Influence of Markets and Forest Composition on Lumber Production in Pennsylvania

William G. Luppold and Matthew S. Bumgardner, *USDA Forest Service, Northeastern Research Station, Princeton, WV 24740.*

ABSTRACT: *In this study, we examine regional differences in the hardwood timber resources of Pennsylvania and how the combined changes in inventory volume, forest composition, and lumber prices have influenced regional lumber production. Isolation of these relationships is important because shifts in lumber production reflect changes in harvesting activity. In turn, harvesting influences long-term forest composition and structure. We define three hardwood regions in Pennsylvania based on forest composition and present a chronology of regional changes in sawtimber volumes, sawtimber composition, and lumber production. Regional changes in hardwood lumber production were found to be positively related to changes in the price of No. 1 Common lumber adjusted for changes in forest composition between 1970 and 1999. This finding supports our contention that regional changes in lumber production are influenced by a combination of changes in interspecies lumber price and changes in species availability. North. J. Appl. For. 23(2):87–93.*

Key Words: Hardwood, lumber, sawmill, sawtimber.

In 2002, Pennsylvania contained nearly 78 bbf of hardwood sawtimber (McWilliams et al. 2003) or approximately 7% of the estimated eastern US inventory (Smith et al. 2001). More than 30% of this timber consists of three species with high current market values: black cherry, hard maple, and northern red oak. Pennsylvania's forests also contain large quantities of commercially important species such as white oak and black oak, ash, red maple, and yellow-poplar. Still, the composition of this forest varies considerably when the state is examined from east to west or north to south (Alerich 1993).

Pennsylvania's timber resource also has been dynamic with respect to volume and composition. Sawtimber volume has tripled since 1965, but the rate of growth has been greatest in the northern and western portions of the state (Table 1). The composition of Pennsylvania's forests also has been changing as selective cutting over the last 70 years has resulted in increased relative volumes of shade-tolerant species such as red and sugar maple (Ferguson 1968, McWilliams et al. 2003).

With its large volume of quality timber, the Keystone State has consistently been the nation's largest producer of hardwood lumber, with annual production exceeding 1.1 bbf (US Census Bureau 2001). Lumber production more than doubled from 1970 to 1999 (US Census Bureau 1971, 2001). Luppold (1996) and Smith et al. (2003) reported that census data has consistently underestimated lumber production, though these alternative estimates and census indicate a similar rate of growth in lumber production in Pennsylvania over the last three decades.

While an increase in hardwood lumber production for the state implies an increase in timber demand, it does not necessarily mean that changes in lumber production and timber demand have been uniform across the state. Regional variation in species composition and the changing relative value of lumber for different hardwood species (interspecies pricing) over the last 30–50 years (Luppold and Prestemon 2003) might have influenced the amount of lumber produced in a given region in any given time period. Understanding the interaction between hardwood lumber production, the timber resource, and the market as expressed by lumber price is important because the timing and magnitude of harvesting activity in a given region can influence regeneration and long-term forest composition and structure in that region.

The objectives of this study are to compare regional changes in Pennsylvania timber resources to regional changes in lumber production and to examine the influence of changing interspecies lumber price, adjusted for changing composition, on lumber production. We approach these objectives by:

- grouping USDA Forest Service survey-units into larger and more manageable regions;

NOTE: William G. Luppold can be reached at (304) 431-2770; Fax: (304) 431-2772; wluppold@fs.fed.us.

Table 1. Changes in total sawtimber inventory (hardwood and softwood) in Pennsylvania by survey-unit, 1965 to 2000.

Survey-unit	1965[a]	1978[b]	1989[b]	2002[c]	Percent change[d]
	million board feet (International log scale)				
Western	3,378	6,770	10,024	11,583	243
Southwestern	2,627	4,401	5,358	7,152	172
North-central	4,503	8,362	11,093	15,307	240
Allegheny	6,700	12,123	18,247	24,753	269
Northeastern	1,397	3,304	5,121	5,817	316
South-central	3,345	5,377	6,175	8,608	157
Pocono	2,193	3,273	5,164	6,362	190
Southeastern	2,126	4,476	5,536	6,651	213
Total[e]	26,269	48,087	66,718	86,235	228

[a] Developed from Ferguson (1968).
[b] Developed from Alerich (1993).
[c] Developed using USDA Forest Service (2004).
[d] For years 1965 to 2002.
[e] May not be the sum of units due to rounding error.

