}}$), and shrinkage was assumed to account for an additional 3.5 cft per $MBF_{\text{lumber tally}}$ (Hartman et al. 1976, Briggs 1994):

$$\text{cft lumber} = 56.5\,\text{cft per } MBF_{\text{lumber tally}}$$
$$\text{shrinkage} = 3.5\,\text{cft per } MBF_{\text{lumber tally}}$$

3. Mill residue is the portion of the log that does not become finished lumber. Mill residue volume (excluding bark) and lumber production were used to produce mill residue factors (i.e., cubic volume of residue produced per MBF lumber tally). Mill residue factors were made and updated somewhat differently depending on the data available for various states and years. For the 1970s, mill residue factors were developed directly from published state reports. These residue factors were from mill surveys done in the 1970s or were based on residue studies done in the late 1960s (e.g., Hiserote and Howard 1978, Howard and Hiserote 1978). Mill residue factors for the 1980s and 1990s were derived directly from mill-level data from in-state surveys conducted during those decades, were estimated from mill surveys in other states during those decades, or were estimated from in-state mill surveys conducted from 2000 through 2006. Factors for Alaska before 2000 were developed from several sources (Brooks and Haynes 1990, 1994; Kilborn 2004). From 2000 through 2006, residue factors based on mill-level data from in-state surveys were available from mill surveys for all states except Washington. Factors for Washington from 2000 through 2006 were estimated from Oregon mill surveys conducted during that time period. The mill residue factors directly quantify changes

in the volume of mill residue generated per MBF lumber tally for each western state through time:

$$\text{cft residue} = \text{residue factor} \times \text{MBF}_{\text{lumber tally}}$$

4. For most states and years, the surveys provided statewide data on the volume of logs processed by sawmills (in MBF Scribner) and total lumber production (in MBF lumber tally), allowing a calculation of lumber overrun. For a few states or years, lumber production was estimated from Western Wood Products Association (WWPA) data (WWPA 1964 to 2007). Overrun is the difference between the board feet of lumber predicted by the SLR (i.e., $\text{MBF}_{\text{log scale}}$) and the actual recovery tallied by the mill (Briggs 1994):

$$\text{overrun} = \frac{\text{MBF}_{\text{lumber tally}} - \text{MBF}_{\text{log scale}}}{\text{MBF}_{\text{log scale}}}$$

5. Total cubic volume of wood fiber (from Steps 1 through 3) was then divided by MBF lumber tally, and the quotient was then multiplied by one plus the statewide overrun (from Step 4) to yield the total cubic volume of wood fiber per MBF Scribner of logs:

$$\text{cft fiber volume per MBF Scribner} = \left(\frac{\text{cft fiber volume}}{\text{MBF}_{\text{lumber tally}}}\right) \times (1 + \text{overrun})$$

6. Once the total cubic volume of wood fiber per MBF Scribner of logs was calculated (in Step 5), that value was divided by 1,000 board feet to produce cubic feet per board foot, the inverse of which yielded the board feet per cubic foot (BF/CF) ratio.

The cubic foot volume of logs in this analysis excluded bark and was estimated as the net *fiber* scale, which is the gross scale adjusted for certain defects (i.e., voids, decay, charred wood, etc.). This net fiber scale is a larger volume than the net *product* scale, which has additional adjustments for other defects (e.g., sweep, cracks, shake) that affect the yield of solid wood products, such as lumber or veneer (Briggs 1994).

Results and Discussion

The BF/CF ratios for the western states from 2000 through 2006 ranged from 3.70 in Montana to 5.71 in the Four Corners Region. Sawmills in the Four Corners Region, Alaska, and California had the highest ratios, with each state's BF/CF ratio greater than 5.0 (Table 2). Based on the geographic source of the harvest reported in the various mill surveys, approximately 80 percent of the volume of sawlogs used in Oregon and Washington during recent years was processed in areas using the Westside SLR. In the 1970s and 1980s, the percentage was only slightly lower (approximately 77%). Virtually all of the sawlogs processed in Alaska used the Westside SLR. All other states have used primarily the Eastside SLR. Among the states using the Eastside SLR, the Four Corners Region had the highest BF/CF ratios, followed by California. Alaska had the highest ratio of states using the Westside SLR.

