Ten-Year Average GROWTH RATES In The Spruce-Fir Region Of Northern New England

by Lawrence O. Safford

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THE QUESTION OF GROWTH

A COOPERATIVE spruce-fir growth study was begun in northern New England in 1950. By 1954 the cooperating landowners had established a total of 1,126 sample plots. The first remeasurement — after five growing seasons — was completed on 866 plots by 1958, and in 1961 a report was published about the average growth based on these remeasured plots.[1] The 5-year report showed that the average growth in the region was considerably greater than the previously used estimates.

By the fall of 1964, a second remeasurement covering 10 seasons of growth had been completed. Average growth rates for the 10-year period — based on 766 plots — are presented in this report.

The growth figures presented here are the answer to a question asked over 16 years ago — What is the wild forest land capable of producing on its own? The results suggest that the forests of 16 years ago grew at a rate sufficient to exceed the drain placed upon them in this period.[2]

In the 16 years since this study was begun, many changes have occurred. The chain-saw has replaced the ax and bucksaw, and it in turn is being challenged by tree-harvesting machines. River-driving has given way to truck-hauling; horses are giving way to crawler tractors and rubber-tired skidders; and so on.

And today, new questions are being asked about intensive forest-management practices designed to meet the ever-increasing

[1] Bickford, C. Allen, Franklin R. Longwood, and Robert Bain. AVERAGE GROWTH RATES IN THE SPRUCE-FIR REGION OF NEW ENGLAND. NE. Forest Exp. Sta., Sta. Paper 140, 23 pp., 1961.

[2] Maine Forest Service. PRIMARY PROCESSOR NEWS LETTER, 1950-1965. Mimeographed. Augusta, Maine.

demands placed upon our spruce-fir forests. The growth figures presented here provide a foundation upon which answers to these questions may be developed.

THE STUDY

The purpose of this study was to obtain estimates of the overall growth rates in the spruce-fir forests of northern New England. The study was designed to estimate the growth rate of the spruce-fir component with an accuracy of plus or minus 10 percent. It was assumed that the accuracy of estimate for the other species groups would be in proportion to their representation in the sample.

The growth of pulpwood species, especially spruce and fir, was our primary interest. In 1950, little value was placed on hardwood species for pulpwood; so sampling in hardwood stands was less intensive.

Sampling Design

Plots were distributed throughout the northern sections of Maine, New Hampshire, and Vermont (fig. 1). Details of the sampling procedure were reported by Bickford *et al.*[1] The sample consisted of randomly selected plots within 27 stand-condition classes. Nonstocked areas (less than 10 percent crown closure) were not sampled. Stand-condition classes were defined on the basis of three levels of stand type, stand height, and stand density, as follows:

Stand type
- S —Softwood (66 to 100 percent softwood species).
- M—Mixedwood (21 to 65 percent softwood species).
- H—Hardwood (0 to 20 percent softwood species).

Stand height
- 1—Less than 35 feet.
- 2—35 to 64 feet.
- 3—65 feet and taller.

Stand density
- A—71 to 100 percent crown closure.
- B—41 to 70 percent crown closure.
- C—11 to 40 percent crown closure.

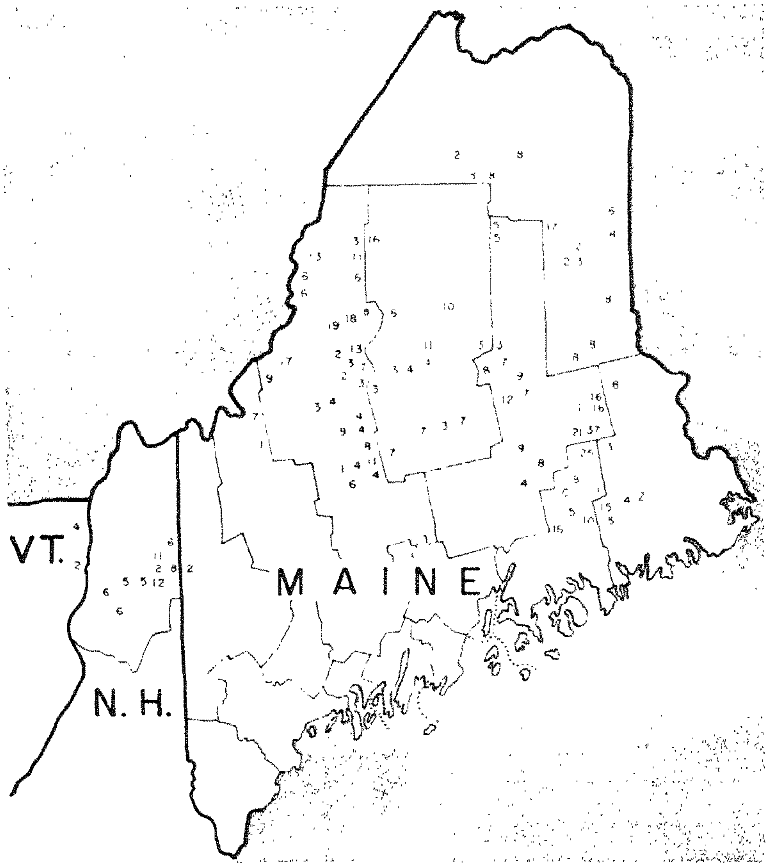

Figure 1.—Distribution of sample plots from which 10-year growth rates were calculated. Numbers indicate plots in a single township.

