United States Department of Agriculture

Forest Service

Northeastern Forest Experiment Station

Research Paper NE-517

1983

Growth Response of Managed Uneven-aged Northern Conifer Stands

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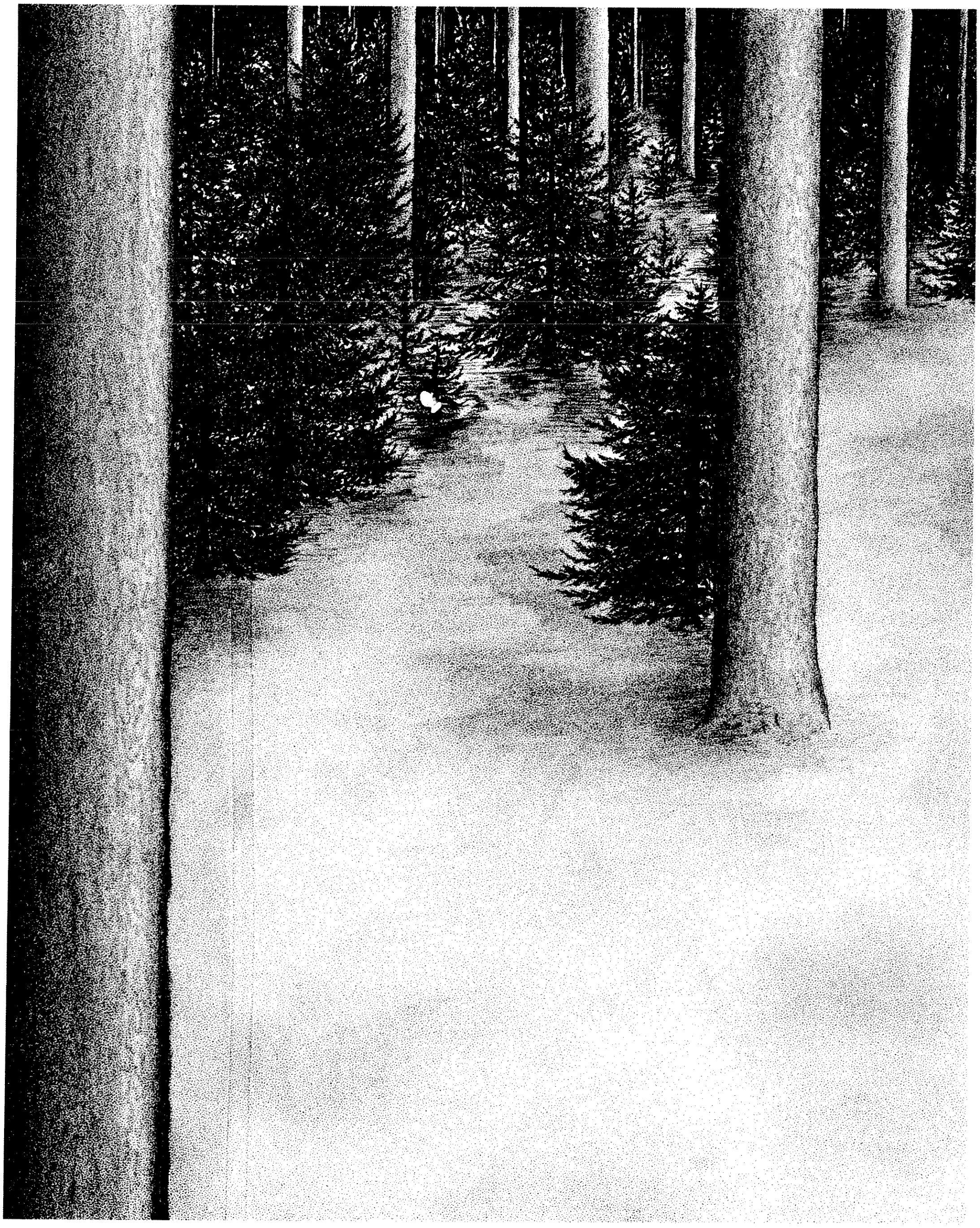

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Abstract

The growth response of trees in spruce-fir-hemlock stands was recorded from plots that were managed to control stand density, species composition, length of harvest interval, and salvage of mortality. Basal area, volume, and diameter increment are presented by species and size classification for harvesting intervals of 5, 10, and 20 years.

Manuscript received
for publication 24 May 1982

Introduction

As landowners intensify forest management, silvicultural decisions need to be based on reliable growth information. Natural spruce-fir stands growing on good locations are capable of fast growth with high levels of growing stock (Hughes 1970). However, mortality may occur in these stands and usable volume may be lost. The growth response of a forest stand depends on the degree and type of management it receives. As a result of management practices, growth responses may vary by size class for differences in species composition, levels of density, and length of harvesting interval. The silvicultural treatment then becomes a basis upon which the forest manager is able to decide on the type and amount of growing stock that will produce the desired growth response.

A study was established in uneven-aged spruce-fir-hemlock stands in the Penobscot Experimental Forest, Bradley, Maine to determine the growth response of northern conifer stands to different levels of management. Permanent plots were located throughout these stands to monitor the growth response.

Methods

The plots selected for analysis had similar species compositions: predominantly red spruce, *Picea rubens* Sarg.; balsam fir, *Abies balsamea* (L.) Mill.; Eastern hemlock, *Tsuga canadensis* (L.) Carr.; white spruce, *Picea glauca* (Moench) Voss; and black spruce, *Picea mariana* (Mill.) B.S.P.. Associated species are white cedar, *Thuja occidentalis* L., and white pine, *Pinus strobus* L., with less than 25 percent hardwoods, red maple *Acer rubrum* L., and paper birch, *Betula papyrifera* Marsh. (Table 1). The soils within the study area are complexes of well-drained to poorly drained soils. Marlow, Peru, and

Table 1.—Species composition after initial treatment (in percent of basal area)

Residual basal area[a]	Harvest interval	Number of plots	Species														
			Balsam fir			Spruces			Eastern hemlock			Other softwood			Hardwoods		
			Pole-timber	Saw-timber	Stand total	Pole-timber	Saw-timber	Stand total	Pole-timber	Saw-timber	Stand total	Pole-timber	Saw-timber	Stand total	Pole-timber	Saw-timber	Stand total
ft²/acre	*Years*																
40	5	12	13.7	0.0	13.7	12.1	3.0	15.2	22.9	16.3	39.2	9.5	6.3	15.8	12.8	3.3	16.1
	10	21	25.3	.0	25.3	10.9	7.2	18.1	8.2	14.0	22.2	13.0	5.6	18.6	14.2	1.7	15.9
	20	21	14.8	.0	14.8	11.1	2.2	13.3	20.0	11.9	31.9	20.0	3.7	23.7	14.1	2.2	16.3
60	5	42	12.1	.1	12.3	7.0	7.8	14.7	17.5	24.4	41.9	11.1	2.5	13.5	12.4	5.2	17.6
	10	54	16.2	.0	16.2	14.8	11.1	25.9	15.5	15.9	31.4	12.6	2.0	14.6	10.3	1.7	11.9
	20	39	14.8	.0	14.8	12.4	4.4	16.8	18.0	14.0	32.0	14.8	3.6	18.4	14.8	3.2	18.0
80	5	65	7.6	.1	7.7	9.2	12.4	21.6	16.3	25.3	41.6	10.9	3.2	14.1	11.2	3.8	15.0
	10	84	14.5	.0	14.5	12.7	10.6	23.3	16.6	21.2	37.8	9.2	2.3	11.5	9.5	3.4	12.9
	20	51	11.4	.0	11.4	16.3	10.4	26.7	18.4	19.3	37.7	11.0	3.4	14.4	8.0	1.8	9.8
100	5	88	6.9	.1	7.1	9.9	9.2	19.1	18.1	26.8	44.9	8.9	3.9	12.8	11.6	4.5	16.1
	10	43	8.8	.3	9.1	13.1	13.0	26.1	18.0	25.1	43.1	10.9	2.3	13.1	5.9	2.8	8.6
	20	30	9.8	.0	9.8	14.5	10.9	25.4	13.5	23.8	37.3	11.9	4.2	16.1	8.3	3.1	11.4
120	5	47	6.8	.0	6.8	10.0	8.9	18.9	20.0	27.8	47.9	5.7	7.2	12.9	9.5	3.9	13.5
	10	19	1.9	.0	1.9	9.6	10.3	19.9	27.9	24.9	52.8	10.1	3.9	14.0	8.8	2.6	11.4
	20	9	5.1	.0	5.1	8.5	10.1	18.6	22.0	33.9	55.9	10.2	3.9	13.6	3.4	3.4	6.8

[a] For conversion to square meters per hectare multiply by 0.229568.

Monarda are the most common well-drained to poorly drained soils on glacial till. Buxton, Stantic, and Bideford are examples of moderately well-drained to poorly drained soils on marine sediments.

A total of 359 one-fifth-acre circular plots were randomly located over similar site conditions in the treated forest stands. Trees were initially marked to remove large diameter trees and nonmerchantable, overmature, and poor quality trees. Harvesting began in 1953, using an interval of 5, 10, or 20 years. The remaining trees were remeasured every 5 years, and before and after harvesting (Frank and Blum 1978).

The number of plots used for analysis was:

Interval	*No.*
20 years	150
10 years	127
5 years	75
Total	352

After each harvest, plots were recategorized by residual basal area class to obtain an average growth response for the next harvesting interval. This reorganization of plots resulted in a total of 645 harvest-interval plots for analysis. Trees 4.5 inches and larger in dbh were measured and placed in 1-inch diameter classes and in condition categories: growing stock, ingrowth, or mortality.

