Analysis of the Interaction Between Timber Markets and the Forest Resources of Maine

William G. Luppold, *USDA Forest Service, Northeastern Research Station, 241 Mercer Springs Road, Princeton, WV 24740; and* **Paul E. Sendak,** *Northeastern Research Station, 271 Mast Road, Durham, NH 03824.*

ABSTRACT: *The abundant timber resources of Maine are critical to the State's timber economy; thus, when the 1995 forest inventory indicated a 20% decline in softwood growing stock, there was great concern by industry and government. Furthermore, declining near-term softwood growing stock levels were forecast. To better understand what was occurring in Maine's forest, we examined changes in composition and evaluated the relative impacts of harvesting versus growth and mortality. Much of the decline in spruce-fir inventory can be attributed to the budworm infestation of the 1970s and 1980s, although continued high utilization contributed to the decline. The high rate of softwood utilization was facilitated by low softwood timber prices due to increased supply from salvage cutting and high prices for softwood dimension lumber. The high price of dimension lumber also allowed the adoption of sawmill technology in Canada and Maine that used small-diameter logs, formerly consumed by the pulp industry, for lumber production. The increased demand for spruce-fir roundwood occurred during a period when changes in paper demand and pulping technology increased the demand for hardwood pulpwood. Unlike spruce-fir and hemlock, hardwood growing-stock volumes have increased steadily due to low utilization, high growth, and low mortality. Ample inventories of hardwoods have allowed increased volumes of these species to be used in the manufacture of pulp and engineered wood products. A recent partial forest survey of Maine indicated that spruce-fir growing stock inventory has stabilized as a result of regeneration of these species that began after the last spruce budworm infestation. North. J. Appl. For. 21(3):135–143.*

Key Words: Forest sustainability, spruce-fir, hardwood substitution.

The extensive timber resource in Maine is a source of roundwood for a diverse forest products industry. It is critical to the State's economy that this resource remains viable. Concerns about the sustainability of harvest level of Maine's forests emerged after a spruce budworm outbreak in the late 1970s that increased the mortality of economically important spruce and fir (Irland et al. 1988). Concerns about the sustainability of the state's hardwood inventory also surfaced during the late 1980s (Seymour and Lemin 1989). While a decline in hardwoods has not occurred, the 1995 inventory of Maine's forests revealed a 20% decline in softwood growing stock since the prior survey in 1982 (Griffith and Alerich 1996). This decrease resulted from high mortality of spruce-fir and a relatively high rate of removals of these species.

Alarmed at the decline in softwood growing stock, the Maine Forest Service conducted an analysis of the state's long-term timber supply (Gadzik et al. 1998). It concluded that total forest inventory would support current harvest levels for the next 50 years but that this level of harvest would result in a decline of softwood inventory. The study provided valuable insight for future management of Maine's forests, but it excluded market dynamics, i.e., how forest products markets respond or adapt to changes in timber supply. It is the interaction between the market and the resource that ultimately influences the structure and composition of the forest and, in turn, the long-term supply of raw material for forest industries.

Understanding the interaction between forest products markets and the resource is fundamental to understanding the forest economy. The decline in spruce-fir inventory in Maine is particularly interesting because it might provide insight into how forest products industries adjust to rapid changes in the timber base and whether these changes influence the demand for other species. To understand the interaction between timber markets and Maine's forest resource, we first explained some limitations of resource and market data and then presented an alternative method of analyzing inventory and economic data in relative terms.

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

We then examined trends in Maine's inventory and roundwood markets for major species and evaluated the relative impact of harvesting, growth, and mortality on forest composition. While the approach used in our study is not a substitute for long-term simulation models, it provides information that is useful in increasing the power of such models.

Data Considerations

Forest inventory data were obtained from the 1959, 1971, 1982, and 1995 forest surveys of Maine (Ferguson and Longwood 1960, Ferguson and Kingsley 1972, Powell and Dickson 1984, Griffith and Alerich 1996). Each survey estimated growing stock and sawtimber volume by species for the specific survey year.[1] Forest surveys also provide estimates of annual growth, removals (primarily harvest), and mortality for growing stock and sawtimber for the period between the current and prior inventory.

Growth can be divided into two categories: growth on trees of growing stock or sawtimber size present in both inventories (accretion); and trees that were too small during the previous inventory but have obtained or surpassed the minimum size by the current survey (ingrowth). Trees classified as mortality were live in the previous inventory but dead by the current inventory. Removals are trees that were present during the previous inventory but were removed by the current survey. Because remeasured trees are used to develop growth, mortality, and removal statistics, the number of trees used to estimate these indicators of forest dynamics are considerably less than the number of trees used to estimate growing stock and sawtimber volumes.

Removal volumes are based on measurement of trees during the previous survey period (for Maine and other Northeastern states). Because the periods between surveys can exceed 12 years, the volume of the tree when it was actually removed might have been substantially greater than when it was last measured. However, growth is based on the difference between current and past measurements. This difference in estimating growth versus removals causes the net growth (growth minus mortality) to removal ratios (NGRR) to be biased upward because removals reported by the Northeastern Research Station are nearly always less than actual removals (Luppold and McWilliams 2000). As a result, we did not rely on interpretation of the NGRR but examined changes in utilization, growth, and mortality relative to changes in the inventory. The calculations used to develop these "relative resource relationship coefficients" are presented in the next section.