Any condition class can be identified by three symbols; for example, S2B designates a stand that contained 66 to 100 percent softwood species, averaged 35 to 64 feet in height, and had 41 to 70 percent crown closure.

Where aerial photos were available, the stand condition classes were interpreted by a single experienced photogrammetrist to avoid possible differenes in interpretation among companies. A stereogram illustrating some of the stand condition classes is presented in figure 2. Most of the photos used were taken in the late 1940's or early 1950's so they were up-to-date when interpretations were made. In cases where no photos were available, classification was made on the ground by the field crew. Since no differences between on-the-ground classification and photo-classification were found in the 5-year analysis,[1] all plots were combined for the 10-year analysis.

The field crews re-estimated condition class at the time of each remeasurement, and some changes from the initial classification were noted. However, no analysis of these changes was made, and study results are reported on the basis of the classification at the time of plot establishment.

In spite of efforts to obtain an adequate sample in each condition class, three of the classes (S3C, M3C, and H1C) were not sampled at all. On the other hand, another three classes (S2B, S2A, and M2B) made up 56 percent of the total plot sample (table 1). This irregularity in distribution may reflect the actual

Table 1.—Number of plots, by stand-condition class

Stand type and height class	Density class		
	11-40	41-70	71 or over
	No. plots	*No. plots*	*No. plots*
Softwood			
0-34 feet	3	14	43
35-64 feet	29	134	138
65 feet or over	0	3	7
Mixedwood			
0-34 feet	8	1	4
35-64 feet	25	161	56
65 feet or over	0	2	6
Hardwood			
0-34 feet	0	1	6
35-64 feet	54	28	25
65 feet or over	2	6	10

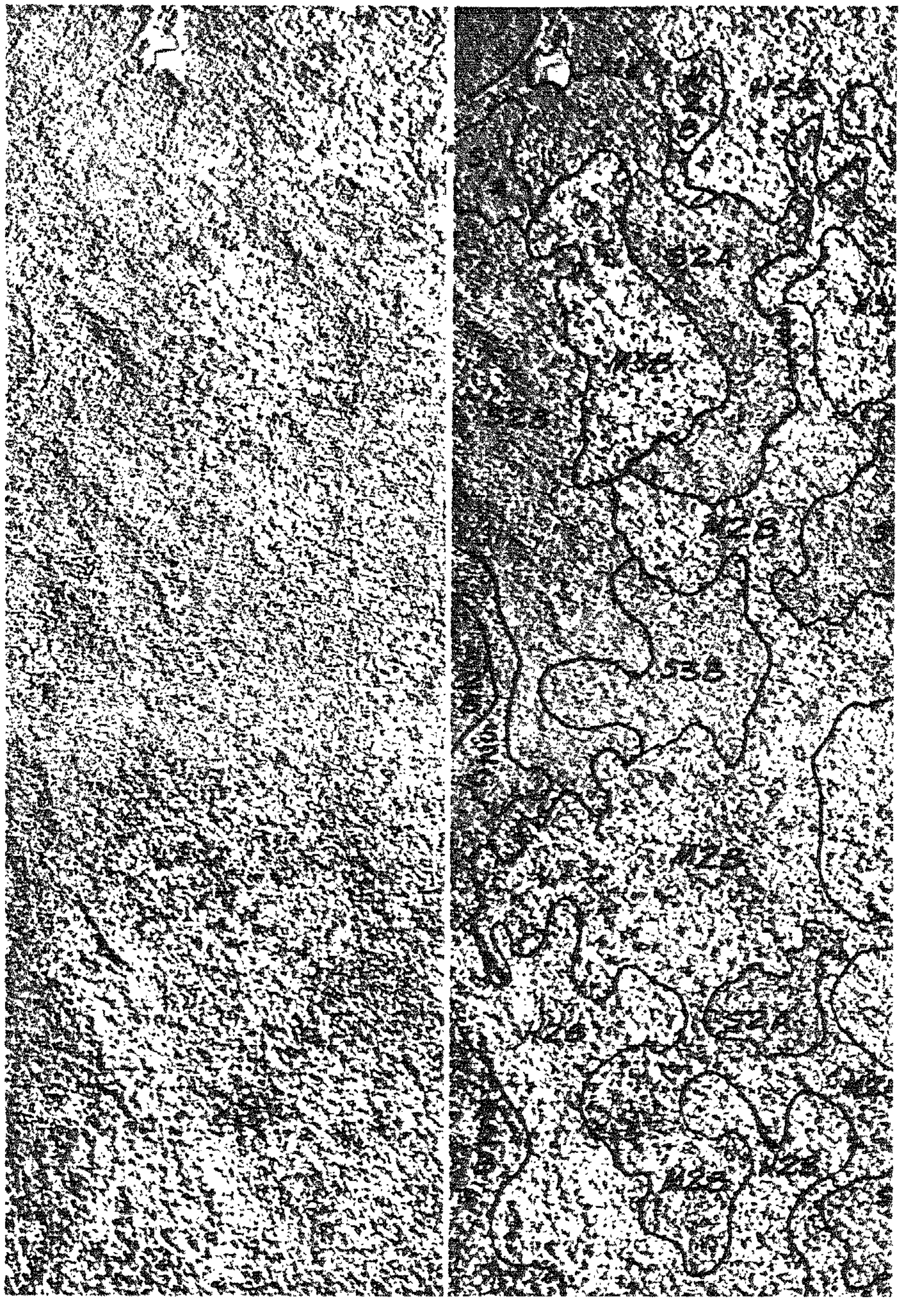

Figure 2.—Stereogram showing examples of some of the stand condition classes sampled. Interpretation by T. Tryon, J. W. Sewall Co., Old Town, Maine. Scale 1:15840; panchromatic film.