The basal area at each inventory was computed for trees 4.5 inches and larger. Each plot was placed in a residual basal area class, from 40 to 120 square feet, by 20-square-foot increments. The mean annual growth rate was then determined for each harvesting interval. The basal area and volume growth were averaged across the plots in each residual basal area class.

Only trees 4.5 inches dbh and larger were used to compute basal area and volume per acre. Volume growth was estimated from local volume tables for the merchantable volume of the tree. Merchantable volume is the volume of the bole from a 1-foot stump to a 4-inch top. An analysis of variance was completed for basal area, volume, and mean stand diameter growth components by residual basal area classes for each harvesting interval, species, and size class of poletimber (4.5 to 9.5 inches dbh) and sawtimber (9.5+ inches dbh). The plots ranged from 20 to 50 percent sawtimber with an average of 40 percent for all plots combined.

The growth components of interest in this paper have been defined (Gilbert 1954; Beers 1962; Marquis and Beers 1969; Solomon 1977). They are:

1. Survivor growth: Growth of trees present at both inventories
2. Ingrowth: Basal area or volume of trees that grew into measurable size between inventories
3. Gross growth: Total growth produced by all trees during the period (net growth + mortality)
4. Net growth: The net change in trees between two inventories (survivor growth + ingrowth − mortality)
5. Mortality: Trees that died during the measurement period (excluding ingrowth trees that died)
6. Accretion: Growth of trees present at the initial inventory plus growth on ingrowth, mortality and harvested trees.

Accretion was not used because trees were not marked and growth recorded for individual trees. Thus, the accretion on harvested and mortality trees could not be determined. The accretion on these trees was combined into mortality. Also, the accretion on ingrowth trees was included in ingrowth because the diameter measurement classes used were broad.

Results

Gross Growth

Average annual gross growth in basal area and volume per acre remained relatively constant over a range of residual basal areas and different harvesting intervals (Tables 2a and 2b). Gross growth increased slightly as the harvesting interval increased. The increase of 2.72 to 3.47 square feet was significant as both the residual basal area in the stand and the length of harvesting interval changed (Tables 2a and 2b). This increase may be due in part to the retention of sawtimber-size trees in the higher basal area classes. The merchantable volume of 52 to 70 cubic feet per acre per year is comparable to the gross growth of other softwood stands in the spruce-fir region of New England (Safford 1968). And, depending upon which volume tables or equations were used, differences in merchantable volume estimates can be expected (Bickford et al. 1961, Hart 1964).

Net Growth

Average annual net growth, expressed in square feet of basal area and cubic foot volume for all species, was significantly different for the different residual basal area classes and harvest intervals (Table 2a). The net growth of the total stand was between 2 and 3 square feet and differed significantly as the residual basal area and harvest interval increased. Also, when trees on plots were separated by size class, poletimber net growth decreased and sawtimber net growth increased significantly as residual

Table 2a.—Average annual gross growth, net growth, survivor growth, ingrowth, and mortality by size class, residual basal area, and harvest interval (in square feet of basal area per acre)[a]

Residual Basal Area	Harvest Interval	Gross Growth	Net Growth			Survivor Growth			Ingrowth		Mortality		
			Pole-timber	Saw-timber	Stand total	Pole-timber	Saw-timber	Stand total	Pole-timber	Saw-timber	Pole-timber	Saw-timber	Stand total
ft²/acre	*Years*												
	5	3.22	1.78	1.39	3.17	1.58	0.61	2.19	1.03	0.79	0.05	0.00	0.05
40	10	2.72	1.05	.92	1.96	1.27	.37	1.64	1.08	.64	.67	.09	.76
	20	3.25	1.23	1.63	2.86	1.53	.58	2.11	1.14	1.08	.36	.03	.39
	5	3.23	1.06	1.68	2.74	1.43	.71	2.14	1.09	1.04	.41	.07	.49
60	10	3.12	1.01	1.53	2.54	1.52	.63	2.15	.97	1.00	.48	.10	.58
	20	3.28	.96	1.71	2.67	1.65	.66	2.31	.97	1.16	.49	.11	.60
	5	3.19	.59	1.92	2.50	1.41	.98	2.40	.80	1.05	.58	.11	.70
80	10	3.15	.63	1.76	2.38	1.51	.85	2.36	.79	1.10	.57	.19	.76
	20	3.27	.58	2.03	2.61	1.57	.92	2.49	.79	1.28	.50	.16	.66
	5	3.28	.40	2.29	2.70	1.46	1.11	2.57	.72	1.30	.47	.11	.58
100	10	3.27	.19	2.39	2.58	1.53	1.06	2.59	.68	1.54	.49	.20	.68
	20	3.23	.43	2.15	2.58	1.42	1.12	2.53	.70	1.15	.53	.12	.65
	5	3.47	.39	2.32	2.71	1.65	1.17	2.81	.67	1.35	.56	.19	.75
120	10	3.04	.09	2.23	2.32	1.44	1.04	2.48	.56	1.43	.50	.22	.72
	20	3.13	−.09	2.72	2.63	1.17	1.56	2.72	.40	1.33	.33	.17	.49

[a] For conversion to square meters per hectare multiply by 0.229568.

Table 2b.—Average annual gross growth, net growth, survivor growth, ingrowth, and mortality by size class, residual basal area, and harvest interval (in merchantable cubic feet per acre—excluding bark, 1-foot stump, and 4-inch top)[a]

Residual Basal Area[b]	Harvest Interval	Gross Growth	Net growth			Survivor Growth			Ingrowth		Mortality		
			Pole-timber	Saw-timber	Stand total	Pole-timber	Saw-timber	Stand total	Pole-timber	Saw-timber	Pole-timber	Saw-timber	Stand total
ft²/acres	*Years*												
	5	60.35	30.64	29.00	59.64	32.20	14.67	46.87	13.48	14.38	0.70	0.00	0.70
40	10	52.13	18.58	20.36	38.94	28.74	9.29	38.03	14.10	12.71	11.56	1.63	13.19
	20	62.54	22.02	33.83	55.85	33.71	14.03	47.74	14.80	20.48	6.10	.58	6.68
	5	61.15	17.62	35.20	52.82	29.87	17.56	47.43	13.77	19.22	6.83	1.49	8.32
60	10	62.02	18.63	33.29	51.92	33.36	16.18	49.54	12.53	19.25	8.02	2.08	10.10
	20	63.96	17.81	35.52	53.33	35.72	15.97	51.69	12.28	21.90	8.29	2.33	10.62
	5	63.80	10.29	41.54	51.83	29.71	24.51	54.22	9.67	19.62	9.40	2.57	11.97
80	10	64.40	12.20	38.68	50.88	32.95	21.65	54.60	9.82	20.99	9.57	3.96	13.53
	20	68.46	11.74	44.72	56.46	34.76	23.65	58.41	10.08	24.75	8.40	3.59	11.99
	5	66.22	6.48	49.61	56.09	30.26	27.53	58.04	8.43	24.45	7.76	2.37	10.13
100	10	68.70	4.63	51.94	56.57	33.39	26.94	60.32	8.34	29.13	8.00	4.13	12.13
	20	68.72	8.94	48.26	57.20	31.33	28.65	59.98	8.74	22.07	9.06	2.46	11.52
	5	70.14	7.10	49.12	56.22	33.58	28.88	62.83	7.68	24.68	9.48	4.44	13.92
120	10	61.94	.97	48.50	49.47	29.07	26.39	55.46	6.44	26.47	8.10	4.35	12.45
	20	68.81	.35	60.11	60.46	24.73	39.15	63.88	4.92	24.32	5.01	3.34	8.35

[a] For conversion to cubic meters per hectare multiply by 0.069973.
[b] For conversion to square meters per hectare multiply by 0.229568.

basal area increased (Fig. 1 and 2). Although there are statistically significant differences among harvest intervals, no direct relationship was apparent for the total stand or when trees were separated by size classes. The difference between poletimber growth and sawtimber growth was less for the 10-year harvest interval than for the other two intervals.

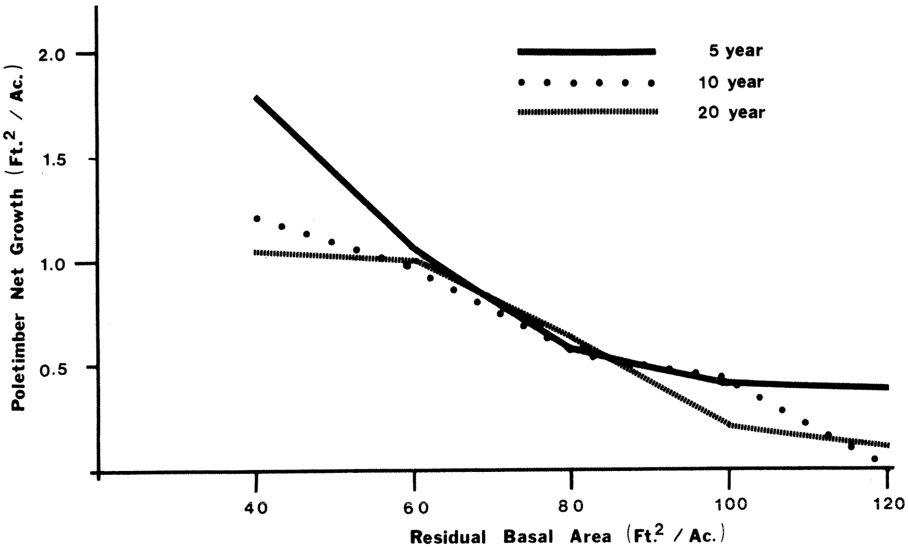


Figure 1.—Average annual poletimber net growth for 5-, 10-, and 20-year harvest intervals by residual basal area.