Data on softwood and hardwood sawtimber and pulpwood harvests reported by the Maine Forest Service were collected from 1950 to 1999 (Maine Forest Service 1961–1992, 1993–2000). Stumpage prices of sawtimber and pulpwood for Maine were developed from price data collected and reported by the Maine Forest Service (1961–1992, 1993–2000). To compare pulpwood and sawtimber markets, pulpwood and sawtimber harvest volumes are reported in cubic feet, and stumpage prices are reported in dollars/thousand cubic feet. It should be noted that the terms sawtimber and pulpwood consumption describe end use and may not be comparable to sawtimber and pole timber volumes reported in forest inventory. For example, lower-grade hardwood sawtimber may be used as pulpwood, and small-diameter spruce-fir may be used to produce lumber.

Luppold and Dempsey (1989, 1994) developed a hardwood lumber production database and procedures to estimate production in later years. Production levels for select softwood species were developed from current industrial reports (US Dept. of Commerce, Bureau of the Census 1961–2000). Hardwood lumber prices were obtained from information published in the Hardwood Market Report for the northern hardwood region. Because of the cyclical nature of forest products markets and the 12- to 14-year frequency of forest surveys, production and price data were examined as 6-year annual averages in an effort to smooth the influence of yearly fluctuations and highlight trends.

Measuring the Impact of Market and Biological Forces

The diversity of Maine's timber industry and the difficulty associated with interpreting forest inventory data over time requires an alternative approach to analyze the impact of market and biological forces on forest composition. In this article, we examined the impact of these forces using relative relationship coefficients for utilization (harvest), growth, and mortality. Because these ratios were estimated independently, the potential for compound errors of the NGRR were reduced. Also, these coefficients were less sensitive to data inconsistency problems associated with long-term times series data because they are based on relative values.

The general formulation for the relative resource relationship coefficients used in this analysis is:

$$RR_{ijk} = PI_{ijk}/PIV_{jk} \tag{1}$$

where:

RR_{ijk} = Relative relationship between indicator i (i = harvest or utilization, growth, or mortality) for species group j, in time period k.

PI_{ijk} = Proportion of indicator i, for species j (i.e., ratio of the growth of species j to total growth), in time period k.

PIV_{jk} = Proportion of the inventory in species j in time period k.

Because measurement of utilization, growth, and mortality is the average between two survey periods, the inventory volumes to calculate PI are the average of period k and $k - 1$.

The coefficients described in Equation 1 are based on the relative utilization coefficients (RUC) developed by Luppold and Baumgras (2001). An RUC of 1 indicates that the species is used in the same proportion as it represents in the inventory. An RUC > 1 indicates that the species is being used at a greater proportion than it represents in the inventory. Similarly, an RUC < 1 indicates that the species is being used at a lesser proportion than it represents in the inventory. The relative growth and relative mortality coefficients are denoted as RGC and RMC, respectively. An RGC or RMC of 1 indicates relative growth or mortality of a species is proportionally the same as it is in the inventory. A value > 1 indicates that proportional growth or mortality of the species is greater than the proportion of the species in the inventory; a value < 1 indicates that proportional growth or mortality is less than the proportion of the species in the inventory. An RUC or RMC > 1 indicates a greater relative utilization or mortality than that species represents in the inventory, leading to an eventual decline in inventory of that species. An RGC > 1 leads to a relative increase in the inventory of that species.

Although direct application of this approach to the inventory and market data discussed in the previous section could prove useful, the complexity of Maine's timber resource and timber markets mandates an interpretive review of these data. We then examined the interaction of markets with the forest resource and the relative impacts of utilization, mortality, and growth.

Changes in Forest Composition 1959–1965

Maine's growing stock inventory increased and the composition of the State's forests changed between 1959 and 1995 (Table 1). Softwoods have been predominant in Maine with spruce (primarily red with smaller amounts of black and white) and balsam fir (spruce-fir) the most dominant species group. Spruce-fir growing stock was greatest during the 1971 forest survey but fell to below 1959 levels by 1995 on an absolute and relative basis. Pines (primarily white) are the second largest softwood component of Maine's growing stock. The proportional volume of pine dropped from 1959 to1971 but has since increased. Hardwood growing stock has followed a similar path, declining proportionally between 1959 and 1971 and then increasing.

Inventories of softwood and hardwood sawtimber also have increased since 1959 (Table 2). The absolute volume of spruce-fir sawtimber continued to increase between 1971 and 1982, though the proportion of these species peaked in 1971. As with pine growing stock, the proportion of pine sawtimber declined from 1959 and 1971 but has since increased. While most hardwood species have increased proportionally over time, the proportion of yellow birch decreased between 1959 and 1995.

The proportion of spruce-fir growing stock has consistently been greater than the proportion of spruce-fir sawtimber, while the proportion of pine sawtimber has been greater than pine's proportion of growing stock (Tables 1 and 2). A higher proportion of spruce-fir volume has been in trees measuring <9 in. dbh, while a higher proportion of pine volume has been in trees measuring ≥9 in.

Roundwood Markets

There are five major roundwood markets in Maine: softwood sawlogs, hardwood sawlogs, softwood pulpwood, hardwood pulpwood, and boltwood. Sawlogs tend to be of a greater diameter than pulpwood, but under certain market conditions, some large-diameter logs are pulped and some small-diameter logs are sawn into lumber. These five roundwood markets use different sets of species and are affected by different national and international demand and supply forces.

