Absorption of Sound by Tree Bark

by

G. Reethof, L. D. Frank, and O. H. McDaniel

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Absorption of Sound by Tree Bark

ABSTRACT

Laboratory tests were conducted with a standing wave tube to measure the acoustic absorption of normally incident sound by the bark of six species of trees. Twelve bark samples, 10 cm in diameter, were tested. Sound of seven frequencies between 400 and 1600 Hz was used in the measurements. Absorption was generally about 5 percent; it exceeded 10 percent for only three samples, and then only at 1250 Hz or above. No general trend was evident in the variation of absorption with frequency.

INTRODUCTION

It has been shown by previous field research that dense forests greater than 50 feet deep provide useful attenuation of noise (*Eyring 1946, Embleton 1963, Cook and Van Haverbeke 1972, Reethof 1973*). However, there is some disagreement on the amount of absorption to be expected. Furthermore, the mechanism of sound attenuation by forests is not well understood. Tree boles may act primarily as scatterers of sound, and the elements that provide the greatest absorption may be soft forest floor, shrubbery, or a combination of these. Once the major absorbing elements are identified, their relative contribution to the overall attenuation of sound can be studied in detail so that forest characteristics and species that will yield the most effective attenuation can be recommended.

This paper describes the initial phase of our comprehensive study of the attenuation of sound by forests. Sound absorption characteristics of bark from trees of six species were studied in the laboratory. There is essentially no literature on the sound absorption characteristics of bark, and none on measurement instrumentation. We plan to examine the sound absorbing mechanisms of various forest elements to determine how these affect the dissipation of acoustic energy in forests. Ground absorption, considered by some to be effective in forests, will be studied next. Attenuation by shrubs and tree canopies will also be examined.

PROCEDURE

The absorption by tree bark of sound of normal (perpendicular) incidence was measured with a commercial impedance tube, also known as a standing wave tube, manufactured by Bruel & Kjaer Instruments, Inc.[1] Cylindrical test samples were cut from slabs, with the natural wood intact behind the bark. Six species were tested: northern red oak (*Quercus rubra* L.), mockernut hickory (*Carya tomentosa* Nutt.), eastern white pine (*Pinus strobus* L.), American beech (*Fagus grandifolia* Ehrh.), eastern hemlock (*Tsuga canadensis* (L) Carr.), and a cork oak (*Quercus suber* L.).

Impedance tubes are used to measure the

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[1]The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the Forest Service or the U. S. Department of Agriculture of any product or service to the exclusion of others that may be suitable.

fraction of the incident acoustic energy absorbed by a material. Pure tone sound waves travel down the tube and strike the sample; part of the acoustic energy is absorbed by the material and the remaining energy is reflected and travels back up the tube. The superposition of the incident wave and the reflected wave establishes a standing wave (*Kinsler and Frey 1962*). The amplitude maxima and minima of the standing wave are measured and the absorption coefficient is calculated using the following relationship:

$$\alpha = 1 - \left(\frac{S - 1}{S + 1}\right)^2$$

where α is the absorption coefficient, the ratio of the absorbed to incident acoustic energy, and

S is the ratio of the maximum to minimum acoustic pressures in the impedance tube.

A typical axial pressure pattern is shown in figure 1.

Figure 2 is a schematic diagram of the apparatus. The sample holder is mounted at one end of the impedance tube, which is 10 cm in diameter and 1 m long. A loudspeaker is mounted in a box at the other end of the tube. A frequency oscillator generates selected tones, and a frequency counter monitors the tone sent to the speaker to insure accuracy within ± 1 Hz. A 1/8-inch-diameter microphone probe tube moves in and out along the central axis of the impedance tube. The microphone in the movable carriage at the end of the probe tube monitors the sound pressure of the standing wave. The signal from the microphone goes through a preamplifier to an audio frequency spectrometer, where the absorption coefficient is read from a calibrated scale. The apparatus is shown assembled in figure 3.

The impedance tube is designed for use with normally incident waves and samples with a flat surface. Bark, with its surface irregularities, does not conform to the definition of a flat surface. Therefore, a hard oak slab, an excellent reflector, was placed in the sample holder and its absorption was measured. Then an additional slab was mounted at an angle to simulate one ridge of a bark surface, and absorption was again measured. The results showed excellent agreement, indicating that absorption by bark can legitimately be measured with the impedance tube.

For proper impedance tube measurements the sample must be properly seated in its holder. This presents no problems for flexible materials, because they make good contact with the surface of the holder, leaving

Figure 1.—A typical axial pressure pattern of the standing wave in the impedance tube.

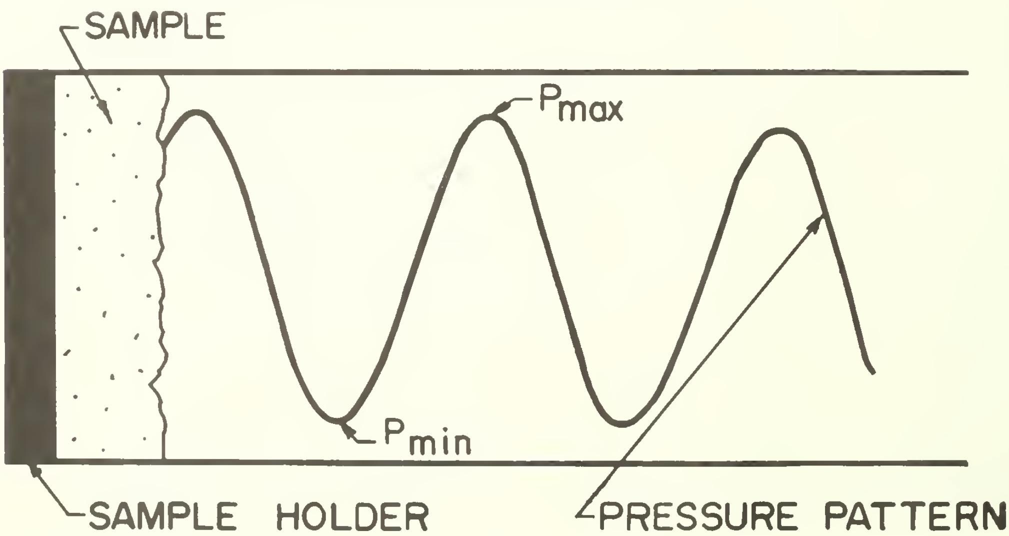


Figure 2.—A schematic diagram of the impedance tube apparatus.

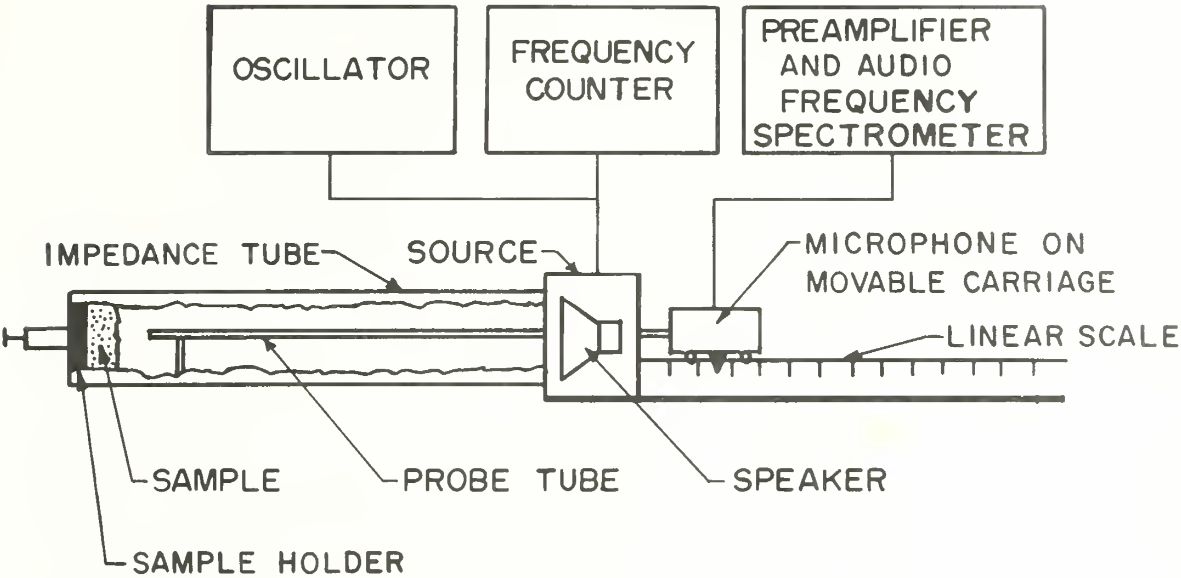
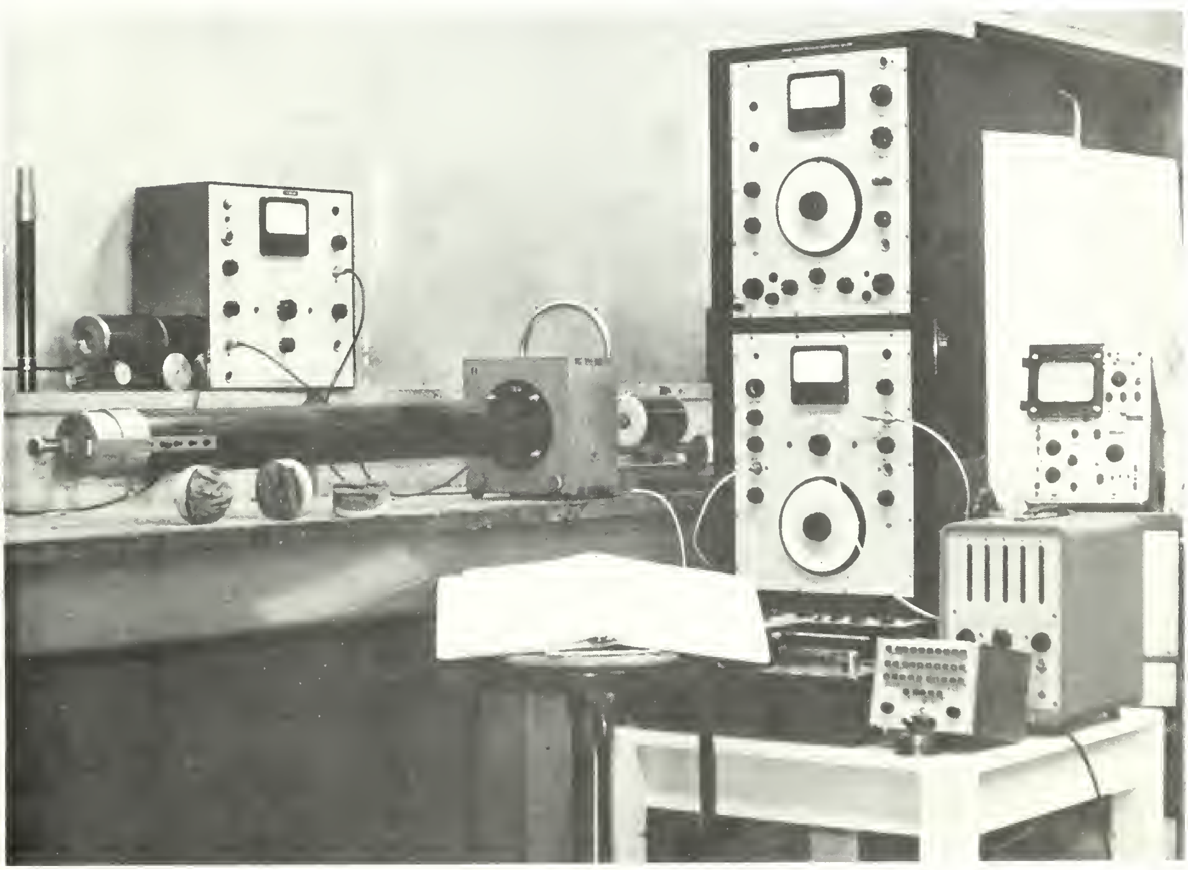


Figure 3.—The impedance tube, instruments, and several samples.



no room for air gaps in which sound would be absorbed. But with wood, problems arise. If the sample is turned on a lathe so that there is just enough tolerance for the sample to be inserted and removed, there is a finite thin ring of air between the sample and holder. The flow resistance of the air passages will provide acoustic absorption, resulting in erroneous absorption coefficients. And the gap allows the sample to vibrate, which also may produce errors.

We tried various ways of holding the sample. Bolting it in place and using various sealers and putties improved results. However, the best method we discovered was to pour liquid paraffin into the sample holder, insert the sample, and let the paraffin solidify to form a seal. Care was taken to assure that the paraffin did not fill any bark crevices.

Our first tests, with no sealer and with the sample not bolted in place, produced absorption coefficients as high as 46 percent. Repeated tests with paraffin-held samples showed absorption coefficients of less than 10 percent. Tests with paraffin alone in the sample holder showed no significant absorption by the paraffin. The absorption coefficients obtained from samples sealed with paraffin were repeatable within 0.01.

Freshness of the bark was of concern, and that measurements were made to determine whether dried samples would yield absorption coefficients different from those of bark on live trees. We obtained several freshly cut bark samples and tested them immediately. The absorption of dry and fresh samples were similar. It was concluded that the moisture content of bark does not significantly alter its absorption. Therefore, our tests, made on dried bark samples obtained from mature trees, were assumed to be representative of natural conditions in the forest.

The 1-meter-long impedance tube is normally capable of providing reliable absorption data at frequencies as low as 125 Hz. However, the presence of irregularities in bark surfaces made it advisable to record the maximal and minimal acoustic pressures at a greater distance from the sample than is required for testing smooth materials (*Skudrzyk, 1971*). This increased the lower limiting frequency, which is dependent on the length of the impedance tube available for measurement, to 400 Hz. The upper limiting frequency, 1600 Hz, was determined by the diameter of the tube.

RESULTS AND DISCUSSION

The absorption coefficients of samples of red oak, mockernut hickory, and white pine are plotted against frequency in figures 4, 5, and 6, respectively. Each figure shows the results for three samples, each checked for repeatability. The absorption coefficients found in repeated tests of each sample seldom differed by more than 0.01. The absorption coefficients for all samples of the three species were less than 0.10, except for hickory, which had absorption coefficients between 0.02 and 0.23 at frequencies above 1250 Hz. The wide variation in this species correlated well with differences in bark thickness; a thin-barked sample consistently gave low values. The high absorption of mockernut hickory bark may be due to its shale-like layers with spaces between them. The spaces may allow individual layers to vibrate, transforming the incident acoustical energy into mechanical energy. This probably accounts for the high absorption.

After tests on oak, hickory, and white pine, we looked for bark characteristics that might alter the absorption of sound, and selected three other species for testing. These species were American beech, eastern hemlock, and a cork oak. The results are shown in figure 7. The hemlock sample had a higher absorption coefficient than the beech or cork oak, but all were less than 0.10.

CONCLUSION

The absorption coefficients of the six species we tested are quite low and largely independent of frequency. The small variation in absorption among the samples shows that sound attenuation by forest trees is little affected by bark characteristics, unless it is highly sensitive to differences in bark absorption.

Although each tree bole absorbs only a

Figure 4.—Absorption of normal-incidence sound by bark of northern red oak.

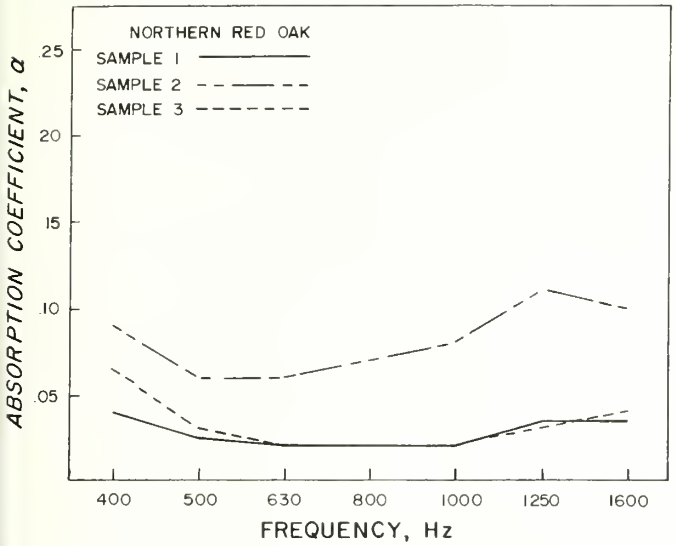


Figure 6.—Absorption of normal-incidence sound by bark of eastern white pine.

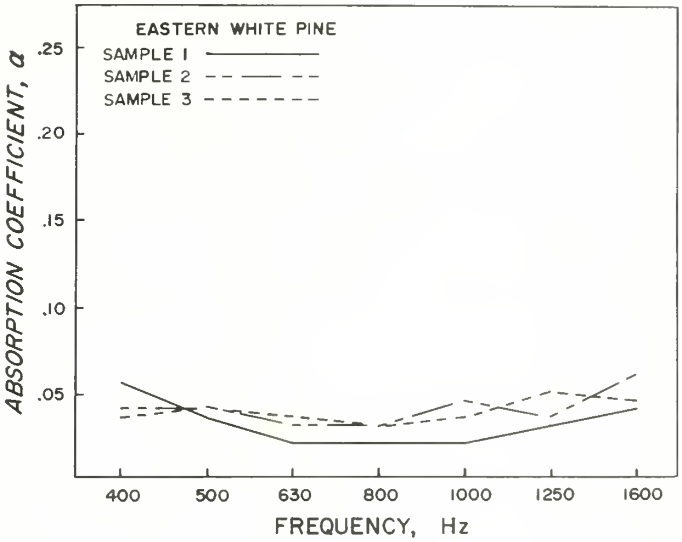


Figure 5.—Absorption of normal-incidence sound by bark of mockernut hickory.

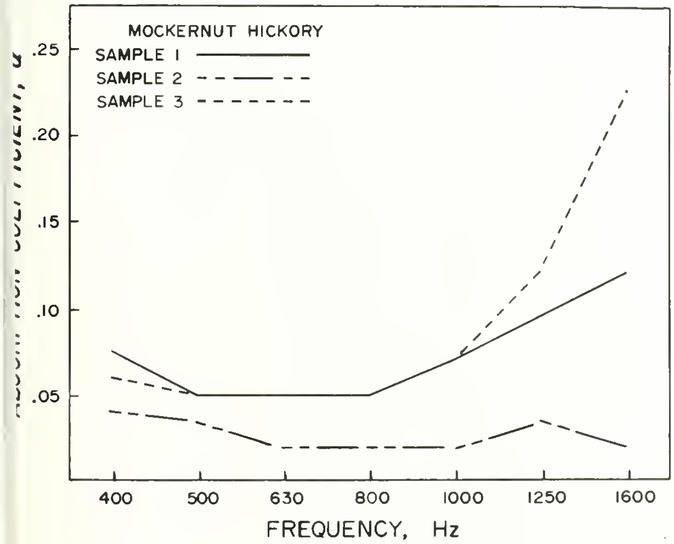
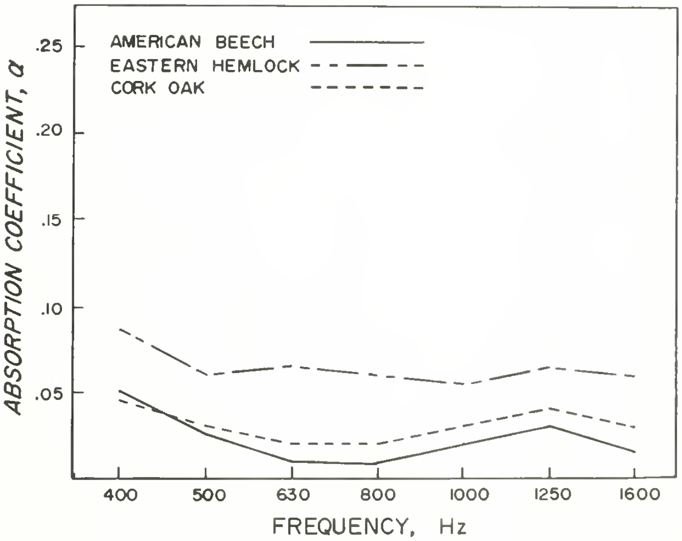


Figure 7.—Absorption of normal-incidence sound by bark of American beech, eastern hemlock, and cork oak.



small fraction of the energy of the incident wave, the effect is repeated as the sound wave is scattered from one tree to another. We do not know how the total absorption by bark compares with that of shrubs, foliage, branches, or the canopy as a whole. It can be assumed that the scattering process makes the sound available to more surface area and therefore gives the ground and the other forest elements more chances to absorb the acoustic energy.

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BETTER LOAD-WEIGHT DISTRIBUTION IS NEEDED FOR TANDEM-AXLE LOGGING TRUCKS

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FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
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BETTER LOAD-WEIGHT DISTRIBUTION IS NEEDED FOR TANDEM-AXLE LOGGING TRUCKS

ABSTRACT

To determine the GVW and axle weights of tandem-axle logging trucks hauling into two West Virginia sawmills, 543 truckloads of hardwood sawlogs were weighed. The results showed that less than 2 percent of the truckloads exceeded the 48,000 pound GVW limit. While 58 percent of the truckloads exceeded the 32,000 pound tandem-axle weight limit, the front-axle weights never exceeded the 18,000-pound single-axle limit and seldom exceeded 10,000 pounds. Because the trucks sampled carried an average of 93 percent of the load weight on the rear axles, they could not haul maximum payloads without exceeding the tandem-axle weight limit on the rear axles.

The wheelbase dimension of the trucks and the location of the body on the truck determined the distribution of load weight. From these results, a truck design guide was developed in the form of an easy-to-use nomogram. The configuration of tandem-axle logging trucks needs to be changed, and loggers should select a truck design that will provide the correct distribution of load weight and have the capacity to handle the front- and rear-axle loads needed for maximum payloads.

BY DISTRIBUTING THE PAYLOAD weight so that both front and rear axle weights are maximized, loggers could very often increase payloads. This would also reduce axle-weight overloads that can result in heavy fines being levied on truck operators.

An increase in payloads would increase trucking efficiency. Martin *(1971)* reported that a 25-percent increase in tandem-truck payloads would reduce the hauling cost by 21 percent. Moreover, maximizing logging-truck payloads would help loggers maintain a more efficient harvesting system because trucking frequently regulates the productivity of the entire logging operation.

In a study at our Forest Products Marketing Laboratory, we found that the payloads transported by tandem-axle logging trucks were located so far to the rear of the truck that it was impossible to attain proper axle loading or maximum payloads. The results from this study point out a real need for improving payload weight distribution so that payloads can be consistently maximized within the legal axle-weight limits prescribed by law.

THE AXLE-WEIGHT STUDY

The study was made at two West Virginia sawmills. At one mill, 464 loads of logs were weighed, on 10 tandem-axle trucks hauling from several different sites. At the second mill, 79 loads were weighed, on 4 tandem-axle trucks hauling from 2 different sites. All the loads weighed were hardwood sawlogs. None of the trucks weighed were equipped with log loaders.

The 464 loads weighed at the first mill were unloaded with a forklift truck. We felt that this method of unloading might affect the truck loading and subsequent weight distribution because all logs had to be accessible to the forklift working between the stakes on the truckbed. Therefore the second sampling site was selected at a mill where trucks were unloaded with trip stakes.

By weighing front and rear axles separately, both loaded and empty, we were able to determine payload weight on the front axle as well as on the rear tandem axles. Dividing the payload on the rear axles by the total payload, we were able to calculate the percentage of the payload transferred to the rear axles. This procedure provided a measure of weight distribution and served as the basis for estimating the load center of gravity (LCG). The following formula for calculating the load center of gravity, measured in inches from the front axle, was derived from a load-transfer equation presented by Fitch *(1969)*:

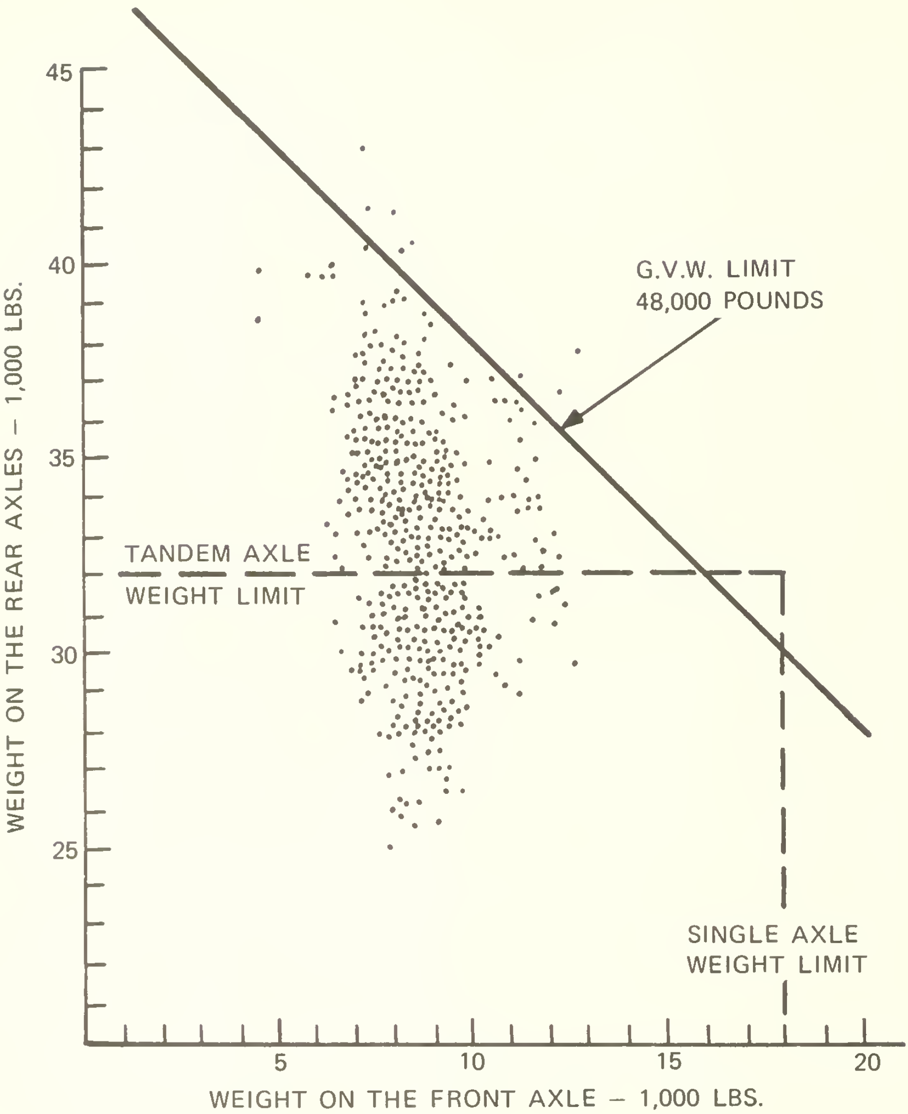
$$\frac{\text{Payload rear axle}}{\text{Total payload}} \text{(Wheelbase)} = \text{LCG (inches from front axle)}$$

GROSS VEHICLE WEIGHTS AND AXLE WEIGHTS

The gross vehicle weight (GVW) limit in West Virginia is 48,000 pounds for three-axle trucks of the wheelbase dimensions we sampled (*W. Va. Dep. Motor Vehicles 1968*). Less than 2 percent of the truckloads sampled exceeded this GVW limit (table 1). Eleven of the 14 study trucks never exceeded 48,000 pounds GVW. The average GVW sampled was 41,465 pounds, and in most cases several thousand pounds of payload could have been added without exceeding the GVW limit.

Although the weight limit for single axles is 18,000 pounds (*North American Rockwell 1970*) none of the trucks used in the study were equipped with front axles or tires capable of safely handling the maximum legal single-axle load. Front-axle weights seldom exceeded 10,000 pounds (fig. 1). The average front-axle weight for all trucks was 8,675 pounds, and the front-axle weights of in-

Figure 1.—Scatter diagram of the front and rear axle weights sampled.



dividual trucks ranged from 7,538 pounds to 11,590 pounds (table 1).

The rear tandem axles of the trucks weighed were frequently overloaded; 58.1 percent of the truckloads exceeded the 32,000-pound tandem-axle weight limit (*North American Rockwell 1970*). All 14 sample trucks carried loads that exceeded the tandem-axle weight limit. However, the frequency of overloads varied from truck to truck, ranging from 9.1 percent to 94.4 percent. The average weight of the rear axles for all truckloads was 32,790 pounds.

The average payload hauled by all trucks was 25,618 pounds. The average payloads for the individual trucks ranged from 22,296 pounds to 29,893 pounds. For all loads sampled, the average payload carried on the front axle was 1,932 pounds and the average payload carried on the rear axles was 23,686 pounds.

Table 1.—Average truck, axle, and payload weights

Truck No.	Loads sampled	Combined weight — payload and truck					Payload weight		
		GVW	Loads over GVW limit [a]	Rear tandem axles	Loads over tandem axle limit [b]	Front axle [c]	Carried on front axle	Carried on rear axles	Total payload
	No.	*Lbs.*	*Percent*	*Lbs.*	*Percent*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
1	22	38,977	0	30,763	31.8	8,213	1,333	21,768	23,102
2	20	41,295	0	32,640	50.0	8,655	1,950	23,565	25,515
3	20	39,766	0	31,808	40.0	7,958	1,363	22,208	23,571
4	17	41,476	0	33,222	64.7	8,254	1,854	24,162	26,016
5	36	43,643	0	34,778	94.4	8,855	2,055	26,048	28,104
6	55	38,441	0	29,643	9.1	8,798	1,548	20,748	22,296
7	18	44,161	0	33,273	77.8	10,887	4,977	24,783	29,761
8	20	45,853	15.0	34,263	75.0	11,590	4,490	25,403	29,893
9	66	40,898	0	31,377	36.4	9,520	2,425	21,877	24,303
10	73	40,126	0	30,874	38.4	9,251	1,751	22,084	23,836
11	31	40,603	0	32,816	55.8	7,787	1,867	24,196	26,063
12	39	42,445	5.1	34,907	76.9	7,538	698	25,087	25,785
13	50	42,864	0	34,701	92.0	8,162	1,972	26,031	28,004
14	76	42,748	3.9	35,120	86.8	7,627	1,467	25,490	26,958
All trucks	543	41,465	1.46	32,790	58.1	8,675	1,932	23,686	25,618

[a] GVW limit equals 48,000 pounds.
[b] Tandem-axle limit equals 32,000 pounds.
[c] No front-axle weights exceeded the single-axle weight limit.

LOAD WEIGHT DISTRIBUTION

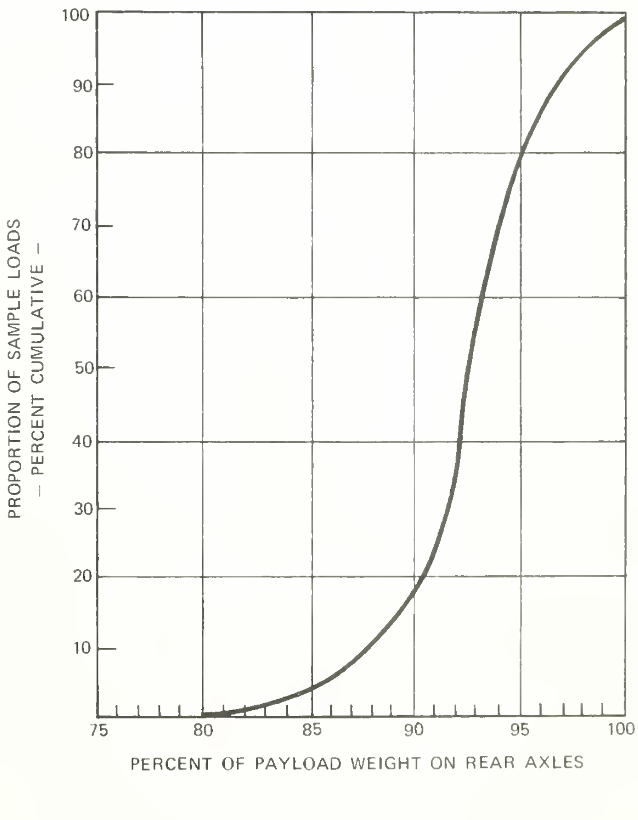
Although the truck payloads we sampled were not excessive, the rear axles were frequently overloaded because so much load weight was carried on the rear axles. Half of the truckloads sampled carried more than 93 percent of the load weight on the rear axles (fig. 2).

The distribution of load weight is determined by the location of the load center of gravity (LCG) relative to the truck axles. When the load center of gravity is measured from the front axle, the proportion of load weight on the rear axles is equal to LCG ÷ Wheelbase.

The distance from the front axle to the load center of gravity is controlled by the location of the truck body on the truck chassis and the position of the load of logs on the truck body.

We measured the location of the truck body from the front axle to the headboard. The headboard was used as a reference point because it regulates the forwardmost place-

Figure 2.—Proportion of payload weight carried on the rear axles.



ment of logs and therefore regulates the distribution of load weight.

We determined the location of the load center of gravity on the truck body by first estimating the load center of gravity relative to the front axle and then subtracting the distance from front axle to headboard. The difference represents the distance from the body headboard to the load center of gravity.

The truck wheelbase was measured from the front axle to the midpoint of the rear tandem axles.

The individual trucks were loaded very consistently. Hence the location of the LCG and the resulting proportion of load weight on the rear axles showed little variation between loads (table 2).

The between-truck weight - distribution variations were due primarily to the dimensions of the trucks rather than the placement of the load on the truck. We computed a regression equation to predict the mean LCG for each truck:

$$Y = 102.39 + 0.96X_1 \qquad [1]$$

In which:

Y = mean LCG

X_1 = distance from the front axle to the headboard.

The coefficient of determination was 0.75, which means that 75 percent of the variation in the mean LCG was accounted for by regressing on the truck-body location.

Using both wheelbase length and body location, we computed a regression equation for predicting the average percentage of payload on the rear axles of each truck:

$$Y = 139.3 + .44X_1 - .42X_2 \qquad [2]$$

In which:

Y = mean percent payload weight on the rear axles

X_1 = distance from front axle to headboard of truck body

X_2 = length of truck wheelbase.

The coefficient of determination (R^2) for equation 2 was 0.78 and the standard error of the estimate was 1.9 percent.

The four trucks unloading with trip stakes had less variation in load center of gravity than those unloaded with a lift truck (table 2). The average percent payload on the rear axles was about the same for both groups of trucks.

Table 2.—Truck dimensions and load weight distribution statistics

Truck No. [a]	Loads sampled	Wheel-base [b]	Body location [c]	Percent of payload on rear axles		LCG inches from front axle	LCG inches from headboard of body	
				Mean	Standard deviation	Mean	Mean	Standard deviation
	No.	*Inches*	*Inches*					
1	22	184	72	94.2	1.74	173.3	101.3	3.22
2	20	186	70	92.4	1.53	171.8	101.8	2.85
3	20	186	75	94.2	2.22	175.3	100.3	4.12
4	17	186	72	92.8	1.46	172.7	100.7	2.72
5	36	198	86	92.7	1.62	183.5	97.5	3.25
6	55	185	79	93.1	2.02	172.2	93.2	3.72
7	18	212	78	83.3	2.30	176.5	98.5	4.88
8	20	211	81	84.9	2.63	179.1	98.1	5.56
9	66	188	76	90.0	2.46	169.2	93.2	4.60
10	73	185	70	92.7	2.17	171.5	101.5	3.99
11	31	196	80	92.8	2.65	182.0	102.0	5.20
12	39	188	80	97.3	2.13	183.0	103.0	4.03
13	50	196	86	92.9	2.54	182.1	96.1	4.99
14	76	206	90	94.6	2.14	194.8	104.8	4.35

[a] Trucks 1 through 4 were unloaded with trip stakes, trucks 5 through 14 were unloaded with a forklift truck.
[b] Measured from front axle to midpoint of tandem rear axle.
[c] Measured from the front axle to headboard of truck body.