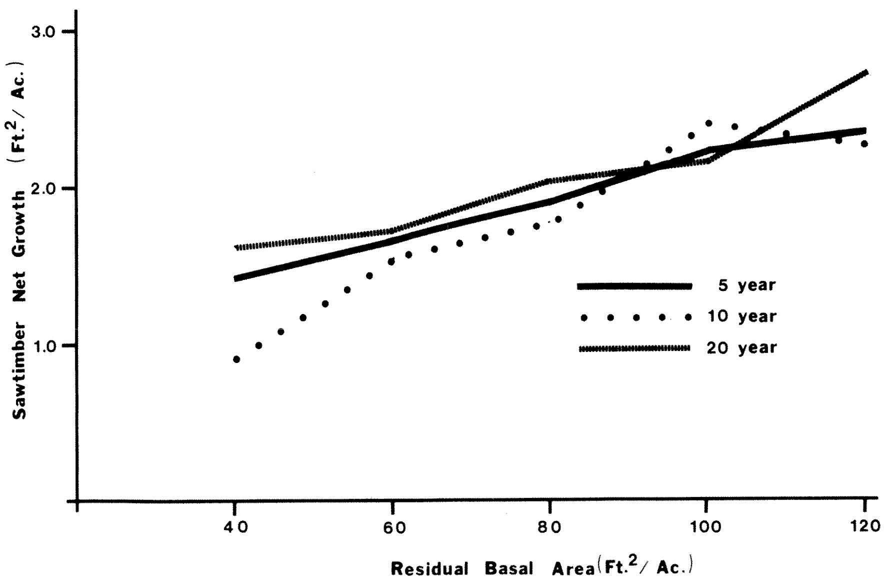


Figure 2.—Average annual sawtimber net growth for 5-, 10-, and 20-year harvest intervals by residual basal area.

Changes in net growth rate similar to those in basal area growth appeared when growth was expressed in volume per acre (Table 2b). The annual merchantable net growth rate of 50 to 60 cubic feet is comparable to the net growth per acre per year reported in other studies (Frayer and Barnard 1966; Bickford et al. 1961; Safford 1968; Frank and Blum 1978). Hart (1964) indicated a higher annual volume growth—70 cubic feet—for a similar residual basal area of 100 to 120 square feet than is reported in this and the other studies. As the residual basal area increases, more large trees are retained as growing stock. This causes the increase in the net growth rate of the sawtimber and the decrease in net growth rate of the poletimber. These changes in growth rate are caused by both a decrease in the number of trees reaching poletimber size and an increase in the number of poletimber-sized trees growing into the sawtimber size class.

Survivor Growth

Average annual survivor growth in both basal area and volume increased significantly as residual basal area increased (Tables 2a and 2b). The growth increase of the total stand from approximately 1.6 to 2.8 square feet was due largely to the increase in sawtimber survivor growth (Fig. 3). This increase appears to continue beyond 120 square feet of residual basal area. The survivor growth in poletimber remained stable over the range of residual basal areas (Fig. 4). The higher residual basal areas had larger trees and a larger proportion of sawtimber, as indicated by volume growth (Table 2b). Our total

Figure 3.—Average annual sawtimber survivor growth for 5-, 10-, and 20-year harvest interval by residual basal area.

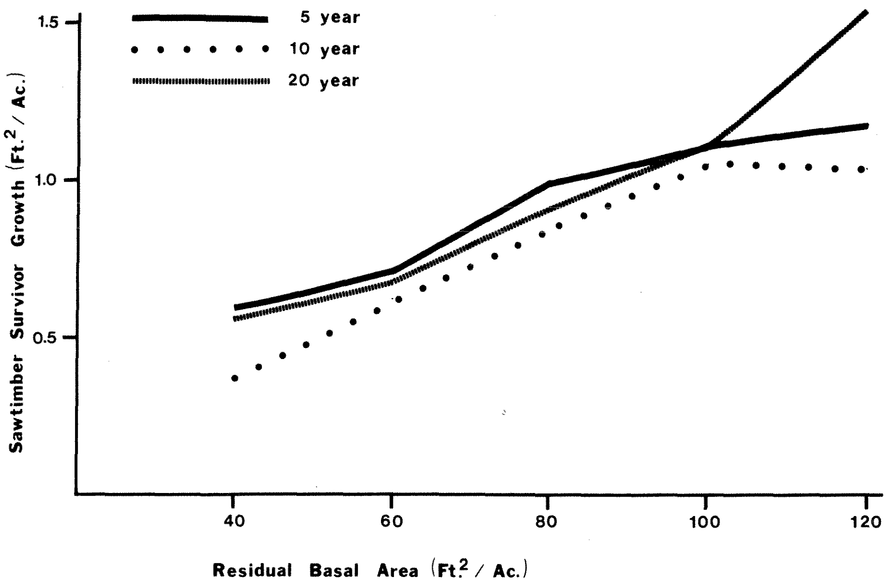
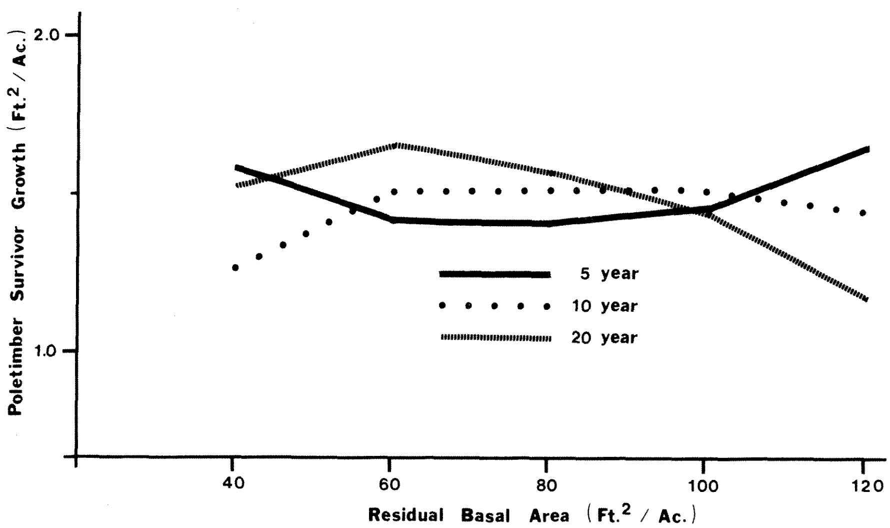


Figure 4.—Average annual poletimber survivor growth for 5-, 10-, and 20-year harvest intervals by residual basal area.



survivor growth response of 40 to 65 cubic feet over a range of densities is similar to the increasing growth rates reported by Safford (1968). This growth rate can increase up to an optimum density of 180 square feet of residual basal area (Brann et al. 1981; Solomon et al. 1982). Our annual survivor growth is higher than that found in large areas, possibly because of differences in species (Safford 1968; Bickford et al. 1961). Survivor growth did not follow a definite pattern as the length between harvests increased, although a significant difference between harvest intervals was found. It was usually less at the 10-year interval than at the other two intervals.

Ingrowth

The poletimber ingrowth for the stand decreased significantly as the residual basal area increased (Table 2a). The ingrowth into the 4.5-inch diameter class at the lower residual basal areas was approximately twice the ingrowth at the higher levels of basal area (Fig. 5). As the length of harvesting interval increased, average annual ingrowth did not change significantly. The annual poletimber ingrowth of 5 to 15 merchantable cubic feet is slightly higher than the 10-year average ingrowth reported for the spruce-fir region of northern New England over a range of densities (Safford 1968) (Table 2b). The ingrowth in Safford's study remained the same as the expression of stand density increased. However, our volume ingrowth at lower densities is approximately three times the ingrowth in Safford's study at higher densities. This may be because residual basal area expresses density differently from crown closure.

The sawtimber ingrowth (trees reaching 9.5 inches dbh) increases with an increase of residual basal area (Fig. 6). This increase was similar for all harvest intervals.

Figure 5.—Average annual poletimber ingrowth for 5-, 10-, and 20-year harvest intervals by residual basal area.