Spruce-fir sawlogs primarily are used to produce dimension lumber for building construction (framing). As dimension lumber, spruce-fir is a substitute material for Canadian spruce and fir, Douglas-fir, and southern yellow pine. Sixty percent of the spruce-fir harvested in Maine was processed within the state in 1999, and 40% was exported, primarily to Canada (Maine Forest Service 2000). Sawmills in eastern Quebec and New Brunswick have lower power costs, tend to have more efficient production technology, and often are not bound by the trade restrictions that limit exports of softwood lumber to the United States from other parts of Canada.

White pine sawlogs are processed into millwork, furniture, and cabinet lumber. As millwork material, white pine can substitute for ponderosa pine, sugar pine, and other western millwork species. Red pine has physical characteristics similar to southern yellow pine and can be used to produce poles and cabin logs.

Hardwood sawlogs of species other than aspen are used to produce lumber used in appearance applications (e.g., furniture) and industrial applications (e.g., pallets). As furniture lumber, Maine's hardwoods substitute for similar species produced in other northeastern and north-central states. Although most hardwood sawlogs harvested in Maine are used in the state, relatively high volumes of yellow birch, sugar maple, and red oak are exported to Canada.

Most aspen sawlogs are used to produce oriented strandboard (OSB), a panel product that substitutes for softwood

Table 1. Softwood and hardwood growing stock inventories for selected species in Maine, by species group.[a]

Year	Spruce-fir	Pine	Hemlock	All softwood	Aspen	All hardwood
			(million ft^3)			
1959	6,882 (41.7)[b]	1,468 (8.9)	892 (5.4)	10,746 (65.1)	605 (3.7)	5,768 (34.9)
1971	10,576 (49.5)	1,508 (7.1)	1,147 (5.4)	14,556 (68.1)	748 (3.5)	6,811 (31.9)
1982	8,946 (39.9)	2,032 (9.1)	1,323 (5.9)	14,298 (63.8)	1,238 (5.5)	8,113 (36.2)
1995	6,130 (29.3)	2,132 (10.2)	1,286 (6.2)	11,680 (55.9)	1,225 (5.5)	9,210 (44.1)

[a] Developed from USDA Forest Service survey data.
[b] Percentage of all species in parentheses.

Table 2. Softwood and hardwood sawtimber inventories for selected species in Maine, by species group.[a]

Year	Spruce-fir	Pine	Hemlock	Yellow birch	Sugar maple	Red maple	Oak
				(million bd ft)			
1959	10,822 (35.5)[b]	5,000 (16.4)	1,833 (6.0)	2,615 (8.6)	3,019 (9.4)	1,248 (4.1)	390 (1.3)
1971	15,842 (41.1)	5,250 (13.6)	2,634 (6.8)	2,073 (5.4)	3,687 (9.6)	2,124 (5.5)	694 (1.8)
1982	17,197 (35.1)	7,919 (16.1)	3,745 (7.6)	2,291 (4.7)	4,205 (8.6)	3,009 (6.1)	920 (1.9)
1995	12,998 (27.7)	8,355 (17.8)	3,878 (8.3)	2,279 (4.9)	4,434 (9.4)	3,538 (7.5)	1,164 (2.5)

[a] Developed from USDA Forest Service survey data.
[b] Percentage of all species in parentheses.

plywood. Three OSB manufacturing plants built in Maine in the late 1980s foreshadowed the increased production of OSB and other engineered wood products in the eastern United States (Schuler et al. 2001).

Although all pulpwood by definition is used to produce paper pulp, species differ in physical characteristics. Spruce-fir produces a strong fiber and is desirable for applications such as high speed printing paper and newsprint. Hemlock pulp is a partial substitute for spruce-fir, but its fiber is not as strong. White pine is not highly valued as pulpwood. Hardwood fibers tend to be shorter, more absorbent, and stiffer than softwoods and can be used to make tissue, printing, computer, and writing papers. In recent years, changes in production technology and paper strength specifications have allowed greater substitution of hardwoods for softwoods in paper manufacturing.

Boltwood is short (50- or 100-in. long) mostly hardwood roundwood used to manufacture specialty forest products (e.g., dowels, toothpicks, furniture squares and rounds, golf tees, etc.) in which the initial breakdown occurs in specialized sawmills termed bolt mills. Normally, boltwood is produced from trees that are of sawlog quality but are too small in diameter to qualify as sawlogs. While the number of bolt mills has declined in recent decades, the market for boltwood is still significant in Maine. However, because bolts are sawn, boltwood has been combined under the sawlog designation in Maine's timber cut and wood processors reports (Maine Forest Service 1961–1992, 1993–2000).

Interactions of Markets With the Forest Resource

While the markets for individual species in Maine can overlap, it was easier to examine these markets on a species basis. We examined the major timber markets in Maine, which include spruce-fir, pine, hemlock, aspen, and other hardwoods.

Spruce-Fir

Spruce-fir has been the most abundant and used species group in Maine but inventories of these species have been influenced by cyclic infestations of spruce budworm. During such periods, salvage harvests increase supplies and lower the price of roundwood. The ample supply of spruce-fir during the last infestation caused prices to decline in real terms. Ironically, these infestations reduce timber supply in near- and long-term because of a decrease in the timber base. However, regeneration following an infestation eventually renews supplies.