- examining regional changes in sawtimber inventories (i.e., volumes and composition);
- examining changes in lumber production within the regions relative to changes in sawtimber inventories; and
- relating relative changes in lumber production to changes in regional lumber price indexes adjusted for changes in forest composition.

Defining Hardwood Regions for Pennsylvania

Pennsylvania contains eight survey-units as designated by the USDA Forest Service's Forest Inventory and Analysis (FIA) unit. While these units were originally defined in terms of physiographic features and county boundaries, neighboring units can contain sawtimber resources with similar composition. The relatively large number and small size of many of these units made it impractical to examine the long-term relationship between the resource and industry at the survey-unit level. There is a tradeoff between region size and the accuracy of inventory and lumber production data used in this study. By combining units, we reduce the statistical errors associated with the estimation of sawtimber volumes of specific species (Luppold and McWilliams 2002). Combining units also reduces the influence of larger mills within an area extending into an adjoining area for a large portion of its roundwood.

The survey-units were combined for this study using cluster analysis (e.g., Malhotra 1996). The analysis was based on three variables: 1989 proportional sawtimber volumes of black cherry, all maples (red and sugar maple combined), and all oaks (chestnut, northern red, select white, and other oaks combined) (Alerich 1993). These groups represent the predominant open-grain species (the oaks) and the predominant closed-grain species (black cherry and the maples) in Pennsylvania. Proportional volumes were calculated by dividing the species volume by total hardwood sawtimber volume in the survey-unit. Three readily identifiable clusters emerged based on the average linkage method (Figure 1). Other methods (complete linkage, single linkage, and Ward's procedure) yielded identical clusters. These clusters were termed the northern, western, and eastern regions for subsequent analysis (Figure 2).

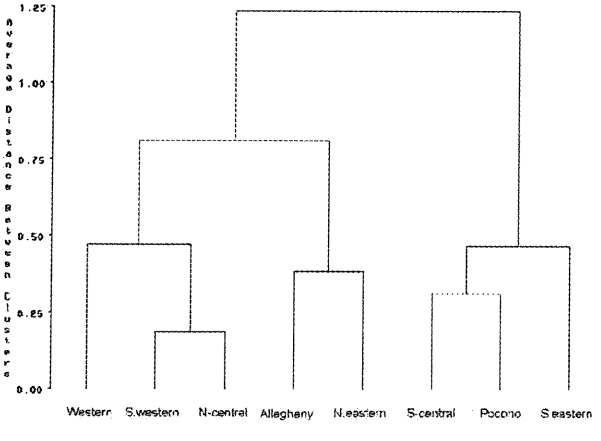

Figure 1. Cluster analysis results based on the average linkage method. Clustered items are FIA survey-units for Pennsylvania. Clusters are based on 1989 proportional sawtimber volume of black cherry, all maples, and all oaks. Shorter lines represent similar survey-units.

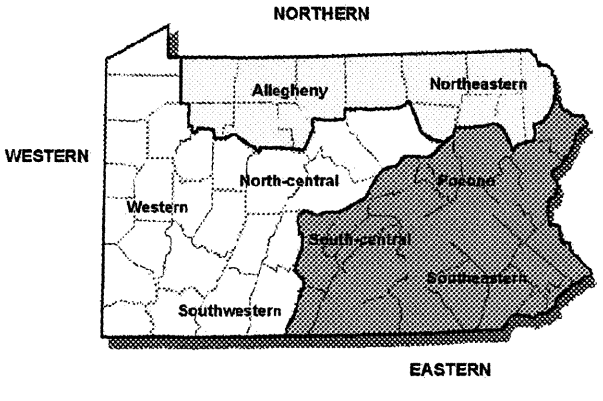

Figure 2. Regions of Pennsylvania analyzed and the FIA survey-units aggregated to form these regions.