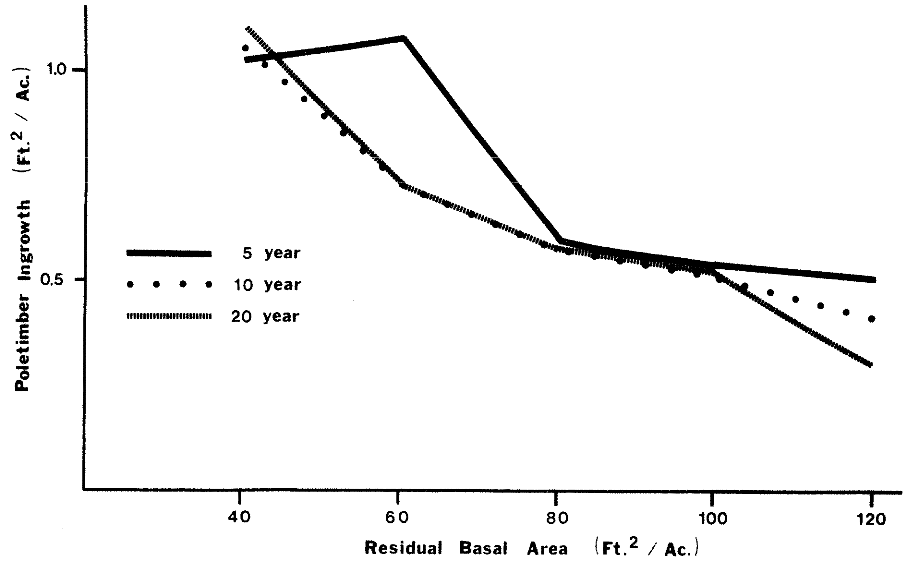
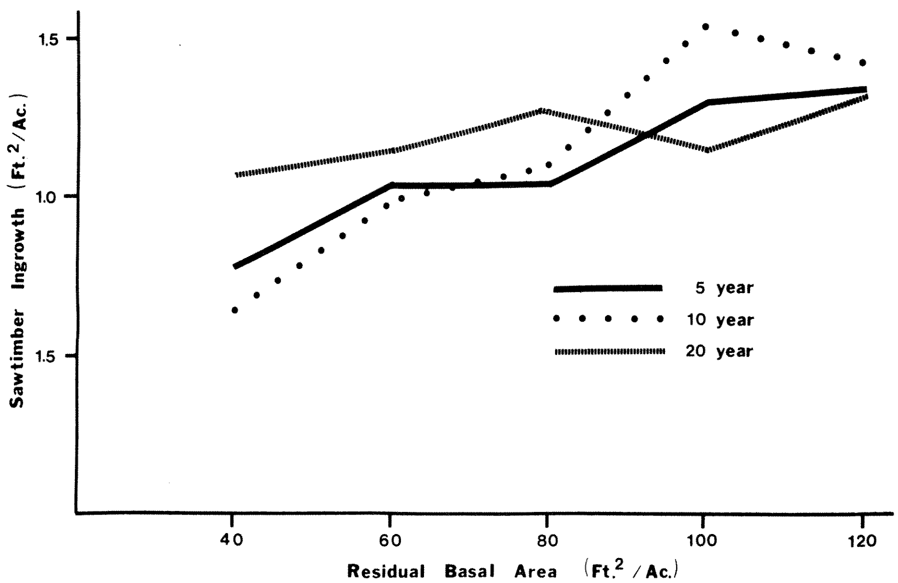


Figure 6.—Average annual sawtimber ingrowth for 5-, 10-, and 20-year harvest intervals by residual basal area.



Mortality

As expected, mortality increased significantly up to 14 cubic feet with increases in the residual basal area (Tables 2a and 2b). The differences in annual mortality between basal area levels were not large for either poletimber or sawtimber (Fig. 7 and 8). This may be because northern conifer stands can sustain higher levels of growing stock than some other timber types. The sawtimber mortality was less than the poletimber mortality, primarily because of the amount of balsam fir in the smaller diameter classes (Table 1) and to the harvesting prescriptions that remove larger trees. Balsam fir, being a short-lived species, tends to die out as the stand matures (Hart 1964). Also ingrowth trees that died during the harvest interval were ignored in this study. This may make poletimber mortality estimates lower in the higher basal area classes.

No pattern of increased mortality appeared as the length of harvest interval increased. It was expected that the 5-year harvesting interval would reduce mortality by harvesting trees that might die during a longer harvesting interval. However, the mortality was not significantly less for the shorter interval.

Stand Growth

The type of management practiced, even-age or uneven-age, determines the silviculture treatments and resulting growth rates. The objective of even-age management is to encourage the growth of overstory trees, which is best done by removing the old stand completely to establish a new stand.

One objective of uneven-age management is to produce a consistant product flow as trees mature. This is best accomplished by selecting trees for removal to maintain optimum growing space. The manager can also improve the spe-

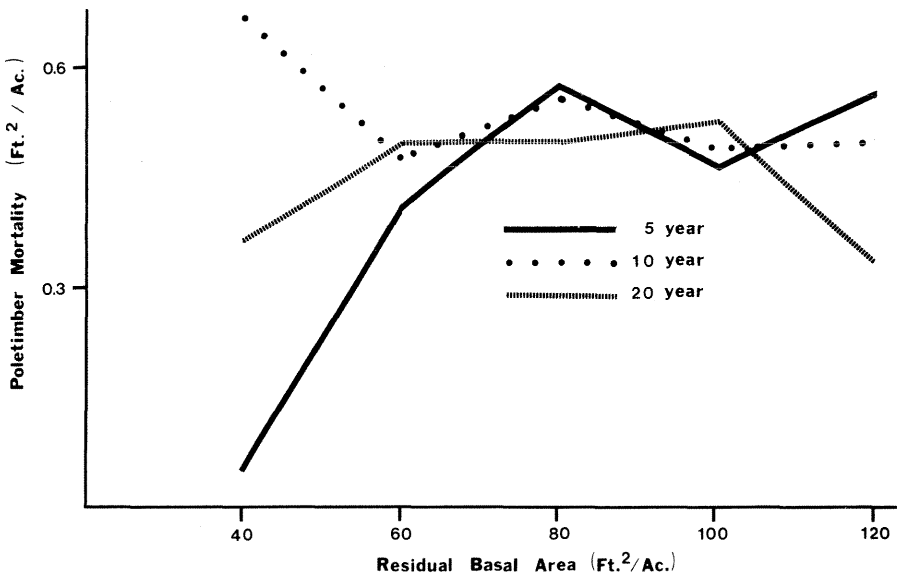


Figure 7.—Average annual poletimber mortality for 5-, 10-, and 20-year harvest intervals by residual basal area.

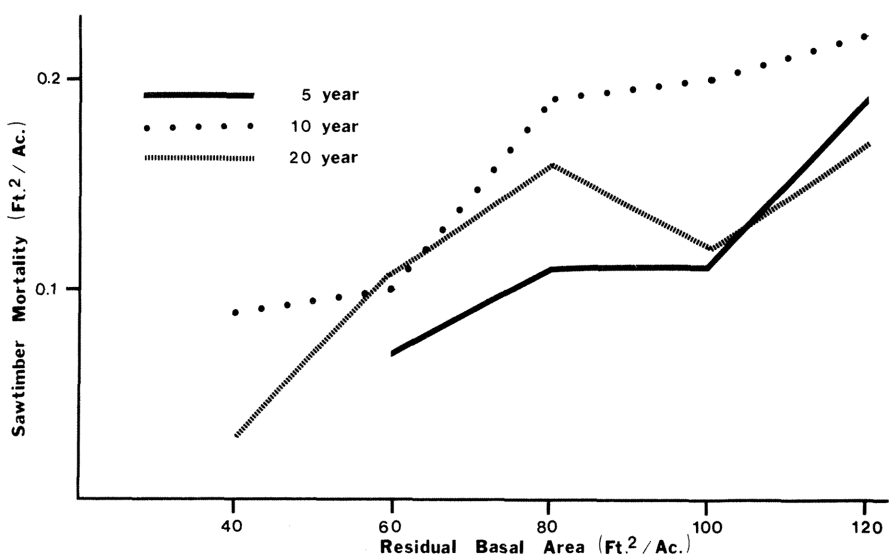


Figure 8.—Average annual sawtimber mortality for 5-, 10-, and 20-year harvest intervals by residual basal area.

cies composition and quality of products by retaining the larger, more valuable trees in the remaining stand. Since a continuous supply of sawlogs is frequently the product goal of uneven-age management, this harvesting practice must leave enough understory trees to grow into sawtimber trees and enough sawtimber trees at the desired density to maintain optimum growing stock.

In order to maintain this flow of products, an adequate amount of poletimber ingrowth is needed to balance mortality. However, if poletimber ingrowth is too high, it may be necessary to remove some of the smaller trees to provide enough growing space for the remaining trees. Thus, size classes of trees should be kept in balance to maintain optimum growth rate.

By keeping the stand at the optimum residual basal area, it is possible to establish and maintain an adequate product flow and have the ingrowth and mortality in balance. This results in a poletimber net growth near zero. Within the limits of this study, the optimum residual basal area density to accomplish this management is 120 square feet or more for a spruce-fir stand with 45 percent sawtimber. Harvest intervals of both 10 and 20 years have high sawtimber survivor growth with a balance of poletimber mortality and ingrowth.

Growth Rates by Species

Annual survivor growth in basal area and volume by species, size class, and residual basal area are shown in Tables 3a and 3b. Annual survivor growth significantly changed as the residual basal area and harvest interval increased for all species. Annual growth of balsam fir decreased as basal area increased, probably because there was a higher proportion of fir poletimber and less fir in the total species composition at the higher residual basal areas (Table 1). Fir, a shorter-lived species, was harvested more intensively at small diameters than longer-lived species such as spruce or hemlock. Balsam fir and spruce had higher annual survivor growth as the harvest interval increased. The survivor growth rate of hemlock and hardwoods decreased as the interval lengthened, perhaps because hemlock and hardwoods can respond more quickly to the removal of a portion of the growing stock. Spruce and fir seem to respond more slowly, especially at longer harvest intervals.

In order to compare the rate of growth between species and basal area classes, the annual survivor growth was calculated as a percentage of the initial basal area or volume in each class (Tables 4a and 4b). Poletimber consistently had a greater growth response than sawtimber (Figs. 3 and 4). Balsam fir and hardwood poletimber outgrew the other species in the lower basal area classes. Hemlock and spruce had the best sawtimber survivor growth as the residual basal area increased. Although no definite pattern emerged when survivor growth was expressed as a percentage of initial basal area, the percentages seemed to decrease as the residual basal area increased. However, the percentages increased as the harvest interval increased for most species except hemlock poletimber and hardwood sawtimber.

Annual mortality of species by basal area classes did not change for the different harvesting intervals (Tables 5a and 5b). The greatest mortality was in balsam fir poletimber—about 6 cubic feet per acre per year. Mortality increased up to a residual basal area of 80 square feet and then declined because the proportion of fir in the species composition declined. In general, poletimber had slightly higher mortality than sawtimber when mortality was expressed as basal area (Table 5a). Annual mortality expressed in cubic feet, however, is higher for taller sawtimber trees because they have proportionally more merchantable volume in the bole than poletimber trees.