The harvest of spruce-fir sawtimber increased dramatically between 1966 and 1977, and again since 1990 (Table 3). By contrast, real prices of spruce-fir sawtimber increased moderately between 1966 and 1977 but increased sharply in the 1990s (Table 4). Much of this increase in harvest volume after 1990 was exported (primarily to Canada) with net exports increasing from 17.3 million cubic feet (mmcf) in 1990 to 45.0 mmcf in 1999.

The harvest of Maine spruce-fir sawtimber was compared to the regional production of dimension lumber from other regions (Table 5). Southern pine lumber production has increased since the 1960s as pine plantations reached commercial size. By contrast, the production of Douglas-fir lumber declined in the 1970s and early 1980s, increased in the late 1980s, and declined in the 1990s as the USDA Forest Service reduced sales of National Forest timber.

The production of spruce-fir pulpwood in Maine increased modestly in the early 1960s, fluctuated from 1966 to 1989, and declined sharply in the 1990s (Table 3). The reduction in spruce-fir pulpwood production in the 1990s occurred during a period when changes in national paper demands and pulping technology favored increased production of hardwood pulp (Luppold et al. 2002). Pulpwood prices increased moderately in the 1960s, decreased through the 1970s and 1980s, and then increased by more than 50% from 1990 to 1999 (Table 4).

The combination of reduced pulpwood production and increased pulpwood prices in the 1990s at first seems contradictory, but an explanation can be found by looking at the total demand for spruce-fir roundwood. Much of the increase in pulpwood prices in the 1990s occurred during a period when Maine's spruce-fir sawtimber production and exports increased. These increases coincided with high softwood lumber prices (Howard 1999) and reduced timber supplies from National Forests. An increase in sawtimber harvest should increase pulpwood production because they tend to be complementary (since they differ in diameter). However, an unspecified but significant portion of the increase in sawlog production was small-diameter (pulpwood size) roundwood processed into dimension lumber. While small log technology has been used since the 1970s, the gradual adoption of this technology, especially by Canadian mills, appears to have facilitated the increase in Maine's spruce-fir sawtimber exports during the 1990s. It should be noted that the distinction between sawtimber and pulpwood in Maine "Wood Processor Reports" is based on end use.

Table 3. Average annual softwood and hardwood sawtimber and pulpwood harvested in Maine for selected periods from 1960 to 1999.

Product	1960–1965	1966–1971	1972–1977	1978–1983	1984–1989	1990–1995	1996–1999
	(million ft^3)						
Sawtimber							
Spruce-fir	32.9	47.0	72.7	83.3	85.6	102.5	128.7
Pine	25.2	24.8	31.1	31.2	30.2	33.7	42.9
Hemlock	5.9	3.8	7.5	10.9	11.8	16.5	16.6
Total softwood sawtimber[a]	68.1	81.9	118.9	131.3	134.3	159.1	196.5
Yellow birch	7.4	6.9	4.4	2.7	2.8	3.4	3.9
Sugar maple	8.9	11.8	10.8	6.3	5.1	7.5	7.8
Red maple	NA	NA	1.9	1.6	1.2	2.8	4.0
Oak	1.5	1.8	2.2	3.0	2.4	2.5	3.0
Aspen	0.4	0.5	0.9	3.8	18.7	20.0	21.6
Total hardwood sawtimber[b]	30.5	33.3	31.9	27.4	39.5	48.8	57.1
Pulpwood							
Spruce-fir	126.3	144.3	133.8	146.2	133.2	78.4	58.4
Pine	4.5	11.7	13.7	17.0	20.6	17.2	20.5
Hemlock	14.5	21.7	17.5	17.2	26.9	26.3	24.5
Total softwood pulpwood	145.8	178.9	165.6	181.7	180.8	128.3	105.3
Total hardwood pulpwood	45.8	63.9	75.7	100.7	114.7	140.1	166.0
Total Pulpwood	191.6	242.7	241.3	282.4	295.5	268.3	271.3

[a] Includes larch, cedar, and other softwood species not listed.
[b] Includes beech, ash, white birch, and other hardwood species not listed.

Table 4. Average price (constant 1982 dollars) of softwood and hardwood sawtimber and pulpwood stumpage in Maine for selected periods from 1960 to 1999.[a]

Product	1960–1965	1966–1971	1972–1977	1978–1983	1984–1989	1990–1995	1996–1999
	($/1,000 ft^3)						
Sawtimber							
Spruce-fir	259.4	263.7	277.2	301.5	283.3	375.2	510.0
Pine	290.8	297.7	328.2	410.0	469.8	492.3	570.2
Hemlock	252.8	243.2	228.5	210.6	175.1	194.8	253.8
Yellow birch	283.8	317.4	372.4	394.8	375.7	385.9	513.4
Sugar maple	289.4	292.2	325.5	364.4	357.4	414.9	678.2
Red maple	210.8	224.3	219.5	200.2	182.0	226.4	342.9
Oak	300.7	328.9	360.2	511.9	685.8	900.1	1113.2
Aspen	190.4	196.4	184.9	166.8	138.3	171.8	200.7
Pulpwood							
Spruce-fir	140.2	141.0	131.6	124.7	122.7	149.4	196.1
Pine	39.8	47.0	57.6	62.5	59.9	62.5	66.8
Hemlock	80.7	78.4	83.3	79.8	70.1	82.6	104.7
Hardwood pulpwood	60.7	76.8	73.9	78.9	79.2	75.1	84.6

[a] Source: Maine Forest Service (1961–1992, 1993–2000).