MAXIMIZING PAYLOADS WITHOUT AXLE OVERLOAD

The trucks we sampled should have carried proportionately more load weight on the front axle. If the distribution of load weight is not changed, axle overloading can be avoided only by reducing payloads. However, near-maximum payloads can be hauled without axle overloading if the load weight is properly distributed.

The location of the load center of gravity dictates load-weight distribution, which in turn dictates the maximum payload that can be transported without exceeding specified axle-weight limits or the rated capacity of the axles. The relationship between the location of the load center of gravity and the maximum payload is shown in figure 3. This represents a 200-inch wheelbase, tandem-axle truck with empty front and rear axle weights of 7,000 and 9,000 pounds respectively. Assuming the desired loaded axle weights are 16,000 pounds on the front and 32,000 pounds on the rear, 9,000 pounds of payload weight can be carried on the front axle and 23,000 pounds on the rear.

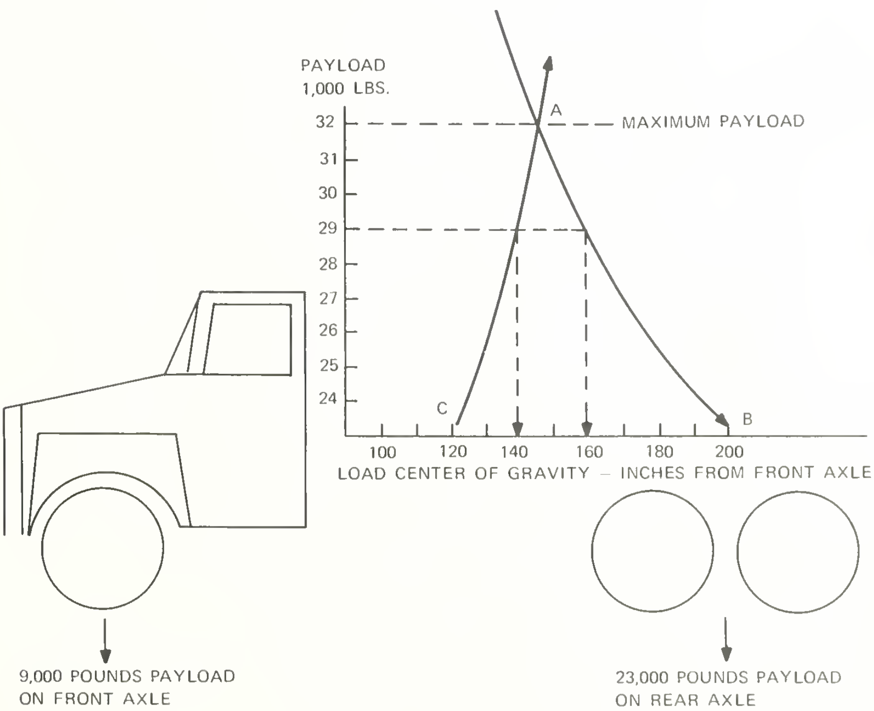
Curve AB in figure 3 represents the combinations of payload weight and LCG that will result in rear-axle weights of 32,000 pounds, or 23,000 pounds of load weight on the rear axles. Any load weight and LCG combination that intersects to the right of AB will overload the rear axles. This curve is described by the equation:

$$\text{Maximum payload} = \frac{\text{Max. load on the rear axles}}{\text{LCG} \div \text{wheelbase}}$$

Curve AC (fig. 3) represents the combinations of payload weight and LCG that result in front-axle weights of 16,000 pounds, or 9,000 pounds of load weight on the front axle. Any load weight and LCG combination that intersects to the left of AC will overload the front axle. This curve is described by the equation:

$$\text{Maximum payload} = \frac{\text{Max. load on front axle}}{1 - (\text{LCG} \div \text{wheelbase})}$$

Figure 3.—Influence of the load center of gravity on the maximum payload.



The AB and AC curves intersect at the maximum payload and the optimum load center of gravity. The maximum payload is equal to the sum of the maximum axle loads. The optimum LCG is at the point where the proportion of load weight carried by each axle is equal to the ratio of the maximum axle load and maximum payload.

In this case, the optimum LCG is 143.75 inches. The proportion of load weight on the rear axle is equal to 143.75 ÷ 200 or .72 which is equal to 23,000 ÷ 32,000 pounds. The proportion of load weight on the front axle would equal 1 — (143.75 ÷ 200) or .28, which is equal to 9,000 ÷ 32,000 pounds.

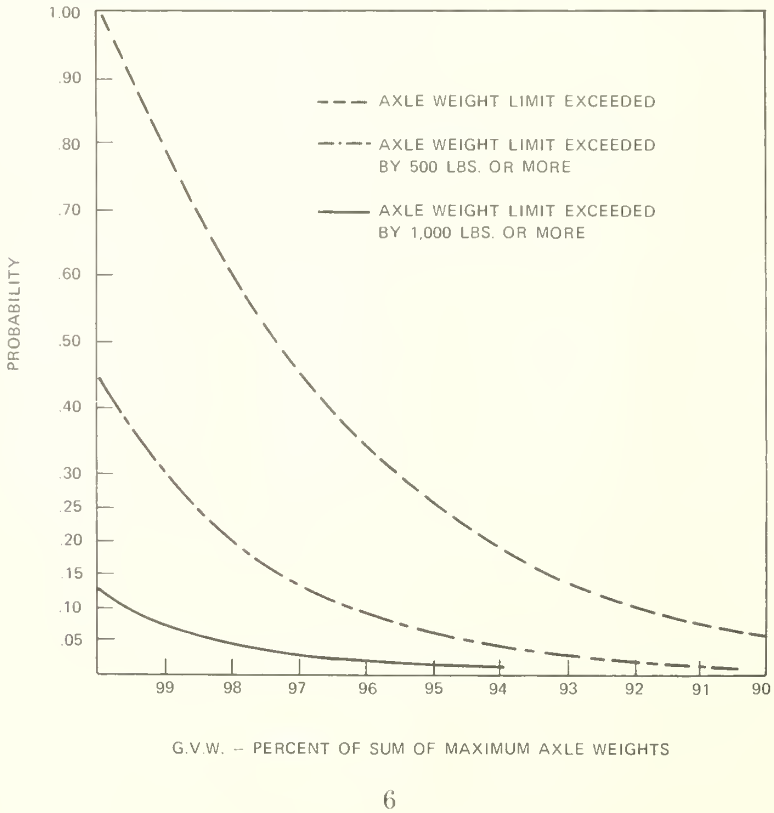
For the 543 loads sampled, the average payload on the rear axle was 93 percent. For this example, this would correspond to a 186-inch center of gravity: $.93 \times 200 = 186$. With the LCG at this point, any load in excess of 25,000 pounds will result in overloaded rear axles. This is 7,000 pounds less than the maximum legal payload.

Because loggers cannot precisely position the center of gravity of each load of logs, the LCG varies from load to load. Although this variation seems to be limited, when GVW is equal to the sum of the maximum axle weights, this variation can cause axle-weight overloads even when the mean LCG is located at the optimum point.

To prevent this type of overloading, the GVW of logging trucks should be less than the sum of the maximum axle weights. This margin allows the LCG to vary without overloading the axles. In the preceding example, the sum of the maximum axle weights is 48,000 pounds. If the payload is reduced to 29,000 pounds so that the GVW is 45,000 pounds, the LCG can vary approximately 20 inches without axle overload (fig. 3).

The nature of the relationship between payload reductions and the probabilities of axle overload is shown in figure 4. In this example, we assumed that the mean LCG was located at the optimum position for the

Figure 4.—The relationship between GVW and the probability of overloads.



maximum payload, and that the standard deviation was 4.0 inches, which is about the average value for the standard deviation of LCG shown in table 2.

Assuming that the LCGs are normally distributed, we can compute the probabilities of overload that are given in figure 4. By reducing the payload 5 percent so that the GVW equals 95 percent of the sum of the maximum axle weights, the probability of overload is only .26 and the probability of a 500-pound overload is less than .06.

RECOMMENDATIONS

The study results show that tandem-axle logging trucks can transport near-maximum payloads without significant axle overload, if more payload weight is shifted to the front axle. To make this change, loggers can change the configuration of the log loads or change the configuration of the logging trucks.

The load configuration can be changed by loading all logs as far forward on the truck body as possible. This practice would shift the weight of 8-, 10-, 12-, and 14-foot logs forward and transfer more weight onto the front axle.

The trucks in this study were loaded so most of the short logs were centered on the truckbed rather than butted up against the headboard. This was done because the retaining stakes were located too far back on the truckbed. By moving the stakes on the truckbed or adding stakes and load binders, the shorter logs could be secured in a forwardmost position.

To optimize the distribution of load weight, the configuration of logging trucks must be changed. With the trucks and sawlog lengths observed in this study, it would be impossible to move the load forward far enough to load the front axle properly. Furthermore, the analysis of weight distribution showed that the dimensions of the logging truck are the most important determinants of weight distribution.

We have prepared a guide to selecting the correct combinations of wheelbase length and body location (fig. 5). This guide is designed to help loggers obtain the distribution of load weight that is compatible with the relative capacities or legal limits for the front and rear axles. The relationship between weight distribution and truck configuration is based upon equation 1.

To use the nomogram, both the maximum payload and maximum load on the rear axles must be determined. The payload weight is the difference between the maximum GVW and the weight of the empty truck. The load on the rear axle is the difference between the maximum tandem-axle weight and the rear-axle weight of the empty truck.

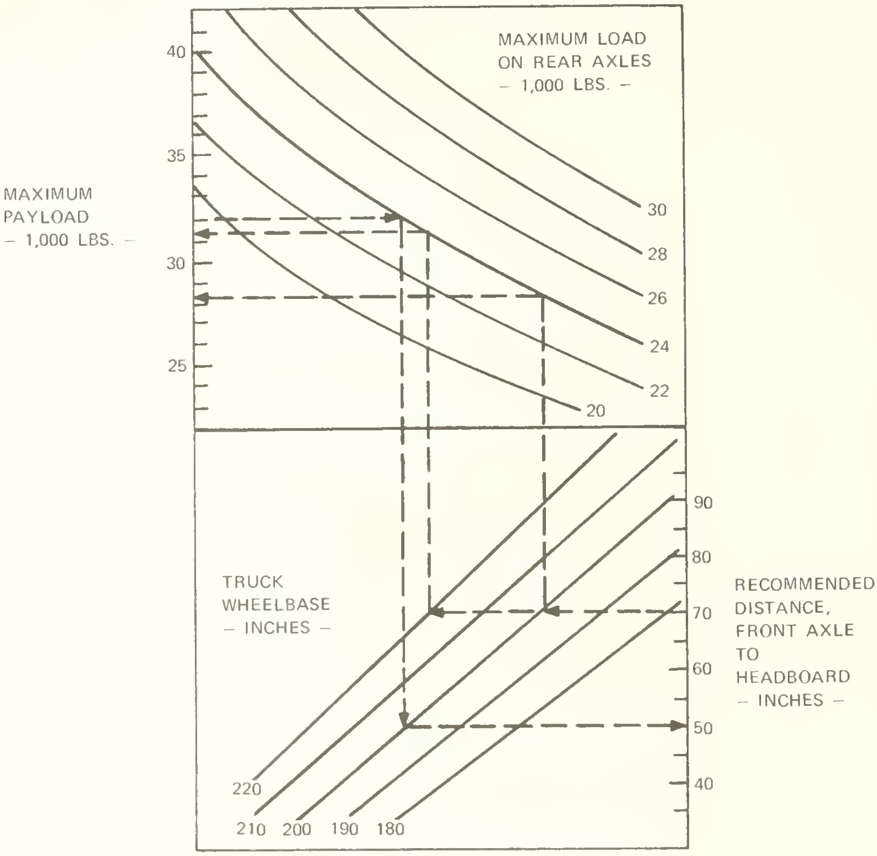
The maximum GVW and rear-axle weights used in these calculations should not exceed either the legal weight limits or the rated capacity specified by the manufacturer. Furthermore, the GVW should not exceed the sum of the front and rear axles weight capacities.

For example, if the front axle and front tires are rated for 12,000 pounds, and the rear axles are rated for 32,000 pounds, regardless of the legal GVW limit, the GVW of the truck shouldn't exceed 44,000 pounds.

To demonstrate the use of the nomogram, suppose that the maximum GVW equals 48,000 pounds and the rear-axle weight limit is 32,000 pounds. If the tare weight of the truck is 16,000 pounds, the maximum payload would equal 32,000 pounds. If the chassis and body weight on the rear axle of the unloaded truck is 8,000 pounds, the maximum load on the rear axles would equal 24,000 pounds. In this case, a 200-inch wheelbase truck should have the headboard located no more than 50 inches from the front axle (fig. 5).

Using figure 5 in reverse, suppose 70 inches is the minimum front-axle-to-headboard distance that could be attained on a particular truck. To maintain a load on the rear axles of 24,000 pounds or less, a truck with a 200-inch wheelbase shouldn't carry a payload exceeding approximately 28,000 pounds. Increasing the wheelbase to 220 inches would increase the allowable payload to approximately 31,000 pounds (fig. 5).

Figure 5.—Tandem-axle logging truck design guide.



DISCUSSION AND SUMMARY

Loggers should put more load weight on the front axle of the tandem-axle logging truck if they expect to maximize payload without exceeding the legal axle-weight limits. To do this, they should select a truck design that will properly distribute the weight between the front and rear axles and safely handle the added front-axle loads.

From the truck-design guide, the combinations of truck wheelbase length and body location can be determined that will distribute the load weight in accordance with the relative capacities of the front and rear axles. The truck dimensions recommended by this guide may require loggers to select a longer-wheelbase truck or one with a setback front-axle design. The bunks and log-retaining stakes on the truck body should also be located as far forward on the truck as possible.

The legal axle-weight limits or the weight capacity of the truck axles should determine how much weight should be carried by both front and rear axles. Certainly, every logger should not load the front axle to the maximum single-axle weight limit, which varies from 18,000 pounds to 22,400 pounds for the various eastern states (4). Such loads on the steering axle would create severe handling problems. However, the average front-axle weight sampled was 8,675 pounds, and any improvement over this would help reduce rear-axle overloads and increase legal payloads.

To keep the capacity of the front axle in line with increased front-axle loads, trucks should be equipped with heavy-duty front axles and tires. Front axles with ratings of 16,000 to 18,000 pounds are offered as options by many truck manufacturers. Wider tires will keep the added loads within the legal weight-per-tire-inch restrictions.

The added cost of these heavy-duty components should be compared with the expected benefits, such as increased payloads and safer operation that would be realized over the life of the truck.

Loggers trying to maintain the most efficient and productive operations possible should carefully select logging trucks, truck components, and truck bodies. To maximize payloads and minimize costs, every aspect of truck design should be considered.

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by R. Bruce Anderson

Factors Influencing Selection of Office Furniture by Corporations and Universities

USDA FOREST SERVICE RESEARCH PAPER NE-343
1976

FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
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MANUSCRIPT RECEIVED FOR PUBLICATION 22 APRIL 1975

SUMMARY ABSTRACT

Evaluation of the factors that influence the selection of office furniture by large corporations and universities shows that quality, appearance, and purchase price have the most important influence on the purchase decision. The intended use of the furniture and the appearance of the furniture were the key factors in the purchase of wooden furniture.

IF YOU MAKE something to sell, you ought to know something about the people who do the buying. As an aid to the makers of wooden office furniture, we made a study of the buying practices of large corporations and universities.

Manufacturers of office furniture have had increasing sales during the past 10 years. Shipments had a total value of $1,099 million in 1972 as compared to $490 million in 1964. However, the proportion of wooden office furniture to metal office furniture shipments has remained nearly constant.

Unlike the household-furniture industry, the office-furniture industry does not have an abundance of information defining the factors that influence their customers' purchasing practices. In our study, we attempted to identify the factors that influence the selection of new office furniture.

PROCEDURE AND OBJECTIVES

Purchasing officials from large corporations and universities in the Northeast were asked to complete a mailed survey questionnaire. The questions were developed from a pilot survey in the Philadelphia area and from interviews with nine state government purchasing officials.

The objectives of the study were:

1. To determine the importance of purchase price, appearance, service life, maintenance costs, delivery time, and overall quality as criteria in the selection of office furniture.
2. To determine the extent to which personal preferences of the purchasing agent are allowed to influence the decision.
3. To determine which specific articles of office furniture are being purchased and the materials of which they are made.
4. To determine the adequacy of technical information about wooden furniture.
5. To determine how much the availability of furniture, in terms of user requirements, affects the decision.

FINDINGS

Overall response to the mailed questionnaire was good. Of 554 questionnaires sent out, 337 (61 percent) were completed and returned. An additional 28 (5 percent) were returned incomplete.

Purchasing Policies

More than 50 percent of both corporations and universities did not have written policies for selection or purchase of new office furniture. Of those that did have such a policy, most also had policies specifying the materials to be used—wood, metal, etc.

Of the purchasing officials who responded, 67 percent had the authority to decide what material the new furniture should be made from. This included 71 percent of the university purchasing officials and 64 percent of the corporation purchasing officials.

More than one-third (37 percent) of the purchasing officials had authority to decide when and what office furniture should be purchased for other units within the organization. University purchasing officials more frequently purchase office furniture for centrally located offices while corporation purchasing officials more frequently purchase for branch offices.

Value of Furniture Purchased

The total value of furniture reported purchased by the 337 respondents was more than $55 million. Of the above dollar value, 28 percent was spent on general-purpose desks; file cabinets accounted for another 13 percent; executive desks, swivel chairs, and occasional chairs accounted for 13, 12, and 11 percent respectively.

Five other types of furniture accounted for the rest:

	Percent
Sofas, couches, settees	6
Bookcases	4
Conference tables	3
Other tables	4
Miscellaneous	5

The value of furniture purchased was also reported by type of material used in construction: wood or metal. Executive desks of wooden construction made up 34 percent of the total wooden office furniture purchased. Occasional chairs (16 percent); sofas, couches, settees (15 percent); general-purpose desks (12 percent); and swivel chairs (8 percent) accounted for most of the other wooden office furniture purchased.

On the other hand, general-purpose desks of metal construction accounted for 37 percent of the total metal office furniture purchased. File cabinets (20 percent), swivel chairs (15 percent), and occasional chairs (9 percent) made up most of the rest.

The pattern of purchasing was similar for both universities and corporations. Both purchased more general-purpose desks than any other single item of office furniture.

Overall, 31 percent of the total value of furniture was purchased for branch offices. Corporations reported that 37 percent of their purchases were for branch offices. Universities reported that 9 percent of their purchases were for branch campuses.

Executive desks made up the largest percentage of purchase values for any of the ten types of wooden office furniture listed in the questionnaire. General-purpose desks made up the largest percentage of purchases for any of the ten types of metal office furniture listed in the questionnaire. However, purchases of general-purpose desks had twice the value of executive desks purchased.

Of the total value of purchases reported, corporations spent nearly 30 percent on general-purpose desks. Universities also spent the largest amount on general-purpose desks —about 23 percent. The other types of furniture broke down this way in value of furniture purchased:

Type of Furniture	*Corporations (percent)*	*Universities (percent)*
Filing cabinets	13	15
Executive desks	13	12
Swivel Chairs	12	12
Occasional chairs	10	10
Sofas, couches, etc.	6	7
Bookcases	3	7
Conference tables	3	3
Other tables	4	5
Miscellaneous	5	6
	70	77

Ratio of Wooden to Metal Furniture

For corporations, the only items of wooden office furniture that had greater purchase values than metal furniture were executive desks, sofas, couches, settees (upholstered furniture), and conference tables. This pattern was the same for both total purchases and purchases for branch offices.

For universities, the only type of wooden furniture having a majority of the purchase value was the upholstered furniture category —sofas, couches, and settees. This was not true for branch purchases: they were predominantly metal office furniture.

Criteria Used in Selecting Furniture

The respondents considered appearance most important in selecting executive office furniture, and purchase price most important in selecting general-purpose office furniture. Service life was ranked intermediate. Delivery time and maintenance costs were consistently ranked lower in importance than the other criteria.

Respondents were also asked if there were any other criteria that they consider more important than the five listed above. The other criteria most frequently mentioned were:

Criteria	*Responses (No.)*
Function or use	24
Quality	14
Service rendered by vendor	14
Installation	5
Availability under contract (state, local, or national)	4
Other	6
Total	67

Aspects of Selection Criteria

Appearance was considered in four ways: style, design, harmony with other furniture, and harmony with general office decor. Eighty percent of the respondents considered harmony with other furniture and with the general office decor as important in selecting both executive and general-purpose office furniture. Design was considered important by 74 percent, and style was considered important by 69 percent.

Although harmony with general office

decor and harmony with other furniture were both rated important, harmony with general office decor was rated more important for general-purpose office furniture than for executive-office furniture. Style and decor were considered more important for executive-office furniture than for general-purpose office furniture.

Delivery time required was considered in two ways: (1) least time between order and delivery, and (2) ability to deliver on schedule. Ability to deliver on schedule was considered important for both types of furniture by 89 percent of the respondents. On the other hand, only 30 percent of the respondents considered least time between order and delivery as important.

Maintenance was considered in four ways: (1) ease of replacing damaged parts, (2) ease of repairing damaged parts, (3) resistance to damage, (4) and durability of working surfaces. The rating of these aspects by the respondents pointed out two attitudes about maintenance in selecting new office furniture. First, maintenance is considered even less important in selecting executive-office furniture than in selecting general-purpose office furniture. Second, the emphasis is placed on resistance to damage and durability of working surfaces; that is, nonmaintenance rather than ease of replacing or repairing damaged parts.

Service life was considered in two ways: (1) length of expected life and (2) value at end of service life. Length of expected service life was of prime concern. Expected value at the end of service life had little effect on the selection.

Advertising and Sales Promotion

Respondents were asked two questions about advertising and sales promotion in an attempt to determine if sufficient information is available for them to make decisions favorable to wooden office furniture. The first question was how often had they seen promotional material (brochures, advertisements, etc.). Overall, 69 percent had seen promotional material for wooden office furniture frequently; and 93 percent had frequently seen promotional material for metal office furniture. Thirty percent had seldom seen promotional material for wooden furniture, and 6 percent had seldom seen promotional material for metal office furniture. In general, metal office furniture is better advertised than wooden office furniture.

Technical Factors

The respondents were also asked whether they considered species of wood used, type of finish, quality of construction, and efficiency of design. A majority replied that all these factors were considered.

Species of Wood Specified

Purchasing officers for 103 universities and 180 corporations ranked the five species of wood they most commonly specified for office furniture in the following order of preference:

Species	*Universities: weighted rank*	*Corporations: weighted rank*
Walnut	1	1
Oak	2	3
Mahogany	4	2
Maple	3	5
Cherry	5	4

In addition to the above five species, 54 university and corporation respondents listed other species of wood sometimes specified for new office furniture:

	Number of Responses	
Species	*Universities*	*Corporations*
Teak	3	26
Ash	5	0
Elm burl	0	3
Birch	1	2
Rosewood	0	3
Pine	1	0

Distribution Channels

The respondents reported that purchases were made through various distribution channels, including direct sales from manufacturers, manufacturers' agents, furniture brokers, furniture wholesalers, and furniture retailers.

The largest value of purchases, 25 percent of the total reported, was made through manufacturers' agents. Direct sales from manufacturers were next, 22 percent. Purchases through wholesalers made up 20 percent, and through retailers 18 percent. Purchases through furniture brokers made up only 5 percent of the total. Purchases through other sources made up about 10 percent.

Corporation purchasing conforms generally to the above pattern. The largest value of purchases, 27 percent, are made through manufacturers' agents. Next furniture retailers, 23 percent; closely followed by furniture wholesalers, 19 percent; and purchases direct from manufacturers, 17 percent. Other channels and furniture brokers make up the remaining 15 percent.

Universities, on the other hand, have a different purchasing pattern. They buy more than 41 percent of their furniture directly from manufacturers. Furniture wholesalers and manufacturers' agents combined sell them another 42 percent. Other channels and furniture brokers make up 13 percent of the purchases, while furniture retailers are last with only 4 percent.

About 87 percent of the total reported purchases were a mix of wooden and metal furniture. Only 3 percent were solely wood and 9 percent were solely metal; the remaining 1 percent was neither wood nor metal.

The "other" sources not listed in the questionnaire had the following frequency of purchases:

	Percent
Coop service	27
Contract dealers and/or distributors	23
Designers and/or interior decorators acting as agents	23
State and other governmental contracts	17
Miscellaneous or not specified sources	10

Future Prospect

Most of the respondents (77 percent) expected the proportion of new office furniture made of wood to remain the same in the future. The other respondents felt that the proportion of new office furniture made of wood would change in the future: about 9 percent expect it to increase and 14 percent expect it to decrease.

CONCLUSIONS AND DISCUSSION

The majority of both universities and corporations had no written policy about the selection or purchase of new office furniture. Those who did have written policies generally also had policies that included guidelines or restrictions on the type of materials.

Since the purchasing officials are generally not constrained by written policies, they have more freedom to make their own decisions as to the type of office furniture to purchase. Only one-third of the purchasing officials also had the authority to decide when and what office furniture should be purchased for other units within the organization. The purchasing authority was generally decentralized, especially for corporations that had only 33 percent of their purchasing officials at the home offices.

Although the authority to decide when and what office furniture to purchase was generally decentralized, the actual purchasing was more frequently done by the purchasing officials at the home office. The decision to buy a particular type of furniture is made at the local level. The resulting request for purchase is then forwarded to the home-office purchasing official for action. In these cases, the purchasing official at the home office will have little power to change the request from one type of furniture to another.

Corporations — and universities to a lesser degree — tend to rely more on the desires and specifications of architects and decorators and less on a lot of detail specifications. As a result, the controlling influence on whether all metal, all wood, or a combination of these materials is used in the furniture is more often the architect or decorator rather than the purchasing official. This complicates the problem of trying to reach that individual within the organization who has the authority to decide what type of materials will be used.

The largest dollar volume of furniture purchased during the reporting period was in general-purpose desks. Most were of metal construction. Although quite a few styles today do combine metal with wood as opposed to all metal, the biggest potential market for wooden office furniture would appear to be in this area.

The importance of appearance and purchase price as selection criteria cannot completely explain why metal has such a lead over wood in general-purpose office furniture. Purchase price was ranked as the most important criteria used in selecting general-purpose office furniture for universities. This was the only case in which the respondents, on the average, ranked purchase price higher in importance than appearance. Purchase price was ranked equal in importance with appearance as a selection criteria for corporations' general-purpose office furniture.

Purchasing officials responding to this questionnaire have offered the opinion that metal desks of the general-purpose type offer more value per dollar than wooden desks. This does not necessarily mean higher quality per dollar of purchases. Rather, the purchasing officials feel that, for a limited amount of money, they can buy more metal desks of satisfactory construction than wooden desks.

Within a given price range, however, the selection of furniture goes beyond whether it is made of metal or wood. The furniture product that is innovative in design and has some degree of flexibility will sell better than one that is limited in these features. Then the selection criteria of appearance, quality of construction, delivery time, utilization of space, and product life become more important.

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- Hamden, Connecticut, in cooperation with Yale University.
- Kingston, Pennsylvania.
- Morgantown, West Virginia, in cooperation with West Virginia University, Morgantown.
- Orono, Maine, in cooperation with the University of Maine, Orono.
- Parsons, West Virginia.
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- Princeton, West Virginia.
- Syracuse, New York, in cooperation with the State University of New York College of Environmental Sciences and Forestry at Syracuse University, Syracuse.
- Warren, Pennsylvania.

Anderson, R. Bruce
1976. **Factors influencing selection of office furniture by corporations and universities.** NE. For. Exp. Stn., Upper Darby, Pa. 5 p. (USDA For. Serv. Res. Pap. NE-343)

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by
Edward L. Adams

USDA FOREST SERVICE RESEARCH PAPER NE-344
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ABSTRACT

A new method of weight-scaling truckloads of mixed hardwood sawlogs systematically adjusts for changes in the weight/volume ratio of logs coming into a sawmill. It uses a conversion factor based on the running average of weight/volume ratios of randomly selected sample loads. A test of the method indicated that over a period of time the weight-scaled volume should average within 3.5 percent of the actual volume.

The Adjusting Factor Method for Weight-Scaling Truckloads of Mixed Hardwood Sawlogs

INTRODUCTION

WEIGHT-SCALING is a relatively new method for estimating log-scale volumes of sawlogs. Although several Northeastern sawmill operators use weight-scaling, many operators have expressed the need for a method of checking the accuracy of their systems and adjusting them to account for changes in timber size and species composition. The adjusting factor method of weight-scaling, discussed here, was developed to meet this need.

The adjusting factor method uses an average weight per board foot as a conversion factor to estimate the volumes of truckloads of mixed hardwood sawlogs from their weight. The method is simple and practical: it does not require a lot of data collection to start, requires little extra effort to check its accuracy, and makes systematic adjustments for changes in the log supply that affect the accuracy of weight-scaling.

Some of the factors that affect the accuracy of weight-scaling truckloads of sawlogs are: (1) changes in the species composition, (2) changes in the distribution of log sizes, (3) changes in the average amount of defect in the logs, (4) logs cut either shorter or longer than standard lengths, and (5) the effect on load weights of bark loss or the presence of mud and ice. Adjustments are not made individually for each factor. Instead, the corrections reflect the combined effect of all the factors on the weight/volume ratios of the loads coming into the sawmill.

I recommend that the adjusting factor method be used for each logging operator separately. Since the system adjusts for changes in the log supply, it is not usually necessary to start the system over when an operator moves from one logging site to another: the only exception is when there is a drastic change, as when a logger moves from an area of large overmature timber into an area of small sawlog-size timber. Although the system would eventually adjust for such a change, the adjustment would be gradual.

The adjusting factor method does not include a way of determining log quality. Of the mill operators presently using weight-scaling, those concerned with determining log quality evaluate the standing timber before cutting. I believe that this is the only practical way at this time.

Obviously, mills that purchase most of their logs on the open market cannot determine quality in the standing timber. Mills that purchase logs by grade cannot use the adjusting factor method. But if they purchase logs of uniform quality, or if quality is of minimum importance, the method should give satisfactory results.

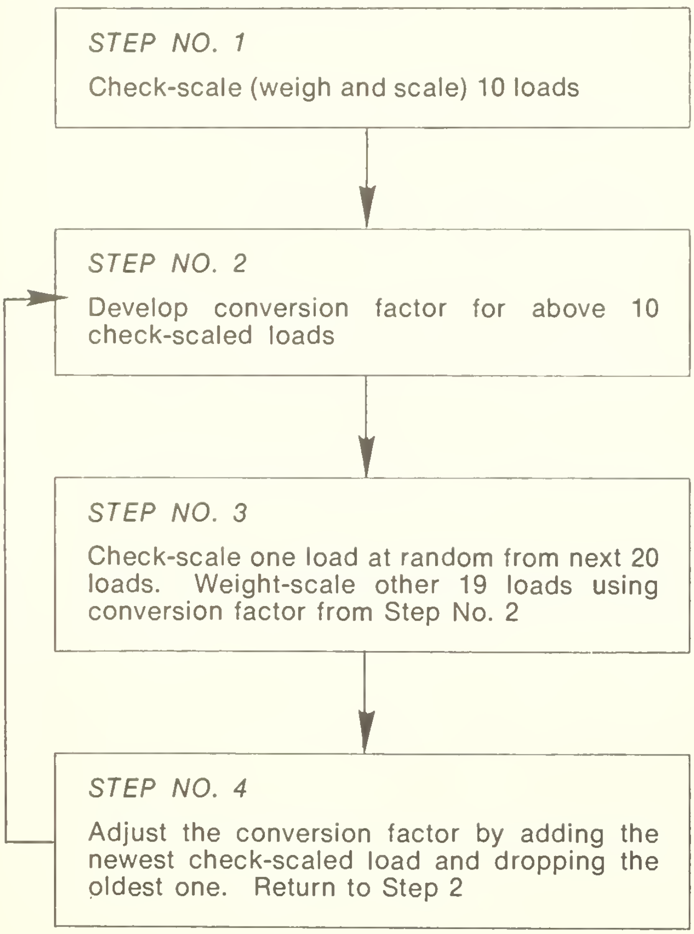
THE ADJUSTING FACTOR METHOD

How It Works

The average weight per board foot used as a conversion factor is systematically adjusted to reflect changes in the weight/volume ratio of truckloads of logs coming into a sawmill. The conversion factor is adjusted by a running average of randomly selected sample loads.

The calculation and use of this running average is not difficult. First the scaler weighs and stick-scales the first 10 truckloads of logs. This procedure is called check-scaling. From the total weight and total volume of these 10 loads, he computes an average weight per board foot (conversion factor). Next, he selects one load at random out of the next 20 loads and check-scales it. The other 19 loads are weighed and their volumes are estimated by using the conversion factor. The scaler then adds the weight and volume of the randomly-selected load to those of the last nine previously check-scaled loads to develop a new average. This procedure is repeated for each 20 loads. Figure 1 shows a step-by-step outline of the procedure.

Figure 1. — Step-by-step procedure for the adjusting factor method of weight-scaling.



This method produces a new conversion factor every 20 loads. Each new factor is based on the 10 most recent check-scaled loads. In this way, the adjusting factor method determines changes in the weight/volume ratios of loads coming into the mill and adjusts the conversion factor to reflect these changes. If the adjustments were not made, these changes could eventually cause considerable error in weight scaling.

A Practical Example

The following example illustrates application of the adjusting factor method, using actual weight-scaling data. Form 1 is used to develop and adjust the conversion factors. And Form 2 is used to weight-scale truckloads of sawlogs. Although I used the Doyle log rule in the example, any log rule can be used with the system.

Step 1

Weigh and stick-scale (check-scale) the first 10 loads. Enter load numbers and corresponding weights and volumes for the 10 loads on Form 1 (opposite page).

Step 2

Add the weights of the 10 loads and enter the total on Form 1 (253,240 pounds, in this example). Add the volumes of the 10 loads and enter the total on Form 1 (20,501 board feet, in this example).

Divide the total weight by the total volume and enter the resulting conversion factor on the form (12.353 pounds/board foot, in this example).

FORM 1

(Adjusting Factor Method)

Load number	Load weight	Total weight for 10 most recent loads	Load volume	Total volume for 10 most recent loads	Average weight per board foot
1	26840		2047		
2	18725		1587		
3	28940		2254		
4	31300		2513		
5	20935		1947		
6	25315		2480		
7	27620		1592		
8	22405		1643		
9	20650		2001		
10	30610		2437		
		253240		20501	12.353

Add the 10 load weights

Enter total load weight here

Add the 10 load volumes

Enter total load volume here

Divide total weight by total volume and enter conversion factor here

Step 3

Determine at random which load out of the next 20 is to be check-scaled. When the selected load is check-scaled, enter the load number, weight, and stick-scaled volume on Form 2 (below). Circle the load number to identify it for use in Step 4 (load number 17, in this example).

Weigh the other 19 loads and enter the load numbers and load weights on Form 2. Enter the current conversion factor from Form 1 on Form 2 (12.353, in this example). For all except the check-scaled load, divide the load weights by the conversion factor and enter the resulting estimated load volumes on Form 2. Total the estimated load volumes and the check-scale volume to determine total volume for this 20 load group (40,691 board feet, in this example).

FORM 2

(Adjusting Factor Method)

Load number	Truckload weight	Conversion factor from Form 1	Estimated load volume
11	26645	12.353	2157
12	28470		2305
13	22935		1857
14	25410		2057
15	32520		2633
16	29180		2362
17	24715		1963
18	31480		2548
19	18630		1508
20	22145		1793
21	29620		2398
22	26240		2124
23	28230		2285
24	25380		2055
25	24565		1989
26	17400		1409
27	26800		2170
28	24805		2008
29	15930		1290
30	21990		1780
		Total volume	40691

Circle the check-scaled load

Use this conversion factor for all but the stick-scaled load

Stick-scale volume is entered for the check-scaled load

Step 4

Transfer the load number, weight, and stick-scaled volume for the check-scaled load from Form 2 to Form 1 (below). On Form 1, mark out the information for the oldest of the last 11 check-scaled loads (load 1, in this example). Also mark out the previous total weight, total volume, and the conversion factor. Return to Step 2 and determine a new conversion factor by using the 10 most recent check-scaled loads on Form 1. In this example, the new total weight (251,115), divided by the new total volume (20,417) results in a new conversion factor of 12.299 (below).