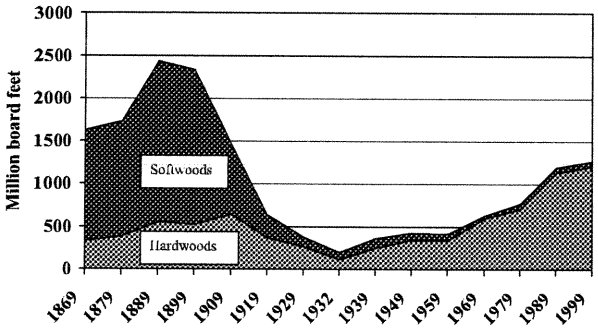

Figure 3. Lumber production in Pennsylvania, 1869 to 1999.

Pennsylvania's Sawtimber Resource

Much of the sawtimber resource that has been harvested in Pennsylvania since 1970 regenerated after a period of extensive cutting and lumber production that occurred from 1889 to 1929 (Figure 3). This virtual clearcut, associated slash fires, and short-term agricultural activities followed by land abandonment allowed even-aged forests with large volumes of shade-intolerant species such as northern red oak and black cherry to become established. The large increase in sawtimber volume since 1965 (Table 1) was primarily the result of maturation of timber that regenerated after these human-associated disturbances. Since the 1930s, partial cutting and absence of fire has left a large portion of Pennsylvania's forest canopy intact, resulting in the regeneration of red maple, sugar maple, and other shade-tolerant species.

While all the regions of Pennsylvania have experienced similar human disturbance, variations in the timing and magnitude of this disturbance, physiographic features, soils, and average rainfall have resulted in regional differences in growth and forest composition. Between 1965 and 2002, total sawtimber volume (hardwood and softwood) increased by 278% in the northern region, 224% in the western region, and 182% in the eastern region (derived from Table 1).

The northern region contains the greatest proportion of northern hardwoods and the lowest proportion of oaks. This region also contains relatively large quantities (49% in 2002) of select species as defined by Araman (1987), i.e., black cherry, sugar maple, white oak, northern red oak, and ash. Between 1965 and 2002, the proportion of oaks in this region has declined by more than 40% while the proportion of maples has increased by nearly 50% (Table 2).

The western region of the state contains a lesser volume of northern hardwoods and a greater volume of oak, and 42% of the sawtimber volume was of select species in 2002. Between 1965 and 2002, the proportion of oak sawtimber in this region declined by more than 37% while the proportion of maple sawtimber increased by more than 60% (Table 2).

The eastern region contained nearly 50% oak species in 2002, but the lowest relative quantities of select species (32%) due to the high percentage of other red oaks (i.e., black, scarlet, pin, and shingle), chestnut oak, and yellow-poplar. This region had the smallest reduction in relative oak volume between 1965 and 2002, declining from 53 to 48% (Table 2).

Table 2. Percent composition of Pennsylvania's sawtimber inventory by region, 1965 and 2002.[a]

	Northern[b]		Western[c]		Eastern[d]	
Species and species group	1965[e]	2002[f]	1965	2002	1965	2002
Oaks						
Northern red oak	14.5	9.3	21.2	13.3	13.2	13.9
Other red oaks[g]	2.2	1.5	9.3	4.5	14.1	11.7
White oak	5.0	2.1	10.0	7.1	9.9	8.1
Chestnut oak	1.9	1.2	7.9	5.5	16.1	14.3
All oaks	23.6	14.1	48.5	30.4	53.3	48.0
Northern hardwoods						
Sugar maple	9.9	11.9	4.7	5.7	0.7	1.6
Red maple	14.1	23.8	8.6	15.6	5.4	7.8
Cherry	19.6	18.6	8.3	12.9	0.6	2.4
Birch	0.7	3.1	0.6	2.4	nr[h]	3.6
Beech	7.2	4.6	2.8	3.1	0.9	1.0
Basswood	2.7	2.0	0.6	2.0	nr	0.7
All northern hardwoods	54.2	64.0	25.6	41.7	7.6[i]	17.1
Other species						
Ash	5.9	7.1	2.1	3.0	3.0	5.9
Yellow-poplar	nr	2.0	3.3	6.0	8.9	10.7
Hickory	0.3	0.9	2.7	2.2	4.0	3.8
Softwoods	14.7	9.9	9.9	10.2	17.1	10.1

[a] Not all species are reported (i.e. percentages do not add to 100).
[b] Includes the Allegheny and northeastern FIA survey-units.
[c] Includes the western, southwestern, and north-central FIA survey-units.
[d] Includes the Pocono, south-central, and southeastern FIA survey-units.
[e] Developed from Ferguson (1968).
[f] Developed from USDA Forest Service (2004).
[g] Includes black, scarlet, pin, and shingle oaks.
[h] Estimate not reported.
[i] Underestimates northern hardwoods because many of these species were not reported in detail for survey-units in this region in 1965.