When annual mortality per acre is expressed as a percentage of initial basal area, it is small in managed stands (Tables 6a and 6b). Although there is a general increase in the proportion of mortality as the residual basal area increases, no real pattern of mortality is evident either for basal area level or for harvest interval. Except for balsam fir, the annual mortality among species is very similar and demonstrates an even utilization of all sizes of trees during harvest. The percentage mortality of spruce is greater than that of hemlock for both poletimber and sawtimber.

Table 3a.—Annual survivor growth by species, size class, residual basal area, and harvest interval (in square feet of basal area per acre)[a]

Residual Basal Area	Harvest Interval	Balsam Fir Pole-timber	Balsam Fir Saw-timber	Spruces Pole-timber	Spruces Saw-timber	Eastern Hemlock Pole-timber	Eastern Hemlock Saw-timber	Other Softwoods Pole-timber	Other Softwoods Saw-timber	Hardwoods Pole-timber	Hardwoods Saw-timber
ft²/acre	*Years*										
	5	0.47	0.00	0.33	0.06	0.50	0.32	0.09	0.14	0.19	0.09
40	10	.43	.00	.22	.12	.16	.17	.12	.05	.34	.04
	20	.43	.00	.23	.11	.39	.37	.16	.05	.33	.04
	5	.30	.00	.18	.11	.49	.49	.16	.03	.30	.08
60	10	.32	.00	.33	.22	.44	.34	.15	.04	.28	.03
	20	.33	.01	.28	.14	.47	.38	.17	.07	.40	.06
	5	.19	.00	.26	.26	.54	.59	.13	.08	.30	.06
80	10	.31	.00	.32	.26	.46	.49	.12	.03	.29	.07
	20	.31	.00	.40	.30	.50	.52	.11	.08	.26	.02
	5	.13	.00	.29	.23	.58	.69	.12	.08	.33	.11
100	10	.20	.01	.36	.28	.60	.64	.15	.05	.22	.08
	20	.23	.00	.36	.33	.42	.64	.14	.10	.26	.05
	5	.11	.01	.31	.19	.78	.64	.09	.21	.37	.11
120	10	.07	—	.19	.27	.83	.62	.10	.08	.26	.08
	20	.14	.00	.20	.33	.63	1.12	.06	.08	.14	.03

[a]For conversion to square meters per hectare multiply by 0.229568.

Table 3b.—Annual survivor growth by species, size class, residual basal area, and harvest interval (in merchantable cubic feet per acre—excluding bark, 1-foot stump, and 4-inch top)[a]

Residual Basal Area[b]	Harvest Interval	Balsam Fir Pole-timber	Balsam Fir Saw-timber	Spruces Pole-timber	Spruces Saw-timber	Eastern Hemlock Pole-timber	Eastern Hemlock Saw-timber	Other Softwoods Pole-timber	Other Softwoods Saw-timber	Hardwoods Pole-timber	Hardwoods Saw-timber
ft²/acre	*Years*										
	5	10.24	0.07	8.05	1.56	8.73	7.44	1.82	3.85	3.36	1.75
40	10	10.81	.01	5.82	3.52	2.85	4.01	2.59	.86	6.68	.88
	20	10.45	.08	6.13	3.26	7.19	8.84	3.33	1.06	6.61	.79
	5	6.95	.01	4.75	3.34	8.96	11.66	3.32	.77	5.88	1.78
60	10	7.96	.04	8.53	6.44	8.06	8.11	3.32	.87	5.49	.72
	20	8.07	.23	7.43	4.02	8.63	9.17	3.73	1.86	7.86	.69
	5	4.51	.00	6.77	7.36	9.77	14.05	2.70	1.76	5.97	1.33
80	10	7.64	.04	8.53	7.62	8.51	11.64	2.49	.80	5.78	1.55
	20	7.53	.05	10.45	8.66	9.32	12.50	2.42	2.01	5.04	.43
	5	3.18	.10	7.66	6.51	10.49	16.50	2.55	2.03	6.37	2.39
100	10	5.08	.19	9.59	8.22	11.02	15.59	3.28	1.11	4.42	1.83
	20	5.80	.03	9.50	9.45	7.83	15.60	3.10	2.43	5.11	1.14
	5	2.62	.25	8.03	5.63	14.07	15.30	1.86	5.26	7.00	2.44
120	10	1.71	—	5.39	7.63	14.80	14.98	2.06	1.99	5.11	1.79
	20	3.37	.01	5.58	9.45	11.64	27.16	1.36	1.83	2.77	.71

[a] For conversion to cubic meters per hectare multiply by 0.069973.
[b] For conversion to square meters per hectare multiply by 0.229568.

Table 4a.—Annual survivor growth by species, size class, residual basal area, and harvest interval (in percent of initial basal area)

Residual Basal Area[a]	Harvest Interval	Balsam Fir		Spruces		Eastern Hemlock		Other Softwoods		Hardwoods	
		Pole-timber	Saw-timber	Pole-timber	Saw-timber	Pole-timber	Saw-timber	Pole-timber	Saw-timber	Pole-timber	Saw-timber
ft²/acre	*Years*										
	5	6.96	0.00	6.06	0.97	6.03	3.63	1.74	1.39	5.11	3.80
40	10	7.42	.00	5.42	1.88	3.01	1.36	2.15	.66	7.69	1.44
	20	8.44	.00	3.82	1.83	4.47	3.54	1.39	.89	8.18	.74
	5	5.02	.00	3.77	1.88	4.15	2.72	1.82	.40	4.55	1.10
60	10	5.35	.00	3.17	3.09	3.83	2.12	1.63	.77	4.77	.52
	20	8.68	.25	4.66	2.74	5.44	4.01	2.17	.88	4.57	.81
	5	4.00	.00	3.21	2.26	4.46	2.51	1.32	.93	3.75	1.07
80	10	3.37	.01	3.72	2.34	3.37	2.18	1.29	.63	4.31	1.07
	20	4.54	.00	3.36	3.81	3.47	3.02	1.20	1.19	4.15	.41
	5	2.34	.02	2.76	2.23	3.80	2.53	1.10	.70	3.31	1.91
100	10	3.31	.39	2.94	2.14	3.50	2.45	1.23	.60	3.93	1.13
	20	3.01	.03	2.86	2.75	3.49	2.14	1.17	1.00	4.03	.86
	5	.68	.00	2.59	1.60	3.34	2.16	.93	1.41	3.81	1.71
120	10	1.58	—	1.81	2.83	2.74	1.85	.74	1.17	2.83	.97
	20	2.78	.00	2.48	3.05	2.79	2.75	.36	1.07	4.59	.76

[a]For conversion to square meters per hectare multiply by 0.229568.

Table 4b.—Annual survivor growth by species, size class, residual basal area, and harvest interval (in percent of initial volume)

Residual Basal Area[a]	Harvest Interval	Balsam Fir		Spruces		Eastern Hemlock		Other Softwoods		Hardwoods	
		Pole-timber	Saw-timber	Pole-timber	Saw-timber	Pole-timber	Saw-timber	Pole-timber	Saw-timber	Pole-timber	Saw-timber
ft²/acre	*Years*										
	5	9.27	0.00	8.48	1.22	8.11	4.55	2.20	1.77	5.77	3.87
40	10	9.97	.00	9.71	2.34	4.20	1.79	3.26	.66	10.65	1.75
	20	12.49	.00	6.26	2.23	6.27	4.82	2.02	.98	14.79	.99
	5	6.89	.00	5.61	2.30	5.56	3.53	2.47	.45	5.99	1.30
60	10	7.93	.00	4.80	3.70	5.36	2.77	2.45	.96	6.98	.65
	20	12.45	.28	7.71	3.38	7.78	5.37	3.18	1.04	6.74	.87
	5	5.64	.00	4.91	2.68	6.06	3.25	2.01	.99	5.16	1.32
80	10	5.02	.01	4.16	2.80	4.46	2.85	1.88	.77	6.14	1.37
	20	6.69	.00	5.08	4.67	4.87	4.10	1.72	1.44	5.85	.51
	5	3.38	.03	4.20	2.63	5.03	3.25	1.65	.81	4.43	2.30
100	10	4.83	.44	4.44	2.56	4.85	2.24	1.81	.68	5.68	1.42
	20	4.51	.04	4.40	3.33	4.77	2.84	1.78	1.17	5.42	1.10
	5	1.04	.00	3.95	1.96	4.53	2.76	1.14	1.62	4.93	2.10
120	10	2.48	—	2.68	3.26	3.70	2.47	1.08	1.38	3.71	1.23
	20	4.25	.00	4.26	3.78	3.83	3.66	.53	1.10	7.11	.96

[a] For conversion to square meters per hectare multiply by 0.229568.

Table 5a.—Annual mortality by species, size class, residual basal area, and harvest interval (in square feet of basal area per acre)[a]

Residual Basal Area	Harvest Interval	Balsam Fir		Spruces		Eastern Hemlock		Other Softwoods		Hardwoods	
		Pole-timber	Saw-timber	Pole-timber	Saw-timber	Pole-timber	Saw-timber	Pole-timber	Saw-timber	Pole-timber	Saw-timber
ft²/acre	*Years*										
	5	0.03	—	0.01	—	0.01	—	—	—	—	—
40	10	.54	—	.03	—	.01	0.05	0.05	0.04	0.04	—
	20	.22	0.01	.04	0.01	.02	—	.03	.01	.06	0.01
	5	.26	—	.02	.03	.03	—	.08	.04	.03	—
60	10	.29	.01	.05	.03	.05	.03	.03	.01	.06	.03
	20	.34	—	.05	.03	.02	.04	.03	.03	.05	.02
	5	.33	—	.05	.04	.05	.03	.11	.02	.04	.02
80	10	.36	.01	.05	.04	.06	.13	.06	.00	.04	01
	20	.31	.01	.07	.05	.04	.03	.05	.03	.04	.04
	5	.29	.01	.05	.03	.02	.02	.07	.06	.04	.01
100	10	.29	—	.04	.07	.05	.08	.09	.03	.02	.02
	20	.32	.02	.07	.02	.02	.06	.07	—	.05	.02
	5	.33	—	.06	.10	.05	.03	.08	.06	.05	—
120	10	.07	—	.11	.03	.16	.14	.11	.04	.05	.02
	20	.12	.02	.03	.03	.04	.03	.09	.08	.04	.02

[a] For conversion to square meters per hectare multiply by 0.229568.