FORM 1

(Adjusting Factor Method)

Load number	Load weight	Total weight for 10 most recent loads	Load volume	Total volume for 10 most recent loads	Average weight per board foot
~~1~~	~~26840~~		~~2047~~		
2	18725		1587		
3	28940		2254		
4	31300		2513		
5	20935		1947		
6	25315		2480		
7	27520		1592		
8	22405		1643		
9	20650		2001		
10	30610		2437		
		253240		20501	12.353
17	24715		1963		
		251115		20417	12.299

Cross out oldest check-scaled load

Add newest check-scaled load

Compute new conversion factor

Accuracy of the Adjusting Factor Method

To test the adjusting factor method, 500 truckloads of mixed hardwood sawlogs were both weighed and stick-scaled at a sawmill. The loads were brought into the mill by 11 different operators from 11 different logging areas. The combined loads contained 10,079 logs, weighed 12,672,450 pounds, and contained a total of 1,000,763 board feet (net Doyle). The study loads contained 12 species and a wide range of log sizes (table 1).

Table 1.—Percentage by volume and average log volume for each species in sample

Species	Percentage of sample by volume	Average log volume
	Pct.	*Bd. ft.*
Ash	1	71
Basswood	3	70
Beech	4	87
Birch	1	44
Black cherry	1	61
Gum	1	50
Hickory	3	77
Hard maple	5	109
Red maple	4	80
Red oak	27	110
White oak	41	123
Yellow-poplar	9	71

Data from the 500 truckloads were then used to simulate the variations in weight/volume ratios that a logging operator might experience over a 1- to 2-year period (about 2,000 loads). To accomplish this, I assumed that the 500 loads were brought in by one operator from 11 different areas. The loads from each of the 11 logging areas were grouped and arranged in the order of their arrival at the mill. Each group was assigned a number from 1 through 11. From this array, groups were picked at random, with replacement, and arranged in order as they were picked. This procedure was continued until the desired 2,000 loads were obtained.

To provide a reliable estimate of the error in using the adjusting factor method, I applied the method 200 separate times to the 2,000 truckloads. The average percent difference between the actual total net volume and the total volume estimated by weight-scaling was —1.0 percent with two standard deviation limits of +1.2 and —3.2 percent. In other words, approximately 95 out of 100 differences between the scaled volumes and the estimated volumes fell between +1.2 percent and —3.2 percent of the actual volume.

The cumulative percent difference between the actual volume and the estimated volume changed as weight-scaling progressed through the 2,000 test loads. For example, at load 100 the average cumulative difference was —6.6 percent, with 95 of 100 differences falling between —5.0 percent and —8.2 percent; at load 1,600 the average cumulative difference was —0.6 percent, with 95 of 100 differences falling between +1.8 percent and —3.2 percent. When the adjusting factor method is used on more than 1,600 truckloads, the estimated volume should be within ±3.5 percent of the actual net volume. This is less than the difference one would expect to find from one scaler to another.

The weight-scaling error of the adjusting factor method can be reduced by starting the system with loads that are representative for a given logging operator. In the test, I started the method with 10 loads containing very small logs. After 440 loads, the average cumulative difference between stick-scaled volume and weight-scaled volume was ±5.0 percent. I then replaced the first 10 loads with 10 loads that were more representative of the log supply, and repeated the test. The ±5.0 cumulative percent difference between stick-scaled and weight-scaled volume was reached before 200 loads had been scaled. And the 95 percent confidence limits for the percent difference fell below ±3.5 percent within 700 loads in this test, compared with 1,600 loads in the first test.

The test indicated that the adjusting factor method should prove satisfactory for weight-scaling truckloads of mixed hardwood sawlogs. If there is a change in the weight-volume ratio of the loads coming into the mill, the average will lag in adjusting to it, because the conversion factor is based on samples of previous loads. However, since this lag will occur when the weight/volume ratios are increasing as well as when they are decreasing, the effect on the accuracy of the volume estimate should average out.

APPLICATION

For best results, the adjusting factor method should be used separately for each operator. This would eliminate the possibility of overpaying some operators and underpaying others. Also, in starting the method, it is important to begin with timber that is representative of that to be cut by a given operator. Beginning with loads that contain unusually large logs or unusually small logs will increase the time required for initial adjustment of the conversion factor. However, even if the method is begun with nonrepresentative loads, the error should not be greater than ±3.5 percent when the method is used on at least 1,600 loads.

Sawmill operators who want to use the adjusting factor method should use forms similar to Forms 1 and 2, and follow the step-by-step procedure described in this paper. I also suggest that the user continue to stick-scale all loads until both he and the log suppliers are satisfied with the accuracy of the weight-scaling.

Some of the adjustments in the conversion factor may seem too small to bother with, but all adjustments must be made to ensure that the running average does in fact average out. If only the larger adjustments are made, a bias will be introduced into the system and its accuracy will be questionable. The only time I would recommend *not* adjusting the average is when there is a temporary, unusual change in the weight/volume ratio, such as could be caused by a bad ice storm or a few loads of severely seasoned logs. In such situations, the user may wish to stick-scale the affected loads and exclude them from the weight-scaling system.

The Adjusting Factor Method requires that the conversion factor be changed every 20 loads. Users should take time to explain to logging operators that this is as much to their benefit as it is to the sawmill operator's benefit. Some of the logging operator's fears may be alleviated if he is allowed to check the weight-scaling records for his loads periodically.

The adjusting factor method can also be used to check other weight-scaling methods. For example, an operator who is using a single weight-per-board-foot conversion factor can apply the Adjusting Factor Method at the same time with little extra effort and cost, and use it to check the error of his method.

Headquarters of the Northeastern Forest Experiment Station are in Upper Darby, Pa. Field laboratories and research units are maintained at:

- Amherst, Massachusetts, in cooperation with the University of Massachusetts.
- Beltsville, Maryland.
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- Pennington, New Jersey.
- Princeton, West Virginia.
- Syracuse, New York, in cooperation with the State University of New York College of Environmental Sciences and Forestry at Syracuse University, Syracuse.
- Warren, Pennsylvania.

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[526.1 : 526.7] : 832.10 -- 176.1

Key words: weight-scalings (logs), log-scaling.

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DUTCH ELM DISEASE CONTROL: PERFORMANCE and COSTS

William N. Cannon, Jr. and David P. Worley

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DUTCH ELM DISEASE CONTROL: PERFORMANCE AND COSTS

ABSTRACT

Municipal programs to suppress Dutch elm disease have had highly variable results. Performance as measured by tree mortality was unrelated to control strategies. Costs for control programs were 37 to 76 percent less than costs without control programs in the 15-year time-span of the study. Only those municipalities that conducted a high-performance program could be expected to retain 75 percent of their elms for more than 20 to 25 years. Communities that experienced the fewest elm losses had a well founded program, applied it conscientiously and sustained their efforts over the years.

"Nature's noblest vegetable" is what the French botanist André Michaux (1746-1802) called the American elm.

SAVING THE ELMS has been a community goal in many of our cities and towns. Some communities are meeting that goal; some are holding their own; some have failed. In many areas highly-valued American elm trees have been virtually eliminated by Dutch elm disease. The methods of disease control have been aimed at blocking the transmission of the fungus to healthy elms by elm bark beetles and through root grafts between diseased and healthy elms.

To find out how well Dutch elm disease control programs are working, we gathered and analyzed public records of control performance and costs for 39 municipalities, many of them in the Midwest, where Dutch elm disease is less likely to be confounded by elm losses due to phloem necrosis. The municipalities studied ranged in population from 3,000 to 1,500,000 and had elm trees ranging in numbers from 2,000 to 50,000.

The records available ranged in time span from 5 years to 18 years. The information reported was: (1) the total number of elm trees in the city or in the control program, (2) the number of elms contracting Dutch elm disease each year, (3) the control measures specified, and (4) the costs of the control program.

Additional data were taken from published sources *(Neely 1967 and 1972, and Neely and others 1960)*.

We combined all these records and other information to find out how well the control measures were keeping the Dutch elm disease within manageable proportions. Community performance in Dutch elm disease control was judged by how successful the community was in saving its elms, and the financial consequences of the control program.

Control Strategies

Control measures can be classified on a technological basis into three major strategies:

Strategy	*Vector control measures*
1. Reduce bark beetle habitat.	Sanitation (prompt removal of infested elms and pruning of infested branches).
2. Reduce bark beetle habitat and control beetle population.	Sanitation and use of insecticide to further reduce beetle population and reduce transmission of the disease.
3. Reduce bark beetle habitat, control beetle population, and prevent tranmission through root grafts.	Sanitation, use of insecticide, and injection of chemicals into soil to prevent transmission through root grafts.

Even though they are technically logical, these strategies cannot be used as a basis for rating performance. We first combined data from different municipalities according to these strategies, expecting to find that those municipalities that had followed strategy 3 got better performance than those that followed strategies 1 or 2. Performance data were measured in number of trees becoming infected each year per 1,000 original elms.

Contrary to our expectations, we found that there was no correlation between performance and strategy. A municipality that sustained a particular level of performance under one strategy (strategy 2) performed similarly when it switched strategies (to strategy 1 or strategy 3). These technological strategies are mere labels, and we question if such labels are relevant to control performance. Good performers (municipalities with a low incidence of Dutch elm disease) did a better job whatever strategy they followed, if the strategy was appropriate to their local situation — that is, tree spacing, disease incidence, factors affecting the beetles, etc.

Control Performance

We grouped municipalities into classes based on sustained control performance. We labeled these:

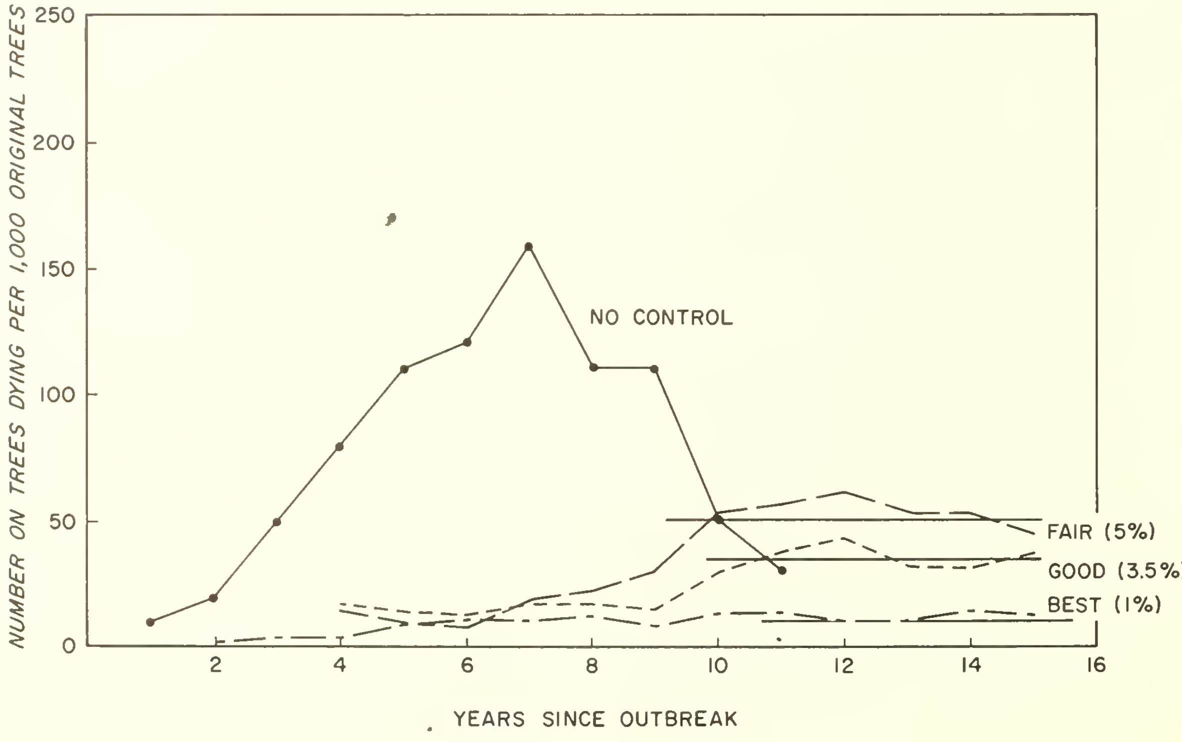
1. Best performance — those municipalities that have an elm mortality of about 1 percent of the original elms per year.
2. Good performance—those municipalities that had a mortality rate of no more than 3.5 percent per year.
3. Fair performance — those municipalities that had a mortality rate of no more than 5 percent per year.
4. No control.

The records of these groups of municipalities were contrasted with those that had no control programs (fig. 1).

To understand the reasons for differences in control performance, we talked to researchers and others in the control business, we read many accounts of how Dutch elm disease progressed in different cities, and we devised a list of reasons for the differences in performance.

Biological reasons.—1. Different spacing of elms call for different control measures. For example, a municipality in which elms are closely clumped together couldn't attain a high performance without root-graft control, whereas a municipality in which elms are widely distributed wouldn't need it. 2. Different physical distributions of elms alter the probability of their contracting the dis-

Figure 1.—Number of trees expected to die each year under each of four control-program performance levels.



ease. For example, elms could be so widely dispersed and such a small part of the total shade-tree population that transmission of the disease by root grafts would be minimal.

Operational reasons.—1. Lack of leadership in the community and failure to understand the gravity of the situation (*Gunderson 1964*). 2. Lack of money. 3. A mixture of authorities, each of which is responsible for a certain group of elms, all operating within different priorities or budget constraints so that their work is inconsistent with a total control program. 4. Group conflicts within the community government or among influential organizations. 5. Lack of effective authority to treat or remove privately owned elms, so that islands of disease elms are left for prolonged periods. 6. Crews in the field who do not conduct their work carefully and conscientiously, and a management that does not allow enough time to do a good job.

Of course, not all of these factors are present in any one municipality, and there could be other ones that are paramount in particular communities. One factor that seems to be of concern in most communities is the privately-owned diseased elm and the community's lack of authority to remove it promptly.

If a community is to have an effective disease-control program, it must plan and study carefully to make sure that it develops a program based on biological conditions. And no matter how good a program is, it will not succeed unless it is carried out vigorously and conscientiously under a unified authority that has the power to compel action.

Control Costs

Different municipalities account for costs differently. We could not relate performance data to cost of control programs. To do so would have required on-site cost studies. The information we brought together was not suitable for a rigorous breakdown of performance against cost. In fact, both good performers and poor performers had a similar range of costs for individual jobs and for the total control program. Some excellent performances seemed very economical while some poor performances seemed very expensive. The costs we did collect are given in table 1.

Save-the-elms Evaluation

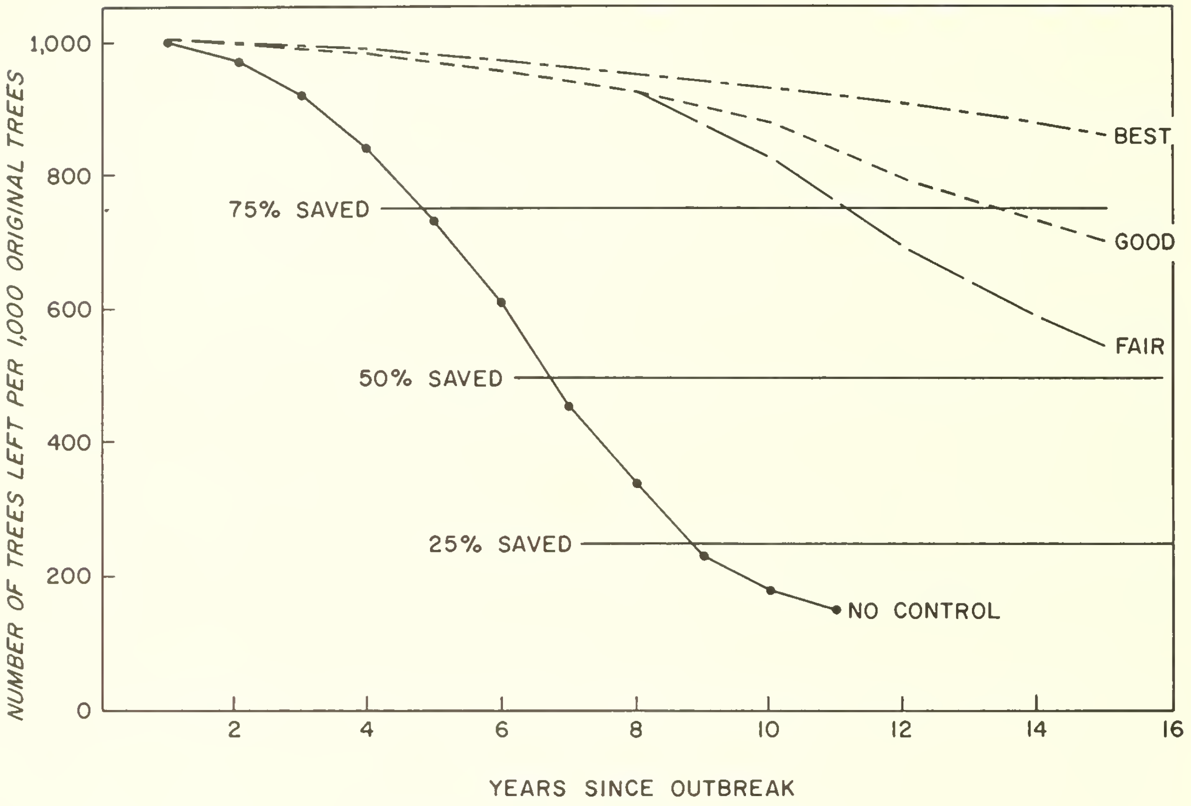
Most communities engaging in a Dutch elm disease control program would like to save as many elms as possible for as long as possible. What do these control performances mean in terms of *save-the-elms*?

For example, we might select *75 percent saved* as a goal. All but the best performance level will allow the elm population to fall below this goal in the 15-year time frame of the study (fig. 2). Without any control, the population of elm trees would drop to the 75-percent level in about 5 years. With the fair and good levels, it would take 11 and 13 years respectively. But with the best

Table 1.—1972 costs of individual jobs comprising the municipal Dutch elm disease control program

Job	Units	Cost	
		Range	Average
Tree removal	Per tree removed	$60.00-250.00	$125.00
Sanitation	Per tree in population	1.00- 2.00	1.50
	Per tree sanitized	15.00- 40.00	25.00
Spraying	Per tree in population	0.50- 0.70	0.60
	Per tree sprayed	1.50- 2.75	2.00
Root-graft control	Per tree treated		5.00
Survey for symptoms	Per tree in population	0.15- 0.30	0.20

Figure 2.—Length of time in which save-the-elms goals can be achieved with different control-program performance levels.



control, it would take 25 to 27 years to drop the population to the 75 percent level.

Of course, if we were willing to use a goal of 50 percent saved, our time frames would be greatly expanded (table 2).

Table 2.—Years before the elm population is reduced to various percentages of the original number of elms by following any one of four municipal performances

Performance class	Years to reduce elm populations to designated levels of the original elms[a]	
	75% Level	50% Level
No control	5	7
Fair control	11	(16-18)
Good control	13	(20-22)
Best control	(25-27)	(44-48)

[a]Estimates in parentheses are extrapolated, assuming continuation of the recorded trends.

Financial Consequences

Most municipalities operate on a budget basis rather than on an investment basis. In our financial evaluation, we did not use a discount rate to conform to budgets. We used our cost data (table 1) and our performances data (fig. 1) to develop a 15-year budget for three alternative courses of action.

1. Tree removal with no control, an estimate of the cost of doing nothing.
2. Tree removal with fair control, using the higher costs from the cost range (table 1). This gives us an estimate of the highest average costs to be expected from an active control program.
3. Tree removal with the best control performance, using the lowest costs from the cost range. This gives us an estimate of the lowest average costs to be expected from an active control program.

The costs of active control measures were used to produce a band of costs rather than cost lines (fig. 3). We would expect that the costs to a community for undertaking a control program would fall inside this band of costs.

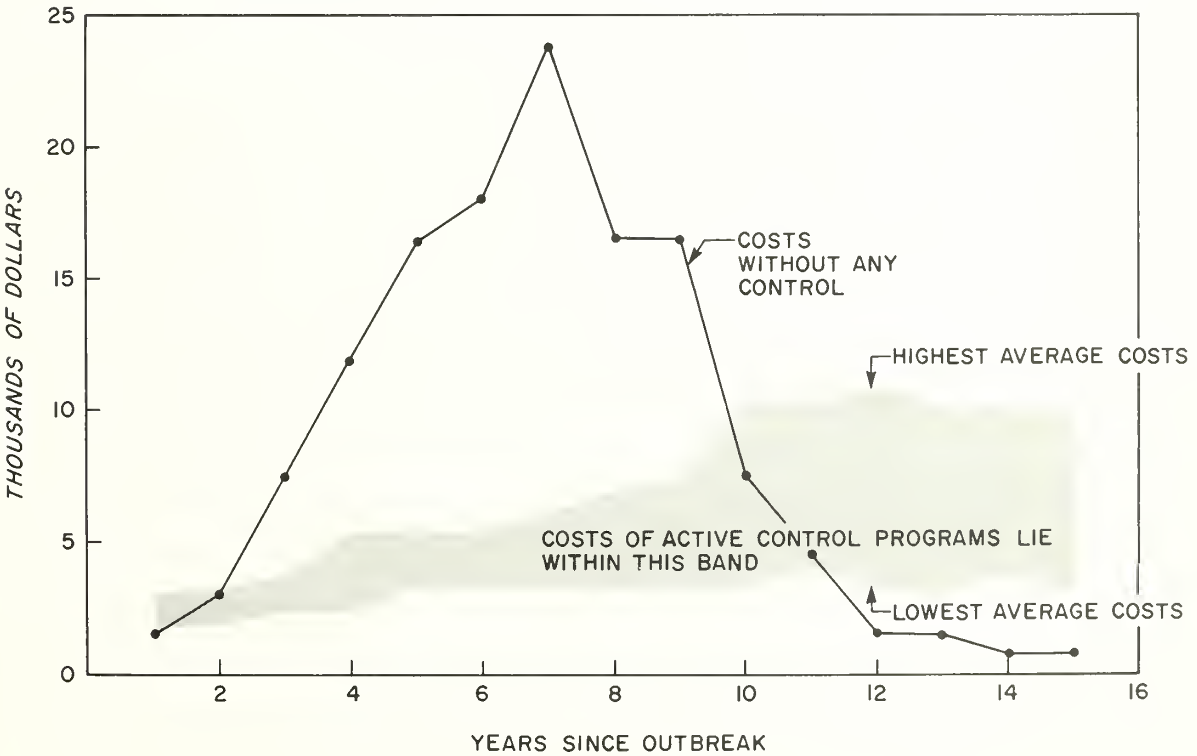
The costs of the no-control alternative rise spectacularly, peaking at about 7 years, then declining to well below the cost band for active control measures at about 12 years. At that time only 10 to 15 percent of the elms remain alive. Early active control efforts slow the increase in costs; and finally, in 5 to 10 years—depending on the efficiency of control—the costs will settle into fairly steady patterns. In 15 years we will still have 55 to 85 percent of the elms left alive, depending on control performance. The benefits of a control program are:

1. More time to enjoy our elms.
2. Fewer budget fluctuations.
3. Time for scientists to find better control measures.

By far the largest loss to the community where control is not undertaken is the reduction of property value associated with loss of shade trees. The minimum value of an elm tree is the cost of removing it, but most people would assign a higher value to it for such esthetic reasons as shade and beauty. Hart (*1965*), in a report on the economic impact of Dutch elm disease in Michigan, stated that the loss in esthetic value greatly overshadowed all other losses. In addition, there are losses of urban wildlife and changes in microclimates. In view of the difficulty in assigning a dollar value to these losses, we chose to use property-value losses since Payne and others (*1973*) suggested that shade, microclimatic, and esthetic benefits can be considered as they relate to residential property values. They indicated that a loss of \$250 per tree was appropriate.

Summary costs and average annual costs for the 15-year period are given in table 3. Tree mortality was multiplied by \$250 per

Figure 3.—Tree removal and control costs, based on a unit of 1,000 trees.



tree to estimate property loss. For the no-control alternatives, annual budget requirements for the peak year are 2.7 times the average budget requirements. Where positive control measures are taken, the peak budget requirements amount to 1.2 to 1.6 times the average.

Total loss during the 15-year period (table 3) includes the cost of control (table 1), disposal of dead and dying trees, and property value loss. If effort is made to remove elms before they become physical hazards, the budget requirements of a do-nothing program can exceed those of a control program, especially during the 12-year period after introduction of the disease. Larger losses of elms each year require greater personnel and equipment to deal with the situation. A recent development to reduce the costs of tree removal and disposal, and also reduce the volume of material going into sanitary landfills, is to sell the wood for lumber, pulpwood, and other useful products.

While we didn't consider replanting values in our costs, a tree-replanting program could lessen the impact of elm losses on property values in future years. One can hardly equate the esthetic and shade value of newly planted trees 2 to 3 inches in diameter with that of elms 20 to 30 inches or more in diameter, but replacement would eventually assure a stable tree population that would benefit the community.

We judged the effectiveness of the control program in terms of the budget figures and in terms of community values, which include property-value loss. The highest and lowest costs were subtracted from the no-control totals and expressed as savings in dollars and as a percentage of the no-control costs (table 3). The budget savings in control and disposal costs alone amounted to between $20,000 and $80,000 for our 1,000-tree unit or between 16 and 63 percent of the no-control option.

These savings were calculated at a zero discount rate as being relevant to a budget situation rather than an investment situa-

Table 3.—Economic impact of control measures for a 15-year period

Items of concern	Cost and performance for three alternatives, based on a 1,000-tree unit[a]		
	No control	Low performance: high cost control	High performance: low cost control
Status of elm population after 15 years:			
Dead (number)	880	438	133
Remaining (number)	120	562	867
Annual budget cost:			
Average (dollars)	8,800	7,400	3,300
Maximum (dollars)	24,000	11,900	4,050
Maximum increase above average: (dollars)	15,200	4,500	650
(percent)	173	60	20
Total loss + cost during the 15-year period:			
Cost of control and disposal (dollars)	132,000	111,290	49,030
Property value loss[b] (dollars)	220,000	109,500	34,250
Total cost + loss (dollars)	352,000	220,790	83,280
Effectiveness of control operation over the 15-year period:			
Savings in control disposal costs: (dollars)		20,710	82,970
(percent)		16	63
Total savings: (dollars)		131,210	268,720
(percent)		37	76

[a]Based on 1972 dollars.
[b]Payne and others (1973).

tion. Had we calculated them with a positive discount rate, say 5 percent, the percentage savings would have been larger. The peak costs of the no-control option against which the active controls were compared would have been disproportionately greater. Our percentage savings on a budget basis are conservative.

Both Marsden (*1953*) and Sinclair and others (*1968*) proposed that the annual expenses of a control program might be substantially less than the expense of elm removals in the absence of a program. The experiences of the municipalities in our study bear this out (fig. 3). Of course, the annual cost of elm removals in a no-control program will decline as fewer and fewer elms remain to be infected with the disease. The additional cost of an active control program will, at that time, be protecting a substantial elm population (table 3).

The implication for managers in terms of budget requirements is that even the costliest control program would create less of an impact on the annual budget than the tree-removal costs of no control (fig. 3). If the disease were allowed to proceed unchecked, the annual budget requirements would rise sharply. This would probably disrupt the budget planning of most communities.

Summary and Discussion

The efforts made by municipalities to suppress Dutch elm disease have had highly variable results. Differences in performance could be traced to both biological and operational reasons. In many instances the operational difficulties outweighed the biological factors. We found that performance was not related to particular control strategies.

The budget costs of control programs were less than the costs of removing the large numbers of elms associated with the no-control alternative. Fluctuations in the annual budget were minimized, enabling managers to plan for the long pull and to maintain control performance. Total savings attributed to control programs ranged from 37 to 76 percent.

A community attempt to save the elms is greatly enhanced by an active control program. If we assume that a reasonable goal is to save 75 percent of the elms, the lack of an active control program will allow the elm population to sink below the goal in 5 years. An active program can extend this time by a factor of 3 to 5, depending on the level of control performance.

The quality and quantity of effort to apply control programs to limit Dutch elm disease inevitably reflects the interests and resources of local communities and their governing bodies. Some communities temporarily suspended control programs during a period of temporary financial stress only to find that they could not regain control of the disease situation later. Faced with increasing elm losses, and lacking the resources to substantially increase their control efforts, they found themselves with an ever worsening situation until few elms remained. The communities that experienced the fewest elm losses not only had well-founded control programs and applied them conscientiously, but sustained their efforts over the years.

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Municipal programs to suppress Dutch elm disease have had highly variable results. Performance as measured by tree mortality was unrelated to control strategies. Costs for control programs were 37 to 76 percent less than costs without control programs in the 15-year time-span of the study. Only those municipalities that conducted a high-performance program could be expected to retain 75 percent of their elms for more than 20 to 25 years.

305 + 355 + 12 × 1.401.50 + 443.3 -- 172.8 + 453 + 907.12

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WOODY PLANTS selected by BEAVERS in the Appalachian Ridge and Valley Province

USDA FOREST SERVICE RESEARCH PAPER NE-346
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ABSTRACT

The availability of woody plants and the selection of plants by beavers along mountain streams was studied in four areas of the Appalachian Ridge and Valley Province in Virginia. Beavers' choice of woody plants varied between areas. Many species of woody plants were cut by beavers. They climbed slopes with gradients up to 80 percent to cut trees. Large as well as small trees were cut and removed for food and dam construction; however, large trees were often girdled and left standing or felled, and the bark was removed. The topography and abundance of many species of woody plants in the Ridge and Valley Province provide suitable beaver habitat in which the plant and animal variety created by beaver impoundments would add to the esthetic and recreational values of these mountain areas.

IN THE EARLIEST DAYS of this country, beaver pelts provided not only clothing, but also an important medium of exchange. Trappers searching for new sources of pelts explored most of North America. More recently, the beaver's value to man has been questioned. Waters impounded by beaver dams have flooded roads, timberland, and farm land. The effects of beaver impoundments upon trout streams have often been debated.

A new benefit of beaver is now recognized by many environmentalists and by public land managers: the beavers' ability to increase the variety of plants and animals in forest ecosystems. This is especially valuable in large expanses of uniform xeric oak communities in the eastern mountains. In these situations beavers increase recreational opportunities and esthetic interest on many acres of public land.

Nuisance beavers trapped and removed from lowland areas could be released in wooded uplands, particularly on public land —and could contribute to the recreational value of the area. However, little information is available about the suitability of such areas for restocking. Will there be suitable trees for beavers to cut for food and for dam construction? What effect does topography have on the accessibility of trees to beavers? If suitable habitat conditions are not available, would stocked animals migrate and again become a nuisance? Many studies have shown that beavers are highly dependent upon aspen for winter food. Aspen is scarce in the mountains of Virginia and West Virginia and the states to the south. What plants are utilized by beavers to meet their needs in these mountain woodlands?

We sampled the woody plants cut by beavers on four sites in the Ridge-Valley Province (*Fenneman 1938*) of western Virginia. We also estimated the availability of these plants. Our objective was to determine if beaver populations might be limited by woody plants suitable for dam-building and for winter food in mountain woodlands. Our findings might help land managers form criteria of suitability of wooded uplands for beavers.

Study Areas

Three sites with active beaver colonies were selected for study in Giles County, Virginia, near the West Virginia border; and one site was studied in Rockbridge County, Virginia. All streams on these sites were narrow, with low summer water levels, and could be waded with knee or hip boots. In contrast, in the beaver ponds, the water often came over the tops of our waders. The elevation of the streams was approximately 3,000 feet in Giles County and about 1,700 feet in Rockbridge County.

White Rocks Branch is a meandering native trout stream that had one simple beaver dam about 1 chain in length, which backed up a small pond about 2 chains long. One active beaver lodge was located on the upper end of the pond. Older beaver activity was found downstream, but no beaver cuttings were found upstream from the study site. Large red maple, black birch, yellow-poplar, white oak, and red oak made up the overstory of the flood plain and the adjacent banks. Alder, witch hazel, deciduous holly, laurel, rhododendron, greenbrier, hemlock, and other less common species made up an understory of moderate density. (Scientific names are included in table 1.)

The North Fork Drainage, another meandering native trout stream, drains an area of old beaver meadows and a woodland with a mixed overstory of mature pitch pine, red maple, white oak, black gum, sassafras, and hemlock. Among other species, mountain laurel, blueberry, rhododendron, viburnum, pepperbush, greenbrier, alder, deciduous holly, and witch hazel make up a dense understory. A complex of dams have flooded an area about 5 chains wide and 10 chains

Table 1.—Stems available and cut on four beaver study areas.[1]

Species	White Rocks Branch			North Fork Drainage			Stony Creek			Pads Creek		
	Stems available per acre	Stems cut per acre by beavers		Stems available per acre	Stems cut per acre by beavers		Stems available per acre	Stems cut per acre by beavers		Stems available per acre	Stems cut per acre by beavers	
	No.	*No.*	*Pct.*	*No.*	*No.*	*Pct.*	*No.*	*No.*	*Pct.*	*No.*	*No.*	*Pct.*
Acer rubrum—red maple	145	1	1	146	11	8	150	60	40	289	50	17
Alnus spp.—alder	561	93	16	222	7	3	2,062	45	2	—	—	—
Amelanchier spp.—serviceberry	13	1	8	65	33	51	8	0	0	292	87	30
Aronia sp.—chokeberry	—	—	—	3	0	0	—	—	—	—	—	—
Betula lenta—black birch	16	8	50	7	1	14	—	—	—	—	—	—
Betula lutea—yellow birch	3	3	100	1	0	0	—	—	—	—	—	—
Carya spp.—hickory	5	1	20	—	—	—	—	—	—	279	8	3
Cercis canadensis—redbud	—	—	—	—	—	—	—	—	—	3	0	0
Chionanthus—fringetree	—	—	—	—	—	—	—	—	—	18	0	0
Clethra acuminata—pepperbush	—	—	—	330	4	1	—	—	—	—	—	—
Cornus alternifolia—alternate-leaved dogwood	—	—	—	—	—	—	22	0	0	—	—	—
C. florida—flowering dogwood	—	—	—	9	2	22	15	0	0	321	89	28
C. stolonifera—red osier dogwood	40	0	0	—	—	—	—	—	—	—	—	—
Crataegus spp.—hawthorn	32	0	0	3	1	33	—	—	—	76	0	0
Fagus grandifolia—beech	70	2	3	—	—	—	—	—	—	—	—	—
Fraxinus spp.—ash	2	2	100	—	—	—	—	—	—	60	16	26
Hamamelis virginiana—witch hazel	275	71	26	151	48	32	120	68	56	168	76	45
Hypericum spp.—St. John's-wort	—	—	—	14	0	0	—	—	—	—	—	—
Ilex spp.—holly	117	1	1	126	8	6	—	—	—	—	—	—
Kalmia latifolia—mountain laurel	1,108	4	(*)	1,459	33	2	832	8	1	24	0	0
Lindera benzoin—spicebush	87	11	13	—	—	—	—	—	—	60	0	0
Liriodendron tulipfera—yellow-poplar	14	6	43	(*)	(*)	(*)	—	—	—	—	—	—
Nyssa sylvatica—black gum	—	—	—	99	33	33	22	8	33	11	5	50
Pieris floribunda—mountain fetterbush	—	—	—	—	—	—	—	—	—	42	0	0
Pinus rigida—pitch pine	—	—	—	67	0	0	60	0	0	—	—	—
P. strobus—white pine	—	—	—	(*)	(*)	(*)	8	0	0	26	0	0
P. virginiana—virginia pine	—	—	—	—	—	—	—	—	—	47	24	50
Populus grandidentata—bigtooth aspen	—	—	—	1	1	100	—	—	—	—	—	—
Prunus serotina—black cherry	16	12	75	30	17	57	22	0	0	—	—	—
Pyrus spp.—pear	—	—	—	29	(*)	(*)	—	—	—	—	—	—
Quercus alba—white oak	25	1	4	40	8	20	22	15	67	379	237	62
Q. montana—chestnut oak	—	—	—	—	—	—	—	—	—	8	0	0
Q. rubra—red oak	12	(*)	(*)	9	5	56	45	8	17	113	13	12
Rhododendron spp.	393	5	1	822	23	3	458	0	0	—	—	—
Robinia pseudo-acacia—black locust	—	—	—	—	—	—	—	—	—	24	0	0
Rosa spp.—rose	—	—	—	—	—	—	8	0	0	—	—	—
Rubus spp.—brambles	2	2	100	2	0	0	30	8	25	3	0	0
Salix spp.—willow	—	—	—	—	—	—	292	195	67	—	—	—
Sambucus canadensis—elderberry	—	—	—	—	—	—	38	0	0	—	—	—
Sassafras albidum—sassafras	1	1	100	74	7	9	—	—	—	58	3	4
Smilax spp.—greenbriar	572	4	1	295	1	(*)	90	0	0	316	0	0
Tsuga canadensis—hemlock	237	1	(*)	65	2	3	99	0	0	—	—	—
Ulmus spp.—elm	—	—	—	—	—	—	—	—	—	116	21	18
Vaccinium spp.—blueberry	12	0	0	1,091	6	1	68	0	0	384	0	0
Viburnum spp.—viburnum	(*)	(*)	(*)	427	20	5	1,815	195	11	18	0	0
Vitis spp.—grape	—	—	—	—	—	—	—	—	—	3	3	100

[1] Percentages are based on computation from raw data and are correct; apparent errors are due to rounding-off per-acre figures.
* Negligible.

long. Two maintained lodges were found within the study area. Older evidence of beaver activity was found upstream from the area.