Table 5. Average annual softwood and hardwood lumber production in the United States by product and regions for selected periods from 1960 and 1999.

Product	1960–1965	1966–1971	1972–1977	1978–1983	1984–1989	1990–1995	1996–1999
	(million ft^3)						
Southern pine[a]	1023.4	1190.0	1315.8	1532.3	1951.3	2359.3	2612.8
Eastern softwood[a]	1181.3	1396.1	1529.5	1760.3	2209.3	2792.2	3125.3
Douglas-fir[a]	1468.6	1384.9	1389.8	1162.3	1575.7	1266.2	1210.5
Ponderosa pine[a]	584.6	626.5	661.7	553.2	662.9	512.7	395.8
All western softwoods[a]	3438.0	3459.0	3548.0	3010.7	3659.0	3071.8	2884.4
Eastern hardwood[b]	NA	1482.9	1375.0	1417.4	1835.1	1984.3	2064.2

[a] Source: US Dept. of Commerce, Bureau of the Census, 1961–2000.
[b] Source: hardwood lumber production database, developed from procedures outlined in Luppold and Dempsey (1989 and 1994), maintained at the Forestry Sciences Laboratory, Northeastern Research Station, Princeton, WV.

Data on relative utilization, growth, and mortality were used to examine the interaction of spruce-fir roundwood harvest and the resource (Tables 6 and 7). Although the relative utilization of spruce-fir growing stock was greater than for hardwood species (but less than pine and hemlock) between the first two forest surveys, the relative growth of this species group was sufficient to offset its relative utilization (Table 6). This allowed the proportion of spruce-fir

Table 6. Relative coefficient of harvest (utilization), removal, and mortality for Maine growing stock.

Ratio/coefficient	Spruce-fir	Pine	Hemlock	Softwood[a]	Aspen	Hardwood
1959–1971						
Relative utilization[b]	1.16	1.29	1.30	1.10	0.39	0.80
Relative growth[b]	1.23	1.32	1.31	1.15	1.02	0.68
Relative mortality[b]	1.19	1.04	0.76	1.10	0.68	0.80
1971–1982						
Relative utilization	1.19	1.37	1.14	1.10	0.52	0.81
Relative growth	0.80	1.27	0.50	0.91	1.92	1.17
Relative mortality	1.72	0.67	0.43	1.37	0.84	0.81
1982–1995						
Relative utilization	1.24	1.12	1.39	1.11	1.29	0.84
Relative growth	0.94	1.04	0.73	0.94	1.35	1.07
Relative mortality	1.83	0.21	0.26	1.22	0.96	0.65
1995–2000						
Relative utilization[c]	1.21	1.14	1.29	1.02	1.30	0.97

[a] Includes underutilized species such as larch and cedar.
[b] Harvest data developed from Maine Forest Service data, inventory data developed from Northeastern Research Station publications.
[c] Based on 1995 inventory estimates.

Table 7. Relative coefficient of harvest (utilization), removal, and mortality for Maine sawtimber.

Ratio/coefficient	Spruce-fir	Pine	Hemlock	Yellow birch	Sugar maple	Red maple	Oak
1959–1971							
Relative utilization[a]	0.93	1.51	0.68	0.95	0.96	NA	0.95
Relative growth[a]	1.21	1.17	1.32	0.17	0.44	1.63	1.43
Relative mortality[a]	1.26	0.68	1.04	1.52	0.19	0.80	0.52
1971–1982							
Relative utilization	1.34	1.32	0.76	0.52	0.67	0.18	0.86
Relative growth	NA	NA	NA	NA	NA	NA	NA
Relative mortality	NA	NA	NA	NA	NA	NA	NA
1982–1995							
Relative utilization	1.47	0.95	0.88	0.32	0.34	0.14	0.59
Relative growth	1.03	1.07	1.12	0.59	0.55	0.91	1.17
Relative mortality	1.84	0.21	0.28	0.80	0.59	0.58	0.27
1995–2000							
Relative utilization[b]	1.76	0.91	0.76	0.35	0.33	0.21	0.52

[a] Harvest data developed from Maine Forest Service data, inventory data developed from Northeastern Research Station publications.
[b] Based on 1995 inventory estimates.

growing stock to increase (Table 1). The high relative growth of spruce-fir resulted from additions to growing stock from trees that regenerated following the previous spruce budworm infestation.

The decline in spruce-fir growing stock volumes between 1971 and 1982 (Table 1) demonstrates the impact of high relative utilization, low growth, and high mortality caused by spruce budworm (Table 6). Although the spruce-fir sawtimber harvest increased during this period, the pulpwood harvest still exceeded the sawtimber harvest (Table 3). Continued high demand for a declining inventory normally would cause prices to increase, but spruce-fir pulpwood prices decreased during this period (Table 4) as supplies of salvaged timber resulting from the spruce budworm infestation became available. Sawtimber inventory increased as a result of ingrowth into the sawtimber-size category of trees that had regenerated following the last spruce budworm infestation (Table 2).