distribution of forest stands in nature. Or it may be the result of bias favoring the condition classes that held the greatest interest for the landowners.

The fact that only 766 of the 1,126 plots originally established were used in these calculations is testimony to the difficulties involved in long-term plot-remeasurement studies. Some plots were lost to natural causes — fire, flooding by beavers, and wind storms. Others were lost through forest-management activities — bulldozing of road systems or harvest cutting. Administrative action — sale of land or failure to remeasure — eliminated still others. The final category — human error — eliminated surprisingly few plots when all the chances for mistakes in relocating the plots, measuring the trees, and recording, transcribing, and processing the data are considered.

Growth Components

The change in sound merchantable wood volume from one point in time to another plus the volume of trees harvested during the period is called *net growth*. Net growth is the algebraic sum of *accretion*[3] (growth on trees present at both inventories plus volume added to trees that die or are cut during the interval), *ingrowth* (volume of trees that grew into the minimum size class during the measurement period), and *mortality* (final volume of trees that died or became unmerchantable during the measurement period). *Gross growth* is equal to accretion plus ingrowth. Since this study is concerned primarily with growth rates in natural stands, plots that had heavy cutting were excluded from the calculations.

The term *merchantable* puts certain size and quality limitations on the trees that make up the stand volume. In this study minimum sizes were the 5-inch d.b.h. class for softwoods and the 7-inch d.b.h. class for hardwoods. Minimum top diameter was 4 inches. Quality limitations were that a tree be satisfactory for

[3] Accretion is synonymous with the term "gross growth of initial volume" as defined in Beers, Thomas W., COMPONENTS OF FOREST GROWTH. J. Forestry 60: 245-248, 1962.

use as pulpwood. Species not widely used for pulpwood such as pine, cedar, and some of the hardwoods were judged on the same basis as comparable merchantable species. Any trees considered unsuited for pulpwood were called *cull*, and their volume was excluded from the calculations.

Many merchantable trees also contain defect that makes a part of their volume unmerchantable. There is now no available means of measuring this unseen or hidden defect in standing trees. Consequently, its influence on the growth figures reported here is not fully known. The cooperating companies estimate unseen defect by a wide range of methods that vary from simple rules of thumb to detailed tables for each species and size class. Deduction figures, which vary with tree species and size, range from 2 percent to over 25 percent of the total volume of the tree. In all cases the amount of defect increases with increasing tree size; thus as trees grow, a certain portion of this growth is cancelled by the increase in unseen defect.

Basic Data and Computations

Basic data for the study consisted of a tally by species and 1-inch d.b.h. classes of softwoods 4.5 inches d.b.h. and larger and of hardwoods 6.5 inches d.b.h. and larger. Separate records were kept of ingrowth, mortality, cull, and cut trees.

Basic data were converted to volumes, using Austin Cary's tables[4] as modified by procedures described in the earlier report.[1] Cary's table 8, which gives tree volume, exclusive of stump, to a 4-inch top, was used for all softwoods. Hardwood tables were the same ones used in the 5-year report. These tables were reviewed by foresters of the cooperating companies, and, based on company experience, were judged satisfactory for this study. All volume data represent cubic feet of wood without bark.

Volumes were computed on the basis of average heights, as determined from height-over-d.b.h. curves developed for each major species. These curves were prepared from data collected

[4] Cary, Austin. WOODSMAN'S MANUAL. Fourth Ed., 323 pp., Harvard University Press, Cambridge. 1932.

on four or five sample trees from each plot, augmented where necessary with data from forest-survey plots located in the same general area.

All computations were performed on an IBM 7090 computer, using a program written especially for this study.

In this study net growth was calculated by subtracting live merchantable volume at the beginning of the measurement period from live merchantable volume at the end of the period and adding the volume of any trees cut. (Net growth figures in the 5-year report did not include the volume of cut trees.) Mortality and ingrowth were calculated from individual tallies. Gross growth was obtained by adding mortality to net growth. Accretion was calculated by subtracting ingrowth from gross growth.

Volume data are presented in cubic feet of bark-free wood per acre per year. Appropriate conversion factors may be used to convert cubic feet to cords. The most widely used conversion factors are 85 cubic feet per rough cord (the figure used in this report wherever cord volumes are mentioned) or 96 cubic feet per peeled cord. Some of the effects of unseen defect discussed earlier might be overcome by choice of conversion factor. For example, a company that has rigid quality standards might adjust for unseen defect by using a conversion factor of 88 to 90 cubic feet per rough cord or 100 to 104 cubic feet per peeled cord.