Stony Creek is a meandering stream that had one dam 1½ to 2 chains long, which formed a pond about 3 chains in length. One lodge was present. Other beaver activity was found downstream. The area had a dense shrubby growth of alder, mountain laurel, rhododendron, willow, and viburnum, with a scattered overstory of mature pitch pine, red oak, hemlock, and maple.

Pads Creek in Rockbridge County is located in a narrow flood plain. A dam about ½ chain long, but over 6 feet in height, backed up a deep narrow impoundment for approximately 4 chains. One lodge was present, and the area appeared to have been used for 2 years. White oak, red oak, chestnut oak, red maple, and hickory are common mature overstory species. Serviceberry, flowering dogwood, witch hazel, greenbrier, and blueberry are common in the relatively open understory. Beaver evidence from previous years was found downstream.

All study areas were located on National Forest lands. No evidence of fire or logging for at least 40 years was found on the sites.

Methods

We sampled two areas in Giles County during March and April 1973, and the other areas in April 1974. In 1973 all stems cut by beavers within the past year were counted on the study areas. The uncut stems were censused by a series of transects 0.2 chain wide, extending from the water to the limit of the most distal tree cutting. Transects were spaced 1 chain apart, parallel to each other, throughout the area of recent cutting. In 1974, both cut and uncut stems were sampled on the transects. Cut and uncut stems were tallied in 1-inch diameter classes, at cutting height, by species. For cut stems we also recorded the distance from water and the percent of slope, whether the stems were felled or partially cut, and whether the bark was removed.

Results

Enough difference in vegetation existed between study areas to give a broad perspective of the type of vegetation found in mountain forests in western Virginia. Our results should give a fair representation of the Province without being biased to one vegetation condition.

In White Rocks Branch, beavers cut alder and witch hazel in greatest numbers (table 1) : 93 and 71 stems per acre respectively, or 16 and 26 percent of the total number of available stems of each species respectively. The percentage of available stems cut was greater for black birch (50 percent), yellow birch (100 percent), ash (100 percent), yellow-poplar (43 percent), black cherry (75 percent), brambles (100 percent), and sassafras (100 percent)—but these species were not abundant. We found no evidence that beavers cut azalea, red osier dogwood, hawthorn, or blueberry.

Twenty-two species were cut. Size of trees was not a deterrent to beavers attempting cutting; however, the number of trees actually felled decreased as tree size increased. A black birch 29 inches in diameter at cutting height and a yellow-poplar 27 inches in diameter were partially cut. Almost all trees were cut within ½ chain of the water, and overland transport of stems was minimal. Steep stream banks, up to 20 feet in length, were traversed by beavers.

In the North Fork Drainage, beavers cut more stems of witch hazel than of any other species. Witch hazel was not as abundant in the North Fork Drainage as in White Rocks Branch—151 stems per acre vs. 275—but 32 percent of the available stems were cut in North Fork. Other species cut heavily were serviceberry (51 percent), black gum (33 percent), and black cherry (57 percent) ; but these species were not as abundant as witch hazel. Only five species or species groups were not found cut on the area: chokeberry, yellow birch, St. John's-wort, and brambles, all of which were scarce; and pitch pine, which was common.

In all, 24 species or species groups were cut, almost identical to the number for White Rocks Branch. Stems of all diameters were cut. A bigtooth aspen 20 inches in diameter at cutting height was felled and the bark was removed. The flood plain was wider in North Fork than in White Rocks, and beavers moved a maximum distance of 165 feet in North Fork to cut stems. Beavers seldom had to travel on slopes greater than 5 percent.

In Stony Creek, beavers cut viburnum and willow most often: 195 stems per acre of each or 67 percent of the relatively scarce willows and 11 percent of the abundant viburnum. Red maple, witch hazel, black gum, and white oak were relatively scarce; but beavers cut a high percentage of the stems. Alder was abundant, but only a small percentage of stems were cut. Only 10 species or species groups were found cut in this area, while no cutting was detected on 13 species. A less intensive sample of cut stems accounts for the decrease from the previously discussed areas in number of species cut. Most cutting was restricted to small stems. The distance traveled to cut stems was not greater than 100 feet, and slopes were 5 percent or less.

On Pads Creek, beavers traveled 250 feet up 65- to 80-percent slopes to cut trees, mostly Virginia pine and serviceberry. Serviceberry occurred throughout the study area, and 30 percent of the stems were cut. Virginia pine was largely restricted to the upper limits of the steep slope located on one side of the stream, and here half of the available stems were cut. White oak occurred commonly on the flood plain and to a lesser degree on the slopes. Sixty percent of these stems were cut. Beavers cut more white oak than any other species. Twenty-eight percent of the abundant flowering dogwood stems, 45 percent of the less common witch hazel, and 26 percent of the 60 ash stems per acre were cut. Our samples indicated cutting of 16 species and no cutting of 13 other species or species groups.

Figure 1.—Beavers often selected white oak in preference to other species.

Discussion

In the Ridge-Valley Physiographic Province, mountain streams having flood plains with at least a slight meander in oak-pine and mixed hardwood types contain an adequate supply of woody plants suitable for beavers. Steep slopes at streamsides do not preclude use of an area and may enhance utilization of distant stems.

Beavers' choice of woody plants to cut seems to be quite flexible. In one area alder was important and moderately abundant; but in another area, where it was four or five times more abundant, it was cut at half the intensity while willow, even though less abundant than alder, was cut intensively. Cutting of witch hazel was common in all areas, ranging from 48 to 76 stems cut per acre. Where viburnum was abundant, it was cut in considerable numbers, but it was not a species that beavers commonly selected to the exclusion of others. However, white oak (fig. 1) could be considered as a species chosen to the exclusion of other species. Red maple was cut heavily on two areas and cut lightly on the other areas. This difference was not uniformly influenced by the availability of stems. Serviceberry was cut heavily in proportion to the available stems on two of the three areas where it occurred.

The heavy utilization of pine on a steep slope destroyed some previously accepted ideas about beavers not cutting pine and the steepness of slopes climbed to cut trees (*McDonald 1956*). Apparently the ease of transporting cut stems a considerable distance down a slope offset any difficulty encountered in climbing the slopes (fig. 2). Such abundant plants as blueberry, greenbrier, mountain laurel, and rhododendron were seldom cut.

The greatest distance traveled from water to cut a tree in this study was 250 feet on a 70- to 80-percent slope. Stegeman (*1954*) found that 250 feet was normal distance traveled on the Huntington forest in New York. Swank (*1949*) found in a West Virginia study that the greatest distance traveled to cut a tree was 260 feet on a 40-percent slope.

Figure 3.—Many standing trees were girdled as high as the beavers could reach.

Figure 2.—Steepness of slope was not a deterrent to beavers. They easily transported stems down steep slopes.

Beavers cut both large and small trees. Standing large trees often were girdled as high as the animals could reach (fig. 3). Other large trees were felled, and the bark was removed from the bole. Though boles of large trees could not be transported to the water for use in dam-building, they did provide food throughout the winter. The branches of these trees were usually cut and removed. Thus areas with large trees are potentially valuable habitats for beaver.

The Ridge and Valley Province of Virginia and West Virginia—and probably Pennsylvania as well—seems to offer suitable habitat for beavers. All of this habitat has not been reoccupied by beavers, and it offers potential for accommodating nuisance beavers that cause damage in lowland areas.

The trellis drainage pattern found in the Ridge and Valley Province offers topography suitable for beaver impoundments; stream gradients are generally gentle, and flood plains have formed in the valley. Streamside slopes are often steep, but do not present a barrier to beavers. Beavers are not dependent on one or two woody plants species for winter food or dam-building, but utilize several species of the abundant variety of woody plants.

Potential for beaver damage exists in the Ridge and Valley Province where beavers are reintroduced or move into agricultural areas, or where tree cutting or flooding is detrimental. However, loss of trees on public land could well be offset by increases in esthetic and recreational values, fostered by the increased variety of plants and animals around beaver impoundments and in the meadows formed after dams are abandoned and drained.

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- Syracuse, New York, in cooperation with the State University of New York College of Environmental Sciences and Forestry at Syracuse University, Syracuse.
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The availability of woody plants and the selection of plants by beavers along mountain streams was studied in four areas of the Appalachian Ridge and Valley Province in Virginia. Beavers' choice of woody plants varied between areas. The topography and abundance of many species of woody plants in the Ridge and Valley Province provide suitable beaver habitat in which the plant and animal variety created by beaver impoundments would add to the esthetic and recreational values of these mountain areas.

451.2--149.32:907.1 + 907.2--(755)

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by John R. Donnelly

Carbohydrate Levels in Current-year Shoots of Sugar Maple

USDA FOREST SERVICE RESEARCH PAPER NE-347
1976

FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
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JOHN R. DONNELLY was employed as a research forester at the Northeastern Forest Experiment Station's laboratory at Burlington, Vermont, at the time this study was made. He is now professor of forestry at the University of Vermont, Burlington.

MANUSCRIPT RECEIVED FOR PUBLICATION 17 NOVEMBER 1975

Carbohydrate Levels in Current-year Shoots of Sugar Maple

Abstract

Diurnal changes in carbohydrate concentrations in leaves and current-year stems of a mature sugar maple tree were studied in June and September. In leaves, alcohol-soluble sugar concentration was highest in the morning and lowest in late afternoon or early evening; diurnal changes in starch lagged about 5 hours behind changes in sugar. Carbohydrate concentrations in current-year stems did not vary diurnally. Leaves weighed much more than current-year stems and contained a higher concentration of sugar and starch. In leaves, sugar concentration was higher in September than it had been in June; starch concentration was much higher in June. The opposite was true for current-year stems; sugar concentration was slightly lower in September than it had been in June, but starch concentration was much higher.

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- Kingston, Pennsylvania.
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- Princeton, West Virginia.
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- Warren, Pennsylvania.

SEASONAL CHANGES in carbohydrate levels in roots, bolewood, and twigs of sugar maple (*Acer saccharum* Marsh.) have been reported by Jones and Bradlee *(1933)*, Witherell *(1963)*, Marvin and others *(1971)*, and Wargo *(1971)*. All found starch to be at a maximum in early fall and at a minimum in winter.

These previous studies have dealt with woody material at least 1 year old. My data are based on carbohydrate levels in current-year shoots of a mature sugar maple tree in Vermont. This is a report on diurnal changes in starch and alcohol-soluble sugars during a 2-day period in late June after shoot elongation had ceased and during a 1-day period in mid-September before leaf coloration and abscission.

METHODS

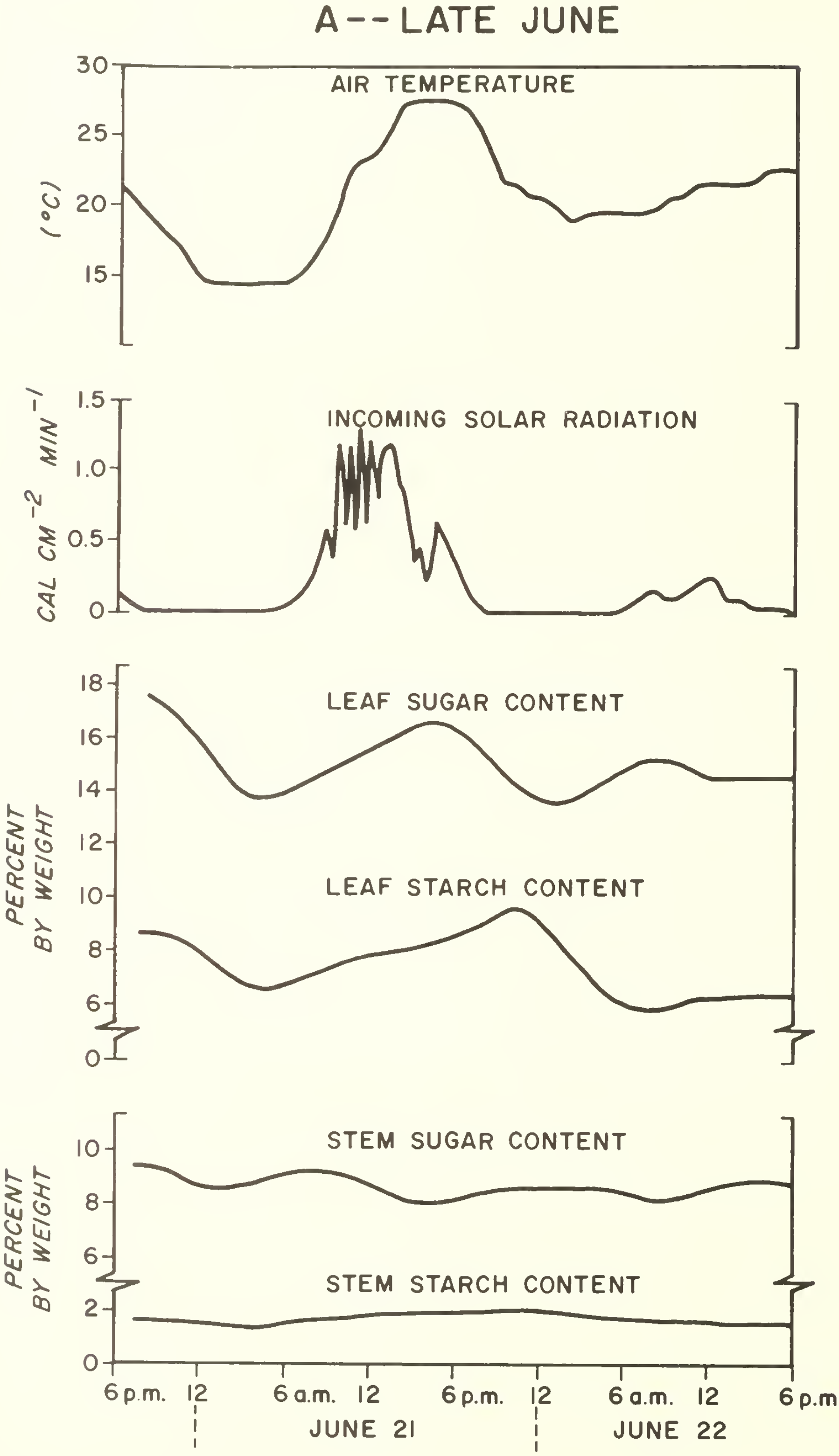
Current-year shoots, about 7 to 27 cm long, were collected at 2-hour intervals from a single open-grown mature sugar maple tree in Fairfax, Franklin County, Vermont. The tree was 59 cm in dbh; total height was 15.5 m; and crown diameter was 11.6 m. Shoots were collected in late June after elongation had ceased, and in mid-September while leaves were still green. In June they were collected during the 46-hour period 8 pm 20 June to 6 pm 22 June. In September, they were collected during the 24-hour period 10 am 13 September to 10 am 14 September.

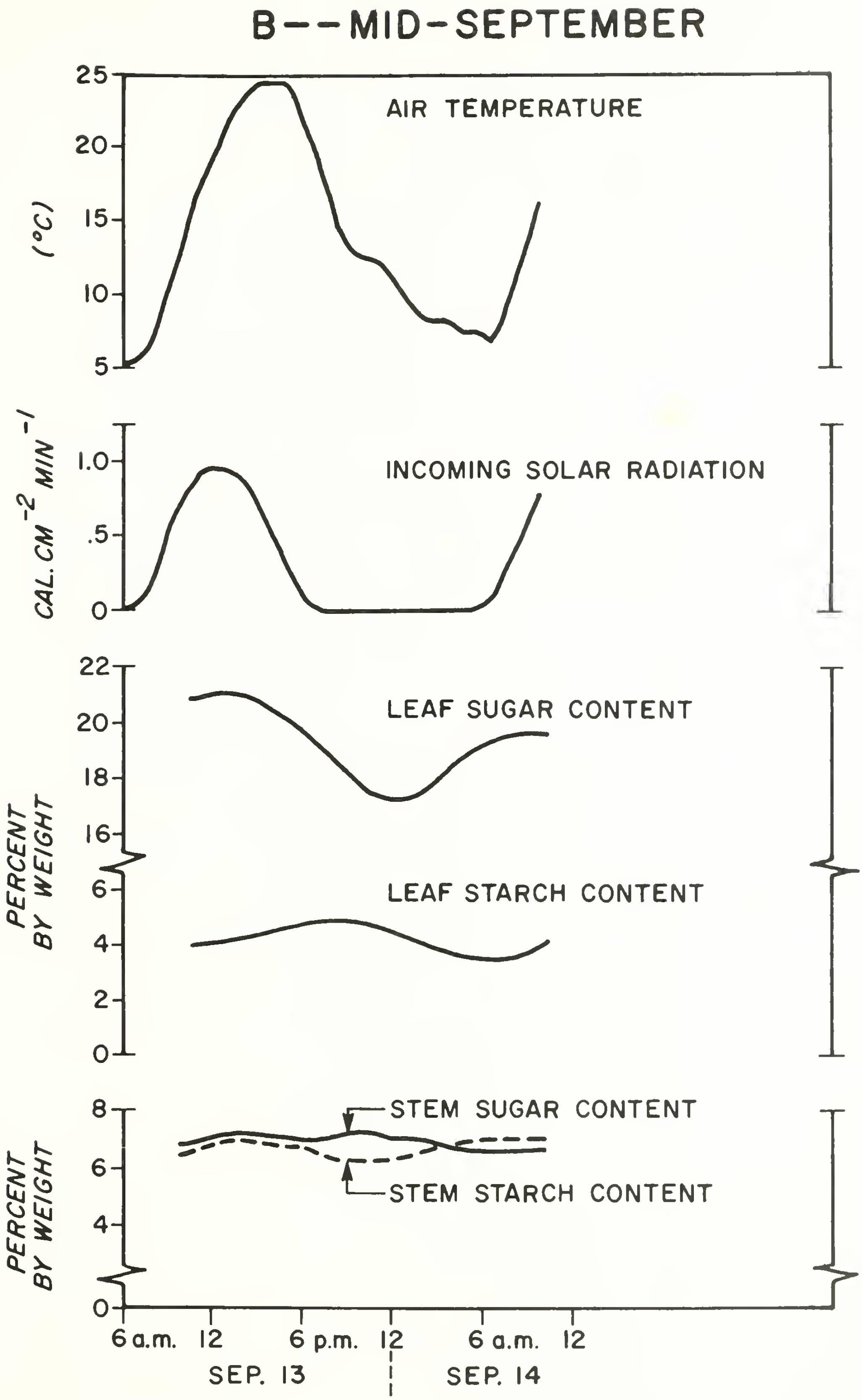
The study tree's crown, as projected onto the ground, was divided into 10 sections to eliminate possible effects of aspect on carbohydrate content. Ten shoots were collected at each 2-hour interval, one from each section. Leaves were removed immediately after shoots were collected. (The term "shoot" refers to the entire current-year growth, and the term "stem" refers to the shoot minus its leaves.)

The 10 stems (including the bark) and 10 sets of leaves were cut up, and 2 leaf and 2 stem samples (approximately 2 gm each) were placed in glass jars and covered immediately with hot 80-percent ethanol. Oven-dry weights of remaining plant material were recorded for estimating total amounts of carbohydrate. Selected samples were stored in the alcohol-filled jars until they were analyzed for starch and sugar with standard procedures.

Air temperature (measured about 4 feet above ground in an instrument shelter) and solar radiation (measured in the open) were monitored during the study period (fig. 1). Scattered clouds were evident on 20 and 21 June. The sky was overcast on 22 June, and about 2 cm of rain fell. Skies were clear throughout the September test period.

Figure 1.—Diurnal changes in air temperature, incoming solar radiation, and leaf and stem sugar and starch content in current-year shoots of sugar maple. A, from samples collected in late June. B, from samples collected in mid-September.





B--MID-SEPTEMBER
AIR TEMPERATURE
(°C)
25
20
15
10
5
INCOMING SOLAR RADIATION
CAL.CM^{-2} MIN^{-1}
1.0
.5
0
LEAF SUGAR CONTENT
LEAF STARCH CONTENT
PERCENT BY WEIGHT
22
20
18
16
6
4
2
0
STEM SUGAR CONTENT
STEM STARCH CONTENT
PERCENT BY WEIGHT
8
6
4
0
6 a.m.
12
6 p.m.
12
6 a.m.
12
SEP. 13
SEP. 14

RESULTS

Amount and Distribution of Carbohydrates

In June, current-year shoots weighed an average of 3.42 gm and contained about 800 mg of carbohydrates (table 1). Approximately two-thirds of this was alcohol-soluble sugar, and one-third was starch. At this time, leaves made up 93 percent of the total shoot weight, had 96 percent of the sugar, 99 percent of the starch, and 97 percent of the total carbohydrates.

The average weight of all leaves on a shoot increased by 0.25 gm from June to September, and there was a moderate increase in total carbohydrate content (from 771 to 849 mg). The composition of leaf carbohydrates changed markedly during this period: leaf sugar increased from 495 to 697 mg, whereas leaf starch decreased from 276 to 152 mg.

The statistical probability of June to September changes in leaf weight, leaf sugar content, leaf starch content, stem weight, stem sugar content, and stem starch content were evaluated with a "t" test; differences were highly significant (probabilities less than 0.01) for all comparisons.

The dry weight of stems more than doubled during the 3-month period June to September, and total carbohydrate content increased from 25 to 85 mg. Stems of current-year shoots had contained only 3 percent of all carbohydrates in June, but this had increased to 9 percent by September. This change was primarily the result of a marked increase in starch. Stem starch increased from 4 mg in June (1 percent of the total starch) to 42 mg in September (22 percent of the total starch). Stem sugar content also increased. Stems had only 4 percent of the total sugar in June; this increased slightly to 6 percent in September. But the increase in stem sugar (from 21 to 43 mg) was less than the corresponding increase in stem dry weight. Thus the concentration of stem sugar decreased from 8.6 to 6.7 percent.

Diurnal Variations

Diurnal variations in carbohydrate levels were not nearly so well defined as seasonal differences. Variations within replications sometimes exceeded variations between sampling times. However, curves for the data revealed consistent diurnal changes in leaf carbohydrates (fig. 1). Curves are based on a 3-point moving average of the data.

Sugar concentrations tended to be lowest early in the morning and highest in late afternoon or early evening. Diurnal changes in leaf starch lagged about 5 hours behind leaf sugar in those minimum and maximum amounts. In June, the daily minimum concentration of total carbohydrates (alcohol-soluble sugar plus starch) was about three-fourths the maximum. Diurnal patterns in September were similar, but sugar concentrations tended to be lowest earlier in the morning and highest

Table 1.—Carbohydrate levels in sugar maple leaves and stems during June and September[1]

Item		June			September		
		Leaves	Stem	Total shoot	Leaves	Stem	Total shoot
Total dry weight	gm	3.17	0.25	3.42	3.61	0.64	4.25
Sugar content:							
Concentration[2]	pct.	15.6	8.6	15.1	19.3	6.7	17.4
Amount	mg.	495	21	516	697	43	740
Starch content:							
Concentration[2]	pct.	8.7	1.7	8.2	4.2	6.6	4.6
Amount	mg.	276	4	280	152	42	194
Total carbohydrates:							
Concentration[2]	pct.	24.3	10.3	23.2	23.5	13.3	22.0
Amount	mg.	771	25	796	849	85	934

[1] June values are the average of those for the period 10 a.m. 21 June through 8 a.m. 22 June; September values are the average for those for the period 10 a.m. 13 September through 8 a.m. 14 September.

[2] Concentration as percentage of dry weight.

earlier in the afternoon. Also, leaf starch concentrations did not vary as much diurnally in September.

We did not find consistent patterns of diurnal fluctuations in stem carbohydrates. Observed differences were more likely due to sampling or analytical procedures.

DISCUSSION

Amount and Distribution of Carbohydrates

Leaf starch content decreased from 276 mg in late June, soon after leaves became fully expanded, to 152 mg in mid-September, when leaves were becoming senescent. During the comparable period, leaf sugar increased from 495 to 697 mg. The seasonal reduction in leaf starch may be due to hydrolysis of "reserve starch", or to a decrease in the synthesis of "assimilation starch". Reserve starch is formed from translocated sugars and is synthesized in storage organs; assimilation starch is a transient form, synthesized in leaf chloroplast *(Akazawa 1965)*.

In sunflower leaves, less photosynthate is assimilated into starch at 10°C than at 20°C *(Smith 1944)*. The average air temperature in our study area was 6°C lower in mid-September than it had been in late June. This may partially explain why the concentration of leaf starch was lower in September whereas the concentration of leaf sugar was higher. It may also explain why diurnal changes in leaf starch were smaller in September than they had been in June. Another, perhaps more important, reason for the September reduction in leaf starch is that maple leaves were becoming senescent at this time. Starch is characteristically hydrolyzed to sugar in senescent leaves *(Salisbury and Ross 1969)*.

Stems contained only 4 mg of starch in June, but 42 mg in September. Current-year stems were undoubtedly importing carbohydrates from leaves in late June. Much of this was being assimilated into plant biomass; consequently, these developing stems contained very little starch. Total carbohydrate reserves in stems were probably at a maximum in mid-September. Starch is also maximum at about this time.

Sugar-starch interconversions are thought to be temperature-dependent. Witherell *(1963)* reported a net conversion of sugar to starch in dormant maple stems when the temperature was 10°C or higher. The average air temperature in our study area was about 15°C during the September test period. This may explain the relatively high concentration of stem starch. Subsequent hydrolysis of starch to sugar later in the fall is thought to be induced by lowering air temperatures. This hydrolysis may take place over a relatively short period of time. Marvin and others *(1971)* reported a 40-percent decrease in starch within maple callus tissue stored at 4°C, rather than 27°C, for 48 hours.

Diurnal Variations

Diurnal patterns of sugar concentrations found for sugar maple leaves (early morning minimum; late afternoon or early evening maximum) have also been reported for potato *(Watson 1936)* and barley *(Gauch and Eaton 1942)*. Apparently there are substantial diurnal changes in the difference between carbohydrate production (photosynthesis) and carbohydrate utilization (respiration, assimilation, and translocation) rather than just temperature-induced interconversions of starch and sugar, because total carbohydrates also fluctuated diurnally. Leaves produce more carbohydrates than the phloem can transport during daylight hours *(Zimmerman 1971)*. Translocation continues at night, so leaf carbohydrate concentrations decrease.

Surprisingly, alcohol-soluble sugar concentration rose during the period 1 to 6 am (before sunrise) on 22 June and 14 September (fig. 1). All leaves were mature in September and nearly so in June, so they probably did not import photosynthates. The increase in September may have been due, at least partially, to a temperature-dependent conversion of starch to sugar. Witherell *(1963)* has reported a net conversion of starch to sugar at temperatures between 3°C and 10°C. Air temperature in the study area was below 10°C at this time, and leaf starch dropped. But this would not explain the similar increase during predawn hours on 22 June, when air temperature did not drop below 18°C.

Leaf carbohydrate concentrations seemed quite responsive to current weather conditions. On 21 June, a warm, mostly sunny day, sugar and starch increased from 6 am to 4 pm, but not on the following cool, overcast, rainy day (fig. 1).

No definite diurnal patterns were found in the concentration of stem carbohydrates. Mason and Maskell *(1928)* found that sugar content did not vary diurnally in the wood of cotton plants, but diurnal changes in the bark resembled those in leaves. We did not analyze separately the bark and wood of our current-year maple stems.

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160.22:164.4:176.1 *Acer saccharum* Marsh.

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LIME HELPS ESTABLISH CROWNVETCH ON COAL-BREAKER REFUSE

by Miroslaw M. Czapowskyj and Edward A. Sowa

USDA FOREST SERVICE RESEARCH PAPER NE-348
1976

FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
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MANUSCRIPT RECEIVED FOR PUBLICATION 23 OCTOBER 1975

ABSTRACT

A study was begun in 1965 to determine the effect of lime, fertilizer, and mulch on the establishment and growth of crownvetch crowns planted on anthracite coal-breaker refuse. After 7 years the lime application had by far the strongest effect. Both 2.5 and 5.0 tons per acre increased survival and ground cover manyfold, and both treatments were equally beneficial from the first to the seventh growing season. The benefits of fertilizer and mulch were much less. Lime raised the pH to the neutral range, and this range was still the same 7 years after treatment. Exchangeable Ca and Mg were raised, and percentage of base saturation and cation exchange capacity increased significantly on areas that received lime and fertilizer treatments.

Keywords: coal-breaker refuse, crownvetch, spoil amendments.

IN MORE THAN 30 YEARS of experience with test plantings in the Anthracite Region of Pennsylvania, few plantings have succeeded on coal-breaker refuse. Now we have recent evidence that coal-breaker refuse will support vegetation if the refuse is adequately limed, fertilized, and mulched.

In a study begun in 1965, we learned that Penngift crownvetch *(Coronilla varia L.)* could be established on coal-breaker refuse by planting crowns and using lime, fertilizer, and mulch treatments; and that, when established, the crownvetch provided quick and effective cover *(Czapowskyj and others 1968; Czapowskyj and Sowa 1973)*.

In the work reported here, our objective was to determine how long effects of lime and fertilizer last. We did this by (1) estimating changes in ground cover of crownvetch during the 7-year period after establishment, (2) comparing pH of the treated refuse immediately after treatment, and (3) comparing chemical characteristics of untreated refuse with those of treated refuse 7 years after treatment.

THE STUDY

The study was established in 1965 in the vicinity of Tamaqua, Pennsylvania, on lands leased by the Greenwood Stripping Company. The site and study design have been briefly described in previous reports.

Site.—The experimental site we selected was on the plateau top of a coal-breaker refuse pile. The refuse consists of fragmented carbonaceous rocks associated with coal seams but separated from coal in a cleaning plant — a breaker. The site was practically level and somewhat compacted by truck traffic. It was bare of vegetation.

An analysis showed that the refuse consisted 75 percent of shale fragments and coal pieces larger than 2 mm and 25 percent of material smaller than 2 mm. Bulk density was 1.6 gm/ccm, and total porosity was 14 percent. The material retained 1.0 inch of available water per foot depth (2.4 cm per 30 cm). Acidity ranged from pH 3.7 to 4.0.

STUDY DESIGN AND ESTABLISHMENT

We had six 30x60-foot blocks, three each for the 1965 and 1966 plantings. Each block was divided into three plots for lime treatments; and each of these was subdivided into three subplots for fertilizer treatments. The subplots were split in two for mulch treatments. Thus the ultimate units were 10 by 10 feet. Lime and fertilizer treatments were assigned randomly, but adjacent plots were used for mulch treatment to minimize the problem of holding the mulch in place.

The treatments consisted of all combinations of three levels of hydrated lime (125 percent calcium carbonate equivalent), three levels of 5-10-5 fertilizer, and two levels of straw mulch, as follows:

Lime: 0, 2.5, and 5.0 tons per acre.
Fertilizer: 0, 250, and 500 pounds per acre.
Mulch: 0 and 1 bale of about 50 pounds of straw per block.

The liming rates were based on lime-neutralization tests. The 2.5- and 5.0-ton rates were calculated to raise the pH to about 6.0 and 6.5 respectively. Rates for fertilizer and mulch represented arbitrary judgments of reasonable amounts.

Lime and fertilizer were applied with a calibrated seed and fertilizer spreader shortly after the spring thaw. The mulch was spread by hand after planting.

In spring 1965, 25 two-year-old crownvetch crowns, each including 8 to 10 inches of taproot, were hand-planted with mattock at 2x2-foot spacing in 3 of the blocks. Each block thus contained 450 crowns, and the entire planting in 1965 totaled 1,350 crowns.

In spring 1966, the other 3 blocks were planted the same way as described above. This resulted in 6 blocks planted with a total of 2,700 crowns.

MEASUREMENTS AND ANALYSIS

Crownvetch

We measured both the survival and ground cover for the first three growing seasons. Ground cover was determined by measuring the diameter of each plant in three directions and computing an average diameter. The ground-cover area of the plants was later calculated and converted to a percentage of the sub-subplot area. In the analysis of variance the survival rates and percentage of ground cover were transformed into arcsine values.

After 3 years the survival had leveled off, and the ground cover had increased by runners so it was difficult to recognize individual plants. Therefore we measured only the ground cover in later years. Ground cover was obtained by averaging visual estimates of three workers.

Breaker Refuse

Seven years after treatments, we collected refuse samples from the 0 to 6-inch surface layer and the 6 to 12-inch layer. The samples were air-dried and passed through a 2-mm sieve. The material less than 2 mm diameter was subjected to the following chemical analyses:

1. pH values were determined, using an electronic pH meter on 1 to 1 refuse: water ratio samples.

2. Exchange acidity was determined according to the method outlined by Adams and Evans *(1962)*; available cations were extracted with neutral 1N NH_4OAc and determined by atomic absorption, phosphorus was extracted as suggested by Nelson and others *(1953)* and was determined colorimetrically.

Table 1.—Percentage survival of crownvetch planted on anthracite coal-breaker refuse

[Average of three replications]

Growing season	Fertilizer applied	Lime 0: No mulch	Lime 0: Straw mulch	Lime 2.5: No mulch	Lime 2.5: Straw mulch	Lime 5.0: No mulch	Lime 5.0: Straw mulch
	Pounds/acre	*Percent*					
PLANTED IN 1965							
1	0	15	21	89	95	92	97
2	0	0	8	79	88	87	92
3	0	0	1	75	88	83	92
1	250	11	15	83	95	84	93
2	250	1	8	79	89	80	80
3	250	0	4	72	87	79	80
1	500	5	11	89	92	85	88
2	500	1	1	84	92	79	88
3	500	0	0	81	92	79	88
PLANTED IN 1966							
1	0	8	1	48	55	65	67
2	0	1	1	41	55	57	67
3	0	0	1	41	55	57	67
1	250	3	0	60	53	56	52
2	250	0	0	49	52	44	51
3	250	0	0	49	52	44	51
1	500	3	2	55	68	74	74
2	500	0	2	54	68	74	74
3	500	0	2	54	68	74	74

RESULTS AND DISCUSSION

Lime, fertilizer, and mulch produced a difference in crownvetch performance and in chemical characteristics of the breaker refuse.