Table 3. Shift-share analysis of regional lumber production (mmbf) in Pennsylvania, 1970–86 and 1986–99 by region.

	Northern	Western	Eastern	All regions
		1970–86		
Production 1970[a]	143	329	134	606
Production 1986[b]	232	479	290	1,001
Expected change	93	214	87	
Actual change	89	150	156	
Percentage difference	–4.3	–29.9	79.3	
		1986–99		
Production 1986	232	479	290	1,001
Production 1999[c]	375	618	318	1,311
Expected change	72	148	90	
Actual change	143	139	28	
Percentage difference	98.6	–6.1	–68.9	

[a] Pennsylvania Department of Environmental Resources (1971); procedures developed by Luppold (1996).
[b] Pennsylvania Department of Environmental Resources (1986); procedures developed by Luppold (1996).
[c] Smith et al. (2003).

Regional Changes in Pennsylvania's Lumber Production

The earliest available estimates of hardwood lumber production for Pennsylvania on a regional level were derived from a 1970 survey of the state's sawmill industry (Pennsylvania Department of Environmental Resources 1971). Subsequent surveys of Pennsylvania's sawmilling industry were conducted in 1975, 1982, and 1986. The most recent production estimates were developed from a sawmill database developed by Smith et al. (2003). However, between 1970 and 1999 there have been two major swings in interspecies pricing associated with changing market preferences. In the 1970s and 1980s, the price of red and white oak surged while the price of maple declined. This corresponds to a period of increasing popularity of oak in furniture styles (Frye 1996). In the late 1980s, the price of red oak remained high while that of white oak began to decline relative to red oak. At the same time, the price of maple and cherry began to increase as styles incorporating closed-grain species increased in popularity. As a result, we decided to examine changes during Pennsylvania's lumber production in two periods: 1970–86 (the red and white oak period) and 1986–99 (the cherry, maple, and red oak period).

Table 3 presents a two-period shift-share analysis for lumber production in the three regions of Pennsylvania. This analysis contrasts actual changes against expected changes assuming a consistent rate of growth in lumber production across all regions. A negative percentage difference indicates less than expected growth, while a positive percentage indicates a greater than expected growth. The formulas are:

$$EC_{i,t,t+n} = (V_{t+n} - V_t) * P_{it}$$

and

$$PD_{i,t,t+n} = (AC_{i,t,t+n} - EC_{i,t,t+n})/EC_{i,t,t+n}$$

Where:

$EC_{i,t,t+n}$ = Expected change in lumber production in region i between periods t and $t + n$
V_{t+n} = Lumber production in all regions in period $t + n$
V_t = Lumber production in all regions in period t
P_{it} = Proportion production volume in region i in period t
$PD_{i,t,t+n}$ = Percentage difference between actual and expected change in region i between periods t and $t + n$
$AC_{i,t,t+n}$ = Actual change in lumber production in region i between periods t and $t + n$

In 1970, more than 54% of the lumber was produced in the western region, while the northern and eastern regions contributed 24 and 22% to production, respectively (Table 3). Between 1970 and 1986, production increased by nearly 400 million board feet. However, the relative production in the western region decreased to 48% with most of the increased proportion shift accruing in the eastern region. In percentage difference, production in the northern region grew slightly less than expected, production in the western region was 30% less than expected, while production in the eastern region was 79% more than expected.

Between 1986 and 1999, lumber production increased by an additional 300 million board feet. However, while increased production in the eastern region accounted for most of the growth between 1970 and 1986, production in the northern region accounted for most of the growth in the later period. In percentage difference, production in the western region grew slightly less than expected, production in the eastern region was 69% less than expected, and production in the northern region was 99% more than expected.

Comparing Changes in Lumber Production to Changes in Sawtimber Inventory

Table 3 allows for examination of relative changes in lumber production in the three regions over two time

Table 4. Hardwood sawtimber inventory to annual lumber production ratios (I/P ratios) for Pennsylvania, 1970, 1986, and 1999, by region.