The standard error of the mean and the sampling error are measures of confidence that have been calculated for the various growth estimates in this paper. The standard error of the mean ($S_{\bar{x}}$) for each stand condition class was calculated as follows:

$$S_{\bar{x}} = \sqrt{\frac{S^2}{n}}$$

where S^2 is variance within the class, and n is number of observations within the class. Standard errors for groups of individual classes were pooled to obtain the standard error for the group.

The standard error of the mean evaluates the relation of the sample mean to the true mean. The odds are approximately 2 to 1 (2 times out of 3) that the true mean of a population will fall within the interval of the sample mean plus and minus its standard error. Thus, since the mean growth of this study sample is 41.9 cubic feet per acre per year and the standard error is 0.9 cubic feet per acre per year, the odds are 2 to 1 that the true mean growth lies between 41.0 and 42.8 cubic feet per acre per year. By increasing the interval to plus and minus 2 times the standard error, the odds are increased to approximately 19 to 1 (95 times out of 100). Thus, the odds are 19 to 1 that the true mean growth lies between 40.1 and 43.7 cubic feet per acre per year.

The sampling error is simply the standard error expressed as a percentage of the mean. Thus the sampling error (at 2 to 1 odds) of this sample mean is 2.1 percent (0.9/41.9 x 100 = 2.1).

Analytical problems caused by unequal sample numbers, probable heterogeneity of variance, and interactions among components hindered rigorous testing of the influences of stand type, stand height, and stand density.

Differences among the three levels of each of these stand condition components were evaluated by comparing the confidence intervals formed by the class mean net growth and 2 times its standard error. Means whose confidence intervals did not overlap were considered to be significantly different at the 5-percent level. This is conservative, and it does not account for interaction among stand components. It was used because it provides a straightforward method of comparing means based on unequal sample numbers. As a check, Duncan's new multiple-range test[5] was also used for these comparisons, using a weighted average standard error term. Results of both techniques were the same.

[5] Steel, R. G. D., and J. H. Torrie. PRINCIPLES AND PROCEDURES OF STATISTICS. 481 pp. McGraw Hill Book Co. Inc., New York. 1960.

RESULTS AND DISCUSSION

Average annual increment by growth component varied widely among species groups and stand conditions (tables 2, 3, 4). The reliability of these growth estimates also varied widely, as evidenced by the sampling errors associated with net growth among stand-condition classes (table 5). Each of the stand-condition components — stand type, stand height, and stand density — influenced the growth components (table 6).

Stand type — or percent softwood species — appeared to be the most important factor influencing net growth. Means of all three stand types were clearly different from each other (fig. 3). Softwood stands had the greatest net growth; mixedwood stands

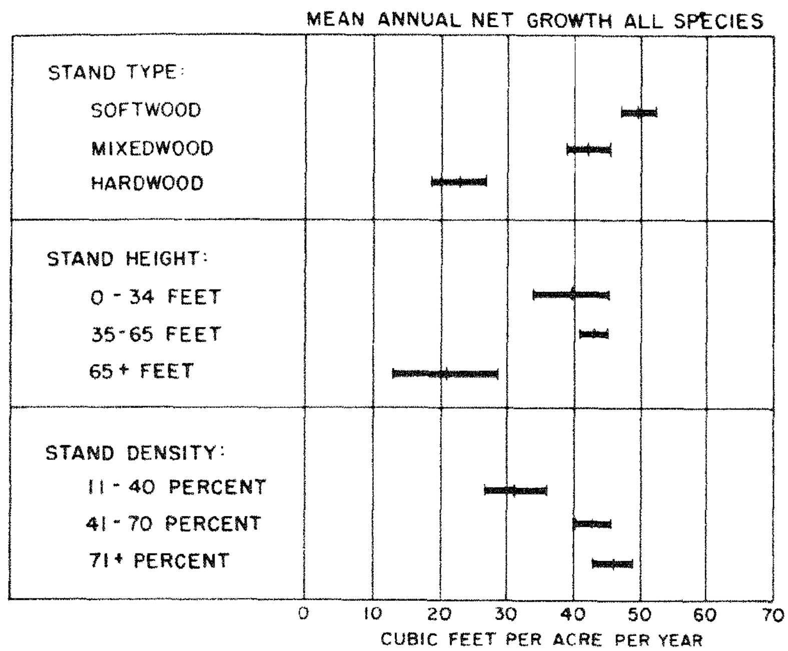

Figure 3.—Weighted mean net growth by stand type, height, and density classes with confidence intervals of 19 to 1 odds ($2S_{\bar{x}}$).