Crownvetch

Lime was the most important factor in survival and growth of crownvetch (tables 1, 2, and 3). Lime increased survival and ground cover manyfold. The rates of lime at 2.5 and 5.0 tons were equally beneficial from the first through the third growing seasons. The strong response to lime was what we expected, because crownvetch requires a relatively high pH and high available calcium for best growth.

From the nearly equal responses to the 2.5- and 5.0-ton-per-acre applications of

Table 2.—Percentage of ground cover produced by crownvetch planted on anthracite coal-breaker refuse

Growing season	Fertilizer (lbs./acre)	Lime applied at rate (tons/acre) of—					
		0		2.5		5.0	
		No mulch	Straw mulch	No mulch	Straw mulch	No mulch	Straw mulch
		PLANTED IN 1965					
1		<1	<1	4	10	6	8
2		0	<1	5	8	4	9
3		0	0	10	20	13	19
4*	0	—	—	—	—	—	—
5		0	0	55	65	55	70
6		0	0	75	80	75	85
7		0	0	80	85	80	85
1		<1	<1	5	17	7	13
2		0	<1	5	13	7	10
3		0	<1	12	27	14	20
4*	250	—	—	—	—	—	—
5		0	0	55	80	60	65
6		0	0	80	95	80	90
7		0	0	85	95	80	90
1		<1	<1	7	12	6	12
2		<1	0	6	10	5	11
3		0	0	15	25	15	23
4*	500	—	—	—	—	—	—
5		0	0	70	75	70	70
6		0	0	80	90	90	90
7		0	0	90	90	90	90
		PLANTED IN 1966					
1		<1	<1	2	3	2	3
2		<1	<1	6	11	7	13
3	0	0	<1	21	34	25	32
4		0	0	45	70	50	70
5		0	0	75	90	70	80
6		0	0	80	90	85	85
1		<1	0	1	2	1	2
2		0	0	6	9	5	9
3	250	0	0	28	31	20	28
4		0	0	50	55	35	55
5		0	0	80	80	65	80
6		0	0	80	85	80	85
1		0	<1	2	3	2	3
2		0	<1	11	16	11	17
3	500	0	<1	43	48	48	51
4		0	0	70	75	70	75
5		0	0	85	80	80	85
6		0	0	90	90	90	90

*No measurements taken.

Table 3.—Significance levels of hypothesis tested in analyses of variance

Source of variation	Survival, by growing season		Ground cover, by growing season	
	First	Third	First	Third
Year planted (Y)	**	**	**	**
Lime (L)	**	**	**	**
Mulch (M)	*	N.S.	**	*
Fertilizer (F)	N.S.	N.S.	*	**
Y x L	**	**	**	**
L x M	N.S.	N.S.	*	N.S.
M x F	N.S.	N.S.	**	**

* = Significant at 5-percent level.
** = Significant at 1-percent level.
N.S. = Not significant.

lime, we infer that the smaller amount was ample. It is possible that less than 2.5 tons per acre may be adequate.

The responses depended on the year of planting. The analyses revealed that the plots planted in 1965 had significantly (1-percent level) higher average survival and percentage of ground cover than those planted in 1966. This was probably because the 1966 growing season was especially dry. However, the effect of planting year was the opposite after the third growing season. The 1966 planting had lower survival (table 1) but better ground cover than the 1965 planting (table 1 and 2).

Furthermore, the analyses showed highly significant effects of both survival and ground-cover percentages due to lime application and planting-year interactions. The analysis showed that this difference was due primarily to the lime alone, because there was practically no survival nor ground cover on unlimed sites — for both planting years.

The fertilizer treatments did not affect the survival of crownvetch. However, added fertilizer did produce more ground cover. These effects were statistically significant at the 5-percent level during the first growing season for planting year 1965. By the third growing season, the effects were highly significant (1-percent level), even though there were some inconsistencies. The favorable response was due mainly to the pronounced increase in ground cover for the 1966 planting. The analysis showed that plots treated with 250 pounds per acre of fertilizer had nearly the same ground cover as the unfertilized plots. The ground cover was considerably higher during the first as well as the third growing season on the plots treated with 500 pounds per acre of fertilizer.

Mulching helped in establishing crownvetch. Mulched plots had 10 percent better survival than unmulched plots in the first growing season in the 1965 planting, and the mulched plots had almost twice as much ground cover as unmulched plots in the first growing season. In the third growing season the differences diminished.

The year and fertilizer interaction effects were examined also. The analyses showed that the percentage cover increases were due to the higher fertilizer application.

Lime and mulch interaction was significant for the ground-cover percentage for the first growing season only. The interaction was due to the lime, because the ground cover was practically zero in both mulched and unmulched plots where lime was not applied.

No significant effects of lime and fertilizer interactions were revealed.

There were practically no differences in crownvetch ground cover between the two levels of lime and two levels of fertilizer after the sixth and seventh years. Percentage of ground cover ranged from 80 to 95 percent, and a recent inspection of the planting site showed that a few subplots were completely covered with vegetation.

Coal-Breaker Refuse

Data on chemical characteristics of coal-breaker refuse 7 years after lime and fertilizer applications are presented in tables 4 and 5. The average values for pH, P, Ca, Mg, cation exchange capacity, and base saturation (table 4) were consistently different for the surface layer (0-6 inch) as compared to those of the subsurface (6-12 inch) layer in most treatments. K and Na did not vary among the treatments.

On the unlimed plots, values for Ca and Mg were consistently higher in the subsurface layer, especially where fertilizer was added. The P values were somewhat higher in the surface layer. On limed plots all values except Mg, K, and Na were consistently and markedly higher in the surface layer. The value for the subsurface layer also increased as compared to that of unlimed plots, indicating that some leaching occurred.

The values for exchangeable micronutrients Mn, Cu, Zn, and Fe are given in table 5. None of these seemed to be in quantities toxic to the plant; and the treatments affected the level only slightly, with the exception of Zn, which was somewhat higher.

Lime had the stronger direct effect on improvement of coal-breaker refuse fertility. Both 2.5- and 5.0-ton-per-acre applications increased the pH values, exchangeable Ca, cation exchange capacity, and percentage of base saturation of the surface layer to satisfactory levels. The Ca values were higher on plots with 5.0 tons per acre as compared to those with only 2.5 tons. The values for P increased only slightly.

The effects of commercial fertilizer were neither of great magnitude nor consistent; perhaps the application of higher rates would have produced more effect.

The biological effects also have to be mentioned. All the crownvetch died on unlimed plots. Crownvetch covered 80 to 95 percent of the ground on limed plots. The crownvetch produced a vigorous vegetative cover above the ground and an extensive root system in the surface layer. Thus the plants themselves contributed to site fertility. The

Table 4.—Selected chemico-nutritional characteristics of anthracite coal-breaker refuse 7 years after lime and fertilizer application

Applications per acre: Lime	Applications per acre: Fertilizer	Depth	pH	Extractable P	Exchangeable bases: C.E.C.	Ca++	Mg++	K+	Na+	Total	Exchange acidity	Base saturation
Tons	*Lbs.*	*In.*	*pH*	*ppm*	*me/100 gm of soil*							*Pct.*
0	0	0-6	3.8	1.0	3.0	0.1	0.1	0.1	0.1	0.4	2.6	13
		6-12	3.9	.7	3.1	.4	.2	.1	.1	.8	2.3	26
	250	6-0	4.0	1.2	3.3	.3	.2	.1	.1	.1	2.6	21
		6-12	4.1	.7	2.9	.6	.4	.1	.1	1.2	1.7	41
	500	0-6	4.0	1.6	3.2	.2	.2	.1	.1	.6	2.6	19
		6-12	4.0	1.0	3.5	.5	.8	.1	.1	1.5	2.0	43
2.5	0	0-6	6.6	1.4	6.5	5.9	.2	.1	.1	6.3	.2	97
		6-12	4.6	.5	3.6	1.7	.3	.1	.1	2.2	1.4	61
	250	0-6	5-1	1.5	4.5	3.2	.2	.1	.1	3.6	.9	80
		6-12	4.0	.8	3.5	1.4	.2	.1	.1	1.8	1.7	51
	500	0-6	5.6	2.4	4.2	3.2	.2	.1	.1	3.6	.6	86
		6-12	4.2	1.4	2.9	1.0	.2	.1	.1	1.4	1.5	48
5.0	0	0-6	7.1	1.6	8.0	7.5	.2	.1	.1	7.9	.1	99
		6-12	5.0	1.2	3.2	2.4	.2	.1	.1	2.8	.4	88
	250	0-6	7.3	1.0	9.6	9.0	.3	.1	.1	9.5	.1	99
		6-12	4.9	1.0	3.7	2.6	.2	.1	.1	3.0	.7	81
	500	0-6	6.6	1.2	6.9	6.4	.3	.1	.1	6.9	.0	100
		6-12	4.7	.7	3.9	2.9	.3	.1	.1	3.4	.5	87

Table 5.—Amount of micronutrients present in anthracite coal-breaker refuse 7 years after lime and fertilizer application

Applications per acre			Exchangeable —			
Lime	Fertilizer	Depth	Mn	Cu	Zn	Fe
Tons	*Lbs.*	*In.*		*ppm*		
0	0	0-6	0.25	0.37	2.67	1.25
		6-12	.75	.25	1.93	1.50
	250	0-6	.62	.25	1.25	2.00
		6-12	1.00	.25	1.73	1.75
	500	0-6	.37	.37	1.39	1.25
		6-12	.88	.25	1.36	2.00
2.5	0	0-6	.37	.62	3.30	.75
		6-12	.88	.63	1.90	.50
	250	0-6	.50	.25	3.09	.75
		6-12	.75	.38	2.05	.50
	500	0-6	.50	.50	2.30	.25
		6-12	.75	.50	1.99	1.00
5.0	0	0-6	.50	.37	2.85	1.50
		6-12	.50	.50	4.06	1.00
	250	0-6	.37	.62	4.35	1.25
		6-12	.50	.62	3.98	1.50
	500	0-6	.13	.50	4.35	.50
		6-12	<.10	.50	3.86	1.00

increases in cation exchange capacity on limed plots may be attributed, in part, to an increase of organic material produced by the crownvetch as well as the direct effect of increased pH on cation exchange capacity.

CONCLUSIONS

The 7-year results from this study permit the following conclusions:

- Lime is essential for establishment and growth of crownvetch on highly acid anthracite coal-breaker refuse.
- The lower liming rate—2.5 tons per acre —was as beneficial as the higher rate— 5.0 tons per acre.
- Effects of lime were evident in neutralizing acidity, increasing availability of Ca, cation exchange capacity, and base saturation of the coal-breaker refuse.
- Lime effects in establishing crownvetch, neutralizing acidity, and improving fertility were still strongly in evidence 7 years after treatment.
- The low rates of fertilizer had little influence upon survival but enhanced the establishment of ground cover.
- Mulch provided some benefit in establishing ground cover.

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Lime, fertilizer, and mulch were tried on anthracite coal-breaker refuse in attempts to establish a ground cover of crownvetch. Lime had an effect after 7 years and is considered essential for establishing crownvetch on these highly acid sites. Fertilizer had little effect on survival but enhanced establishment of ground cover. Mulch also provided some benefit. Chemical characteristics of the refuse were improved on areas that received lime and fertilizer treatments.

114.449.8 : 237.4 : 182.47/.48

Keywords: coal-breaker, refuse, crownvetch, spoil amendments

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RELATIONSHIPS BETWEEN FOREST CUTTING AND UNDERSTORY VEGETATION:

An Overview of Eastern Hardwood Stands

by Hewlette S. Crawford

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PLANT NAMES

To avoid repetition of long scientific names, only common names of plants are used in the text. The common and scientific names of the plants mentioned are:

COMMON NAME	SCIENTIFIC NAME
Angelica	*Angelica*
Aster	*Aster*
Blackgum	*Nyssa sylvatica* Marsh.
Blueberry	*Vaccinium*
Bramble	*Rubus*
Cinquefoil	*Potentilla*
Coralberry	*Symphoricarpos orbiculatus* Moench.
Dogwood, flowering	*Cornus florida* L.
Fern, bracken	*Pteridium aquilinum* L.
Galax	*Galax aphylla* L.
Goldenrod	*Solidago*
Grape	*Vitis*
Hawkweed	*Hieracium*
Hazelnut	*Corylus*
Hickory	*Carya*
Mountain laurel	*Kalmia latifolia* L.
New Jersey Tea	*Ceanothus*
Oak, bear	*Quercus ilicifolia* Wang.
Oak, black	*Q. velutina* Lam.
Oak, Northern red	*Q. rubra* L.
Oak, post	*Q. stellata* Wang.
Oak, scarlet	*Q. coccinea* Muench.
Oak, white	*Q. alba* L.
Panic grass	*Panicum*
Persimmon	*Diospyros virginiana* L.
Pipsissewa	*Chimaphila*
Plum, American	*Prunus americana* Marsh.
Poverty grass	*Danthonia spicata* L.
Pussytoes	*Antennaria*
Rose	*Rosa*
Sassafras	*Sassafras*
Sumac	*Rhus*
Teaberry	*Gaultheria procumbens* L.
Tickseed	*Coreopsis*
Tick-trefoil	*Desmodium*
Trailing arbutus	*Epigaea repens* L.
Virginia creeper	*Parthenocissus quinquefolia* L.
Wild lettuce	*Lactuca*

RELATIONSHIPS BETWEEN FOREST CUTTING AND UNDERSTORY VEGETATION:

An Overview of Eastern Hardwood Stands

by Hewlette S. Crawford

ABSTRACT

The impacts of forest cutting upon understory vegetation were evaluated for Ozark oak-hickory and Appalachian oak-pine stands. These findings were related to similar information from other eastern forest types. Production of understory vegetation is related to stand type, stand structure, stand disturbance, and site. Stand type, structure, and site operate together to influence the understory of uncut stands. Cutting the stand increases the amount of understory vegetation, but this increase is regulated by site quality, stand type, and structure. Unless undetected changes are occurring in populations of endangered plant species, it seems that understory variety and production in managed even-age stands will not differ drastically from that in naturally occurring even-age stands.

AN EVEN-AGE SILVICAL SYSTEM for eastern hardwood stands has been applied on public land since the mid-1960s. On thousands of acres, the past practice of some form of selective cutting was replaced by clearcutting for regeneration and intermediate cutting for stand improvement. Controversy arose about the application of even-age management because of its impact upon several woodland resources, including understory vegetation. Will some of the less common plant species disappear under even-age management? Will a decrease in overstory variety cause a loss of variety in the understory? Will the initial flush of understory growth soon decrease, leaving a biological desert under dense coppice overstory?

I have searched the literature, reworked old studies, and analyzed new studies in an attempt to explain the impact of even-age management upon understory vegetation and to form a conceptual model of understory response to overstory change. I will present this information by comparing composition and production of understory vegetation in stands managed with an uneven-age system, stands subjected to intermediate cutting in an even-age management scheme, and stands that have been clearcut. Upland oak and oak-pine stands in the Ozarks and Appalachian Ridge-Valley Province will provide much of the new data for this analysis because of my experience in these areas. Information from published studies in other eastern hardwood stands will provide a base for comparison. Together, this information will be used to create a broad summary of understory and overstory relationships in eastern hardwood stands. This summary, in turn, will provide a base for detecting emerging patterns of plant change due to changing silvical systems.

Ozark Selective Cutting and Understory

I went back to the late 1950s and early 1960s to obtain data on understories in selectively cut stands. Murphy and Crawford *(1970)*, reported on understory that was within reach of deer—from ground level to a height of 5 feet—throughout the Missouri Ozarks. Their data are summarized here for comparison with data presented later.

Oak-pine/black oak/scarlet oak and white oak forest types had 150 to 200 pounds per acre of current annual understory growth less than 5 feet tall. More than two-thirds was woody vegetation, 10 percent was grasses and sedges, and the remainder was forbs. The greatest volumes of forbs were produced in seedling-sapling and sawtimber stands, the least in pole stands. Post oak/blackjack oak stands had approximately 225 pounds per acre of understory vegetation, 15 percent of the total in grass and about 20 percent in forbs. Mixed hardwood stands had approximately 160 pounds per acre of forbs and 160 pounds per acre of woody plants. Grasses and sedges yielded 50 pounds per acre.

Ozark Intermediate Cuttings

I studied the impact of intermediate cuttings upon dormant season understory (below 5 feet) vegetation in 20- and 40-year-old black oak/scarlet oak stands subjected to different intensities of cutting in the Missouri Ozarks. Stands were heavily, moderately, or lightly cut, which corresponded to leaving 30, 50, or between 70 and 90 percent stocking in the residual stands respectively. This spread in cutting intensities approached clearcutting at one extreme and light selective cutting at the other, providing opportunity to study understory response to different cutting intensities. Study sites were classified as good (site index for black oak 75 or greater) or fair (site index greater than 60 but less than 75). I reported the sampling method for this work elsewhere *(Crawford 1971)*.

Heavily cut stands had the greatest standing crop of dormant-season vegetation (table 1). Vegetation decreased as cutting was decreased except in 20-year-old stands on fair sites, where lightly cut stands had more vegetation than moderately cut stands. Twenty-year-old stands had more vegetation than 40-year-old stands having similar sites and cutting intensities. Herbaceous vegetation made up only a small part of the total standing crop: heavily cut 40-year-old stands on both sites yielded about 3 pounds per acre, but all other stands yielded less than 1 pound per acre. Mushrooms occurred sparingly (about ½ pound per acre) on almost all treatments. However, lightly cut 20-year-old stands on fair sites produced 3.3 pounds of mushrooms per acre.

Table 1.—Production of dormant-season vegetation below 5 feet in height 3 years after intermediate cutting at stand age 20 and 4 years after cutting at stand age 40

[In oven-dry pounds per acre]

Age and site	Cutting intensity		
	Heavy	Moderate	Light
AGE 20:			
Good (>75)	171	87	58
Fair (61-75)	99	68	82
AGE 40:			
Good (>75)	112	51	37
Fair (61-75)	59	24	5

After heavy cutting, the average number of plant species increased substantially in 40-year-old stands but only slightly in 20-year-old stands (table 2). Many species eliminated from the stands after 40 years of no cutting or only light cutting returned after heavy cutting. The response was greater on good sites than on fair sites. Twenty years without substantial cutting did not eliminate as many species as did 40 years without substantial cutting.

Table 2.—Average number of species per plot for stands thinned at age 20 and 40

Age and site	Cutting intensity		
	Heavy	Moderate	Light
AGE 20:			
Good	8.9	7.9	8.4
Fair	7.5	5.6	6.4
AGE 40:			
Good	10.1	6.9	6.6
Fair	6.1	5.4	2.8

The most abundant species by weight in stands of both ages were flowering dogwood, several species of oak, and species of hickory. Blackgum was abundant on good sites in 20-year-old stands and on fair sites in 40-year-old stands after light cutting. Grape was relatively common in the understory except on fair sites in older stands. Grape, blueberry, New Jersey tea, hazelnut, and rose were the most abundant nonarboreal genera. Succulent green plant material was sparse.

Some difference in species composition occurred between lightly and heavily cut stands. In 20-year-old stands, plants more abundant after light cutting than after heavy cutting were blackgum, mushrooms, blueberry, hawkweed, bramble, and Virginia creeper. In 40-year-old stands, red oak decreased after heavy cutting. These plants are all common in Ozark oak-hickory stands and in time will reappear naturally after heavy cutting.

In contrast, several species increased as cutting intensity increased: New Jersey tea, hazelnut, and American plum in 20-year-old

Table 3.—White, black, and scarlet oak sprouts 3 years after cutting at stand age 20 and 4 years after cutting at stand age 40

[Weights in pounds per acre]

Age and site	Cutting intensity					
	Heavy		Moderate		Light	
	Oven-dry weight	Plots stocked[a]	Oven-dry weight	Plots stocked[a]	Oven-dry weight	Plots stocked[a]
	Lbs.	*Pct.*	*Lbs.*	*Pct.*	*Lbs.*	*Pct.*
AGE 20:						
Good	69	94	19	89	3	78
Fair	42	94	21	78	13	78
AGE 40:						
Good	32	94	26	78	11	100
Fair	20	75	5	56	1	67

[a] Plot area is 115.32 square feet.

stands; and rose, cinquefoil, goldenrod, aster, coralberry, persimmon, New Jersey tea, panic grass, and poverty grass in 40-year-old stands. The common woodland poverty grass has often been reported as decreasing in abundance with decreasing overstory. I found that it increased less with heavy cutting on good sites than on fair sites, probably because of less competition on fair sites.

The sprout growth of commercial species in the understory of 20-year-old stands was compared with that in 40-year-old stands (table 3). In 20-year-old stands, light cutting gave fair distribution of oak sprouts but little weight. Heavier cutting substantially increased the weight on good and fair sites, but more on good sites. Light thinning on good sites in 40-year-old stands gave best distribution of sprouting, and additional thinning increased the weight. This suggests that, on good sites, it may not be necessary to substantially open 40-year-old stands to get reproduction started. Initial cutting to 70- and 90-percent stocking, followed by later cutting to release the oak reproduction, may provide adequate early regeneration.

Ozark Clearcutting

All stems greater than 0.5 inch dbh were cut from an oak-hickory stand that had a range in black oak site index from 50 to over 70. The dormant-season standing crop of vegetation produced during the third growing season after cutting was reported by Crawford and Harrison *(1971)* and is shown tabularly in comparisons with other data later in this paper. Most production was in woody stems. Grasses, sedges, and forbs amounted to 2.3 percent, 1.1 percent, and 1.8 percent by weight of the production on low (SI=50–60), medium (SI=61–70), and high (SI=>70) sites, respectively. The unreported compositional aspects of this study follow.

Sassafras yielded more than any other species on poor and good sites, 28 and 19 percent of the total weight, respectively (table 4). White oak attained the greatest weight of any species, 36 percent of the total, on sites between site index 61 and 70, and was also prominent on good sites, amounting to 18 percent of the total.

The weight of sprouts of commercial oak species (white, scarlet, and black) was greatest on the medium site, although distribution was the same on all sites, 92 percent of the plots being stocked with at least one of the three species. Black oak decreased with increasing site quality; scarlet oak, though scarce, increased with site quality; and white oak reached its maximum on medium sites and was more abundant on good sites than on poor sites. Growth competition with oak coppice on good sites came mainly from sassafras and grape. Blackgum was the primary competitor

Table 4.—Plant weight (in oven-dry pounds per acre) and percentage of plots[a] occupied, by species, 3 years after clearcutting

Species	Black oak site index					
	50-60		61-70		71+	
	Lbs.	*Pct.*	*Lbs.*	*Pct.*	*Lbs.*	*Pct.*
Carya Nutt spp.	9	42	25	67	22	58
Ceanothus L. spp.	3	25	1	33	3	50
Cornus florida L.	59	50	8	50	50	42
Corylus L. spp.	(t)[b]	17	5	33	16	67
Nyssa sylvatica Marsh.	23	33	76	67	43	33
Parthenocissus Planch. spp.	0	0	(t)	17	8	33
Quercus alba L.	56	67	145	67	99	83
Q. coccinca Muench.	2	17	12	25	25	42
Q. velutina Lam.	30	75	18	75	4	42
Rhus L. spp.	3	17	0	0	8	8
Rosa L. spp.	(t)	33	(t)	33	3	33
Rubus L. spp.	(t)	33	8	67	48	83
Sassafras Nees. sp.	110	100	58	92	102	92
Vaccinium L. spp.	24	75	6	83	5	67
Vitis L. spp.	47	58	33	92	94	83

[a] Plot area is 115.32 square feet.
[b]t = trace.

on moderate sites, followed by sassafras. Sassafras was by far the major competitor on poor sites, followed by dogwood and grape. On medium and good sites hickory production exceeded that of black oak.

Nontree species of importance in addition to grape were hazelnut, Virginia creeper, sumac, and rose spp. on good sites. Bramble increased with site quality. Blueberry reversed the trend. New Jersey tea produced more on low and high sites than on medium sites.

With the exception of grape, sprouting tree species made up most of the dormant-season aspect of clearcut stands. It may be this dormant-season view of an expanse of woody sprouts that causes the concern about a loss in variety of plant species after heavy cutting. This concern is not supported by the Ozark growing-season studies reported previously here.

Selective and Clearcutting in Appalachian Oak-Pine Stands

In southwestern Virginia, the summer understory production of vegetation was sampled with a modified double-sampling technique 6 years after a cutting that removed all stems larger than 2 inches dbh. An adjacent area comparable in stand and site conditions (site index 55 for upland oaks) was partially cut 5 years before sampling, and approximately 20 percent of the stand or 30 square feet basal area was removed. These stands had been managed under an uneven-aged system.

This work was reported by Crawford and others *(1975)*, and production data by vegetation class are included later in this paper for comparison with other work. Previously unreported details of species abundance are reported here for comparison with other stands.

Table 5.—Production of summer understory vegetation on southwestern Virginia clearcut and partial cuts

Vegetation	Clearcut		Partial cut	
	Lbs. per acre	*Percent of total weight*	*Lbs. per acre*	*Percent of total weight*
Ferns	55.6	2.2	0.3	< 0.1
Mushrooms	.4	<.1	3.4	.4
Grasses	5.1	.1	3.8	.5
Forbs	144.2	5.7	69.2	9.2
Shrubs	1,033.6	40.6	476.7	63.6
Trees	1,308.3	51.4	196.2	26.2
Miscellaneous	1.1	—	2.9	—
Totals	2,548 ± 237	—	753 ± 109	—

Plants that were more abundant in lightly cut than in clearcut stands included mushrooms, dogwood, aster, tick-trefoil, red oak, New Jersey tea, hickory, angelica, grape, and pipsissewa. Again, as in Ozark stands, these plants are common and will reappear in time in heavily cut stands.

In heavily cut stands several species were more abundant: bracken fern, scarlet oak, bear oak, blackgum, mountain laurel, tickseed, galax, and wild lettuce.

Woody plants made up approximately the same proportion of weight in both clearcut and partially cut areas (table 5). Shrub species were proportionately greater in the partial cut than in the clearcut. Forb production in the clearcut was more than twice that in the partial cut. Grass production was approximately equal in both areas.

As part of a larger study at another location in southwestern Virginia, we sampled understory vegetation during winter in a 7-year-old clearcut and in a mature stand formerly managed under uneven-age management and uncut for at least 7 years *(Harlow and others 1975)*. Both stands were in the oak-pine type.

The differences in understory plant composition between heavily and lightly cut stands were small in comparison with the differences found in Ozark stands. The lightly cut stand had twice the standing crops of dormant-season herbaceous vegetation, but composition was almost the same as in the clearcut; galax was the major contributor to herbaceous yield. Leaves of mountain laurel, teaberry, and trailing arbutus were common, as were fungi. Woody twigs of blueberry and oaks were more abundant in the clearcut than in the lightly cut stand, as were twigs and leaves of pine.

Comparisons of Understory Production

Thus far I have concentrated primarily upon previously unreported compositional aspects of several studies. Now let's compare understory production data reported in several studies throughout the eastern forest types.

In stands uncut for 40 years or more, understory production measured during summer was, in pounds per acre:

Forest type, location, and reference	*Woody plants*	*Herbaceous plants*
Oak-pine Long Island *(Whittaker and Woodwell 1969)*	543[a]	20
Pine-oak Smoky Mountains *(Whittaker and Woodwell 1969)*	418	70
Cove forest Smoky Mountains *(Whittaker and Woodwell 1969)*	13	338
Birch-beech-maple Hubbard Brook NH *(Siccama and others 1970)*	78[b]	65
Mixed oak Pennsylvania *(Wood 1971)*	34	5

In stands that had been selectively cut, understory production measured during summer was, in pounds per acre:

Forest type, location, and reference	*Woody plants*	*Herbaceous plants*
Oak-pine Southwestern Virginia *(Crawford and others 1975)*	674[c]	77
Oak-pine Ozarks *(Murphy and Crawford 1970)*	125	62
Black/scarlet oak Ozarks *(Murphy and Crawford 1970)*	110	45
White oak Ozarks *(Murphy and Crawford 1970)*	115	60
Post/blackjack oak Ozarks *(Murphy and Crawford 1970)*	155	75
Mixed hardwood Ozarks *(Murphy and Crawford 1970)*	160	210

[a] Weights include contribution from radial wood in addition to twig and leaf growth.
[b] Leaves and current twigs of woody plants less than 2 cm dbh.
[c] Weights include contribution from evergreen leaves older than 1 year.

In selectively cut stands, understory vegetation production measured during winter was, in pounds per acre:

Forest type, location, and reference	*Woody plants*	*Herbaceous plants*
Oak-pine Southwestern Virginia *(Harlow and others 1975)*	45[c]	20
Mixed hardwood Southwestern Virginia *(Harlow and others 1975)*	42[c]	9
Cove hardwood North Carolina *(Harlow and Downing 1966)*	39[c]	17

For comparison with intermediate cutting in even-age management, see table 1.

In clearcut stands, understory vegetation production measured during summer was, in pounds per acre:

Forest type, location, and reference	*Woody plants*	*Herbaceous plants*
Oak-pine 6 years after cutting Southwestern Virginia *(Crawford and others 1975)*	2,346	206

In clearcut stands, understory vegetation measured during the winter was, in pounds per acre:

Forest type, location, and reference	*Woody plants*	*Herbaceous plants*
Cove forest 3 years after cutting North Carolina *(Harlow and Downing 1969)*	310	53
Oak-pine 7 years after cutting Southwestern Virginia *(Harlow and others 1975)*	197[c]	11
Oak-hickory 3 years after cutting Ozarks *(Crawford 1971)*		
SI 50–60	386	9
61–70	402	4
70+	504	10

Discussion

Taking some intuitive license, I hypothesized the following conceptual model to explain how forest understory is affected by overstory change.

Production of understory vegetation is related to forest type, stand structure, stand disturbance, and site. In stands that have not been disturbed by cutting for approximately 40 years, type, structure, and site operate together to influence the understory. Site influences forest type and—along with age—affects stand structure. The three factors to a large degree determine the amount and composition of the understory.

Cove forests are found on mesic rich sites with site-index values between 100 to 150. Tree canopies are deep and well developed and permit little light to reach the forest floor. However, abundant moisture and adequate nutrients allow a relatively luxurious growth of shade-adapted forbs. Deer populations are low in extensive acreages of old-growth forests and do not severely influence growth of understory vegetation.

Pine-oak and oak-pine stands are usually found on more xeric and somewhat infertile sites with site-index values from 45 to 70 feet per 50 years with occasional stands over site index 70. More light penetrates the more open canopies and encourages growth of substantial volumes of woody plants, often ericaceous species adapted to dry infertile soils. Herbaceous species biomass and diversity are often related inversely to the woody understory and are related directly to site quality. In extensive areas of undisturbed forest, deer populations are likely to be in balance with the vegetation.

Other stands fall between the xeric pine-oak and mesic cove hardwood types. As the hardwood component increases in the overstory, woody understory usually decreases. Herbaceous plants are influenced by site quality and may become more abundant as site quality improves.

Stand disturbance through cutting increases the amount of understory vegetation. Stimulated by increased light, freshly cut stumps of many hardwood species produce new sprouts, fed by an extensive root system. Root and stool sprouts and seedlings may be abundant. The number of sprouts is influenced by the composition of the forest type and the size of stems at the time of cutting (stand structure).

Woody growth increases as cutting intensity increases. On better sites, herbaceous growth is better able to compete initially with woody vegetation, although on the better sites the released woody growth soon forms a complete canopy and reduces the growth of herbaceous material, leaving only those species that are more shade-tolerant or capable of photosynthesizing when the overstory is leafless. Production of understory vegetation decreases as stands close after cutting and develop deeper canopies. When stands mature into sawtimber size, production of understory vegetation increases slightly as natural mortality thins the canopy, permitting increased light filtration to the understory.

Distribution and presence or absence of plant species also influences production of understory vegetation. Stands of similar forest type, structure, and site subjected to equal cutting are likely to have greater amounts of understory vegetation if there is an abundance of understory species that are more shade-tolerant and remain green over winter.

Galax is an example of such a plant. It maintains evergreen leaves and its low growing habit enables it to take advantage of a more favorable climate near the ground and to photosynthesize during warm spells throughout the winter. Galax is abundant in several types in the Appalachians but is absent from the Ozarks. Its nearest functional cognate in the Ozarks is antennaria, which does not grow as vigorously or in as dense a group as does Galax.

Many low-growing evergreen woody species present in Appalachian stands during winter are absent or scarce in Ozark stands. Species such as teaberry, trailing arbutus, and mountain laurel are common in the Appalachians. These nonarboreal evergreen plants are important wildlife foods. The differences in amounts of herbaceous and low-growing evergreen woody plants available for winter food help explain the ability of many Appalachian stands to support more deer and turkeys than Ozark stands.

Substantial disturbance of many stands results in a surge of new vegetation growth and may trigger an irruption in the deer herd. Generally, deer reach peak numbers after the stand has started to close and the peak of understory vegetation growth is past. An increasing herd on a decreasing range results in overuse and decline of many plant species. We found in Ozark stands that a recovering range may include a preponderance of plants that are not utilized by deer and lack formerly abundant plants that were favored deer foods *(Halls and Crawford 1960)*. This was also substantiated in an Appalachian study by Wood *(1971)*, who found that continually abused ranges may have little understory vegetation.

Thus many interacting factors determine the volume and composition of understory vegetation. Light, water, nutrients, seed source, and plant and animal competition all interact. This mosaic of interacting factors still determines forest understory despite all of man's product-oriented managerial practices applied to date. Forest ecosystems are resilient. From evidence gathered thus far, it does not appear that understory composition or yields with even-age forest management will change drastically from conditions we now find in naturally occurring even-age stands. Understory yields will increase for a few years after cutting, but will decrease as the canopy closes. Species of plants appear, disappear, and reappear in subsequent stands after the forest regenerates.

However, focusing on endangered plant species may provide a more sensitive indicator of potential problems than does the broader understory-analysis approach I have taken here. Unfortunately most emphasis on endangered species has been focused upon animals. Significant changes in any land-use practice are likely to affect sensitive plants before they affect sensitive animals. A reordering of priorities may be needed in existing endangered-species programs.

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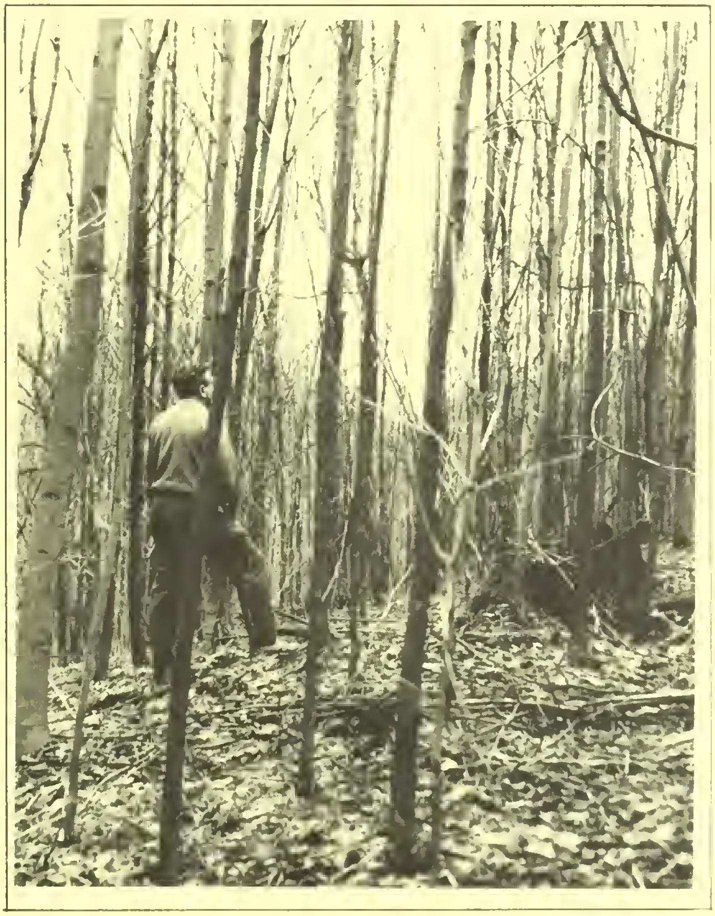
by H. Clay Smith, Robert L. Rosier, and K. P. Hammack

Reproduction 12 Years after Seed-tree Harvest Cutting in Appalachian Hardwoods



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ABSTRACT

Woody reproduction 12 years after a seed-tree harvest cutting was evaluated for three central Appalachian hardwood sites in West Virginia, including species composition; size, number, and distribution; stem quality; effects of early cultural treatments; and influence of grapevines. Reproduction ranged from 1,250 to 1,700 stems per acre in the 1.0 to 4.9 inch dbh size class. Partial estimates revealed that about 250 potential dominant and codominant crop trees per acre were present on oak site index 70 and about 500 on site index 60. Sweet birch, sugar maple, yellow-poplar, and black cherry were the most numerous species on the excellent sites; sugar maple, sassafras, red oak, red maple, and yellow-poplar on the good sites; and sassafras, red maple, red oak, chestnut oak, and sweet birch on the fair sites.