With the exception of Alaska, all states or regions have shown declines in BF/CF ratios since the 1970s. The ratio in the Four Corners Region declined through the 1990s and then increased from 2000 through 2006. Montana showed the largest estimated decline in BF/CF ratio (29%), followed by Oregon (23%). The increase in Alaska was the smallest change (<2%) among states.

Table 2.—Ratio of board feet Scribner per cubic foot of bole wood, inside bark.

	1970s	1980s	1990s	2000–2006	% change[a]
Eastside scale					
California	6.02	5.35	5.07	5.02	−16
Four Corners[b]	5.86	5.42	5.06	5.71	−3
Idaho	4.97	4.89	4.83	4.20	−15
Montana	5.22	4.43	3.93	3.70	−29
Wyoming	5.77	NA[c]	NA	4.68	−19
Westside scale					
Alaska	5.20	5.20	5.41	5.29	2
Oregon	5.42	5.17	4.55	4.19	−23
Washington	5.51	5.48	4.89	4.44	−19

[a] Percent change represents the total change between the first (1970s) and last (2000 to 2006) periods.
[b] Arizona, Colorado, New Mexico, and Utah.
[c] NA = not applicable.

A number of factors influence the BF/CF relationship, including log scale, log diameter and length, and merchantability standards related to log defect. Two major factors in the western United States appear to have largely influenced BF/CF ratios: the use of Westside versus Eastside variants of the SLR and changes in log diameter processed by western sawmills. Both the Eastside and Westside variants underestimate the volume of wood fiber in a log to a greater degree as the log diameter decreases (Cahill 1984, Spelter 2004, Fonseca 2005). For a given log, the Westside (long-log) scale generally scales a lower board foot volume, resulting in a lower BF/CF ratio than the Eastside (short-log) scale. There is no specific ratio between the two SLR variants.

Because both variants of the SLR yield a lower board foot Scribner measure relative to the cubic bole content of the log as the diameter of the log decreases, a decreasing BF/CF ratio indicates a decline in log size. Among states, differences in log size and the variant of the SLR both strongly influence differences in BF/CF ratios. Changes in the BF/CF ratio through time within a state are primarily the result of changes in log size. Although a relationship exists between log size and BF/CF ratios, with BF/CF ratios declining as log size declines, this relationship is neither consistent nor precisely defined.

Trends in BF/CF ratios reflect land management trends and other data that suggest a strong shift toward smaller logs. Certainly, public and private lands have moved to harvesting smaller trees and processing smaller logs. For example, changes in federal and state harvest policies to emphasize low thinnings for fire hazard reduction and protection of old-growth values, increased regulation of private harvest in some states, and relatively high historic rates of harvest on private lands as owners converted natural stands to more regulated forest conditions (e.g., plantations) all point to timber harvests composed of smaller trees in recent years versus those in the 1970s and 1980s.

In addition, mill censuses and related analyses clearly indicate a substantial shift to smaller timber and differences in average log sizes among the regions that reinforce trends

Table 3.—Proportion of logs processed by sawmills by small-end diameter.

State and year	0–7 in.	>7–10 in.	≤10 in.	>10 in.	>10–24 in.	>24 in.
Eastside scale						
California 2006	0.08	0.18	0.26	0.74	0.56	0.18
Idaho 2006	0.29	0.26	0.55	0.45	0.39	0.05
Montana 2004	0.54	0.26	0.80	0.20	0.20	<0.005
Wyoming 2005	0.42	0.13	0.55	0.45	0.45	<0.005
Westside scale						
Alaska 2005	0.01	0.23	0.24	0.76	0.36	0.39
Oregon 2003	0.14	0.32	0.46	0.54	0.49	0.05
Washington 2006	0.06	0.43	0.49	0.51	0.42	0.09

observed in BF/CF ratios. Mills in California, Oregon, and Washington—all of which have seen substantial decreases in BF/CF ratios—have shown a decline in the harvest of timber with an age of 100 years or older. In the 1970s, mills in these three states indicated that more than 60 percent of the timber processed was older than 100 years. By the early 1990s, less than 33 percent of the timber was older than 100 years (Ward 1997a, 1997b). Data from Washington indicate that by 1996, only 5 percent of the timber processed by Washington sawmills was classified as old growth (Larsen and Aust 2000). The same general pattern appears to have taken place in Idaho and Montana (Morgan et al. 2005a). The increased proportion of stud mills and sawmills producing smaller sizes of dimension lumber offers further evidence for declining harvested tree sizes in the two states (Forest Industry Data Collection System [FIDACS] 2009).