Table 2.—Average annual growth of softwoods, by components and stand-condition classes

Condition class			Plots	Spruce-fir-hemlock			All softwoods			
Type	Height	Density		Accretion	Ingrowth	Mortality	Accretion	Ingrowth	Mortality	Net[1] growth
	Feet	*Percent*	*No.*	*Cubic feet per acre*						
Softwood	0-34	11-40	3	8.8	1.1	0.9	12.2	1.1	0.9	12.4
	35-64	11-40	29	38.0	7.8	4.6	41.2	7.9	7 2	41.9
	65 +	11-40	0	—	—	—	—	—	—	—
Softwood	0-34	41-70	14	32.9	8.9	3.4	34.6	9.1	3.7	40 0
	35-64	41-70	134	45 0	6.2	6.2	52.5	6.6	10 8	48 3
	65 +	41-70	3	25.8	2.2	7 1	51.6	2.2	14.4	39.4
Softwood	0-34	71 +	43	29 1	13.1	2.3	34 1	13.7	3.7	44.1
	35-64	71 +	138	48 8	7.3	7.7	54.8	7.7	10.0	52.5
	65 +	71 +	7	40.7	3.1	11.1	48.8	3 5	14.6	37.7
Mixedwood	0-34	11-40	8	14.1	4.9	.5	14 1	4.9	.5	18.5
	35-64	11-40	25	36.1	6.6	4 8	37 0	6 7	6.3	37.4
	65 +	11-40	0	—	—	—	—	—	—	—
Mixedwood	0-34	41-70	1	12.2	1.6	.0	12.9	1.6	.0	14 5
	35-64	41-70	161	33 1	4 8	5.2	37 3	5.0	6 8	35 5
	65 +	41-70	2	25.1	5.5	12 6	28.0	5 5	20.4	13 1
Mixedwood	0-34	71 +	4	34.1	5.8	1 4	35.8	5 9	1 7	40 0
	35-64	71 +	56	38.4	5.7	7.7	41.2	5.9	7 9	39 2
	65 +	71 +	6	25.8	2.4	13.9	26 4	2.5	14 4	14.5
Hardwood	0-34	11-40	0	—	—	—	—	—	—	—
	35-64	11-40	54	10.8	3.0	1.3	0 8	3.0	1.3	12.5
	65 +	11-40	2	3.5	.7	.0	3.5	.7	.0	4.2
Hardwood	0-34	41-70	1	.0	.5	.0	.0	.5	.0	.5
	35-64	41-70	28	10 5	1.9	3 4	10.9	2.0	3 6	9.3
	65 +	41-70	6	6.6	1.1	4.5	7.8	1.1	4.5	4 4
Hardwood	0-34	71 +	6	7.0	.2	4.0	7.9	.2	4.0	4 1
	35-64	71 +	25	3.9	.9	1.6	3 9	.9	1.6	3.2
	65 +	71 +	10	6.7	.9	.0	6.7	.9	.0	7.6
All stands[2]	—	—	766	33.9	5.7	5.3	38.1	6.0	7.2	36.9

[1] May differ slightly from gross growth minus mortality because of rounding-off the calculations
[2] Weighted average.

Table 3.—Average annual growth of hardwoods, by components and stand-condition classes

Condition class			Plots	Beech-birch-maple[1]			All hardwoods			
Type	Height	Density		Accretion	Ingrowth	Mortality	Accretion	Ingrowth	Mortality	Net[2] growth
	Feet	*Percent*	*No.*	*Cubic feet per acre*						
	0-34	11-40	3	0.0	0.8	0.0	0.0	0.8	0.0	0.8
Softwood	35-64	11-40	29	1.7	.9	3.3	1.3	1.0	3.9	— 1.6
	65 +	11-40	0	—	—	—	—	—	—	—
	0-34	41-70	14	1.6	2.4	3.2	1.6	2.8	3.2	1.2
Softwood	35-64	41-70	134	3.3	2.3	4.6	3.8	2.7	5.1	1.4
	65 +	41-70	3	1.7	1.4	4.0	1.7	1.4	4.0	— .9
	0-34	71 +	43	.5	.1	.3	.5	.2	.3	.4
Softwood	35-64	71 +	138	3.3	2.3	3.2	3.9	2.5	3.7	2.7
	65 +	71 +	7	.0	2.0	4.5	.1	2.3	4.5	— 2.1
	0-34	11-40	8	4.2	5.9	.8	5.7	11.5	2.6	14.6
Mixedwood	35-64	11-40	25	6.0	4.8	4.9	6.7	5.0	4.9	6.8
	65 +	11-40	0	—	—	—	—	—	—	—
	0-34	41-70	1	6.9	16.4	.0	14.7	21.0	.0	35.7
Mixedwood	35-64	41-70	161	10.0	5.0	8.6	10.3	5.6	9.8	6.1
	65 +	41-70	2	16.8	4.5	2.6	16.8	4.5	2.6	18.7
	0-34	71 +	4	2.5	2.3	2.2	2.7	2.3	3.0	2.0
Mixedwood	35-64	71 +	56	9.5	4.0	9.4	10.1	4.4	10.3	4.2
	65 +	71 +	6	14.1	2.8	31.4	14.1	3.1	31.9	—14.7
	0-34	11-40	0	—	—	—	—	—	—	—
Hardwood	35-64	11-40	54	14.1	6.4	13.6	14.6	6.9	13.9	7.6
	65 +	11-40	2	10.0	12.4	.0	10.0	12.4	.0	22.4
	0-34	41-70	1	10.1	6.7	7.1	14.0	17.8	7.1	24.7
Hardwood	35-64	41-70	28	21.1	9.7	17.8	23.1	10.1	19.6	13.6
	65 +	41-70	6	25.1	5.5	21.6	25.1	5.8	21.6	9.3
	0-34	71 +	6	9.9	4.9	3.6	10.4	9.0	3.6	15.8
Hardwood	35-64	71 +	25	12.9	11.2	9.6	22.3	16.9	12.0	27.2
	65 +	71 +	10	22.9	8.2	20.0	23.9	8.6	20.0	12.5
All stands[3]	—	—	766	7.3	4.0	7.0	8.1	4.6	7.7	5.0

[1] Includes beech, sugar maple, red maple, and yellow birch.
[2] May differ slightly from gross growth minus mortality because of rounding-off the calculations.
[3] Weighted average.