THIS IS A REPORT on reproduction in an Appalachian hardwood forest 12 years after a seed-tree harvest cutting. In the study, made on the Fernow Experimental Forest near Parsons, West Virginia, the following aspects of reproduction were studied:

1. Size, number, and distribution of stems.
2. Species composition.
3. Stem quality.
4. Effects of early cultural treatments.
5. Influence of grapevines.

This is the third report on this study. Reproduction was studied 3 years after cutting (*Wendel and Trimble 1968*) and again 7 years after cutting (*Trimble 1972*). The cutting practice used was an even-age treatment.

In this study, the reproduction data were stratified according to three site-quality classes for red oak (*Schnur 1937*). The results are applicable to central Appalachian hardwoods on site indexes (SI) of 60 or higher.

STUDY AREAS AND METHODS

This study was made on 9 compartments averaging 12 acres each. Three compartments were laid out on each of three classes of oak sites: SI 60 (fair site), SI 70 (good site), and SI 80 (excellent site). The three areas on a given site were not exact replicates because there was a difference in afterlogging cultural treatments.

The soils on the study areas are medium-textured and well-drained, average more than 3 feet deep, and are derived largely from sandstone shale with occasional limestone influence. Annual precipitation averages about 58 inches and is well distributed throughout the year; the frost-free growing season is about 145 days.

Between 1905 and 1910 the study areas were logged heavily by commercial operators. Fires were numerous. The American chestnut died in the early 1930s, and most of the dead stems were logged before 1948.

All nine study areas contained a large proportion of sawtimber volume before the initial seed-tree cutting (table 1). Most of the sawtimber trees harvested on the three excellent sites were 90 to 100 years old. On the other sites, sawtimber trees were about 55 years old, with some older red oaks and sugar maples. Before treatment the study areas contained the following sawtimber species:

Excellent sites.—Sugar maple, red oak, white oak, black cherry, yellow-poplar, and hickory.

Good sites.—Yellow-poplar, red oak, hickory, chestnut oak, and white oak.

Table 1.—Average stand-per-acre data before the initial seed-tree cutting

Site class	Volume before cutting						Merchantable stems		Basal area in merchantable stems	
	Board-foot[a]			Cubic-foot[b]						
	Merchantable	Cull	Total	Merchantable	Cull	Total	5-10 inches dbh	11+ inches dbh	5-10 inches dbh	11+ inches dbh
	- - - - - *Board feet* - - - - -			- - - - *Cubic feet* - - - -			- - - *No.* - - -		- - - *Sq. ft.* - - -	
Excellent (SI 80)	21,088	631	21,719	3,822	117	3,939	59	72	20.7	115.6
Good (SI 70)	10,629	1,320	11,949	2,436	235	2,671	111	46	34.3	68.1
Fair (SI 60)	6,726	480	7,206	1,857	130	1,987	142	42	44.4	55.4

[a] Board-foot volume for trees 11.0 inches dbh to an 8.0-inch top dib merchantable height.
[b] Cubic-foot volume for trees 5.0 inches dbh to 4.0-inch dib merchantable height.

Fair sites.—Chestnut oak, red oak, black gum, and white oak. Species scientific names and tolerance ratings are listed at the end of this paper.

Seed-tree Harvest Treatment

The same harvest-cutting procedures were used on all study areas. Initially all stems over 5.0 inches dbh were logged except designated seed trees. On the better sites, 10 seed trees were retained per acre, on good sites 20, and on fair sites 30. Most of these seed trees were yellow-poplar, black cherry, red oak, white ash, and basswood on the better sites and oaks on the lower sites. Three growing seasons after logging, the seed trees were removed.

Within each site class, three types of cultural treatments were applied to the 1.0- to 4.9-inch stems: commercial, extensive, and intensive—as follows:

Commercial treatment.—No treatment of the 1.0- to 4.9-inch dbh stems planned until the next commercial cutting period, estimated at 20 years on the excellent site, 25 years on the good site, and 30 years on the fair site.

Extensive treatment.—One cultural operation involving the release of crop trees at 7 years after the original cutting on two compartments and at 9 years on one compartment.

Intensive treatment.—1.0- to 4.9-inch dbh residual stems were to be killed 3 years after the initial cutting. Living stems in two compartments were basal-sprayed with a mixture of 2,4,5-T and fuel oil at 20 pounds ahg. In a third compartment, the small stems were cut with a chain saw. At 7 years, crop trees were released in all compartments (*Trimble 1973 and 1974*).

Reproduction Surveys

In this study, commercial species were considered those that are normally marketed for veneer, sawlogs, posts, etc. Noncommercial species are those important primarily for esthetic or wildlife purposes.

Stem counts were made before the original harvest cutting, before and after the seed trees were removed at 3 years, and at the 7-year and 12-year periods. Reproduction tallies were made for commercial and noncommercial species. These included number of stems by species, size class, stem origin, and stocking.

Small reproduction included woody stems 1.0 foot high to 0.9 inch dbh. Large reproduction was defined as woody stems 1.0 inch to 4.9 inches dbh.

Small reproduction was sampled on permanent circular 0.001-acre plots (3.7-foot radius). Large reproduction was sampled on permanent 0.01-acre plots (11.8-foot radius). Plot centers were the same for both plot sizes. An average of 45 permanent plots was established within a 5-acre interior on each study area. Also, reproduction was tallied by crown class on four areas, using the crown class designation in Forest Terminology (*Society of American Foresters 1958*). A measure of the effect of the cultural treatment on residual stems was evaluated by using a stem-dominance estimate for each 0.01-acre plot.

Sprout stems were those originating from a stump that was at least 2 inches in diameter. Seedlings and seedling-sprouts were combined into the same class. Good-quality stems were those having desirable form, no rot, low stem origin, and relatively free of any noticeable superficial defects or injuries. Only the large reproduction was classed by quality.

The age of the study trees ranged from 12 to 15 years.

Grapevines

After the 1974 growing season, occurrence of grapevines was recorded on all areas, using the permanent 0.01-acre reproduction plots. This information included number of grapevines per acre and total number of woody stems with grapevines (*Smith and Lamson 1975*).

RESULTS

Though a seed-tree cutting practice was used, silviculturists in this locale generally believe that it is not necessary to leave seed trees to supply seed for purposes of regeneration.

Table 2.—Status of average small commercial reproduction 12 growing seasons after a seed-tree harvest cutting

Site class	Total stems	Sprouts	Percentage of sprouts	Percentage of plots stocked (total stems)
	- *Number per acre* -		*Percent*	*Percent*
Excellent (SI 80)	4,792	266	5.9	88.2
Good (SI 70)	4,081	777	19.6	82.2
Fair (SI 60)	3,716	583	16.3	83.7

Table 3.—Average species composition and periodic development of small reproduction at 3, 7, and 12 years for 3 site classes

[Reproduction 1.0 foot high to 0.9 inch dbh]

At 3 years		At 7 years		At 12 years	
Species	Per acre	Species	Per acre	Species	Per acre
	No.		*No.*		*No.*
		EXCELLENT SITE			
Sugar maple	3,909	Sweet birch	3,124	Sugar maple	2,059
Sweet birch	3,530	Sugar maple	2,617	Sweet birch	1,304
White ash	1,399	Yellow-poplar	1,158	White ash	408
Yellow-poplar	1,288	White ash	1,089	Black cherry	356
Black cherry	1,244	Black cherry	994	Yellow-poplar	252
Hickory	363	E. hophornbeam	518	Elm	133
Others	1,605	Basswood	303	Hickory	74
- -	- -	Hickory	296	Basswood	66
- -	- -	Others	642	Others	140
Total	13,338	Total	10,741	Total	4,792
		GOOD SITE			
Sugar maple	2,540	Sugar maple	1,970	Sugar maple	1,852
Yellow-poplar	1,881	Yellow-poplar	696	White ash	400
Sassafras	1,273	Sassafras	600	Yellow-poplar	348
Red oak	659	Sweet birch	356	Red oak	252
White ash	642	Red maple	348	Red maple	185
Black locust	526	White ash	289	Hickory	185
Black cherry	518	Red oak	259	Sweet birch	170
Sweet birch	466	Black cherry	259	Black cherry	156
Others	1,678	Others	1,208	Others	533
Total	10,183	Total	5,985	Total	4,081
		FAIR SITE			
Sassafras	5,544	Sassafras	2,664	Red maple	693
Chestnut oak	1,992	Sweet birch	1,372	Sweet birch	682
Red maple	1,820	Red maple	1,103	Red oak	594
Sweet birch	1,518	Chestnut oak	1,044	Blackgum	437
Sourwood	926	Blackgum	556	Chestnut oak	405
Red oak	785	Red oak	413	Sassafras	390
- -	- -	White oak	277	Black cherry	166
- -	- -	- -	- -	Yellow-poplar	157
Others	1,019	Others	752	Others	192
Total	13,604	Total	8,181	Total	3,716

Small Reproduction

After 12 years, about 4,000 small stems were present per acre on all sites, and about 85 percent of the 0.001-acre plots were stocked with a commercial species. Stems of sprout origin ranged from about 6 to 20 percent (tables 2 and 3).

At 3 and 7 years there was little change among the most numerous species on each site. At 12 years these species were still similar on the excellent site, but sassafras was dropping out on the lower sites. The number of small stems per acre on all plots decreased between the 3-year and 12-year measurement periods.

At 12 years sugar maple and sweet birch accounted for 70 percent of the total number of commercial stems on the excellent site; sugar maple (45 percent) on the good sites; and red maple, sweet birch, and red oak (52 percent) on the fair sites (table 3). Intermediate to intolerant species including red oak, white ash, basswood, yellow-poplar, and black cherry, averaged about 25 percent of the total number of small stems present. However, experience indicates that many of the intolerant species in this small class die and will not respond if released.

The stocking of small reproduction on the 0.001-acre plots at 12 years averaged 88 percent on the excellent sites and 82 to 84 percent on the good and fair sites (table 2). At 7 years the stocking of small reproduction was between 93 and 97 percent for all three sites.

Large Reproduction

Number of stems per acre.—Because there were no consistent trends due to cultural treatment, data for all three study areas in each site class were combined. General information on sprouting, quality, and stocking were summarized (table 4). Excellent and fair sites averaged about 1,700 large stems per acre after 12 years, and good sites averaged 1,250 stems per acre (fig. 1).

Figure 1.—Some of the 12-year-old reproduction after a seed-tree cutting on an excellent hardwood site (oak site 80).

Table 4.—Status of large commercial reproduction 12 growing seasons after a seed-tree harvest cutting

Site class	Total stems	Total sprouts	Total good stems		Percentage of good seedling stems	Percentage of sprouts (includes good and poor stems)	1/100-acre plots stocked
			Seedlings	Sprouts			
	No.	*No.*	*No.*	*No.*	*Pct.*	*Pct.*	*Pct.*
Excellent (SI 80)	1,794	334	1,032	166	57.5	18.6	99.3
Good (SI 70)	1,248	581	294	175	23.6	46.6	100.0
Fair (SI 60)	1,653	821	489	396	29.6	49.7	100.0

On the excellent site, sweet birch, yellow-poplar, sugar maple, and black cherry accounted for about 800 good stems per acre or about 67 percent of the good stems (table 4). On the good site, sassafras, black locust, sugar maple, red maple, and black cherry accounted for about 250 good stems per acre (53 percent). On the fair site, good-quality sassafras, red maple, sweet birch, red oak, and chestnut oak totalled 777 good stems per acre or about 88 percent of the good stems.

About half of the total large reproduction on the good and fair sites was of sprout origin. However, on the excellent sites less than 20 percent of the stems were of sprout origin. This was not surprising because the excellent sites had older trees when logged, and older stumps usually sprout less fre-

Table 5.—Average species composition and periodic development of large reproduction at 3, 7, and 12 years on 3 site classes

[Reproduction 1.0 to 4.9 inches dbh]

At 3 years		At 7 years		At 12 years	
Species	Per acre	Species	Per acre	Species	Per acre
	No.		*No.*		*No.*
		EXCELLENT SITE			
Sugar maple	46	Sugar maple	91	Sweet birch	518
Basswood	18	Basswood	49	Sugar maple	247
Beech	12	E. hophornbeam	43	Yellow-poplar	236
Elm	6	Black locust	38	Black cherry	158
Cucumbertree	4	Black cherry	27	E. hophornbeam	137
Sweet birch	3	Sweet birch	25	White ash	96
—	—	Hickory	22	Basswood	92
—	—	Red oak	19	Black locust	79
—	—	Yellow-poplar	14	Red oak	65
Others	7	Others	34	Others	167
Total	96	Total	362	Total	1,795
				Intermediate-intolerants	647
		GOOD SITE			
Sugar maple	73	Black locust	124	Sugar maple	184
Beech	24	Sugar maple	111	Sassafras	148
Red maple	24	Red maple	107	Red maple	142
Hickory	16	Sassafras	97	Red oak	124
White oak	12	Red oak	91	Yellow-poplar	118
Black cherry	10	Yellow-poplar	75	Black locust	95
Yellow-poplar	7	Black cherry	49	Black cherry	89
—	—	Basswood	39	Sweet birch	76
Others	30	Others	179	Others	272
Total	196	Total	872	Total	1,248
				Intermediate-intolerants	303
		FAIR SITE			
Red maple	89	Red maple	204	Sassafras	483
Sweet birch	39	Sassafras	176	Red maple	372
Sugar maple	15	Chestnut oak	103	Red oak	184
Sassafras	13	Red oak	84	Chestnut oak	184
Beech	11	Sourwood	49	Sweet birch	169
Chestnut oak	10	Sweet birch	33	Sourwood	70
—	—	Sugar maple	27	—	—
Others	33	Others	98	Others	191
Total	210	Total	774	Total	1,653
				Intermediate-intolerants	214

quently than younger stumps (*Wendel 1975*). The major sprouting species on all sites were red maple, sugar maple, red and chestnut oaks, basswood, and sassafras.

Periodic species composition.—As expected, the number of large stems changed considerably during the 12-year period (table 5). On the excellent sites sweet birch, yellow-poplar, and black cherry have moved rapidly into this large reproduction category between the 7th and 12th years. Sugar maple was present in large numbers throughout all measurement periods. On the good site, sugar maple, red maple, yellow-poplar, and black cherry were abundant at each measurement period; and most species except black locust increased in number. On the fair site, species composition was similar. The development of red oak, chestnut oak, and sassafras, and the consistency of red maple and sweet birch were readily apparent.

At the 12-year period, sugar maple occurred in large quantities on both good and excellent sites, as did red maple and sassafras on the good and fair sites. Sweet birch occurred on all three sites. Also, on the excellent site more than one-third of the stems present after 12 years were intermediate-intolerant species (yellow-poplar, red oak, black cherry, basswood, and white ash) while the good sites had about one-fourth and the fair sites one-eighth of the stems in this intermediate-intolerant category.

On the good site, about 250 stems were classed as good dominant or codominant stems. About 500 stems were judged as good dominant-codominant stems for one sample area on the fair site. The excellent site areas were not sampled. A summary of individual species crown classes (table 6) revealed that on the good sites black locust and yellow-poplar had an average of 40 and 30 good dominant and codominant stems per acre while black cherry and red oak averaged about 20 stems per acre. On the fair site chestnut oak, red maple, and sassafras had

Table 6.—Summary of individual species per acre by crown and quality class for good and fair sites

[Large stems — 1.0 inch to 4.9 inches dbh]

Species	Dominant-codominant		Intermediate-overtopped	
	Good[a]	Poor[a]	Good	Poor
	No.	*No.*	*No.*	*No.*
GOOD SITE (SI 70)				
Black locust	40	11	11	34
Yellow-poplar	30	7	23	59
Sassafras	29	20	35	64
Red maple	26	8	24	85
Sweet birch	22	6	16	32
Black cherry	20	6	17	46
Red oak	19	13	25	68
Sugar maple	16	13	46	109
Chestnut oak	12	2	5	16
Others	24	19	31	160
Total	238	105	233	673
FAIR SITE (SI 60)				
Red maple	125	32	66	141
Chestnut oak	122	66	34	100
Sassafras	102	48	100	211
Red oak	68	45	23	75
Sweet birch	23	5	14	9
Others	53	65	31	146
Total	493	261	268	682

[a] Estimates of stem quality. All 3 areas were sampled on the good site; only 1 area was sampled on the fair site; no areas were sampled on the excellent site.

more than 100 good dominant-codominant stems per acre while red oak had 70 stems.

Occurrence.—After 12 years nearly all study areas had at least one large commercial stem present on each reproduction plot (table 4). At 7 years only the good and fair sites had approached 100-percent stocking, while the excellent sites had averaged 85 percent of plots stocked with at least one large stem.

Grapevines

Grapevines (summer grape and silverleaf grape) are rapidly becoming a major problem in young even-aged Appalachian hardwood stands (fig. 2). They damage reproduction by reducing stem quality through bending, breaking or uprooting the stems, reducing growth, or causing death. In association with snow and freezing rain, grapevine damage increases drastically (*Trimble and Tryon 1974*). In February 1975 we estimated the number of grapevines on all study areas and counted the number of saplings with grapevines in their crowns (*Smith and Lamson 1975*).

On the three good sites, grapevines averaged about 900 stems per acre, and nearly 75 percent of the saplings had grapevines in their crowns (table 7). On the excellent sites, about 450 vines were present per acre, and about 50 percent of the saplings had grapevines in their crowns. The fair site averaged 16 vines per acre, but two areas had fewer than 10 vines per acre, and only about 2 percent of the saplings had grapevines in their crowns.

Table 7.—Assessment of grapevines 12 to 15 years after a seed-tree cutting on fair, good, and excellent oak sites

Site class	Reproduction stems 1.0 inch dbh and larger			
	Grapevines per acre	Stems[a] per acre	Stems per acre with grapevines[b]	
	No.	*No.*	*No.*	*Pct.*
Excellent (SI 80)	457	2,065	993	47.7
Good (SI 70)	895	1,512	1,115	73.7
Fair (SI 60)	16	1,902	44	2.3

[a] Includes both commercial and noncommercial stems.
[b] Stem considered to have grapevines if a vine was touching crown branches.

Figure 2.—Grapevines have become a major problem in managing young hardwood stands. Left, a mass of grapevines covering the crowns of young trees. Right, a winter view reveals the mat of vines.

Grapevine damage is increasing rapidly on the better sites. Unless control measures are taken, the excellent sites will soon have fewer good stems suitable for crop trees. The good sites averaged nearly twice as many grapevines per acre as the excellent sites—895 to 457. Sapling quality on the good sites was lower than that on the excellent sites largely because of grapevines. About 50 percent of the saplings on the fair site were of poor quality, but grapevines were not the main cause of poor quality on these sites.

We do not consider the difference in site quality to be the reason for a higher number of grapevines on the good sites than on the excellent sites. We speculate that this difference resulted from some past occurrence in the stand.

Noncommercial Reproduction after 12 Growing Seasons

Noncommercial species include American chestnut, pin cherry, flowering dogwood, serviceberry, striped maple, and American hornbeam. Noncommercial stems occurring on the three sites were mainly striped maple, flowering dogwood, and American chestnut sprouts (table 8). The number of small noncommercial reproduction stems per acre averaged 215 for the excellent site, 607 for the good site, and 584 for the fair site. The number of large stems present on all three sites was similar—110 to 169 stems per acre. On the fair sites, many large American chestnuts were present at 12 years (129 per acre); however about 70 percent had the chestnut blight. All chestnuts are expected to die within a few years. Presently the dying chestnuts are serving and will serve to promote natural thinning, especially on the fair sites.

Effects of Early Cultural Treatments

Within each site class, three cultural treatments were applied—commercial, extensive, and intensive. For the commercial treatment—residual stems left after logging were not treated; extensive—crop trees were released at 7 years except for one area where the trees were released at 9 years; intensive—advanced regeneration was removed at 3 years and crop trees selected and released at 7 years. The effects of these treatments were observed on the 0.01-acre plots to determine if the

Table 8.—Small and large noncommercial reproduction 12 growing seasons after a seed-tree cutting on 3 oak site classes

Excellent site (SI 80)		Good site (SI 70)		Fair site (SI 60)	
Species	Average per acre	Species	Average per acre	Species	Average per acre
	No.		*No.*		*No.*
SMALL STEMS, 1.0 FOOT TO 0.9 INCH DBH					
Striped maple	163	Flowering dogwood	296	American chestnut	196
Sumac	30	American chestnut	96	Serviceberry	196
Flowering dogwood	15	Serviceberry	96	Striped maple	163
American chestnut	7	Striped maple	89	Flowering dogwood	22
—	—	American hornbeam	30	Pin cherry	7
Others	0	Others	0	Others	0
Total	215	Total	607	Total	584
LARGE STEMS, 1.0 INCH DBH TO 4.9 INCHES DBH					
Striped maple	77	Flowering dogwood	34	American chestnut	129
Pin cherry	29	American chestnut	26	Serviceberry	25
Flowering dogwood	5	Serviceberry	24	Striped maple	10
American chestnut	1	Pin cherry	14	Pin cherry	5
—	—	Striped maple	12	—	—
Others	0	Others	0	Others	0
Total	112	Total	110	Total	169

plots were dominated by residual stems left after logging.

On the three commercially treated areas, residual stems dominated 13 to 50 percent of the area. Results from the extensively treated areas varied to a lesser degree than the commercially treated areas. Ten to 25 percent of the new reproduction was dominated by residual stems. From the intensive cultural treatment we did not expect any of the residual stems to be dominating the new reproduction. One area was as expected because all advanced stems were cut at the 3-year period. However, on two areas residual stems were dominating between 15 and 20 percent of the area. These stems were supposed to have been basal-sprayed at 3 years. Some residual stems were missed, but many that were treated did not die.

Some residual stems were 9 inches dbh 12 years after the seed-tree harvest. We observed that sugar maple was the most vigorous species with good stem form. In our opinion, the results of the cultural treatments were too variable, and the intensive and extensive treatments so similar, that one must question the effectiveness of the cultural practices on development of reproduction. In later years we plan to complete thinnings by using different basal-area guidelines at 20, 25 and 30 years depending on cultural treatment and site class.

SUMMARY

The status of reproduction after seed-tree cutting on three oak sites (excellent SI 80, good SI 70, and fair SI 60) for 12-year-old even-aged West Virginia central Appalachian hardwood stands can be summarized this way:

Small Reproduction

(1 foot high to 0.9 inch dbh)

- Averaged about 4,000 stems per site class.
- 85 percent of the milacres were stocked with commercial woody species.
- Sprout-origin stems ranged from 6 to 20 percent.
- Sugar maple and sweet birch were predominant on the good and excellent sites; red maple, sweet birch, and red oak on the fair site.
- Main noncommercial species were striped maple, flowering dogwood, and American chestnut sprouts. All the chestnuts are expected to die.

Large Reproduction

(1.0 to 4.9 inches dbh)

- After 12 years, the large reproduction will provide most of the future sawtimber crop trees.
- Numbers of desirable species were more than adequate for future stand management.
- Stands averaged 1,250 to 1,700 commercial stems per acre.
- On the fair and good sites about 500 and 250 stems were judged as good dominant-codominant stems.
- About 50 percent of the total reproduction was sprout origin on the good and fair sites. Excellent sites averaged 20 percent, but this is explained by the cutting of older trees during logging.
- Nearly all of the 0.01-acre sample plots were stocked with a commercial species.
- Sweet birch, sugar maple, yellow-poplar, and black cherry were the most numerous species on the excellent sites; sugar maple, sassafras, red oak, red maple, and yellow-poplar on the good sites; sassafras, red maple, red oak, chestnut oak, and sweet birch on the fair sites.
- One-third of the commercial stems on the excellent sites, one-fourth on good sites, and one-eighth on fair sites were yellow-poplar, black cherry, red oak, basswood, and white ash.
- Noncommercial species ranged from an average of 110 to 169 stems per acre for the three site classes.
- Major noncommercial species were striped maple, serviceberry, American chestnut,

dogwood, and pin cherry. About 70 percent of the chestnuts were blighted.

General

- In this locale, grapevine development on the better sites (oak SI 70 and 80) is a major deterrent to the development of future sawtimber in these young even-aged stands.
- Average number of grapevines ranged from 16 per acre on the fair sites to 900 per acre on the better sites.
- Residual stems dominated a smaller portion of reproduction from the extensive and intensive treatments than from the commercial cultural treatment. However, these results were so variable that the effects of early cultural treatments are uncertain.

These results indicate what is happening to the species composition after the seed-tree cutting treatment. No doubt there is more than adequate quality reproduction on all sites. However, grapevines are seriously hampering the stem and quality development on the better sites. After 12 years, stems present in the large reproduction class will be the major source for the future dominant canopy. The results indicate there is such a variety of species present on each area that most foresters should have little difficulty manipulating these stands to their individual objectives.

Table 9.—Species referred to in this study

Common name	Scientific name
Ash, white	*Fraxinus americana* L.
Aspen, bigtooth	*Populus grandidentata* Michx.
Basswood	*Tilia americana* L.
Beech, American	*Fagus grandifolia* Ehrh.
Birch, sweet	*Betula lenta* L.
Chestnut, American	*Castanea dentata* (Marsh.) Borkh.
Cherry, black	*Prunus serotina* Ehrh.
Cherry, pin	*Prunus pensylvanica* L. f.
Cucumbertree	*Magnolia acuminata* L.
Dogwood, flowering	*Cornus florida* L.
Elm, slippery	*Ulmus rubra* Muhl.
Grape, summer	*Vitis aestivalis* Michx.
Grape, silverleaf	*Vitis aestivalis* var. *argentifolia* [Munson] Fern
Gum, black	*Nyssa sylvatica* Marsh.
Hickory	*Carya* spp.
Hophornbeam, eastern	*Ostrya virginiana* (Mill.) K. Koch
Hornbeam, American	*Carpinus caroliniana* Walt.
Locust, black	*Robinia pseudoacacia* L.
Magnolia, Fraser	*Magnolia fraseri* Walt.
Maple, red	*Acer rubrum* L.
Maple, striped	*Acer pensylvanicum* L.
Maple, sugar	*Acer saccharum* Marsh.
Oak, black	*Quercus velutina* Lam.
Oak, chestnut	*Quercus prinus* L.
Oak, northern red	*Quercus rubra* L.
Oak, scarlet	*Quercus coccinea* Muenchh.
Oak, white	*Quercus alba* L.
Sassafras	*Sassafras albidum* (Nutt.) Nees.
Serviceberry, downy	*Amelanchier arborea* (Michx. f.) Fern.
Sourwood	*Oxydendrum arboreum* (L.) DC.
Yellow-poplar	*Liriodendron tulipfera* L.

Table 10.—Tolerance ratings for central Appalachian hardwood species[a]

Species	Very tolerant	Tolerant	Intermediate	Intolerant	Very intolerant
Eastern hophornbeam	X				
American beech	X				
Sugar maple	X				
Flowering dogwood	X				
Red maple		X			
Sweet birch		X			
Fraser magnolia			X		
Cucumbertree			X		
White ash			X		
Basswood			X		
Black gum			X		
Yellow birch			X		
White oak			X		
Northern red oak			X		
Black oak			X		
Chestnut oak			X		
Slippery elm			X		
Hickories			X		
Downy serviceberry			X		
Sourwood			X		
Scarlet oak				X	
Butternut				X	
Yellow-poplar				X	
Sassafras				X	
Black cherry				X	
Bigtooth aspen					X
Black locust					X
Pin cherry					X

[a] Trimble, George R., Jr. SUMMARIES OF SOME SILVICAL CHARACTERISTICS OF SEVERAL APPALACHIAN HARDWOOD TREES. USDA For. Serv. Gen. Tech. Rep. NE-16. 5 p. 1975.

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Status of woody reproduction 12 years after a seed-tree harvest cutting was evaluated on three central Appalachian hardwood sites in West Virginia. Data studied include species composition; size, number, and distribution of reproduction; stem quality; effects of early cultural treatments; and influence of grapevines.

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Relation of Tolerant Species to Habitat in the White Mountains of New Hampshire

Abstract

The occurrence of red spruce, hemlock, beech, and sugar maple stands was related to habitat classified by substratum (generally C horizon or parent material), drainage, aspect, and elevation. Softwoods were found on rocky, outwashed, compacted, and poorly drained substrata; hardwoods were common on open glacial tills. Species was related to climate and apparent resistance of the substratum to weathering.

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FOREST SITE or habitat classification in northern hardwoods and associated types in New England is not well advanced. We need an accurate system for classifying forest land for inventory, management, and reporting research results. Certain types of information are already available: yields of even-aged northern hardwoods have been related to site index *(Curtis and Post 1964)*; site index and diameter growth of yellow birch have been found higher on moist soils than on dry, apparently because of higher nutrient concentrations *(Post et al. 1969, Hoyle 1965a)*; the physical-chemical status of certain soils and the associated species mixes have been reported for the Bartlett Experimental Forest, Bartlett, New Hampshire *(Hoyle 1973)*; and a program of broad habitat classification has recently been initiated by Alvis and Lanier[1] of the White Mountain National Forest. They have related current species to broad geologic classes that can be recognized on aerial photographs. This classification works well, but more refinement from on-site measurements would be helpful for certain silvicultural applications.

Hoyle *(1965b)* recognized the relationship of species to forest soil type in the White Mountains, and described the following habitat classification:

Forest soil	*Species*
Rock outcrop soils	spruce-fir
Shallow organic soils over bedrock	spruce-fir, birch
Colluvial soils (talus)	—
Peat soils	spruce, fir, pine, larch, red maple, paper birch, black cherry
Outwash	oak and pine
Till:	
Low elevations:	
south aspect	oak and pine
north aspect	beech, birch, maple, hemlock
Middle elevations	mixed wood[2]
Higher elevations	spruce-fir

[1] Proc. Region 9 Land Systems Conference, White Mountain National Forest, October 15-17, 1974. Unpublished report, 76 p.

[2] Mixed wood is a local designation for a mixture of softwoods and northern hardwoods in which neither makes up 75 percent of the stand.

However, this classification requires additional specification and definition of the forest soil classes, ignores successional position of the species, and does not accord well with the site/species correlations used by the White Mountain National Forest for till and outwash.

To provide some additional information on the relationship of habitat to species composition, successional trend, and productivity, I started a study in the southern half of the White Mountains during the summer of 1974.

RATIONALE

Efforts to relate species and productivity to habitat in New England have not been very successful, possibly because of the complex relationship between soils and species in this glaciated region. Standard soils classifications do not seem to provide a strong basis for relating soils to current species composition *(Pilgrim et al. 1968)*. A new approach seemed necessary.

The competitive exclusion principle *(e.g. Ayala 1972)* indicates that in a given habitat, composition should tend toward the one species (or small number of species) best adapted to that particular habitat. It follows that important differences in habitat should be reflected in differences in species composition, provided that sampling is restricted to old stands of tolerant species where most of the effects of disturbance and chance regeneration have been erased. On this premise, I sampled stands containing trees at least 150 years old (occasionally down to 100), composed mostly of one or two tolerant species, and regenerating to these same species.

Past work, previously cited, had indicated that soil drainage class and geologic history (geomorphic class) may be important in defining site classes. So in taking site measurements I concentrated on the substratum (generally the C horizon or parent material) and drainage class. It is true that tree growth should be directly related to physical and chemical conditions in the upper horizons, but in old stands we might confuse cause and effect in dealing with upper horizons. For example, humus depth and thickness of the A_2 horizon tend to be greater under old softwoods than hardwoods. But these features tend to be a result rather than a cause of the presence of softwoods. Furthermore, upper-horizon conditions should be a product of substratum, drainage, climate, and the resulting vegetative history with one important exception: where a site has been noticeably enriched by the downhill movement of materials. Because of their relationship to landform, certain substrate conditions can be mapped fairly well from aerial photos or on the site.

In summary, then, my approach was to relate the tolerant species in a stand to habitat, classified primarily by substratum and drainage. The first phase is described here. After this preliminary classification is developed, the next steps are to relate succession and silvicultural response to habitat and, of course, to revise and extend the original classification.

METHODS

A total of 84 plots were established in old stands, primarily of red spruce, red spruce-hemlock, hemlock, beech, beech-sugar maple, and pure sugar maple. Most stands were uneven-aged, and they were free from apparent cutting or windthrow in the area sampled. All sites were below 2,500 feet elevation. Most of these stands were several acres in size, although some of the pure sugar maple stands were only about an acre. I made a visual check to be sure that the regeneration was generally the same species as the overstory, and that intolerant species were uncommon in the area.

At each location, a 3-m^2-factor prism sample was taken by species of all trees in the overstory 125 mm (5 inches) dbh and larger. The two or three most common woody species in the regeneration were noted and ranked by abundance. The predominant herb species also were listed. The diameter (just above root collar) and, where possible, the height and age of the largest tree on the plot were determined.

A pit was dug to a depth of at least 1 meter (where feasible) at the center of the plot. Where obstructions were encountered, a second pit was dug. The substratum was classified as open (noncompacted) till, compacted till, boulder till, grus (weathered fragments of granite), bedrock, outwash sands, or gravel. All of these substrate materials are predominantly of granitic origin in this section of the White Mountains. How to recognize these classes is described later. Horizon thicknesses were measured, as well as depths to mottled or compacted layers; texture at the top of the C horizon was classified by hand into sandy (sands, loamy sands) or loamy (sandy loams, loams); and notes were made of elevation (from U.S.G.S. maps), aspect, slope, and general surface conditions.

The first step in the analysis was to discard those plots where vegetation or site could not be classified accurately. Seven plots were dropped because the trees were less than 100 years old or too mixed in species, i.e., no one or two tolerant species dominated. Nine plots were dropped because the site classifications were not clear; the main problem appeared to be mixed classes, e.g., outwash or grus that seemed to have been compacted, or tills that apparently had been partially compacted. Thus, 68 plots remained for analysis.

The overstory and understory on each plot were classified as pure red spruce (RS), red spruce with more or less hemlock (RS / Hem or Hem / RS), pure hemlock (Hem), pure beech (Be), beech with less sugar maple (Be/SM), and pure sugar maple or sugar maple predominating over beech (SM or SM/Be). Plots were sorted by substratum, drainage class, aspect, and elevation. These site factors were then combined into a smaller number of habitat classes that corresponded to apparent differences in vegetation.

HABITAT CLASSES

Habitat classes based on substratum and drainage conditions together with certain features of elevation and aspect separated both overstory and understory species composition (table 1). Softwoods occupied the rocky, outwashed, compacted, and poorly drained habitats. Red spruce predominated on the higher, cooler areas; hemlock was more abundant at lower elevations and on south or west exposures. Hardwoods occupied the open (noncompacted) till soils. Sugar maple predominated over beech where soil texture was finer or more moisture was available.