	Northern		Western		Eastern	
Year	I/P ratio[a]	Indexed ratio	I/P ratio	Indexed ratio	I/P ratio	Indexed ratio
1970	75.5	100.0	38.3	100.0	63.5	100.0
1986	83.4	110.4	45.7	119.4	47.9	75.4
1999	68.0	90.1	46.8	122.2	57.7	90.9

[a] Inventory volumes used to calculate ratios were extrapolated from estimates reported by Ferguson (1968) for survey year 1965, Alerich (1993) for survey years 1978 and 1989, and USDA Forest Service (2004) for 2002.

periods, but provides little insight into why these changes occurred. One factor influencing these changes is sawtimber availability. Table 4 presents ratios of extrapolated[1] sawtimber inventories in Table 1, grouped by region (Figure 2), divided by annual lumber production (Table 3). These ratios of inventory to production (I/P ratios) are the number of years it would take industry to deplete the resource in the absence of ingrowth and accretion and are rough measures of regional timber utilization. Therefore, a lower I/P ratio indicates higher production relative to inventory.

The western region has consistently been associated with the lowest I/P ratios (the lowest being reported for 1970). This low ratio may partially explain why this region had lower than expected growth in lumber production in both periods examined. A low I/P ratio is indicative of high relative demand. In turn, high relative demand increases the price of the available resource hindering large increases in lumber production.

The I/P ratio for the northern region has been consistently the highest among the three regions. This high ratio is surprising given the quality and composition of timber in this region, though public ownership accounted for 33% of the timberland and 50% of the sawtimber volume in this region in 2002 (USDA Forest Service 2004). Furthermore, as overall sawtimber inventory in the northern region increased by 32% between 1989 and 2003, sawtimber volume on private land increased by only 5% (USDA Forest Service 2004). All of the increases in sawtimber volume on private timberland in this region can be attributed to softwood as hardwood sawtimber volumes decreased by 0.5%.

The eastern region had the most erratic I/P ratio, declining by 25% between 1970 and 1986 and then increasing by 20% from 1986 to 1999. This variation is consistent with the large increase in relative production between 1970 and 1986 followed by the large decrease in relative production from 1986 to 1999.

While the I/P ratio may indicate the level of harvesting activity in a region, the indexed I/P ratio (1970 = 100) provides a relative measure of trends over time that make interpretation easier when contrasting changes among regions. The northern and eastern regions ended with nearly identical indexed ratios in 1999, but the ratio for the northern region increased between 1970 and 1986 before decreasing between 1986 and 1999. The opposite was true in the eastern region.

Influence of Lumber Prices on Regional Lumber Production

When examining the hardwood resource for the three timber regions of Pennsylvania, it was noted that the eastern region had the lowest rate of growth in sawtimber but the highest relative rate of growth in lumber production between 1970 and 1986. These two trends seem inconsistent especially given that the eastern region also contained the lowest percentage of select species as defined by Araman (1987). However, changes in lumber production are ultimately influenced by the interaction of changing input prices and changing prices of lumber.

The major inputs in lumber production are stumpage or timber, labor, capital, and energy. It is assumed that the prices of nontimber inputs have changed in a similar manner across regions. Changes in timber demand ultimately influence stumpage prices, but stumpage price increases occur after demand or capacity has increased. Such increases therefore could slow or moderate regional changes in lumber production, but they will not stop such changes in capacity from initially occurring. For these reasons, it is assumed that a major influence on changes in regional lumber production is regional lumber prices. However, the price that any region faces is influenced by species existing in the region and the price of those species (relative interspecies price). Relative interspecies pricing in turn is influenced by the changing price of individual species and changes in forest composition.[2]

Figure 4 presents a 5-year moving average of deflated regional price series based on the composite prices of No. 1 Common (1C) lumber for the species in each region. A 5-year moving average was selected to reduce cyclical variation in lumber prices that could confuse the analysis and because changes in lumber production are the result of both current and past prices (Luppold 1984). The price of 1C lumber was obtained from the Hardwood Market Report (1966–2000) for the Appalachian region in the first week in

[1] Because the years for forest inventories did not correspond to those in which production estimates were available, we estimated sawtimber volumes for 1970, 1986, and 1999 by linearly extrapolating the two survey estimates for the years less than and greater than the year lumber production was estimated.