During the 1990s, spruce-fir sawtimber harvest increased by 40%. The low prices caused by the temporary increase in supply of salvaged roundwood may have sent market signals that caused industry to underestimate the impact of the spruce budworm, resulting in an apparent (as indicated by sawlog consumption) increase in lumber production capacity in Maine during the 1980s. The lack of resource data showing the actual decline in spruce-fir supplies could have contributed to underestimation. High prices of dimension lumber during the 1990s allowed these mills to continue to economically produce lumber even as timber prices increased. The continued high relative utilization of sawtimber and pulpwood, low growth rate, and high mortality of spruce-fir between 1982 and 1995 resulted in large declines in spruce-fir inventory (Tables 1 and 3). This increase in sawtimber harvest combined with declining inventory caused the relative utilization of these species to increase (Tables 6 and 7).

Pine

The harvest of pine sawtimber (primarily white pine) in Maine has increased since 1959, with the greatest increase occurring during the 1990s (Table 3). Because white pine is a millwork and furniture species, pine sawtimber consistently has brought high prices. The production of pine pulpwood also increased fourfold during this period but from a low initial level. Between 1959 and 1971, the relative utilization of pine sawtimber was higher than for other species (Table 7) resulting in a proportional decrease of pine in Maine's forest inventory (Tables 1 and 2). High relative growth and low mortality counteracted this high rate of utilization resulting in a small absolute increase in inventory. Between 1971 and 1982, the harvest of pine sawtimber fluctuated, causing relative utilization to decline (Table 7). The continued high relative growth of pine growing stock (most of which was in sawtimber-size material) allowed proportional increases in sawtimber and growing stock inventories during the 1970s (Tables 1 and 2).

Pine harvest has increased since 1982; the greatest increase occurred after West Coast supplies of competing millwork species declined (Table 5). However, relative utilization of pine sawtimber declined while growth remained high and mortality low, resulting in proportional increases in pine inventory.

Hemlock

In Maine, hemlock has been harvested mostly for pulpwood. However, in the 1990s harvest of hemlock, sawtimber increased while pulpwood production remained constant. Between 1959 and 1971, hemlock growing stock had high relative utilization and growth (similar to those for white pine) but low relative mortality (Table 6). The combination of high growth and low mortality offset high utilization, so the proportion of the hemlock growing stock remained constant. The relative utilization of hemlock growing stock dropped between 1971 and 1982, as did relative growth and relative mortality resulting in absolute and relative increases in inventory of this species (Table 1). Since 1982, the relative utilization of hemlock increased resulting in an absolute decline in growing stock inventory. However, this decline was not as great as that for spruce-fir, so hemlock volume increased relatively.

Although the relative utilization of hemlock growing stock has been high, relative utilization of hemlock sawtimber has been low (Table 7), reflecting the use of this species as pulpwood. This low utilization apparently was the dominant factor in the absolute and proportional increases in hemlock sawtimber volumes and the decline in real prices through the late 1980s. As with most softwood species, prices of hemlock sawtimber increased sharply during the 1990s as sawmills and stud mills converted increased volumes of this species to dimension lumber. The price of hemlock pulpwood has increased even though harvest stabilized during the 1990s.

Aspen

The harvest of aspen sawtimber was extremely low between 1960 and the early 1980s but expanded to nearly half of hardwood sawtimber harvest during the mid-1970s. However, most of the sawtimber-size aspen was used to produce OSB rather than lumber. The real price of aspen sawtimber consistently has been the lowest of major softwood and hardwood species (Table 4). The low price of this species facilitated the development of OSB. Since the construction of OSB plants in Maine, aspen growing stock inventory has remained constant.

Low relative utilization of aspen, combined with moderate growth and low mortality, allowed this species to maintain its proportional representation in Maine's forests between 1959 and 1971 (Table 6). Between 1971 and 1982, aspen's low relative utilization and high growth caused inventory of this species to nearly double. However, inventory of this species has stabilized since 1982 as the high relative utilization has counteracted the high relative growth. The most notable biological impact of the market for aspen is that this pioneer species requires site disturbance associated with clearcut harvests to regenerate. Without the large OSB market for aspen, stands heavy to this species probably would not be cut.

Other Hardwood

In the early 1960s, more than 60% of the hardwood roundwood harvested was pulpwood (Table 3). By the late 1990s, the volume of hardwood roundwood pulpwood production had increased by more than 250%, or nearly 75% of total hardwood roundwood production. The increase in hardwood pulpwood production occurred in two stages. Between 1960 and the late 1980s, increased use of hardwood fueled the expansion of Maine's paper industry, while spruce-fir pulpwood consumption remained relatively constant, even though the supply of salvaged material increased. Again, this illustrates the diversion of pulpwood-size spruce-fir to lumber production. In the 1990s, hardwood pulpwood production increased, apparently making up half the void in capacity left by the decline in spruce-fir pulpwood production. The reasons for the increased use of hardwood pulpwood are abundant hardwood inventory, increased demand for hardwood-based papers, and related low prices of hardwood pulpwood (Table 4).