Table 4.—Average annual growth of all species, by components and stand-condition classes

Condition class			Plots	All species				
Type	Height	Density		Accretion	In-growth	Mor-tality	Net growth	Gross growth
	Feet	*Percent*	*No.*	- - -	*Cubic feet per acre*	- - -		
	0-34	11-40	3	12.2	1.9	0.9	13.4	14.1
Softwood	35-64	11-40	29	42.5	8.9	11.1	40.2	51.4
	65+	11-40	0	—	—	—	—	—
	0-34	41-70	14	36.2	11.9	6.9	41.4	48.1
Softwood	35-64	41-70	134	56.3	9.3	15.9	49.5	65.6
	65+	41-70	3	53.3	3.6	18.4	38.4	56.9
	0-34	71+	43	34.6	13.9	4.0	44.5	48.5
Softwood	35-64	71+	138	58.7	10.2	13.7	55.1	68.9
	65+	71+	7	48.9	5.8	19.1	35.6	54.7
	0-34	11-40	8	19.8	16.4	3.1	33.0	36.2
Mixedwood	35-64	11-40	25	43.7	11.7	11.2	44.4	55.4
	65+	11-40	0	—	—	—	—	—
	0-34	41-70	1	27.6	22.6	.0	50.4	50.2
Mixedwood	35-64	41-70	161	47.6	10.6	16.6	41.7	58.2
	65+	41-70	2	44.8	10.0	23.0	31.9	54.8
	0-34	71+	4	38.5	8.2	4.7	42.1	46.7
Mixedwood	35-64	71+	56	51.3	10.3	18.2	43.6	61.6
	65+	71+	6	40.5	5.6	46.3	.1	46.1
	0-34	11-40	0	—	—	—	—	—
Hardwood	35-64	11-40	54	25.4	9.9	15.2	20.1	35.3
	65+	11-40	2	13.5	13.1	.0	26.7	26.6
	0-34	41-70	1	14.0	18.3	7.1	25.4	32.3
Hardwood	35-64	41-70	28	34.0	12.1	23.2	22.8	46.1
	65+	41-70	6	32.9	6.9	26.1	13.8	39.8
	0-34	71+	6	18.3	9.2	7.6	19.8	27.5
Hardwood	35-64	71+	25	26.2	17.8	13.6	30.4	44.0
	65+	71+	10	30.6	9.5	20.0	20.1	40.1
All stands[2]	—	—	766	46.1	10.6	14.8	41.9	56.7

[1] May differ slightly from gross growth minus mortality because of rounding-off the calculations.

[2] Weighted average.

Table 5.—Mean annual net growth of all species, by stand-condition class, with associated standard errors and sampling errors at 2 to 1 odds

Condition class			Plots	Net growth	Standard error	Sampling error
Type	Height	Density				
	Feet	*Percent*	*No.*	*Cubic feet*	*Cubic feet*	*Percent*
	0-34	11-40	3	13.4	14.2	106
Softwood	35-64	11-40	29	40.2	4.6	11
	65+	11-40	0	—	—	—
	0-34	41-70	14	41.4	6.6	16
Softwood	35-64	41-70	134	49.5	2.1	4
	65+	41-70	3	38.4	14.2	37
	0-34	71+	43	44.5	3.8	8
Softwood	35-64	71+	138	55.1	2.1	4
	65+	71+	7	35.6	9.3	26
	0-34	11-40	8	33.0	8.7	26
Mixedwood	35-64	11-40	25	44.4	4.9	11
	65+	11-40	0	—	—	—
	0-34	41-70	1	50.4	24.6	49
Mixedwood	35-64	41-70	161	41.7	1.9	4
	65+	41-70	2	31.9	17.4	54
	0-34	71+	4	42.1	12.3	29
Mixedwood	35-64	71+	56	43.6	3.3	8
	65+	71+	6	.1	10.0	10,000
	0-34	11-40	0	—	—	—
Hardwood	35-64	11-40	54	20.1	3.4	17
	65+	11-40	2	26.7	17.4	65
	0-34	41-70	1	25.4	24.6	97
Hardwood	35-64	41-70	28	22.8	4.6	20
	65+	41-70	6	13.8	10.0	72
	0-34	71+	6	19.8	10.0	50
Hardwood	35-64	71+	25	30.4	4.9	16
	65+	71+	10	20.1	7.8	39
All stands	—	—	766	41.9	0.9	2.1

Table 6.—Weighted means of growth components for all species by stand condition class component