Red maple was the most common associate in softwood stands, regardless of whether the habitat was dry (rock, outwash) or wet (poorly drained); yellow birch was second in importance. Yellow birch was the only important associate on the hardwood plots. In this study, herbs did not appear closely related to habitat, although blueberry, wintergreen, or bracken fern often were found on dry areas (shallow bedrock, outwash) while violets and asters often were found on the better hardwood sites.

The most important feature of any habitat-classification scheme is careful definition of the categories, so the seven substrate or drainage categories in table 2 and their associated features are described in the sections that follow.

Rock

This category includes three distinct substrate conditions. First, it includes those plots underlain with tight, smooth bedrock at depths of 11 to 55 cm below the top of the mineral soil (i.e., excluding the L, F, and H layers). Bedrock sites usually are evident from areas of exposed bedrock, or bedrock in nearby trails. There may be no surface rocks; if there are any, they have sharp angles that have not been worn down by the glacier.

In the second condition soils are underlain at depths from a few centimeters up to 65 cm below the top of mineral soil with a matrix of either sharp-angled or, occasionally, somewhat rounded boulders. The sharp-

Table 1.—Numbers of overstories and understories (in parentheses) in each species group in plots of each habitat class

Substratum	Drainage	Elevation	Aspect	Number of overstories (understories) in species group					
				RS	RS/Hem Hem/RS	Hem	Be	Be/SM	SM/Be or SM
		Ft.							
Rock	Well-drained	1,000-1,500	S-W		2 (2)				
		1,500+	Any	9 (11)	2				
Outwash sands and gravels	Well-drained, occasionally moderately well-drained	1,000-1,500	S-W		1 (1)	1 (1)			
			Other	1 (1)	1 (1)				
		1,500-2,000	Any	1 (3)	2				
Compact coarse till	Well-to somewhat poorly drained	0-1,000	Any		(3)	4 (1)			
		1,000-2,000		(1)	5 (5)	1			
Open coarse till	Well-drained	0-2,000	Any				3 (4)	1	
Open fine till	Well-drained	1,500-2,000	Any				1 (2)	3 (2)	1 (1)
Enriched till	Well-to somewhat poorly drained	1,000+	Any					5 (12)	19 (12)
Any	Poorly drained	0-1,000	Any		(1)	1			
		1,000-1,500		(2)	3 (1)				
		2,000+		1 (1)					

Table 2.—Average horizon thicknesses, depths, and maximum tree height for each habitat class

Habitat	Horizon thickness			Depth from top of mineral to:			Maximum tree height	
	Organic	A_2	B	Compact layer	Mottling or water	Rock or grus	Average of plots	Range
	- - - - - - - - -			cm - - - - - - - - -			- - - - m - - - -	
Rock	16	9	25	—	—	32	20	14-28
Outwash sands and gravels	25	13	37	—	—	—	25	22-29
Compact coarse till	22	12	43	49	Variable[a]	—	24	20-28
Open coarse till	6	4	42	—	—	over 65	23	19-29
Open fine till	7	5	43	—	—	—	24	23-24
Enriched till	12	4[b]	55	—	32[a]	—	28	22-30
Poorly drained	24	6[a]		—	0-15	—	23	21-25

[a] If applicable.
[b] Often absent.

angled boulders are often associated with shallow bedrock; the boulders have been produced by frost churning with little subsequent glacial abrasion; surface rocks usually are readily visible. Rounded boulders are sometimes found in drainage bottoms; apparently the glacial water has rinsed away the finer materials, leaving a matrix of adjacent (touching), rounded boulders; surface boulders may or may not be evident.

A third condition, again often associated with shallow bedrock, is where the substratum is almost pure coarse fragments of weathered granite (grus).

The rock habitats encountered in this study were occupied primarily by red spruce at elevations above 1,500 feet, and by red spruce and hemlock mixtures at lower elevations or on south to west exposures. In some areas, oak occupies a successional role on shallow, tight bedrock — or on interspersed pockets of deeper material — especially on south to west exposures. And scattered white pine also may be found on rock habitats. Some of the poorest sites occur in this category, especially on shallow, tight bedrock where maximum tree heights may be as low as 14 meters.

No fine-textured, shallow-to-rock habitats were encountered in this study. However, observations indicate that beech and sugar maple are more common on rock habitats with finer texture.

Rock habitats are generally found at the beginning of the spruce-fir cap found on the taller mountains. Siccama *(1974)* suggested that this boreal cap on one mountain in Vermont was due to the climate at 2,500 to 2,600 feet, rather than to soil conditions. However, climate does not seem to determine the position of the boreal cap in the White Mountains since it appears in association with rock habitats at anywhere from 1,800 feet to over 2,600 feet elevation. And red spruce mixed with hemlock occurs lower.

Outwash Sands and Gravels

These are materials that have been partly to well sorted and deposited by glacial water. These deposits occur as mounds, level slopes, or flats with few if any surface stones. Outwash substrata usually are loose and single-grained in structure, although B horizons may have iron cementation. Stones, if any, near the bottom of the B horizon generally are rounded and do not have the silt caps found on soils classed as tills. Well-sorted, uniform substrata with few fragments larger than 2 mm were classed as sands. Less well-sorted substrata with stones and fragments larger than 2 mm were called gravels. The outwash habitats supported red spruce and hemlock, with hemlock often more abundant in lower or warmer areas. Some of the best white pine also were found on outwash habitats, and possibilities for white

gure 1.—Outwash sand supporting red spruce ith some white pine and hemlock. Note level to lling topography and absence of surface stones.

pine management appear to be best on this class *(Hoyle 1965b)*. Maximum tree (softwood) heights ranged from 22 to 29 meters (fig. 1).

Compact Coarse Till

Glacial till soils are characterized by a complete mixture of particle sizes from large boulders down through silts and clays. The compact tills — sometimes called basal till, indurated till, hardpan, or platy tills — are those that apparently have been plastered down by the glacier. Horizons are well defined; the A_2 is distinct. The C horizon is a hard, gray, abrupt layer that is somewhat mottled at the surface. Under this category, I include only the coarse compact tills in which the C horizon usually contains lenses of coarse sand; but a few softwood-dominated plots (not included in the analysis) had very compact C horizon containing a high proportion (over 50 percent) of coarse rotten fragments. The compact C horizon began at 15 to 80 (average = 49) cm below the top of the mineral soil. Most of these habitats were well drained (no evidence of mottling in the B horizon), but a few were moderately to somewhat poorly drained (mottling part way to throughout the B horizon). The degree of compaction on these areas varies, so identification is not always made with confidence. I think that the important criterion is whether the compact surface acts as a barrier to downward water movement. Some of the well-drained habitats had iron-cemented B horizons above the compact C horizon.

Surface boulders often are present on compact tills, but may be alined or pressed into the ground by glacial action. Although pits and mounds may be present, local relief often is subdued even though slopes may range from flat to quite steep. The general area occupied by compact tills usually shows evidence of seeps and meandering intermittent streams. Such areas sometimes contain a great variety of species because of the range in drainage conditions and the presence of pockets of loose till, outwash, and enriched materials.

The compact tills supported hemlock at the lower elevations, and hemlock mixed with red spruce at elevations above 1,000 feet. However, the general area usually appears to be mixed wood.[2] Maximum tree heights ranged from 20 to 28 meters (fig. 2).

Open Coarse Till

These are well-drained coarse-textured tills that have not been compacted. The surface looks like an assortment of boulders, smaller stones, and finer material that has been dumped in place. Topography and local relief are irregular. The soil presents a typical podzol profile: an organic layer about 6 cm thick, a distinct white A_2 horizon about 4 cm thick, and a well-colored yellowish B horizon between 30 and 50 cm thick, grading quite distinctly into a lighter colored C horizon. Stones occur throughout the profile. C horizon textures are coarse (sands and

Figure 2.—Nearly pure hemlock on compact till. Note level terrain. Stones are common but buried.

loamy sands). These habitats run heavily to beech, with a slight admixture of sugar maple. Maximum tree heights ranged from 19 to 29 meters (fig. 3 A-C).

Open Fine Till

These also are typical podzol soils with distinct A, A_2, B, and C horizons. The textures in the upper C horizon are noticeably finer than in the coarse tills. The B horizon often is less brightly colored, and the C horizon firmer, than in the coarse tills. These finer textured tills support a greater proportion of sugar maple than the coarse tills, but beech still is abundant.

In some areas, fine-textured soils are underlain with fine-textured compacted C horizons. I found no old stands of tolerant species on such sites. However, I would expect that well-drained sites of this type would support vegetation similar to that on the fine open tills. The moderately drained sites are similar to the enriched tills described in the next section.

Enriched Till

This category covers those till soils that are enriched by water or materials moving down from above. Most of these sites are on benches, coves, or slope bottoms in areas with open till or occasionally compact till soils. The A_2 horizon frequently is missing or indistinct; the horizons generally are indistinct, apparently because of the lateral movement of water and materials.

The class includes moderately to somewhat poorly drained tills, which have mottling or moving water up into the B horizon. Occasionally, these moist habitats have coarse, sandy or gravelly B or C horizons; tree growth apparently is maintained by flowing nutrient-rich water. Other areas have moist, humus-rich surface layers. Although any of these moist habitats may occur in areas in-

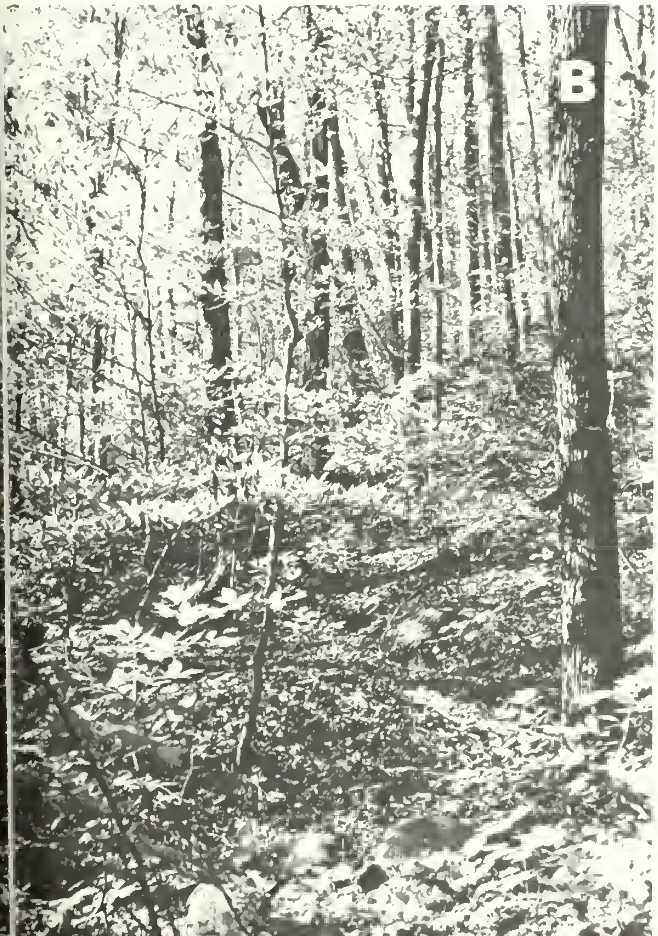

Figure 3.—A. Standing in pure softwoods (red spruce and hemlock) on west-facing streambank, looking toward pure hardwoods on east-facing bank. B. Hardwoods are growing in open till, mostly coarse till. Note surface rocks and topography. C. Prominent bedrock in streambank provides initial evidence that softwoods are growing on a rock substratum. Farther uphill, softwoods are growing on smooth, steep slope with only 30 to 35 cm of mineral soil over rotten granitic fragments.

fluenced by a compact layer, softwood-dominated compact tills previously described have a typical podzol profile coupled with a gray, mottled compact layer at the top of the C horizon.

This category also includes well-drained soils where buried A_2 and humus layers, deep uniform B horizons, markedly different C horizons, or generally poor differentiation of horizons indicate that fine-textured or humus-rich materials have moved in from above.

Enriched tills were dominated by sugar maple in combination with beech. Apparently, these are some of the better sites in the White Mountains, although they frequently occur in small, scattered units. Maximum tree heights ranged up to 30 meters, and averaged 28 meters.

Poorly Drained

This category includes those flat areas of at least a few acres where the soils consist of an organic layer over gray mottled subsoil. Standing water sometimes is visible; water often is present in shallow dug holes. These areas are dominated by hemlock and red spruce mixtures, with greater proportions of spruce as the elevation increases. Maximum tree heights of 21 to 25 meters were measured.

CLIMATIC AND WEATHERING GRADIENTS

Pollen profiles from New England indicate that softwoods preceded hardwoods in the recolonization that followed the retreat of the glacier over 10,000 years ago *(Davis 1969)*. From the peaks of the pollen influx, the trend in certain major species was about as follows:

Spruce
  Pine
    Hemlock
      Beech and sugar maple

Hemlock did not precede beech and sugar maple by very much, but it began to decline much earlier. The driving force behind this recolonization usually is considered to be climate, acting upon reproductive characteristics of the species *(Fuller and Conard 1932)*. A climatic gradient still is evident in the species/site relationships shown in table 1. Note that hemlock tends to be more abundant than spruce on lower or warmer sites. Also, it is well known that beech and sugar maple do not reach as high an elevation as red spruce. Differences between hemlock and the hardwoods are not obvious.

Differences in vegetation among the substrata might be broadly interpreted as a gradient in degree of weathering or soil maturity. Weathering processes include the mechanical disintegration of soil materials and their chemical decomposition. The two types of processes tend to move together: "Vigorous chemical changes will accompany disintegration, and the result will be shown in the greater fineness of the product" *(Lyon and Buckman 1950)*. Organic matter also accumulates. Thus, greater weathering or soil maturity is reflected in a greater departure from the original character of the soil, finer soil texture, increased solum depth, and many associated chemical changes.[3]

If we rank the substrata according to increasing degree of physical disintegration or increased susceptibility to chemical weathering, the order appears to be similar to that of the first five or six entries in table 1:

Rock
  Outwash and compact till
    Coarse till
      Fine till
        Enriched till (position questionable)
          Poorly drained (position unknown)

I place the compact tills before the open tills in the sequence because, although the materials are similar, the compact tills must weather more slowly because they are quite impervious to water, gases, and root penetration. The relative positions of outwash and compact till are not clear. Outwash, especially gravel, apparently is quite resistant to weathering because it contains much coarse material; it also is possible that less

[3] Johnson et al. (1968) describe the fragmentation of rock and increasing solum depth that accompanies chemical weathering of silicate minerals in New Hampshire; they also mention that chemical weathering proceeds more rapidly in finer materials such as till than in consolidated material such as bedrock.

resistant materials have been washed away. Compact till is physically much firmer than outwash, but it contains more fine material. Also, some compact tills probably had an initial surface layer of loose till.

Notice that the sequence of species in table 1 goes from softwoods to hardwoods, corresponding to the weathering sequence given above. Furthermore, the species sequence in table 1 resembles the recolonization sequence given at the beginning of this section. Perhaps recolonization after the glacier can be interpreted as a response to climate and weathering combined.

Apparently, the site/species relationships that now exist in the White Mountains can be broadly correlated with two gradients: a climatic gradient along which species change with elevation or aspect, and a degree-of-weathering gradient along which species change with habitat class. This interpretation provides some basis for predicting how the major tolerant species might change with changes in climate or with increased weathering.

SUCCESSIONAL AND SILVICULTURAL IMPLICATIONS

Successional trends and silvicultural responses on these habitats will be worked out by future studies. However, certain general statements can be made now. Light silvicultural treatments, such as single-tree selection, will tend to maintain the tolerant types identified in this study. However, any cutting or other distrubance in softwood stands tends to increase the proportion of successional hardwoods (such as the birches) and sometimes tolerant hardwoods (such as beech) as well. Disturbance in hardwood stands tends to increase the proportion of successional hardwoods, but it does not generally result in an increase in softwoods. Softwood sites probably average poorer for tree growth than hardwood sites, although this could be changed by culture measures such as fertilization, irrigation, or drainage.

Cover-type changes (changes in the predominant tolerant species) probably can occur and have occurred on some habitats, often following a disturbance. They could happen on those habitats that are marginal between two classes, such as bedrock habitats where the bedrock is 55 cm or more below the surface of the mineral soil, or on partially compacted tills, or on compact tills where the compacted layer is deep. On such habitats, the trend in cover-type changes should be from softwoods toward hardwoods such as beech together with red maple and successional hardwoods. In similar fashion, the time required for the original tolerant species to return following disturbance probably is related to whether the habitat is marginal between two classes or not: e.g., the greater the depth to bedrock or compact C horizon, the slower the return to softwood species, if it ever occurs.

The habitat classes recognized in this study may help provide a basis for classifying forest land into meaningful management units, and should also help provide some basis for laying out and reporting field research. This classification system appears to fit — in habitat definitions and species relationships — the broader system being used on the White Mountain National Forest. Some units of 50 acres or more could be of a single habitat class. Other areas — such as certain ones influenced by compact tills — have a mixed array of habitat classes and a corresponding array of species. Some areas are hard to categorize. The influence of habitat on species composition is more pronounced on larger areas of a single site type, except perhaps for enriched sites, which are usually small. For example, small pockets of compact till or outwash within a general area of open till may not influence vegetation very much.

Classifications like these require modification if they are extended very far outside the area in which they were developed, because the competitive position of the species will change. However, the approach followed in this study may prove useful in other regions.

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ABSTRACT

Uncertainty and inadequate information for prediction hinder attempts to judge the chances for success on logging jobs. In this study, variation in the success of commercial logging jobs in the Northeast was examined to relate the kinds of conditions present to the chances of logging being most successful under those conditions. Respondents rated half of the sample logging jobs most successful; they agreed that these jobs were excellent business ventures compared to other recent logging jobs. Splitting the sample on key variables substantially improved our ability to explain success on these logging jobs. Among 22 characteristics, total timber harvest, hauling distance, crew size, and distance from the preceding job were key determinants of the most successful jobs.

THE ABILITY to sort out the most favorable opportunities for investment is a major asset in any business. If, for example, the manpower and capital investments committed to a logging business are to be used wisely, somebody must estimate the chances for a successful business venture based on the conditions under which logging is to be done. Likewise, knowledge of the underlying conditions for successful logging should guide the activities of landowners toward developing operable tracts of timber.

Recent research on commercial logging has provided industry-wide data about logging operations in the Northeast *(Herrick 1975a, 1975b)*. This information supports much of the state-of-the-art knowledge about the industry through documentation of facts. In addition, an analysis was made to identify the key determinants of successful logging jobs. This paper is a report on the organizational effectiveness, or success, of logging jobs in the Northeast.

APPROACH

Uncertainty is a fact of life, and in dealing with it one need not judge the outcome of future activities at the polar extremes of successful or unsuccessful. In the face of uncertainty there are acceptable degrees of success. This probe into the range of success experienced on commercial logging jobs across the Northeast revealed the kinds of conditions present and the chances of logging being most successful under those conditions.

The data were derived from a study describing the combination of men, equipment, and actions that logging firms in the Northeast employed on recent (1974) logging jobs *(Herrick 1975a, 1975b)*. Logging was defined to include the activities involved in cutting and moving timber products from the stump to the mill or purchase point.

Variables

Dependent variable.—The dependent variable was based on each firms' comparative judgment about the success of their most recent logging job compared to other recent logging jobs done by the firm. If respondents said that they (1) strongly agreed or (2) tended to agree that their job was an excellent business venture, it was classified as *most successful*. Jobs for which the response was (3) hard to decide, (4) tended to disagree, or (5) strongly disagreed were labeled *least successful*.

Independent variables. — Characteristics that describe the logging job and the operating unit that did the job were used as 22 independent (predictor) variables for analyzing job success (table 1).

Table 1.—Statistical relationships between logging and job success rating

Characteristics of logging unit and job	Chi-square significance level
	Pct.
1. Status of firms' logging business; major or partial activity	—[1]
2. Number of logging crews in firm	7.8
3. Regional subarea of logging job	—
4. Number of timber products produced on this job	—
5. Major timber product produced on job	—
6. Major type of timber cut	6.3
7. Capital-labor ratio of crew	—
8. Equipment investment on job	9.1
9. Number of workers in crew	7.1
10. Distance moved from preceding job	—
11. Acres in job	—
12. Ownership of tract logged	—
13. Ownership of timber logged	—
14. Volume of timber products cut per acre	9.8
15. Total volume of timber products cut	3.8
16. Value of timber cut	—
17. Most common skidding distance (stump to loading point)	—
18. Longest skidding distance	—
19. Most common temporary road distance (loading point to permanent road)	—
20. Longest temporary road distance	—
21. Most common hauling distance (to mill or purchase point)	—
22. Longest hauling distance	3.5

[1] Indicates not significant at the 10 percent level.

Contingency Analysis

The relationship between logging-job success and each characteristic of the job was tested by contingency analysis (table 1). Results showed a significant dependence (at the 5.0-percent level) between job success and two characteristics: hauling distance for timber products, and total volume of timber products cut. The predominant type of timber, number of workers in the logging crew, number of logging crews in the firm, average investment in equipment on the job, and volume of timber products cut per acre were also related to job success, but at lower levels of significance.

The contingency analysis identified several variables for explaining logging success. However, it did not indicate what combination of characteristics best explains successful logging jobs. To do this we have to use this information in another analysis.

Multiple Variable Analysis

What combination of logging job characteristics spells the most success? One way to approach this question is by subdividing the logging jobs into a series of subgroups that will maximize our ability to explain characteristics of the most successful jobs. The analytical technique called AID—Automatic Interaction Detector—is useful for this purpose *(Sonquist and Morgan 1964, Sonquist and others 1971).*

The AID technique divides the data set, through a series of two-way splits, into a series of subgroups. Every job is a member of one of these subgroups. They are chosen so that, at each step of the procedure, the two new groups will reduce the variance of the dependent variable more than any other pair of subgroups. Thus the procedure starts with the most stable and dependable finding and works down to less and less dependable findings on smaller and smaller subgroups. The splitting process is constrained by a lower limit for predictive error reduction and sample size in order to keep the final information relevant and valid.

In this study the following specifications were used for splitting:

1. The split of any group had to reduce total predictive error at least 1.0 percent.
2. Each subgroup had to contain at least 25 observations.
3. Where a predictor had a natural order, that ordered series of categories was preserved in any resulting two new groups.

RESULTS

The analysis resulted in 10 mutually exclusive groups of logging jobs showing the corresponding proportion of jobs that were rated "most successful" in each group. These results were arrived at by the following procedure, as represented by a tree-diagram of the splits (fig. 1).

When the total sample (group 1) was examined, the maximum reduction in the predictive error was attained by splitting the sample into two new groups: "timber harvest 25,000 cubic feet or less" (group 2), and "timber harvest greater than 25,000 cubic feet" (group 3).

Group 3, the over-25,000-cubic-foot jobs, was then split into "longest hauling distance is 15 miles or less" and "longest hauling distance exceeds 15 miles." Similarly the "exceeds 15 miles, greater than 25,000 cubic feet" group was further divided into "larger than 4-man crew" and "crew of 4-men or less," etc.

A group that could no longer be split became one of the 10 final groups. When all final groups had been formed, some of the original variables (table 1) still had not been used. At each step there was another variable that proved more useful in explaining the variance remaining in that particular group.

Only final groups—those at the ends of the tree branches—are of major concern. Group descriptions define the job characteristics

Figure 1.—Variables used to explain success on logging jobs. In each cell, the percentage figure shows the proportion of jobs in each group that were rated most successful. N=size of final groups.

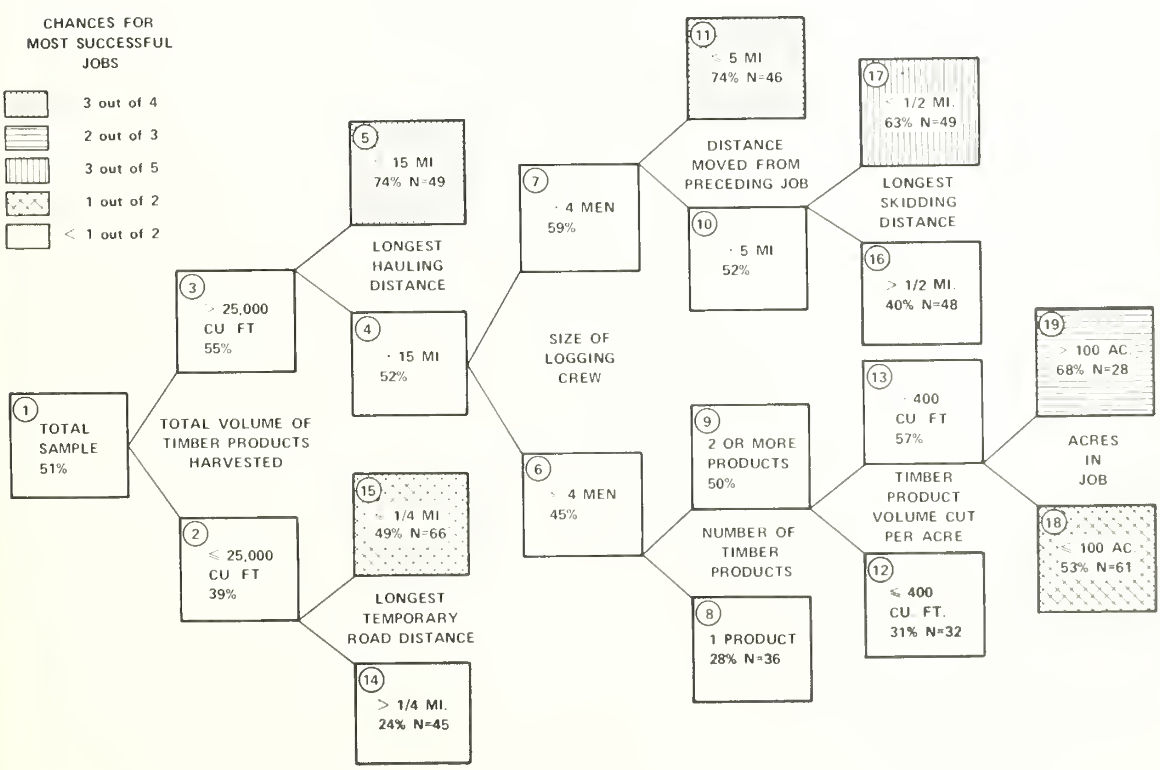

Table 2.—Final groups of Northeastern logging jobs, in rank by their proportions of most successful jobs

Group no.	Job characteristics	Proportion of jobs rated most successful
		Pct.
5	Job produced more than 25,000 cubic feet of timber product volume, and the longest distance products were hauled did not exceed 15 miles	74
11	Job was within 5 miles of the job that preceded it; more than 4 men were used on the job; the longest hauling distance was greater than 15 miles; and the job produced more than 25,000 cubic feet of timber product volume.	74
19	Job involved more than 100 acres, had more than 400 cubic feet per acre and more than one timber product; at most it involved 4 men; the longest hauling distance was greater than 15 miles; and total volume produced was greater than 25,000 cubic feet.	68
17	Longest skidding distance did not exceed ½ mile; the job was more than 5 miles from the job that preceded it; more than 4 men were used on the job; the longest hauling distance was greater than 15 miles; and total volume was more than 25,000 cubic feet.	63
18	Job involved 100 acres or less (otherwise the same as group No. 19).	53
15	Longest temporary road distance on the job did not exceed ¼ mile, and total timber product volume did not exceed 25,000 cubic feet.	49
16	Longest skidding distance on the job was more than ½ mile (otherwise the same as group No. 17).	40
12	Volume per acre was 400 cubic feet or less; job produced more than one timber product; 4 men or less were used on the job; the longest hauling distance was greater than 15 miles; and total volume was more than 25,000 cubic feet.	31
8	Job produced only one product; 4 men or less were used on the job; the longest hauling distance was greater than 15 miles; and total volume was more than 25,000 cubic feet.	28
14	Longest temporary road distance on the job was more than ¼ mile, and total timber product volume did not exceed 25,000 cubic feet.	24

needed to get the odds of most success associated with each final group (table 2). For example, 74 percent (3 out of 4) of the logging jobs were most successful when the volume cut exceeded 25,000 cubic feet and the hauling distance was 15 miles or less (group 5).

The key groups for explaining logging job success are those that have the highest and lowest proportions of jobs rated most successful in the tree of two-way splits. These groups characterize success extremes. According to our analysis, logging jobs that rated most successful were least prevalent in group 14 and most prevalent in groups 5 and 11.

DISCUSSION

Fifty-one percent of the original sample of logging jobs were rated most successful. Respondents agreed that these jobs were excellent business ventures compared to other recent logging jobs done by the firm. Splitting the sample on key variables substantially improved our ability to explain success on these logging jobs. For example, look at jobs on which total timber product volume did not exceed 25,000 cubic feet and the longest temporary road distance on the job was greater than ¼ mile. Only one in four of these jobs was perceived as being most successful (group 14, fig. 1).

On the other hand, consider those logging jobs yielding more than 25,000 cubic feet of timber products. If the products were hauled no farther than 15 miles to a mill or purchase point, chances were relatively good (three out of four) that the job was rated most successful (group 5).

Moreover, where the hauling distance exceeded 15 miles, chances of rating most successful were also three out of four if the job used a crew of more than four workers and was located within 5 miles of the preceding logging job (group 11). Where distance from the preceding job exceeded 5 miles, three out of five jobs were rated most successful if the distance that timber products were skidded or forwarded did not exceed ½ mile (group 17).

If the logging was done by four workers or less, and the job produced more than one timber product, averaged more than 400 cubic feet per acre, and covered more than 100 acres, chances were two out of three that the job was rated most successful (group 19). If 100 acres or less were involved, chances that the job rated most successful dropped to one out of two (group 18).

The conditions under which loggers operate differ from job to job. This analysis shows the odds that logging jobs have of being most successful under various combinations of conditions. Conversely, it indicates which combinations of conditions represent the most favorable commercial logging opportunities. The results suggest that predicting logging job success on the basis of total timber harvest, hauling distance, crew size, and distance from preceding job would provide a considerable reduction in error.

In application, the emphasis may be on buyers acting to avoid the least favorable situations, or on sellers acting to upgrade these situations. But in terms of the parameters that make for operable tracts of timber, the implications are similar for buyer and seller alike. Knowing the array of chances associated with the various conditions under which timber is being bought, cut, and sold helps to sort things out a little better for those trying to assess the operability of timber resources.

Variables that work are, of course, the most logical candidates to include in a framework for judging the potential for success of a logging job. It should be noted, however, that the above framework is not a decision-making model. It is an additional guide that can be used to reach a more rational decision, which will have to be made anyway. As a guide, the suggested framework is a supplement to the other guides and means used to investigate or evaluate logging jobs in the region.

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DUTCH ELM DISEASE and METHOXYCHLOR

by
Jack H. Barger

USDA FOREST SERVICE RESEARCH PAPER NE-353
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NORTHEASTERN FOREST EXPERIMENT STATION
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DUTCH ELM DISEASE and METHOXYCHLOR

ABSTRACT

American elm trees, *Ulmus americana* L., in Milwaukee, Wisconsin, were sprayed with methoxychlor by helicopter or mist blower once each year for 3 years to control the smaller European elm bark beetle *Scolytus multistriatus* (Marsham). Twig crotches were collected from sprayed trees each year for bioassay. Methoxychlor residues persisted for at least 1 year. There were differences in beetle control between spray techniques, but these differences decreased as years of successive spraying increased, suggesting that methoxychlor residues accumulate on elms. Tree surveys were made each year to determine the incidence of Dutch elm disease. Average incidence remained stable in the areas treated by helicopter and mist blower, while it rose sharply in the control areas. Despite differences in beetle control between spray techniques, there were no differences in disease incidence between the helicopter and mist blower treatments. Later observations indicated that methoxychlor spraying can reduce disease incidence for several years after treatments have ceased, but unidentified factors also significantly affect disease incidence.

KEY WORDS: helicopter; mist blower; elm bark beetle; control; disease incidence; spray residue; elm twig; spraying.

DUTCH ELM disease (DED), caused by the fungus *Ceratocystis ulmi* (Buism.) C. Moreau, continues to spread and to destroy the American elm, *Ulmus americana* L., in the United States. DED is spread by the smaller European elm bark beetle, *Scolytus multistriatus* (Marsham), which introduces spores of the fungus into the water-conducting system of elms while feeding on twig crotches, and by transmission of the fungus through root grafts.

Before DDT was banned, chemical control recommendations were directed at preventing twig-crotch feeding by dormant-season applications of DDT or methoxychlor *(Norris 1961, Whitten and Swingle 1964)*, and at preventing the spread of fungus through roots by injecting the soil with Vapam to kill grafted roots *(Himelick et al. 1963)*.

Methoxychlor was included in the control recommendations, but most commercial and city arborists resisted using it because it increased cost and there was some question that its persistence was enough to be effective. For example, Norris *(1961)* found that methoxychlor gave 93.7 to 96.4 percent control of beetle feeding for 102 days, while DDT gave 95.1 to 99.3 percent control over the same period. Wootten *(1962)* found methoxychlor as effective as DDT for 150 days in preventing beetle feeding on twigs. But Doane *(1962)* compared methoxychlor to DDT and found methoxychlor ineffective, although the average size of the feeding scars indicated that the beetles had not fed extensively. Later laboratory tests by Cuthbert et al. *(1970)* showed that 100 times more methoxychlor than DDT was required to kill 50 percent of the beetles exposed to treated filter paper, but they did not imply that 100 times more methoxychlor would be needed to protect elms.

Wallner and Leeling *(1968)* compared helicopter and mist blower applications of methoxychlor on elms by assaying twig-crotch bark for deposits. They found larger deposits from helicopter applications. Barger et al. *(1973)* reported a similar study, but found that larger deposits were obtained by mist-blower applications.

This study began because the performance of methoxychlor had been determined mainly by beetle feeding bioassays or chemical assay. Little was known about the effect of methoxychlor on disease incidence.

Methods and Procedures

Tree selection.—American elm trees (Moline variety) were selected from one contiguous area of Milwaukee, Wisconsin. The area was divided into spray and check plots. Elm trees were rejected if they were: (1) suspected of disease; (2) adjacent to a stump, recent stump mark, or diseased tree; (3) less than 30 feet apart; (4) in poor health; or (5) if they had been sprayed with an insecticide in the last 3 years. The assumption was made that trees with latent disease were evenly distributed throughout the experimental area. For all trees, the mean dbh (diameter at breast height) was 16 inches and the mean height was 45 feet. Treatments were assigned to plots at random.

At its beginning in 1969, the study included 856 trees in the plots sprayed by helicopter, 859 in the plots sprayed by mist blower, and 1,950 in the untreated check plots. By the end of the follow-up in 1975, attrition had reduced these numbers to 245 sprayed by helicopter, 448 sprayed by mist blower, and 458 untreated controls.

Treatments.—One plot was sprayed by mist blower in the fall of 1968. Three other plots were sprayed by mist blower in the spring of 1969, and all four plots were sprayed again in the spring of 1970 and 1971. Each tree received an average of 2.5 gallons of 12.5 percent methoxychlor emulsion. A John Bean Model 300G Rotomist mist blower equipped with three number 5 nozzles was used.[1] The two outer and one center nozzle had number 45 and number 46 cores respectively.

[1] The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U. S. Department of Agriculture of any product or service to the exclusion of others that may be suitable.

Elm trees in three other plots were sprayed in 1969 with an average of 1 gallon per tree of 12.5 percent methoxychlor emulsion, by a Bell 47G-2 helicopter equipped with a 32-foot boom and number D6 nozzles with number 45 cores. Only two of these plots were sprayed in 1970 and 1971, so only those two were used in the computations.

The same trees were sprayed each year in all spray plots, but plots or single trees that were not sprayed initially or in some other year because of inclement weather or parked cars were dropped from the study that year and all following years.