Table 5b.—Annual mortality by species, size class, residual basal area, and harvest interval (in merchantable cubic feet per acre—excluding bark, 1-foot stump, and 4-inch top)[a]

Residual Basal Area[b]	Harvest Interval	Balsam Fir		Spruces		Eastern Hemlock		Other Softwoods		Hardwoods	
		Pole-timber	Saw-timber	Pole-timber	Saw-timber	Pole-timber	Saw-timber	Pole-timber	Saw-timber	Pole-timber	Saw-timber
ft²/acre	*Years*										
	5	0.43	—	0.18	—	0.10	—	—	—	—	—
40	10	9.69	—	.49	—	.14	0.92	0.78	0.71	0.47	—
	20	3.97	0.16	.61	0.19	.33	—	.37	.13	.83	0.10
	5	4.70	—	.37	.69	.42	—	.99	.80	.36	—
60	10	5.24	.15	.90	.66	.67	.63	.39	.19	.82	.45
	20	6.09	—	.83	.77	.29	.75	.45	.50	.63	.32
	5	5.73	—	.87	1.04	.66	.68	1.56	.56	.59	.29
80	10	6.38	.23	.91	.99	.78	2.50	.90	.07	.61	.17
	20	5.51	.26	1.18	1.20	.54	.60	.65	.58	.54	.96
	5	4.99	.15	.87	.65	.28	.34	1.03	1.14	.60	.09
100	10	5.17	—	.65	1.68	.64	1.55	1.29	.52	.25	.39
	20	5.75	.39	1.24	.48	.28	1.09	1.02	—	.77	.50
	5	5.88	—	.92	2.51	.68	.56	1.21	1.37	.79	—
120	10	1.37	—	2.14	.66	2.23	2.67	1.63	.72	.73	.31
	20	2.23	.37	.41	.66	.47	.57	1.25	1.48	.65	.26

[a] For conversion to cubic meters per hectare multiply by 0.069973.
[b] For conversion to square meters per hectare multiply by 0.229568.

Table 6a.—Annual mortality by species, size class, residual basal area, and harvest interval (in percent of initial basal area)

Residual Basal Area[a]	Harvest Interval	Species									
		Balsam Fir		Spruces		Eastern Hemlock		Other Softwoods		Hardwoods	
		Pole-timber	Saw-timber	Pole-timber	Saw-timber	Pole-timber	Saw-timber	Pole-timber	Saw-timber	Pole-timber	Saw-timber
ft²/acre	*Years*										
	5	0.41	—	0.19	—	0.10	—	—	—	—	—
40	10	5.49	—	.24	—	.10	0.29	0.35	0.31	0.48	—
	20	2.76	0.00	.64	0.31	.17	—	.67	.24	.71	0.00
	5	2.58	—	.26	.65	.35	—	.65	.58	.37	—
60	10	2.90	.00	.38	.49	.45	.28	.45	.19	.70	.62
	20	3.55	—	.48	.67	.29	.29	.38	.32	.65	.37
	5	3.72	—	.75	.47	.40	.18	1.28	.12	.71	.15
80	10	3.18	.00	.36	.42	.30	.46	1.14	.11	.48	.09
	20	2.99	.10	.52	.54	.21	.12	.47	.36	.57	.47
	5	3.43	.00	.40	.19	.16	.04	.93	.35	.28	.06
100	10	1.74	—	.32	.41	.26	.32	.96	.33	.23	.27
	20	3.11	.50	.46	.14	.25	.16	.68	—	.97	.36
	5	4.16	—	.74	.32	.16	.07	1.39	.23	.98	—
120	10	2.79	—	1.73	.39	.48	.30	1.44	.19	.34	.67
	20	2.04	.56	.18	.10	.14	.06	1.03	1.68	1.10	.20

[a] For conversion to square meters per hectare multiply by 0.229568.

Table 6b.—Annual mortality by species, size class, residual basal area, and harvest interval (in percent of initial volume)

Residual Basal Area[a]	Harvest Interval	Species									
		Balsam Fir		Spruces		Eastern Hemlock		Other Softwoods		Hardwoods	
		Pole-timber	Saw-timber	Pole-timber	Saw-timber	Pole-timber	Saw-timber	Pole-timber	Saw-timber	Pole-timber	Saw-timber
ft²/acre	*Years*										
	5	0.36	—	0.19	—	0.77	—	—	—	—	—
40	10	5.63	—	.26	—	.10	0.29	0.37	0.30	0.47	—
	20	3.14	0.00	.68	0.33	.18	—	.31	.24	.73	0.00
	5	2.63	—	.26	.65	.36	—	.61	.58	.36	—
60	10	3.02	.00	.38	.49	.46	.28	.45	.19	.73	.62
	20	2.69	—	.49	.69	.29	.30	.34	.30	.68	.37
	5	3.79	—	.73	.47	.41	.18	1.27	.13	.68	.13
80	10	3.32	.00	.37	.42	.31	.48	.88	.11	.48	.09
	20	3.24	.71	.50	.55	.21	.12	.44	.36	.59	.48
	5	3.45	.00	.40	1.36	.17	.05	.70	.35	.26	.06
100	10	1.84	—	.31	.41	.26	.33	.69	.33	.24	.27
	20	3.29	.50	.46	.14	.26	.16	.69	—	.84	.38
	5	4.21	—	.67	.33	.16	.08	1.45	.23	.98	—
120	10	2.89	—	1.76	.37	.50	.32	1.35	.17	.33	.69
	20	2.14	.56	.14	.11	.13	.06	.94	1.68	1.09	.19

[a] For conversion to square meters per hectare multiply by 0.229568.

The poletimber ingrowth of balsam fir, hardwoods, and other softwoods decreased significantly as the residual basal area increased (Tables 7a and 7b). Balsam fir had the most ingrowth and declined significantly as both residual basal area and harvest interval increased. This amount of fir ingrowth is more than the fir mortality (Table 5a). Hemlock and spruce ingrowth decreased significantly as the harvest interval lengthened. Both are tolerant species, and can survive even though the ingrowth rates are reduced.

Table 7a.—Average annual ingrowth of poletimber by species, residual basal area, and harvest interval (in square feet of basal area per acre)[a]

Residual Basal Area	Harvest Interval	Species				
		Balsam Fir	Spruces	Eastern Hemlock	Other Softwoods	Hardwoods
ft²/acre	*Years*					
	5	0.54	0.10	0.22	0.04	0.14
40	10	.54	.08	.09	.10	.28
	20	.56	.07	.16	.08	.27
	5	.46	.06	.21	.18	.19
60	10	.46	.10	.15	.08	.19
	20	.39	.08	.15	.09	.26
	5	.25	.06	.25	.11	.14
80	10	.30	.09	.17	.07	.16
	20	.35	.12	.11	.08	.14
	5	.16	.06	.28	.07	.16
100	10	.24	.07	.17	.08	.13
	20	.26	.07	.12	.10	.15
	5	.09	.08	.29	.03	.18
120	10	.10	.04	.24	.07	.11
	20	.12	.04	.14	.02	.08

[a] For conversion to square meters per hectare multiply by 0.229568.

Table 7b.—Average annual ingrowth of poletimber by species, residual basal area, and harvest interval (in merchantable cubic feet per acre—excluding bark, 1-foot stump, and 4-inch top)[a]

Residual Basal Area[b]	Harvest Interval	Species				
		Balsam Fir	Spruces	Eastern Hemlock	Other Softwoods	Hardwoods
ft²/acre	*Years*					
	5	7.98	1.27	2.31	0.37	1.54
40	10	8.02	.91	.95	1.02	3.20
	20	8.37	.80	1.74	.80	3.09
	5	6.89	.70	2.18	1.86	2.14
60	10	6.79	1.24	1.53	.80	2.16
	20	5.80	1.00	1.56	.92	3.02
	5	3.63	.70	2.56	1.18	1.59
80	10	4.42	1.12	1.73	.72	1.83
	20	5.17	1.39	1.18	.78	1.56
	5	2.33	.65	2.90	.72	1.84
100	10	3.56	.77	1.73	.85	1.46
	20	3.85	.86	1.25	1.04	1.74
	5	1.37	.94	3.06	.27	2.04
120	10	1.43	.49	2.48	.77	1.27
	20	1.81	.53	1.45	.23	.90

[a] For conversion to cubic meters per hectare multiply by 0.069973.
[b] For conversion to square meters per hectare multiply by 0.229568.

Average annual ingrowth into the sawtimber class increased for most species as both residual basal area and harvest interval increased (Tables 8a and 8b). The species with the largest amount of ingrowth into the sawtimber size was hemlock, followed by spruce. Spruce sawtimber ingrowth seems to have leveled off or declined between 100 and 120 square feet of basal area, while hemlock is still increasing. Stands of softwoods are able to sustain larger trees at higher densities than hardwoods.