[2] There also are additional factors that can influence the availability of timber at any given time period, including imports or exports from or to adjoining regions, road quality, availability of secondary markets for roundwood residuals, and land-clearing activities associated with urbanization. However, it is difficult to assess the impacts of these factors.

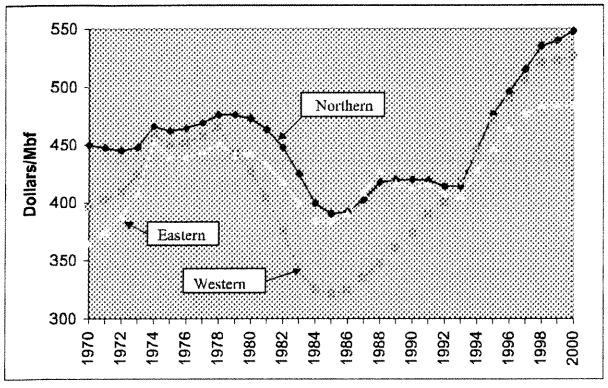

Figure 4. Five-year moving average of deflated No. 1 Common hardwood lumber price in the northern, western, and eastern regions of Pennsylvania, adjusted for changing sawtimber composition within regions.

January from 1966 to 2000 and deflated using the Producer's Price Index for all industrial commodities (US Department of Labor 2003). Because regional forest composition in each region has changed over time (Table 2), Figure 4 was developed to allow the relative species weights to change as regional sawtimber composition changed. These variable weights were developed yearly by extrapolating the proportional volumes of the hardwood species reported in Ferguson (1968), Alerich (1993), and USDA Forest Service (2004) for the inventory years 1965, 1978, 1989, and 2002.

Figure 4 reveals that the lumber prices sawmills faced in each region followed different trends. The northern region consistently had the highest or near highest price for the 30-year period examined. By contrast, prices in the western region began to increase in the early 1970s, dramatically declined in the mid-1980s, but have sharply increased since 1986. In the eastern region, prices increased during the 1970s and remained relatively high until the early 1990s.

Changes in relative prices between 1970 and 1986 are reflected in the changes in the shift-share analysis (Table 3) and the indexed I/P ratio (Table 4). During this period, the price of species in the eastern region increased the most, prices in the western region decreased, while prices in the northern region were the least variable. The large increase in relative prices in the eastern region resulted from increases in the price of red and white oak (the most common species in that region). The large drop in relative prices in the western region resulted from a combination of declining prices for hard and soft maple and an increase in the proportions of these species (Table 2). Compared to the western region, relative prices in the northern region remained high during this period due to continued high prices for black cherry, a smaller decrease in the relative volume of red oak, and a smaller increase in the relative volume of maple.

In the late 1980s, red oak prices remained high, white oak prices began to decline relative to red oak, and maple and cherry prices began to increase. This caused relative production in the northern region to increase, virtually no change in relative production in the western region, and a decrease in relative production in the eastern region. Again, these trends are reflected in the decline in the indexed I/P ratios for the northern and western regions and the increased indexed I/P ratio for the eastern region. The relationship between the extreme changes in the indexed I/P ratios and indexed lumber prices for the northern and eastern regions supports our contention that relative lumber prices influence changes in lumber production.

Summary and Conclusions

The hardwood sawtimber inventory in Pennsylvania more than tripled in volume between 1965 and 2002. Coincident with this increase has been a change in forest composition as proportional inventories of maples have increased and oaks have declined. However, the rate of growth and the change in forest composition have not been uniform across the state. The northern region of the state has had the greatest increase in sawtimber volume and the largest proportional change from oaks to maples. By contrast, the eastern region has had the smallest increase in inventory and the smallest shift in forest composition.

Pennsylvania's sawmilling industry also has grown over the last 35 years as timber inventories have increased and the prices for most species of hardwood lumber have cycled upward. However, the rate of growth in regional lumber production has been variable and has not coincided strictly with increases in inventories or as consistently with expectations regarding timber quality. Between 1970 and 1986, lumber production in the eastern region more than doubled even though this region had the least relative increase in sawtimber inventory and the lowest proportion of select species. However, since 1986, production in the northern and western regions has increased while production in the eastern region has remained nearly constant. An examination of regional indexes of lumber prices revealed that regional changes in lumber production are influenced by changes in interspecies pricing along with changes in forest composition.

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