Condition-class component	Plots	Growth component				
		Accretion	Ingrowth	Mortality	Gross growth	Net growth[1]
	No.	*Cubic feet per acre per year*				
Stand type:						
Softwood	371	52.3	10.1	13.0	62.4	49.3
Mixedwood	263	46.8	10.7	16.5	57.5	41.1
Hardwood	132	27.5	11.8	16.8	39.3	22.5
Stand height:						
0-34 feet	80	31.2	12.9	4.6	44.1	39.5
35-64 feet	650	48.4	10.5	15.6	58.9	43.3
65 feet or over	36	37.9	7.4	24.2	45.4	21.3
Stand density:						
11-40 percent	121	32.4	10.3	12.0	42.7	30.7
41-70 percent	350	49.0	10.2	16.6	59.2	42.6
71 percent or over	295	48.4	11.1	13.9	59.5	45.6

[1] May differ slightly from gross growth minus mortality because of rounding-off the calculations.

were intermediate in net growth; and hardwood stands were much lower in net growth than either of the others. Hardwood species grew poorly regardless of the stand type in which they occurred. In hardwood stands — which were at least 80 percent hardwoods — hardwood species contributed only 61 percent of the net growth; in mixedwood stands — which were between 35 and 80 percent hardwoods — hardwood species contributed only 13 percent of the net growth (table 7).

The contribution of spruce and fir to net growth ranged from 86 percent (0.5 cord per acre) in softwood stands to 30 percent (0.1 cord per acre) in hardwood stands, and they accounted for 75 percent (0.4 cord per acre) of total net growth of all stands. Softwood species contributed 88 percent of the net growth on all plots. Softwood species even acocunted for 39 percent of the growth in hardwood stands. Most softwood species made their greatest growth in softwood stands, but hemlock made its greatest growth in mixedwood stands where it was most abundant. Cedar did equally well in softwood and mixedwood stands.

The greatest contributions to overall net growth by hardwood

Table 7.—Average annual net growth by individual species per acre

Species	Softwood stands		Mixedwood stands		Hardwood stands		All stands	
	Cubic feet	*Percent*	*Cubic feet*	*Percent*	*Cubic feet*	*Percent*	*Cubic feet*	*Percent*
Pine	1.5	3	0.2	1	0.1	([1])	0.8	2
Spruce	25.0	51	15.8	39	5.8	26	18.6	44
Fir	17.1	35	13.1	32	.8	4	12.9	31
Hemlock	2.3	5	4.3	10	1.9	9	2.9	7
Cedar	2.0	4	2.0	5	.1	([1])	1.5	4
Tamarack	.1	([1])	([2])	([1])	([2])	([1])	([2])	([1])
Total softwoods	48.0	98	35.5	87	8.7	39	36.7[3]	88
Sugar maple	([2])	([1])	0.8	2	4.4	19	1.1	3
Red maple	1.5	3	3.7	9	1.9	9	2.3	6
Yellow birch	—.8	—2	—.1	([1])	.2	1	—.4	—1
Paper birch	.4	1	1.0	2	.4	2	.6	1
Beech	.1	([1])	.1	([1])	3.5	16	.7	2
Aspen	.1	([1])	.2	([1])	2.5	11	.6	1
Miscellaneous[4]	([2])	([1])	—.1	([1])	.8	3	.1	([1])
Total hardwoods	1.3	2	5.6	13	13.7	61	5.0[3]	12
Total all species	49.3	100	41.1	100	22.4	100	41.7[3]	100

[1] Less than 0.5 percent.
[2] Less than 0.05 cubic feet.
[3] Differs slightly from overall average calculated on plot basis because of rounding-off calculations.
[4] Ash (white, green, black), basswood, cherry, elm, grey birch, hornbeam, and striped maple.

species were made by the maples, beech, aspen and white birch — a total of 13 percent (0.1 cord per acre). Red maple and white birch made their greatest growth in mixedwood stands. All other hardwood species made their greatest growth in the hardwood stands. Yellow birch had an overall negative net growth; only in hardwood stands did its growth factors exceed mortality.

One possible explanation for the slower growth of hardwood stands (and species) may be tree size. Because of the larger minimum diameter for hardwood species, the diameter of the tree of average basal area — calculated on the basis of 491 of these plots used in another study — was 11 inches versus 7 inches for softwoods. Thus many of the young vigorous hardwoods may have been excluded and more emphasis placed on the larger, older trees that were perhaps less vigorous.

A large proportion of the plots (85 percent) in this study were in the 35- to 64-foot height class. Since so few plots were involved in the 0- to 34-foot and 65+-foot height classes, no strong statements can be made about the influence of height on net growth. However, the 65+-foot height class had significantly lower average net growth than the other two classes (fig. 3). The high mortality rate (table 6) for this height class is one reason for this result. Spruce-fir stands in this region do not grow much taller than 65 to 70 feet, even on the best sites, before the stands start to break up. There also may have been some confounding with stand types: of the 36 plots in the 65+-foot height class, 50 percent were in the hardwood stand type.

In general, net growth increased as stand density increased (table 6). The lowest class (11 to 40 percent) was significantly lower than the other two classes (fig. 3). This result differs slightly from the 5-year results, which showed the upper class (greater than 71 percent) significantly higher than the lower two classes. The low net growth in the lower density class was consistent for all stand types when the trees were less than 65 feet tall. Stands in the 11-to-40-percent density class and greater than 65 feet tall are apparently not common, for only two plots were sampled in these classes.