Table 8a.—Average annual ingrowth of sawtimber by species, residual basal area, and harvest interval (in square feet of basal area per acre)[a]

Residual Basal Area	Harvest Interval	Species				
		Balsam Fir	Spruces	Eastern Hemlock	Other Softwoods	Hardwoods
ft²/acre	*Years*					
	5	0.05	0.11	0.42	0.03	0.18
40	10	.05	.22	.14	.06	.17
	20	.06	.28	.51	.11	.12
	5	.04	.22	.52	.03	.23
60	10	.03	.32	.40	.09	.16
	20	.04	.29	.53	.13	.17
	5	.02	.29	.54	.06	.16
80	10	.03	.38	.52	.05	.12
	20	.03	.47	.57	.06	.15
	5	.03	.37	.57	.06	.27
100	10	.02	.50	.76	.13	.13
	20	.03	.42	.53	.05	.13
	5	.01	.29	.77	.06	.23
120	10	—	.43	.62	.11	.27
	20	.02	.33	.88	.06	.05

[a] For conversion to square meters per hectare multiply by 0.229568.

Table 8b.—Average annual ingrowth of sawtimber by species, residual basal area, and harvest interval (in merchantable cubic feet per acre—excluding bark, 1-foot stump, and 4-inch top)[a]

Residual Basal Area[b]	Harvest Interval	Species				
		Balsam Fir	Spruces	Eastern Hemlock	Other Softwoods	Hardwoods
ft²/acre	*Years*					
	5	1.21	2.42	6.95	0.66	3.15
40	10	1.29	4.97	2.26	1.20	2.99
	20	1.39	6.57	8.52	1.93	2.08
	5	.86	5.12	8.62	.56	4.07
60	10	.76	7.53	6.58	1.62	2.76
	20	.92	6.63	8.88	2.53	2.95
	5	.37	6.67	8.84	1.02	2.71
80	10	.72	8.69	8.56	.96	2.05
	20	.70	10.67	9.61	1.16	2.60
	5	.78	8.42	9.33	1.14	4.79
100	10	.54	11.49	12.48	2.33	2.28
	20	.78	9.55	8.73	.84	2.18
	5	.28	6.68	12.62	1.11	3.99
120	10	—	9.79	10.20	1.94	4.55
	20	.37	7.63	14.44	1.09	.79

[a] For conversion to cubic meters per hectare multiply by 0.069973.
[b] For conversion to square meters per hectare multiply by 0.229568.

Diameter Growth

Since individual remeasured data were not recorded for each tree, diameter growth by species and size classes cannot be exactly determined. However, from the mean stand diameter at the beginning and end of the measurement period, excluding mortality trees, the average annual diameter growth can be approximated (Table 9).

As expected, poletimber of all species grew faster in the lower residual basal area classes and total stand diameter growth declined as the basal area increased. Balsam fir declined most in diameter growth, because of increased competition and the decreasing proportion of fir poletimber in the species composition. The diameter growth of spruce and hemlock poletimber was approximately the same.

Hemlock had the best sawtimber diameter growth. The difference was greater in the lower basal area classes where the larger hemlock trees respond to release. The diameter growth of spruce equals that of hemlock in the denser stands.

For fir, diameter growth increased as the length of harvest interval increased. However, no definite pattern was evident for the other species, which seemed to decline as the harvest interval increased. For most density classes, balsam fir is capable of more rapid growth than spruce or hemlock in the longer harvest intervals of 10 or 20 years. Fir was removed more heavily in the 5 year harvesting interval, thus fewer of the faster-growing fir were present.

Table 9.—Average annual diameter growth by species, size class, residual basal area, and harvest interval (in inches)[a]

Residual Basal Area[b]	Harvest Interval	Species														
		Balsam Fir			Spruces			Eastern Hemlock			Other Softwoods			Hardwoods		
		Pole-timber	Saw-timber	Merchan-table	Pole-timber	Saw-timber	Merchan-table	Pole-timber	Saw-timber	Merchan-table	Pole-timber	Saw-timber	Merchan-table	Pole-timber	Saw-timber	Merchan-table
ft²/acre	*Years*															
40	5	0.19	0.00	0.19	0.19	0.05	0.19	0.18	0.20	0.20	0.05	0.08	0.07	0.17	0.10	0.17
	10	.23	.00	.23	.14	.09	.14	.09	.08	.09	.07	.05	.07	.17	.06	.17
	20	.27	.00	.27	.12	.04	.12	.13	.14	.14	.04	.04	.04	.16	.03	.16
60	5	.14	.00	.14	.13	.10	.11	.14	.15	.15	.05	.02	.05	.12	.06	.12
	10	.14	.00	.14	.10	.14	.12	.12	.11	.12	.05	.04	.05	.13	.02	.13
	20	.20	.01	.20	.13	.10	.13	.14	.18	.16	.06	.03	.06	.12	.03	.12
80	5	.11	.00	.11	.10	.14	.12	.14	.14	.14	.04	.06	.06	.12	.05	.12
	10	.10	.00	.10	.09	.12	.11	.11	.12	.12	.04	.03	.04	.12	.06	.12
	20	.18	.00	.18	.11	.15	.13	.10	.14	.12	.04	.06	.05	.11	.02	.11
100	5	.07	.00	.07	.10	.13	.11	.12	.15	.13	.03	.04	.04	.10	.09	.10
	10	.10	.01	.10	.10	.11	.11	.11	.13	.12	.04	.03	.04	.11	.05	.11
	20	.18	.00	.18	.09	.13	.11	.11	.11	.11	.04	.05	.05	.11	.05	.11
120	5	.03	.04	.03	.09	.09	.09	.11	.11	.11	.03	.09	.07	.13	.09	.13
	10	.04	—	.04	.07	.17	.09	.09	.10	.09	.02	.08	.05	.09	.05	.09
	20	.10	.00	.10	.08	.14	.11	.09	.14	.11	.02	.05	.04	.10	.04	.10

[a] For conversion to centimeters multiply by 2.54.
[b] For conversion to square meters per hectare multiply by 0.229568.

The average diameter of trees that died is given in Table 10. When mortality is expressed in square feet of basal area (Table 5), balsam fir poletimber had the highest annual mortality. However, fir had the smallest average diameter of trees that died (Table 10). On the average, hemlock and spruce had similar diameters for the trees that died, between 7.0 and 9.5 inches. No change in the size of trees that died was obvious as either the residual basal area or harvest interval increased.

Conclusion

The gross growth of managed northern conifer stands varied little across the different levels of residual basal area from 40 to 120 square feet. Net growth did not indicate a definite relationship as the residual basal area increased for the total stand. However, net growth of sawtimber increased as residual basal area increased. Although net growth of poletimber decreased as density increased, the increase in sawtimber more than compensated for that reduction.

Of the components of net growth, survivor growth increases as residual basal area increases. This increase is primarily due to the increase in growth rate of sawtimber. Survivor growth of poletimber remains relatively constant across density.

Poletimber ingrowth had the largest influence on net growth, since ingrowth decreases as residual basal area increases. This result influences the number of trees that grow into the lower diameter classes, affecting stand stability. The low net growth of poletimber is comparable to poletimber ingrowth and is balanced by poletimber mortality. If a residual basal area of 120 square feet or more is maintained, the sawtimber survivor growth increases, sawtimber ingrowth is high, and poletimber mortality keeps poletimber ingrowth balanced. Therefore, excess poletimber does not have to be removed to maintain desired growing stock.

Table 10.—Average diameter of trees that died by species, size class, residual basal area, and harvest interval (in inches)[a]

Residual Basal Area[b]	Harvest Interval	Species				
		Balsam Fir	Spruces	Eastern Hemlock	Other Softwoods	Hardwoods
ft²/acre	*Years*					
	5	5.80	6.00	5.76	—	—
40	10	6.20	7.40	10.40	7.37	5.19
	20	6.37	6.88	7.18	6.23	6.33
	5	6.34	8.69	7.88	6.89	6.09
60	10	6.28	8.23	8.27	6.59	6.89
	20	6.09	7.36	8.15	7.18	6.43
	5	5.86	8.05	7.28	6.76	6.42
80	10	6.19	8.13	9.53	6.01	6.56
	20	6.15	7.40	7.97	6.87	7.69
	5	5.99	7.86	8.00	6.33	6.36
100	10	6.31	8.16	7.76	6.43	7.19
	20	6.06	7.18	8.97	6.03	6.72
	5	6.08	8.14	7.43	7.03	6.82
120	10	6.47	8.42	8.59	6.55	7.63
	20	6.25	6.57	7.36	6.56	7.01

[a] For conversion to centimeters multiply by 2.54.
[b] For conversion to square meters per hectare multiply by 0.229568.

Although short-lived species such as balsam fir have rapid poletimber survivor growth in the lower basal area classes, spruce and hemlock poletimber did better at the upper levels of density. Some of this difference may be due to the decreasing proportion of fir at the higher density classes. Hemlock had the highest sawtimber survivor growth.

Mortality did not show a definite relationship to increases in density over the stands as a whole, primarily because of the intensive utilization of the shorter-lived species. Fir poletimber had the highest mortality, which influenced the low net growth, especially at the higher densities. Most species on the plots had similar annual mortality rates, except fir which had significantly higher mortality.

The greatest amount of ingrowth was also into the balsam fir poletimber class. Most species declined in ingrowth as density increased. Hemlock had the smallest increase. Hardwoods had more ingrowth than spruce and, in some instances, were second only to fir. Hemlock had the highest sawtimber ingrowth rate of the species studied. This is to be expected, since hemlock is a long-lived species and made up a large proportion of the stands. The harvest interval had very little influence on growth response. As the harvest interval increased, ingrowth declined and mortality increased slightly.

Overall diameter growth declined as the residual basal area increased, especially in balsam fir. Hemlock had the best sawtimber diameter growth, although spruce grew as fast in the higher residual levels of basal area. As harvest interval increased, the diameter growth of balsam fir increased. However, the diameter growth rate of the other species remained similar for different harvest intervals.