Although the production of hardwood pulpwood in Maine has increased nearly fourfold since 1960, hardwood sawtimber harvest has only doubled (Table 3). Subtracting aspen volume, which is primarily used for OSB production, from sawtimber harvest, only 16% of the hardwood harvested in the 1990s was used for lumber production. Furthermore, this adjustment in sawtimber volume indicates that hardwood lumber production in Maine decreased in the 1980s, while hardwood lumber production increased nationally during this period.

The decline of hardwood lumber production in Maine during the 1980s probably reflects the high proportion of northern hardwood species (maple, beech, and birch) in the state. These species were not in high demand by the furniture and cabinet industries during this period as seen in the decline in lumber price (Table 8). However, since 1990, the demand and price for northern hardwoods have increased, resulting in an increase in hardwood sawtimber harvest in Maine.

Between 1959 and 1971, utilization of hardwood growing stock was low relative to softwood, but relative growth was even lower than relative utilization (Table 6). This low rate of growth resulted in a small absolute increase in hardwood growing stock and a decline in the proportion of hardwoods from 35 to 32%. During the 1970s, relative use

Table 8. Inflation adjusted price indices (average of 1960–1965 = 100) for softwood and hardwood lumber for selected periods from 1960 to 1999.

Product	1960–1965	1966–1971	1972–1977	1978–1983	1984–1989	1990–1995	1996–1999
Birch[a]	100.0	98.0	78.0	62.2	55.3	55.2	73.7
Hard maple	100.0	101.4	93.6	77.5	68.4	98.2	125.2
Soft maple	100.0	106.2	95.8	74.5	66.4	84.1	95.5
Red oak	100.0	113.8	128.7	128.6	149.9	159.3	169.1

[a] Developed from northern region prices published in *Hardwood Market Report.*

of hardwood remained low while relative growth increased, resulting in an increase in hardwood growing stock in both absolute and proportional terms. This low rate of utilization and higher rate of relative growth resulted in increased inventory of hardwood through the 1980s and early 1990s.

Because of the increasing utilization of spruce-fir sawtimber, the relative utilization of hardwood sawtimber has been declining (Table 7). However, different hardwood species have different rates of use, growth, and mortality. Since the first Maine forest surveys, the greatest increases in hardwood sawtimber inventories have been in red oak and red maple. The increase in oak is the result of moderate to low relative utilization, high growth, and low mortality (Table 7). The increase in red maple is the result of extremely low utilization, high growth (especially between 1959 and 1971), and low mortality. By contrast, inventory of yellow birch sawtimber has fluctuated in absolute volume and declined in relative terms. This decline likely is the result of low growth and high mortality (Table 7). As with other hardwood species, the utilization of sugar maple sawtimber has decreased over time, though the low rate of growth of this species has caused proportional sawtimber inventory volumes to fluctuate.

Changes in the Resource and the Market Since 1995

Since the 1995 forest survey of Maine, the Maine Forest Service and Northeastern Research Station have adopted an annual inventory approach. Maine was the first state in the Northeast to be surveyed using this system, which surveys 20% of the plots annually. Although only 40% of the State has been surveyed, initial findings indicate that spruce-fir growing stock is increasing (Maine Department of Conservation, Forest Service, www.state.me.us/doc/mfs/pubs. Sept. 6, 2001). Although such an increase was expected, it may be occurring earlier than previously anticipated. If these findings are supported by subsequent measurement, fears of continued decline in the spruce-fir resource appear to be unwarranted.

Another trend that has occurred since 1995 is the convergence of relative utilization coefficients for hardwood and softwood growing stock in Maine (Table 6). This convergence has not occurred with respect to sawtimber (Table 7). One explanation for low relative utilization of hardwood sawtimber is that a large volume classified as sawtimber in forest surveys is consumed as pulpwood and does not enter into the calculation of the coefficients for sawtimber utilization even though sawtimber-size material is being used by the pulp industry. This means that data concerning relative utilization of hardwood sawtimber (Table 7) may not be accurate and may not reflect the actual relative utilization of hardwood sawtimber.

Although it is unlikely that relative utilization coefficients for all species will converge to 1 over the long term, the fact that species-relative utilization coefficients have converged on a narrow range may be indicative of the market's ability to adapt and use all species. Relative price is the economic factor that would facilitate this type of behavior. As the relative price of one species increases, uses are found for other species even though the products being produced are not identical and perhaps only loosely related. For instance, paper manufactured from hardwood pulp may not have the same markets as paper manufactured from softwood pulp, but hardwood pulp may be produced at mills that previously manufactured softwood pulp. OSB manufactured from aspen does not substitute for spruce-fir lumber, but the same macromarket forces that influence demand for dimension lumber influence the demand for OSB.

Discussion and Conclusions

Although biological factors as reflected in changes in growth and mortality have been the primary forces shaping Maine's forests, market factors have augmented or counteracted these natural forces, thus influencing forest composition. The most notable example of how biological and market factors interact is the decline in spruce-fir growing stock and sawtimber inventories.

The initial decline in spruce-fir growing stock was caused by high relative utilization and spruce budworm-induced mortality that offset high relative growth. Salvage timber sales resulting from the infestation kept sawtimber prices low, which in turn caused an apparent increase in sawmilling capacity during a period of declining inventory. Increasing dimension lumber prices that resulted from declines in supplies of Douglas-fir lumber, technology that converts small-diameter roundwood into lumber, and restrictive softwood lumber trade policies with Canada also encouraged increases in the harvest of spruce-fir sawtimber in Maine. The decline in spruce-fir inventory caused relative growth to decline. Increased utilization and mortality caused further declines in growing stock and sawtimber inventories. Although the decline in spruce-fir inventory is troubling, the high utilization of these species at a time of natural decline resulting from the spruce budworm infestation likely is economically unsustainable because the price of spruce-fir products will eventually rise faster than that of substitute products in greater supply.