Comparison with 5-Year Results

The overall average annual net growth figure reported here is not significantly different from the overall average based on the 5-year remeasurement data (41.9 ± 1.8 versus 45.0 ± 3.0 cubic feet per acre). Doubling the length of the measurement period decreased variation even though 100 fewer plots were used in the calculation of the 10-year results. The standard error of mean annual net growth decreased from 1.5 cubic feet for the 5-year data to 0.9 cubic feet for the 10-year data. The corresponding sampling errors decreased from 3.3 to 2.1 percent. Ten-year mean values for condition classes that were based on a large number of plots were closer to corresponding 5-year means than those 10-year values based on only a few plots.

Mortality expressed as a percent of net growth was slightly greater this time than for the 5-year figure (35 percent versus 26 percent). Ingrowth as a percent of accretion was decidedly lower than the 5-year figure (23 percent versus 47 percent), while the actual amount of accretion remained equal (46 cubic feet per acre per year). Thus it appears that a slight increase in mortality coupled with a decrease in ingrowth has added up to a slightly lower overall average growth figure than the 5-year results.

Using the Growth Figures

Strictly speaking, the growth figures presented in this report provide an estimate of how much the various forest condition classes grew under the conditions that existed during the measurement period. This fact must be recognized and the assumption made that conditions are equivalent when attempting to apply these figures to other areas of land for the purpose of estimating forest growth.

These data represent growth of natural stands that have had a minimum of past silvicultural treatment. In most cases stands were cut lightly in the past, and only the largest and best trees were removed. In some cases the residual stand was young and vigorous; in other cases poor-quality, low-vigor trees made the residual stand less desirable. Application of modern management techniques and silvicultural practices to present and future stands will influence the applicability of these growth estimates. Work should be directed toward developing stands wtih growth rates above our present wild levels by bringing the underproducing stands up to their full capacity. For example, net growth could be boosted to an annual average of 0.7 cord per acre by keeping present stands healthy and by harvesting the 35 percent of net growth that is currently lost to mortality.

On the other hand, application of management could have some negative aspects. Logging damage to residual trees could result in a period of increased mortality or larger numbers of cull trees, which could cause a decrease in net growth. Partial cutting may result in stands susceptible to windthrow — another source of mortality. These are problems that the silviculturalist and forest manager will have to face in applying management to the forests. Certainly forest management should boost net growth above that possible under natural conditions.

There is always a risk involved in trying to apply averages to specific cases. In the case of these average growth figures the larger the forest area to be evaluated, the better the chances are that the estimated growth rate will be close to the true growth rate.

The best estimate of growth for any size of area can be obtained by using the individual stand-condition-class averages (tables 2, 3, 4). If the area is large — 5,000 acres or more — the average thus obtained will approach the overall average of 41.9 cubic feet per acre, and this figure may be used if one wants a quick estimate of growth for such a large area. Similarly for medium-sized areas — 1,000 to 5,000 acres — the averages by stand type (table 6) should provide adequate estimates of growth without detailed typing.

No shortcuts are possible with areas of 1,000 acres or less. The reliability of the estimate here depends on the distribution of stands within the original stand classification. If all or a major portion of the area is in one of the 27 condition classes for which a large number of plots was measured — S2C, S2B or M2B — the estimate of growth based on the figures from tables 2, 3 and 4 should be satisfactory. The large sampling errors for classes represented by small numbers of plots make estimates based on these classes unreliable.

Thus the use of these growth figures in predicting growth requires caution and judgment on the part of the user. A good knowledge of the stands to which the growth figures are to be applied is required. These stands should be natural — without silvicultural treatment — and should have a species composition similar to the sampled stands. If aerial photos are used to interpret stand-condition class, the age of the photos is of prime importance. Stand interpretation based on 10-year-old photos can be used to estimate what the stand grew during the past 10-year period. To estimate future growth, current stand classifications obtained from new photos or on-the-ground interpretations should be used.

These average growth figures definitely should not be applied to plantations or other intensively managed stands or to cutover areas.

SUMMARY AND CONCLUSIONS

This report presents average annual values for the components of forest growth in the spruce-fir region of northern New England by stand-condition classes. A sample of 766 plots was used. The overall average annual net growth for all species was 41.9 cubic feet per acre with a sampling error of 2.1 percent. Sampling error decreased from 3.3 percent on the 5-year data even though there were 100 fewer plots in the sample. This 10-year average is lower than the previously reported 5-year average beacuse of a slight increase in the proportion of mortality and a fairly substantial decrease in ingrowth.

Softwood stands had the highest growth rates. Spruce and fir made major contributions to the growth of softwood stands and even contributed 30 percent of growth in hardwood stands. Hardwood stands and species had lower growth rates. These lower rates were at least partly explained by the higher minimum diameter for hardwood species.

These results provide a reliable estimate of growth in the natural extensively-managed stands of the region during the past 10-years. Precautions must be taken when using these results to predict future growth of forest stands.

These average growth rates can serve as a basis for forest managers to appraise the effects of their management practices. Silvicultural treatments that increase net growth above these wild stand rates should be sought and applied.

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