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Solomon, Dale S.; Frank M. **Growth response of managed uneven-aged northern conifer stands.** Res. Pap. NE-517 Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1983. 17 p.

The growth response of trees in spruce-fir-hemlock stands was recorded from plots that were managed to control stand density, species composition, length of harvest interval, and salvage of mortality. Basal area, volume, and diameter increment are presented by species and size classification for harvesting intervals of 5, 10, and 20 years.

ODC: 228.6: 561.2: 562.2—174.7(741)

Keywords: Basal area, volume, harvest interval

Errata for Research Paper NE-517 --
Tables 4a, 4b, 6a, and 6b should read:

Table 4a.- Annual survivor growth by species, size class, residual basal area, and harvest interval (in percent of initial basal area).

Residual Basal Area[a]	Harvest	Balsam Fir		Spruces		Eastern Hemlock		Other Softwoods		Hardwoods	
		Pole-Timber	Saw-Timber[b]	Pole-Timber	Saw-Timber	Pole-Timber	Saw-Timber	Pole-Timber	Saw-Timber	Pole-Timber	Saw-Timber
ft²/acre	Years										
40	5	8.54	0.00	6.86	3.71	5.76	4.16	2.39	4.95	3.59	6.73
	10	3.94	0.00	5.06	3.82	4.56	2.78	2.18	2.04	5.50	5.37
	20	6.61	0.00	4.55	13.40	4.52	7.80	1.81	2.90	5.61	4.01
60	5	4.18	0.41	4.52	2.35	4.60	3.26	2.30	2.60	3.88	2.65
	10	3.38	0.00	3.77	3.23	4.57	3.27	1.92	3.07	4.36	2.93
	20	3.67	22.82	3.82	5.35	4.39	4.61	1.89	3.50	4.70	2.81
80	5	3.16	0.39	3.47	2.53	4.10	2.92	1.47	2.81	3.37	2.01
	10	2.70	3.74	3.16	2.97	3.66	2.82	1.65	2.04	3.81	2.34
	20	3.33	2.74	2.98	3.51	3.40	3.28	1.24	2.82	4.01	1.23
100	5	1.96	3.80	2.92	2.43	3.24	2.56	1.38	2.07	2.92	2.51
	10	2.27	3.92	2.81	2.27	3.39	2.66	1.35	2.08	3.83	2.47
	20	2.47	0.42	2.55	3.02	3.25	2.73	1.26	2.31	3.16	1.80
120	5	1.22	0.00	2.59	1.81	3.32	2.06	1.36	2.41	3.33	2.28
	10	2.94	0.00	1.71	2.17	2.67	2.01	0.85	1.62	2.38	2.37
	20	2.59	0.09	2.16	2.83	2.56	2.75	0.52	1.62	3.07	1.13

[a] For conversion to square meters per hectare multiply by 0.229568
[b] Large percentages may be due to small initial basal area

Table 4b.-Annual survivor growth by species, size class, residual basal area, and harvest interval (in percent of initial volume).

Residual Basal Area[a]	Harvest Interval	Balsam Fir		Spruces		Eastern Hemlock		Other Softwoods		Hardwoods	
		Pole-Timber	Saw-Timber[b]	Pole-Timber	Saw-Timber	Pole-Timber	Saw-Timber	Pole-Timber	Saw-Timber	Pole-Timber	Saw-Timber
ft²/acre	Years										
40	5	10.59	0.00	9.69	4.11	7.48	5.22	3.09	6.27	4.17	6.86
	10	5.75	0.00	7.53	4.60	6.12	3.68	3.24	1.95	7.76	6.52
	20	9.79	0.00	7.04	16.02	6.04	10.22	2.50	3.26	8.02	5.10
60	5	5.67	0.41	6.55	2.81	6.12	4.19	3.47	3.28	5.19	3.06
	10	4.92	0.00	5.59	3.86	6.20	4.24	2.81	3.68	5.91	3.64
	20	5.46	27.61	5.85	6.53	6.07	5.91	2.67	4.43	6.55	1.74
80	5	4.39	0.39	5.14	2.91	5.50	3.75	2.16	2.92	4.57	2.43
	10	3.93	4.55	4.72	3.50	4.92	3.64	2.38	2.56	5.16	2.95
	20	4.91	3.33	4.48	4.19	4.66	4.38	1.84	3.56	5.45	1.27
100	5	2.76	3.88	4.38	2.84	4.33	3.25	2.04	2.43	3.75	3.03
	10	3.31	4.43	4.17	2.70	4.60	3.47	1.91	2.51	5.17	3.14
	20	3.66	0.55	3.86	3.59	4.47	3.61	1.88	2.90	4.22	2.26
120	5	1.74	0.00	3.92	2.19	4.45	2.63	1.94	2.62	4.34	2.74
	10	4.38	0.00	2.57	2.53	3.61	2.63	1.19	2.04	3.09	2.90
	20	3.81	0.09	3.36	3.43	3.49	3.65	0.74	1.86	4.27	1.21

[a] For conversion to square meters per hectare multiply by 0.229568
[b] Large percentages may be due to small initial basal area.

Table 6a.- Annual mortality by species, size class, residual basal area, and harvest interval (in percent of initial basal area).

Residual Basal Area[a]	Harvest Interval	Balsam Fir Pole-Timber	Balsam Fir Saw-Timber[b]	Spruces Pole-Timber	Spruces Saw-Timber	Eastern Hemlock Pole-Timber	Eastern Hemlock Saw-Timber	Other Softwoods Pole-Timber	Other Softwoods Saw-Timber	Hardwoods Pole-Timber	Hardwoods Saw-Timber
ft^2/acre	Years										
	5	0.47	0.00	0.24	0.00	0.11	0.00	0.00	0.00	0.00	0.00
40	10	4.92	0.00	0.61	0.00	0.26	0.86	0.97	1.73	0.62	0.00
	20	3.38	0.00	0.70	0.93	0.27	0.00	0.31	0.38	0.98	0.69
	5	3.64	0.00	0.52	0.57	0.27	0.00	1.15	3.79	0.36	0.00
60	10	3.08	0.00	0.59	0.40	0.51	0.32	0.34	0.84	0.86	2.38
	20	3.85	0.00	0.65	1.26	0.21	0.47	0.35	1.18	0.53	0.89
	5	5.51	0.00	0.71	0.40	0.37	0.17	1.23	0.85	0.48	0.55
80	10	3.14	26.77	0.50	0.46	0.44	0.74	0.88	0.22	0.55	0.36
	20	3.36	17.23	0.53	0.57	0.26	0.21	0.51	0.97	0.59	2.62
	5	4.28	5.85	0.51	0.30	0.11	0.07	0.82	1.44	0.36	0.12
100	10	3.23	0.00	0.31	0.55	0.28	0.33	0.79	1.22	0.30	0.70
	20	3.41	7.66	0.50	0.19	0.16	0.25	0.61	0.00	0.65	0.87
	5	3.85	0.00	0.47	0.94	0.20	0.10	1.16	0.68	0.47	0.00
120	10	3.06	0.00	0.98	0.23	0.52	0.45	0.94	0.86	0.45	0.54
	20	2.36	5.03	0.30	0.22	0.15	0.08	0.80	1.63	0.97	0.55

[a] For conversion to square meters per hectare multiply by 0.229568
[b] Large percentages may be due to small initial basal area.

Table 6b.- Annual mortality by species, size class, residual basal area, and harvest interval (in percent of initial volume).

Residual Basal Area[a]	Harvest Interval	Balsam Fir Pole-Timber	Balsam Fir Saw-Timber[b]	Spruces Pole-Timber	Spruces Saw-Timber	Eastern Hemlock Pole-Timber	Eastern Hemlock Saw-Timber	Other Softwoods Pole-Timber	Other Softwoods Saw-Timber	Hardwoods Pole-Timber	Hardwoods Saw-Timber
ft^2/acre	Years										
	5	0.44	0.00	0.22	0.00	0.08	0.00	0.00	0.00	0.00	0.00
40	10	5.15	0.00	0.63	0.00	0.29	0.85	0.98	1.61	0.54	0.00
	20	3.73	0.00	0.70	0.93	0.28	0.00	0.28	0.40	1.00	0.66
	5	3.83	0.00	0.51	0.58	0.28	0.00	1.03	3.40	0.32	0.00
60	10	3.24	0.00	0.59	0.40	0.52	0.33	0.33	0.80	0.88	2.27
	20	4.12	0.00	0.65	1.25	0.21	0.48	0.33	1.20	0.52	0.80
	5	5.58	0.00	0.66	0.41	0.37	0.18	1.24	0.93	0.45	0.52
80	10	3.28	25.97	0.50	0.45	0.45	0.78	0.86	0.21	0.54	0.32
	20	3.59	17.23	0.50	0.58	0.27	0.21	0.49	1.02	0.58	2.84
	5	4.33	5.62	0.50	0.28	0.12	0.07	0.82	1.35	0.34	0.11
100	10	3.36	0.00	0.28	0.55	0.27	0.34	0.75	1.17	0.29	0.66
	20	3.63	7.73	0.50	0.18	0.16	0.25	0.62	0.00	0.63	1.00
	5	3.90	0.00	0.45	0.98	0.22	0.10	1.26	0.68	0.46	0.00
120	10	3.50	0.00	1.02	0.22	0.54	0.47	0.95	0.74	0.44	0.49
	20	2.52	5.03	0.25	0.24	0.14	0.08	0.68	1.50	1.00	0.44

[a] For conversion to square meters per hectare multiply by 0.229568
[b] Large percentages may be due to small initial basal area.

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