Log size differences among states are clearly seen in results from recent mill censuses that collected data on the proportion of logs processed by small-end diameter (SED). Data since 2000 are available for Alaska, California, Idaho, Montana, Oregon, Washington, and Wyoming (Table 3). These data show considerable differences among states and indicate that much of the variation in BF/CF ratios is the result of log diameter. Alaska, with the highest BF/CF ratio (5.29) among states using the Westside SLR, had 76 percent of its sawlog volume in logs with SED $>$ 10 inches and 39 percent in logs with SED $>$ 24 inches. Seventy-four percent of the log volume processed by California sawmills had SED $>$ 10 inches, with 18 percent from logs with SED $>$ 24 inches. Montana sawmills, which had the lowest BF/CF ratio (3.70), processed the smallest logs, with 80 percent of logs received by sawmills having SED $\leq$ 10 inches.

The BF/CF ratios indicate no substantial decline in average log size during the last three decades in the Four Corners Region and Alaska. A number of factors in those states have likely acted to keep average log sizes relatively larger. The operating climate in these areas, especially during the 1990s, was not conducive to large-scale investment, which would allow more efficient use of smaller timber. Historically, both regions were very heavily dependent on federal timber and have suffered substantial downturns in capacity and/or capacity utilization as the federal harvest dropped dramatically in the 1990s. The Four Corners Region lost more than 75 percent of its sawmilling capacity between 1990 and 2008 (Keegan et al. 2006, FIDACS 2009). The proportionate loss in milling capacity in Alaska was not as great as in the Four Corners Region, but milling capacity utilization fell from nearly 80 percent in the 1980s to just over 20 percent in 2005 (Halbrook et al. 2009). Coupled with losses in the market for mill residue, especially pulp and paper mill closures in both areas, the remaining sawmills found it difficult to process small logs, which produce more residue volume per unit of output than larger logs (C.E.K., T.A.M., K.A.B., and J.M.D., unpublished data). It appears sawmills in the Four Corners Region and Alaska subsist on relatively large timber but in much smaller quantities than in past decades (Morgan et al. 2006, Halbrook et al. 2009).

A number of additional factors confound making estimates and interpreting changes over time for the Four Corners Region. These factors include (1) the number of mills in the region is limited, (2) many of the mills in the region are relatively small, multiproduct mills, and (3) much of the timber available in the region during recent years has been fire salvage.

Conclusions

The results presented in this article indicate that, throughout most of the western United States, timber volume, when expressed in board foot Scribner, accounts for substantially more cubic feet of wood fiber today than it has historically. The implications for analysts are obvious. Using improper, outdated conversion factors introduces sources of measurement error and bias. For example, in Oregon, the largest softwood lumber producing state in the nation, the BF/CF ratio decreased from 5.42 in the 1970s to 4.19 in the 2000s. This shift means that 1 MBF Scribner of logs processed by sawmills in Oregon contained 185 cubic feet of wood fiber during the 1970s, whereas during the 2000s, 1 MBF Scribner of logs contained 239 cubic feet, or 29 percent more wood fiber. Given the limitations of the SLR in the face of underlying changes in the size of logs harvested and used by sawmills, the use of appropriate BF/CF ratios is essential for estimating production efficiency, timber supply and demand, and whole-tree volume required for biomass assessment and carbon accounting.

This article provides important insights regarding trends in BF/CF ratios over the past four decades across the western United States. Failure to incorporate changes in BF/CF ratios and accurate recovery factors (e.g., overrun, lumber recovery factor, and cubic feet of lumber per cubic feet of logs), as discussed in Keegan et al. (2010), into analyses could lead to grossly inaccurate estimates of past, current, and future demand for timber and of the impact of harvest on forest inventories.

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Appendix—Mill Surveys Used

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