Another notable change in Maine's forest product markets has been the shift from use of spruce-fir pulpwood to hardwood pulpwood. The reasons for the decline in spruce-fir pulpwood harvests are high relative price, changing pulping technologies, and changing demands for paper. Price of hardwood pulpwood is considerably less than that for spruce-fir. The relative difference between hardwood and softwood pulpwood prices has provided an economic incentive to change pulping technologies. Also, the demand for papers requiring the strength of spruce-fir fiber has not grown as fast as the demand for papers that can be manufactured from hardwoods (Luppold et al. 2002).

The availability of a resource sets in motion a series of economic and technological mechanisms to exploit the resource and satisfy a current or latent demand for a specific set of goods and services. Once an infrastructure is developed to harvest and process roundwood, changes in local and national demand influence the type of material extracted from the forest. As relative prices for a particular species continue to increase, demand will shift as technology or other structural shifts force change. It is because of market dynamics that unsustainable use of a resource is self-limiting. A further shift in the use of hardwood in the production of engineered wood products and pulp may be possible in the future because of continued regeneration and growth of these species.

The impact of markets on forest composition and structure is fairly easy to demonstrate but not as easy to incorporate into forest simulation models. The use of demand and supply in simulation models is one way of including markets, but it is difficult to develop these dynamic relationships. An alternative is to constrain the model so that the long-term relative utilization of growing stock of all species is equal to 1, or to impose constraints that hold relative utilization within a range, which is occurring in Maine over the long run. Additional research is needed on the interpretation of the interrelationship between relative growth, mortality, and utilization coefficients.

End Note

[1] Growing stock includes trees of commercial species of good form and at least 5 in. dbh. Softwood sawtimber trees are at least 9 in. dbh, and hardwood trees are at least 11 in. dbh and contain at least one 12-ft. sawlog or two noncontiguous 8-ft. sawlogs.

Literature Cited

Ferguson, R.H., and F.R. Longwood. 1960. The timber resources of Maine. USDA For. Serv. Northeast For. Exp. Sta. 75 p.

Ferguson, R.H., and N.P. Kingsley. 1972. The timber resources of Maine. USDA For. Serv. Resour. Bull. NE-26. 129 p.

Gadzik, C.J., J.H. Blanck, and L.E. Caldwell. 1998. Timber supply outlook for Maine: 1995–2045. Maine Dep. Cons., For. Serv. 39 p.

Griffith, D.M., and C.L. Alerich. 1996. Forest statistics for Maine, 1995. USDA Forest. Serv. Resour. Bull. NE-35. 134 p.

Howard, J.L. 1999. U.S. timber production, trade, consumption, and price statistics 1965–1997. USDA For. Serv., Gen. Tech. Rep. FPL-116. 76 p.

Irland, L.C., J.B. Dimond, J.L. Stone, J. Falk, and E. Baum. 1988. The spruce budworm outbreak in Maine in the 1970s—Assessment and directions for the future. Univ. Maine Agric. Exp. Sta. Bull. 819. 119 p.

Luppold, W., and J. Baumgras. 2001. Utilization of the eastern hardwood resource by the hardwood sawmilling industry. North. J. Appl. For. 18(2):37–41.

Luppold, W.G., and G.P. Dempsey. 1989. New estimates of central and eastern U. S. hardwood lumber production. North. J. Appl. For. 6(3):120–123.

Luppold, W.G., and G.P. Dempsey. 1994. Factors affecting regional changes in hardwood lumber production. For. Prod. J. 44(6):8–14.

Luppold, W.G., J.P. Prestemon, and A. Schuler. 2002. Changing markets for hardwood roundwood. P. 96–100 *in* Proceedings of the 2001 annual meeting of the Southern Forest Economic Workers, March 27–28, 2001, Atlanta, GA.

Luppold, W.G., and W.H. McWilliams. 2000. Issues affecting the interpretation of eastern hardwood resource statistics. For. Prod. J. 50(4):21–24.

Maine Forest Service. 1961–1992. Timber cut report (annual). Maine For. Serv., Dept. Conserv., Augusta.

Maine Forest Service. 1993–2000. Wood processor report (annual). Maine For. Serv., Dept. Conserv., Augusta.

Powell, D.S., and D.R. Dickson. 1984. Forest statistics for Maine 1971 and 1982. USDA For. Serv. Res. Bull. NE-81. 194 p.

US Department of Commerce, Bureau of the Census. 1961–2000. Current industrial reports:Lumber production and mill stocks. US Dept. of Commerce, Bureau of the Census, Washington, DC.

Schuler, A., C. Adair, and E. Elias. 2001. Engineered lumber products, taking their place in the global market. J. For. 90(12):28–35.

Seymour, R.S., and R.C. Lemin, Jr. 1989. Timber supply projections for Maine, 1980–2080. Univ. Maine Agric. Exp. Stn. Misc. Rep. 337. 39 p.