Sampling plan.—To determine how long the effects of methoxychlor persist, the plot that was sprayed in the fall of 1968 was sampled approximately every 6 weeks for a year. To compare residues from helicopter and mist blower applications, trees in all the sprayed plots were sampled in May, June, July, and September, 1969, and in June and October of 1970 and 1971. Ten twigs were collected from each of 16 sectors (4 levels and 4 quadrants) on each sample tree crown. Three trees in each plot sprayed by mist blower and six trees in each plot sprayed by helicopter were selected at random on each sampling date from among the trees that were sprayed at the same time; a total of 12 trees per treatment.

Bioassay.—The bioassay was made by confining bark beetles on twig crotches in small cages *(Barger et al. 1971)*. The mean percentage of beetles that failed to feed to the xylem of the twigs was used as a measure of the effect of the methoxychlor treatment.

Disease survey.—During August and early September, from 1969 through 1975, elm trees in the study area were inspected by two different crews for symptoms of DED. No attempt was made to determine which trees had become diseased from root grafts and which by beetle inoculation. Diseased trees were marked on the street side with a red nail, and were removed during the following winter and early spring. Trees removed for reasons other than DED were dropped from the study. The percentage of DED-infected trees each year in each plot was the incidence of the disease. The average of the incidences for all plots under each treatment is the average incidence.

Results and Discussion

Persistence of methoxychlor.—The first bioassay to measure the persistence of methoxychlor after fall application was made in January, 56 days after spraying. It showed 92.3 percent of the beetles deterred from feeding. The second bioassay, in March, 99 days after spraying, showed an 88.8 percent control. The percentage control was rather constant for the remaining bioassays and 1 year after spraying, methoxychlor residue was high enough to control 62.1 percent of the beetles (fig. 1).

These results showed that little methoxychlor disappeared from the trees during the winter, and they support a recommendation for fall application. The lower average temperature and precipitation slow the evaporation and removal of methoxychlor by water, and may account for the higher bioassay readings during the winter sampling periods.

Comparison of treatments.—To compare methods of application, bioassays were made on twig samples collected from trees in the plots sprayed in the spring by mist blower and by helicopter from 1969 through 1971. For trees sprayed by mist blower, the first and last bioassays in 1969 showed 73.5 and 45.9 percent feeding control respectively; in 1970, the percentages were 78.0 and 71.6; for 1971 they were 55.2 and 60.7 percent (fig. 2). Generally, beetle control was greater at the bottom of tree crowns than at the top.

Bioassays from the trees sprayed by helicopter always gave a lower percentage control. The lower bioassay readings were expected because these trees received less than half the spray volume delivered by the mist blower. This does not, however, suggest that one treatment is better than the other for suppressing DED. Beetle control was greatest at the tree tops and progressively lower at each lower crown level. The first and last bioassays in 1969 showed 38.0 and 11.7 percent control; in 1970, the percentages were 29.6 and 20.8; for 1971 they were 50.9 and 45.6 percent (fig. 2).

These comparative bioassays show that residues of methoxychlor may accumulate on sprayed elms from one year to the next. Bioassay readings increased every year in the

Figure 1.—Persistence of methoxychlor sprayed in the fall. Average percentage of beetles that failed to penetrate the xylem of elm twigs collected at 6-week intervals from a plot sprayed by mist blower in the fall of 1968.

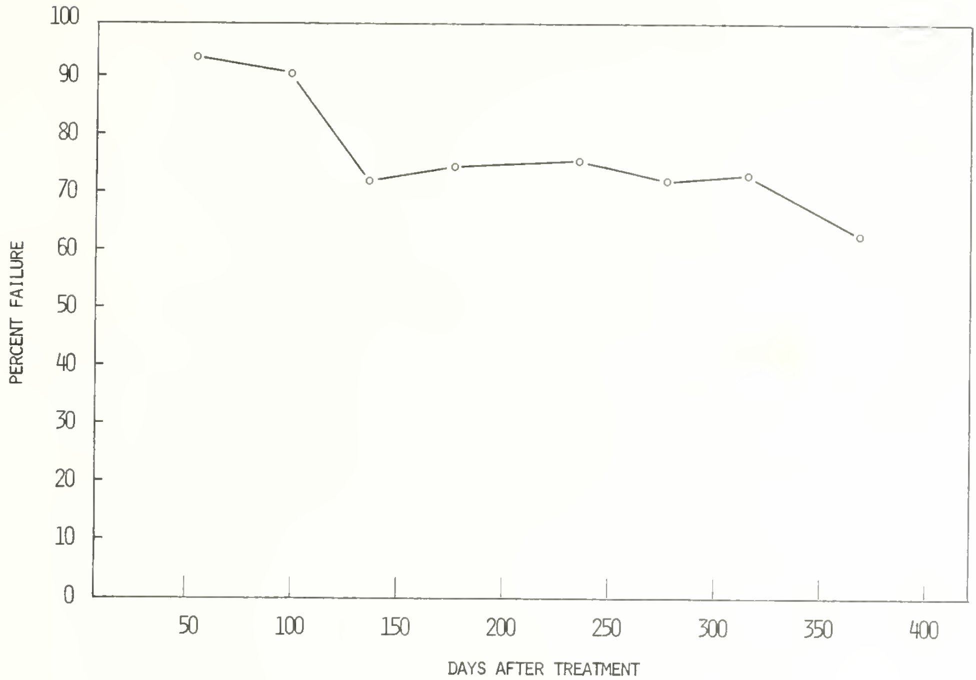
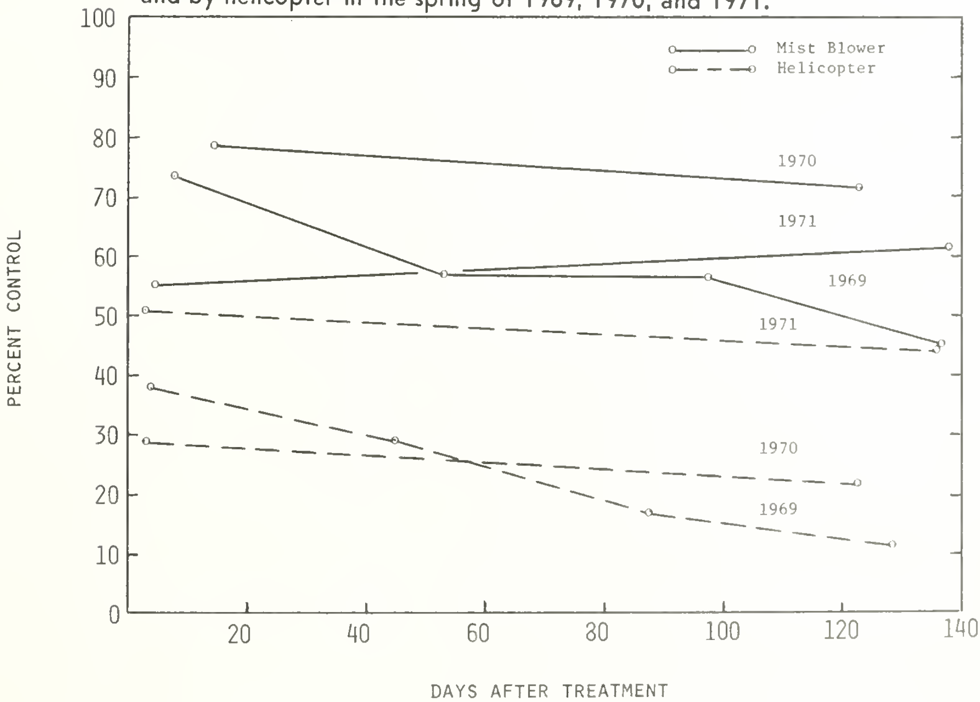


Figure 2.—Average percentage of beetles that failed to penetrate the xylem of elm twigs from plots sprayed by mist blower and by helicopter in the spring of 1969, 1970, and 1971.



plots sprayed by helicopter and increased all but 1 year in the plots sprayed by mist blower. Also, differences between the first and last readings decreased as the number of successive years of spraying increased.

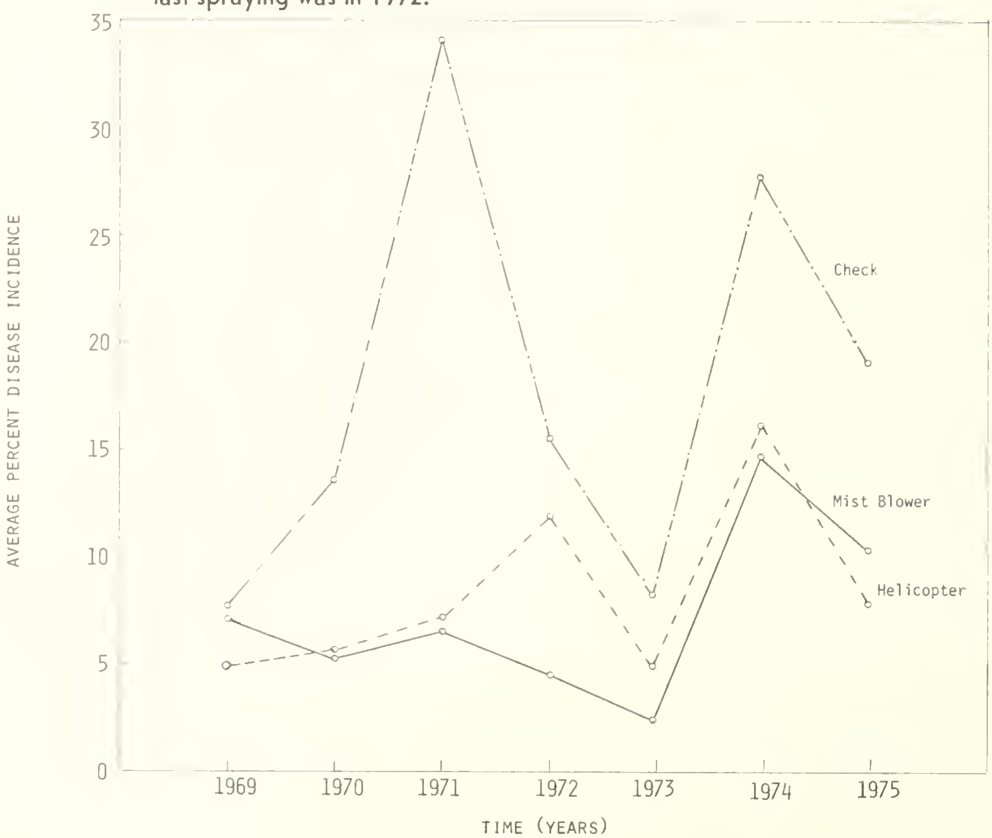
Disease incidence.—In 1969, no significant differences in disease incidence were found between plots sprayed by helicopter and those sprayed by mist blower, nor between either of these and the unsprayed check plots. Because the criteria used to select trees minimized root-graft transmissions during the first year of this study, the incidence of disease in 1969 was due mainly to new inoculations by beetles. Latent infections not detected when the trees were selected may have caused the death of some elms, but these infections were assumed to be equally distributed among the plots. In 1970 and 1971, the disease incidence fluctuated in the plots treated by helicopter and mist blower but remained near the 1969 level while the disease increased dramatically in the check plots (fig. 3).

Figure 3 shows clearly that DED was contained by spraying elms with methoxychlor by either treatment technique. Had measures been taken to reduce root-graft infections or had the incidence been computed only on beetle-vectored cases of DED, the incidence would have been lower for both treatments.

Conclusions

Although bioassays clearly showed differences in bark beetle control between trees sprayed by helicopter and those sprayed by mist blower, these differences were not reflected in the incidence of DED. And although trees treated by mist blower received an average of 2.5 times as much methoxychlor as

Figure 3.—Incidence of Dutch elm disease in plots sprayed by helicopter and mist blower and in control plots, 1968-1975. The last spraying was in 1972.



those treated by helicopter, the disease incidence was the same. Therefore, the idea that every elm tree or twig crotch must be heavily sprayed with methoxychlor to provide good protection against beetle inoculations should be reexamined. The chain of events leading to beetle feeding on elm twigs has not been determined, but there is no reason to assume that beetles in flight zero in on one twig crotch to feed. It is more likely that the beetles walk on branches after landing. Because methoxychlor is both a contact and a stomach poison, this would greatly increase the probability of the beetles' contacting methoxychlor residues before they begin feeding on twigs.

Other conclusions are that spraying elms with methoxychlor annually for 3 years, either by helicopter or mist blower, controlled the disease while its incidence increased among elms that were not sprayed. Furthermore, my data indicate that: (1) fall spraying of elms is effective; (2) residues accumulate on elms from successive yearly sprays; and (3) heavy doses of methoxychlor are not necessary to control the disease.

Observations After the Study

Although this study was not intended to continue beyond 1971, sufficient methoxychlor was on hand to spray about 800 elms in 1972. The plots treated by mist blower were sprayed, but not those that had been sprayed by helicopter. The incidence of DED increased sharply on the plots previously sprayed by helicopter, while it declined slightly on those sprayed by mist blower. However, it declined even more sharply on the check plots, although it was still higher there than on the treated plots (fig. 3).

Though no trees were sprayed in 1973 or thereafter, the disease incidence continued to decline in all the plots. It declined to levels at or below those before the study, demonstrating that unknown factors significantly affect the incidence of DED.

In 1974, the incidence of the disease rose sharply in all plots, although it was still lower in those that had been treated than in the check plots. In 1975 it declined in all plots. Thus the plots that had been treated had a continuing advantage.

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KEY WORDS: helicopter; mist blower; elm bark beetle; control; disease incidence; spray residue; elm twig; spraying.

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PROGRAM HTVOL
The Determination of Tree Crown Volume by Layers

by
Joseph C. Mawson
Jack Ward Thomas
Richard M. DeGraaf

USDA FOREST SERVICE RESEARCH PAPER NE-354
1976
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
NORTHEASTERN FOREST EXPERIMENT STATION
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PROGRAM HTVOL

The Determination of Tree Crown Volume by Layers

ABSTRACT

A FORTRAN IV computer program calculates, from a few field measurements, the volume of tree crowns. This volume is in layers of a specified thickness of trees or large shrubs. Each tree is assigned one of 15 solid forms, formed by using one of five side shapes (a circle, an ellipse, a neiloid, a triangle, or a parabolalike shape), and one of three bottom shapes (a circle, an ellipse, or a triangle).

A test of the accuracy of this technique shows that it produces estimates within acceptable limits of error if the shape is carefully selected.

The program sorts these volume data by layer within species for each sample plot. Any number of plots can be run at one pass through the computer, and up to 100 species can be designated.

Keyword: Crown Volume

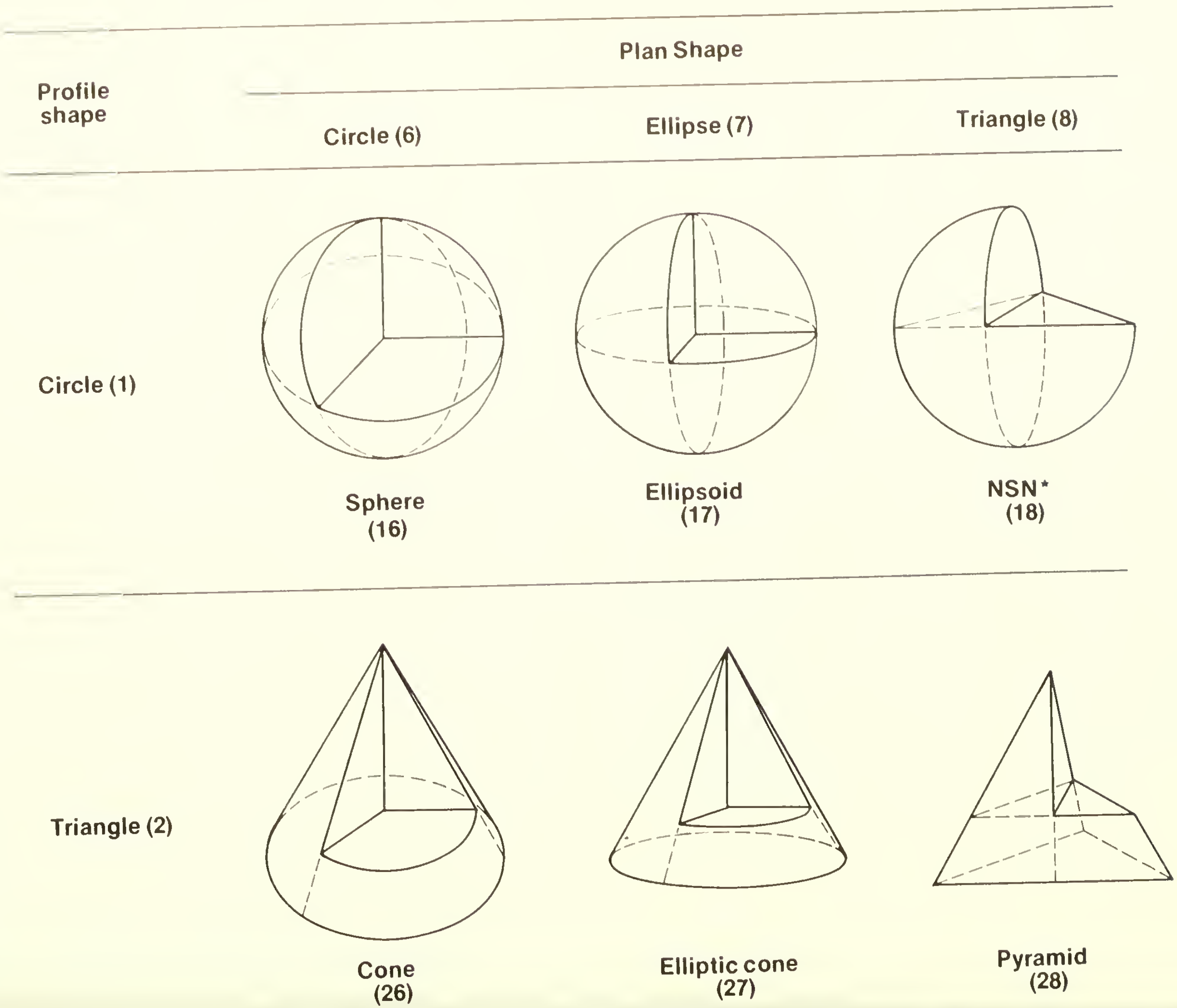
Estimates of the crown volume of trees and shrubs are often useful, particularly for understanding habitat associations of birds (*Sturman 1968, Thomas 1973*). Accurate measurement of these volumes is difficult, and estimating them by height classes requires difficult and tedious calculations. We have developed a computer program that calculates crown volume from a few simple field measurements and produces volume estimates for layers of any thickness. We use the term "crown volume" for the number of cubic feet of space within the crown. Bentley et al. (*1970*) used it with a similar meaning when they presented a technique for sampling low shrub vegetation by crown-volume classes.

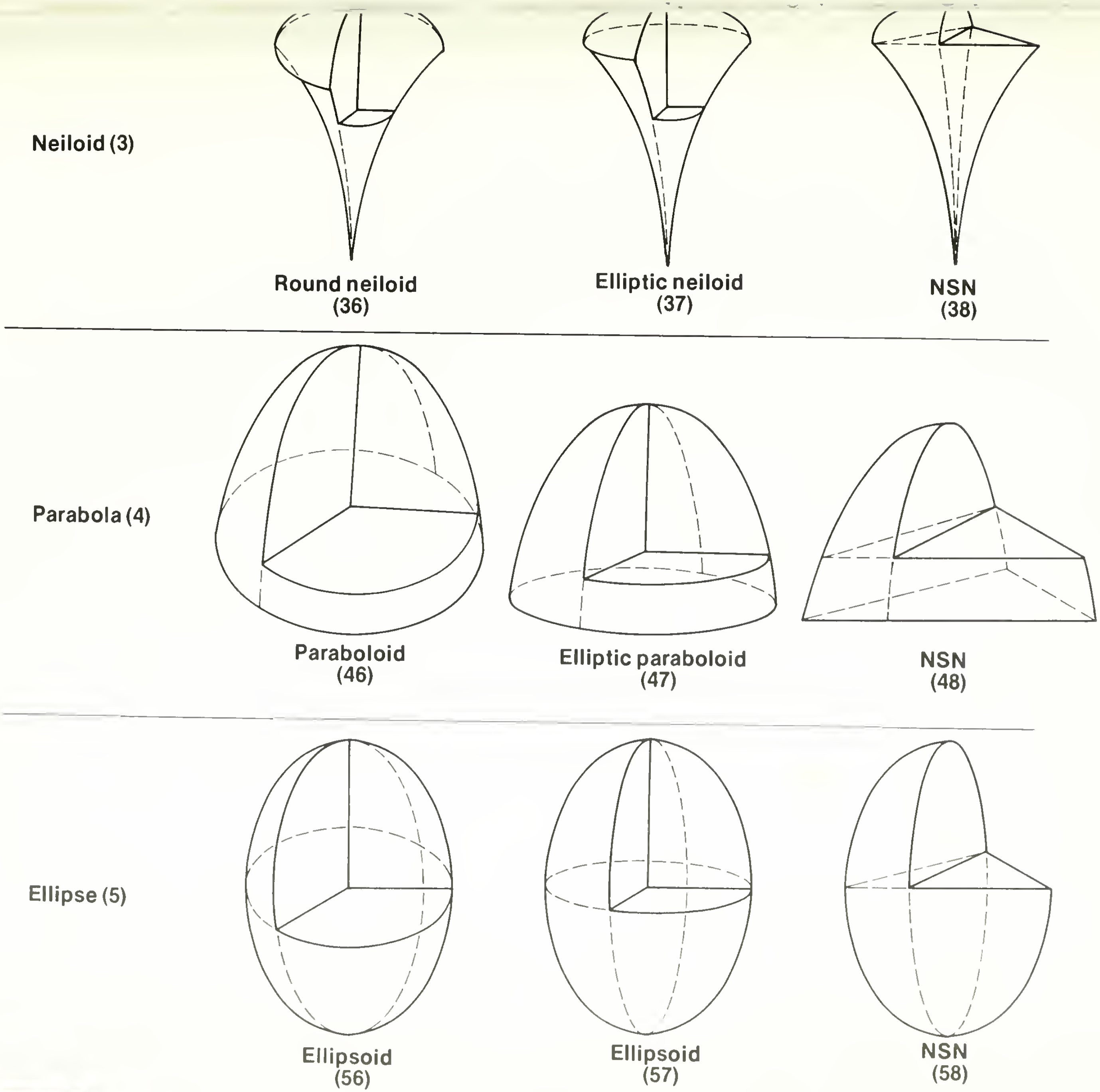
Earlier studies of bird habitat (*Sturman 1968*) refer only to the total crown volume, with the assumption that one or two general shapes (usually a circle or ellipse for the side shape and a circle for the bottom) are sufficient to determine this total. Others recognized that forest canopy layers affect bird distribution (*MacArthur and MacArthur 1961, MacArthur et al. 1962, MacArthur 1964*), but considered only ground vegetation, understory, and overstory, and did not attempt to quantify the volumes of the layers.

Bird habitat studies are not the only use for crown volume. Studies of crown fuels for evaluation of potential fire behavior (*Sando and Wick 1972*) or classical studies of crown development for site evaluation or thinning (competition studies) also would require some expression of this crown volume.

Program HTVOL (*H*eigh*t* *Vol*ume) calculates the gross volume occupied by the crown, including stems, branches, leaves, and the air between them. To do so it assumes that each tree or large shrub fits one of 15 geometric shapes. The program incorporates a density variable to supplement the estimate of crown volume. The program can calculate volumes for up to 100 layers, but each layer must be of the same thickness for a single program run. Subroutines can calculate volumes of other layers or combinations merely by adding volumes. The volumes are cal-

Figure 1. Shapes used in HTVOL program (with identifying numbers)




Neiloid (3)
Round neiloid
(36)
Elliptic neiloid
(37)
NSN
(38)
Parabola (4)
Paraboloid
(46)
Elliptic paraboloid
(47)
NSN
(48)
Ellipse (5)
Ellipsoid
(56)
Ellipsoid
(57)
NSN
(58)

culated and presented by plot. There is no limit to the number of plots in any one run, nor to the number of trees in a plot.

TREE SHAPE

No one geometric form can be used to describe the crown shape of all species. But if a side view or profile shape and a bottom or plan shape are estimated, the resultant geometric solid can be used to describe volume. HTVOL uses five profile and three plan shapes to describe 15 geometric solid forms. The shapes are shown in figure 1, each with its name and an identification number. These identification numbers are used in the field (and in the program) to describe the shape.

The shapes are not evenly distributed among trees in any region of the country. A sample of the relative distribution from a suburban bird habitat study in Amherst, Massachusetts (*Thomas 1973*), illustrates this for 2,700 trees (table 1).

FIELD MEASUREMENTS

The following variables were measured or estimated for each tree:

1. Species—Species are identified with a four letter code. We used a species code using the first two letters of the genus and species. Example: Acer rubrum = ACRU; Salix species = SASP.
2. Crown profile class—assigned shape 1 to 5.
3. Crown plan class—assigned shape 6 to 8.
4. Total height—measured to nearest foot.
5. Bole height—average height to the live crown.
6. Plan radius—for a circle the radius R, for an ellipse plan the large (RL) and small (RS) radii. For a triangle the height (L) and base (W).
7. Diameter—dbh to nearest inch.
8. Density class—rated 1 to 5 according to the density of the crown. 1 = very dense; 5 = very sparse.

Diameter and density class are the only two variables not used in the calculations. They were useful for photographic interpretation and description of the kind of volume, and are included in all data formats of the program.

TEST OF ACCURACY OF PREDICTED VOLUMES

We estimated the error of our assumption that trees conform to one of 15 shapes for a sample of 49 trees. The selection was purposive, to try to include all the shapes.

The test was conducted in three stages:

1. For each selected tree, we measured total height, height to crown, and plan radius or radii in the field.
2. Two black and white photographs were taken of each tree at right angles to one another. A 10-foot range pole (graduated at one foot intervals) was placed against the tree.
3. In the office, each negative was projected on 1 inch x 1 inch graph paper and adjusted to a convenient scale (1 inch = 5 feet or 1 inch = 2 feet). The crown was sliced into layers at 5-foot height intervals, and the radii of each slice were recorded.

We calculated the true volume of each tree from the office measurements and compared it with the volume calculated by the HTVOL program.

Two points should be considered if this technique is applied to any study:

Table 1. ***Frequency distribution of tree shapes in a bird habitat study in Amherst, Massachusetts***

Profile shape	Plan shape						Total	
	Circle		Ellipse		Triangle			
	No.	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*
Circle	314	11.5	49	1.8	103	3.8	466	17.1
Triangle	296	10.9	44	1.6	85	3.1	425	15.6
Neiloid	432	15.8	126	4.6	400	14.7	958	35.1
Parabola	195	7.1	26	1.0	81	3.0	302	11.1
Ellipse	438	16.0	38	1.4	101	3.7	577	21.1
Total	1,675	61.3	283	10.4	770	28.3	2,728	100.0

1. Although a conifer may generally appear to be conical in profile, no tree tested had a true triangular shape—all were rather parabolic, i.e., the sides curved outward. The difference in volume estimates between the two shapes, real and assigned, was significant. This should be tested on the true firs of the West or other conical-crown types.

2. Most elm trees followed a neiloid profile only if the crown shape started at the base of the tree, i.e., the height to the live crown (bole height) is assumed to be 0 feet. Therefore, it is likely that any tree that looks like a neiloid should be given a bole height of 0. Again, this assumption should be tested before field work is started.

Table 2 is a summary of observed differences in volume for each solid and by side and bottom shapes. These differences were calculated by comparing the volumes obtained from the photographs with those obtained from field measurements used by the HTVOL program. Their frequency distribution is shown in table 3.

Table 2. *Differences between estimated and actual crown volume for trees of each solid shape by profile, plan shape, and height class*

Category	Number of trees	Percent difference
Shape no.		
16	3	− 3.56
36	4	−19.00
37	2	− .04
38	1	− 1.96
46	12	− 7.06
56	21	+ 5.32
57	1	+25.50
58	5	+ 1.00
Profile shape		
1	3	− 3.56
3	7	−14.09
4	12	− 7.06
5	27	+ 7.31
Plan shape		
6	40	− 4.30
7	2	+12.18
8	7	+ .21
Height class		
0-19	8	− 1.12
20-39	24	− .64
40-59	24	− 1.14
60+	6	− 5.12

Table 3. *Frequency distribution of individual tree differences between true and estimated volume*

Difference range	Positive differences	Negative differences	Total
Percent	*Number*	*Number*	*Number*
0-5	4	11	15
6-10	1	7	8
11-15	8	2	10
16-20	4	3	7
21-25	2	1	3
26-30	4	0	4
31-35	0	0	0
36-41	1	1	2
Total	24	25	49

Several general statements can be made about the results:

1. Although we tried to find samples of all the shapes, only 8 of the 15 were represented. Shapes 17, 18, 26, 27, 28, 47, and 48 (fig. 1) were not observed. This does not mean they do not exist, but it does mean that the conditions under which trees grow along roadsides in the Town of Amherst do not produce many trees that are conical in side view or ellipsoidal or triangular in plan. This is to be expected. Trees in open or semiopen locations tend to have circular crown bases. In tight or closed stands, triangular and elliptical plan shapes would be more prevalent.

2. The exact profile shape must be considered carefully. In the original choice in the field, conical profile shapes (Profile Shape 2) were assigned to conifers from 20 to 60 feet in height. After we looked at the photographs and took measurements in the office, we changed the profile shape to parabolic (Profile Shape 4) because it more closely represented the shape of the test trees.

3. The least accurate profile shape is the neiloid (Profile Shape 3), originally thought to fit the elm tree best. In our small test sample, the errors of volume exceeded our 10 percent limit. But when the profile was changed in the office to an ellipse or a parabola, the errors dropped to 8 percent, which was within our acceptable range.

4. Differences between estimated and actual volume for individual trees ranged from −40.9 to +38.2 percent. But the estimates for 33 trees were within 15 percent of the true volume. With sufficient numbers of trees—say 20 or more for

any one shape—the differences would average between 5 and 10 percent—a deviation we would call acceptable. The overall difference for the 49 trees we tested was 2.25 percent, well within our acceptable limits.

5. An analysis of the differences *by layer* (estimated volume minus true volume) showed differences ranging from ± 1 percent to more than 150 percent, but clustered around ± 20 percent. The typical profile of differences by layer showed that at the bottom of a crown the estimate tended to be low, while at the top it tended to be high. Only profile 3 showed a different pattern. For all samples of profile shape 3, the negative differences were in the middle layers. This is significant and caution is urged in selecting this profile shape because trees assigned neiloid shapes tend to be wider in the crown than the regular geometric profile shape allows.

6. To aid in selecting the best shape, a clear plastic templet with all the shapes etched on it could be used in the field. The tree would be viewed through the templet, held at the proper distance from the eye to place the tree entirely within the etched shape outline. This would also help choose the radius that would best insure a representative volume calculation by the single shape technique.

NOTE: Copies of Program HTVOL may be obtained from the authors at the Northeastern Forest Experiment Station, Hilton House, University of Massachusetts, Amherst, Mass. 01002.

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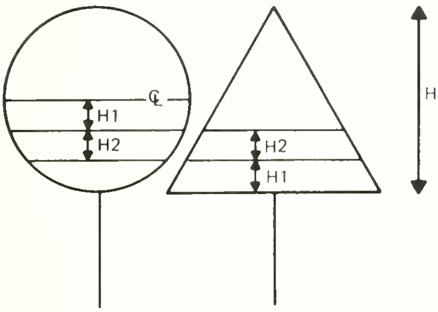
APPENDIX
FORMULAS FOR FRUSTRUMS OF SHAPES

The following formulas are used in HTVOL to compute the volume of a layer:

Definitions

- π = Pi = 3.141593
- R = Radius of a circle for bottom shape 6
- RS = Radius of small side for bottom shape 7
- RL = Radius of long side for bottom shape 7
- W = Width of triangle for bottom shape 8
- L = Length of triangle for bottom shape 8
- H1 = Distance from base to lower plane of frustrum. The base is the bottom of the crown for shapes triangle, neiloid, and parabola-like, and the base is the mid-diameter for an ellipse or circle.
- H2 = The thickness of a frustrum
- HC = Height of crown—the total height of the solid.



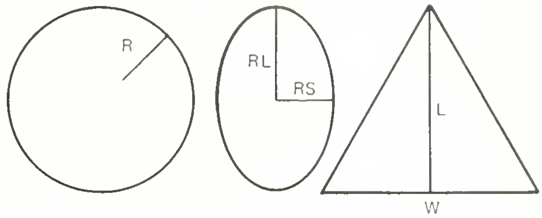


Figure No.	*Frustrum*	*Solid**
16	$\frac{\pi H2}{3}\left[3R^2-3H1^2-3H1H2-H2^2\right]$	$\frac{4\pi R^3}{3}$ 4.18879 R^3
17	$\frac{\pi H2RS}{3R}\left[3R^2-3H1^2-3H1H2-H2^2\right]$ where R = RL	$\frac{4\pi RSR^2}{3}$ 4.18879 $RSRL^2$
18	$\frac{2H2}{3}\left[3R^2-3H1^2-3H1H2-H2^2\right]$ $\left\{R=\frac{W}{2}\text{ or }\frac{L}{2}\text{ Since }W=L\right\}$	$\frac{8R^3}{3}$ 2.667 R^3
or	$\frac{2H2RS}{3R}\left[3R^2-3H1^2-3H1H2-H2^2\right]$ $\left\{\begin{array}{l}RS=\frac{W}{2}\text{ or }\frac{L}{2}\text{ whichever is smaller}\\ R=\frac{W}{2}\text{ or }\frac{L}{2}\text{ whichever is }=\frac{HC}{2}\text{ since }W\neq L\end{array}\right\}$	$8\ \frac{RSR^2}{3}$ 2.667 RL^2RS

*Solid is calculated by setting $H2=\frac{HC}{2}=R, H1=0$

Figure No.	*Frustrum*	*Solid*
26	$\frac{\pi R^2 H2}{3}\left[\left(1-\frac{H1}{HC}\right)^2+\left(1-\frac{(H1+H2)}{HC}\right)^2+\left(1-\frac{H1}{HC}\right)\left(1-\frac{(H1+H2)}{HC}\right)\right]$	$\frac{\pi R^2 HC}{3}$ 1.04719 HCR^2
27	$\frac{\pi RLRSH2}{3}\left[\left(1-\frac{H1}{HC}\right)^2+\left(1-\frac{(H1+H2)}{HC}\right)^2+\left(1-\frac{H1}{HC}\right)\left(1-\frac{(H1+H2)}{HC}\right)\right]$	$\frac{\pi RLRSHC}{3}$ 1.04719 HCRSRL
28	$\frac{LWH2}{6}\left[\left(1-\frac{H1}{HC}\right)^2+\left(1-\frac{(H1+H2)}{HC}\right)^2+\left(1-\frac{H1}{HC}\right)\left(1-\frac{(H1+H2)}{HC}\right)\right]$	$\frac{LWHC}{6}$ .1667 LWRC
36	$\frac{\pi H2}{6}\left[\left(R-\sqrt{R^2\left(\frac{HC^1-H1}{HC^1}\right)}\right)^2+4\left(R-\sqrt{R^2\left(\frac{HC^1-H1-\frac{H2}{2}}{HC^1}\right)}\right)^2+\left(R-\sqrt{R^2\left(\frac{HC^1-H1-H2}{HC^1}\right)}\right)^2\right]$	$\frac{\pi HCR^2}{6}$ 1.7573 .9201512 HCR^2
37	$\frac{\pi H2}{6}\left[\left(RL-\sqrt{RL^2\left(\frac{HC^1-H1}{HC^1}\right)}\right)\left(RS-\sqrt{RS^2\left(\frac{HC^1-H1}{HC^1}\right)}\right)+4\left(RL-\sqrt{RL^2\left(\frac{HC^1-H1-\frac{H2}{2}}{HC^1}\right)}\right)\left(RS-\sqrt{RS^2\left(\frac{HC^1-H1-\frac{H2}{2}}{HC^1}\right)}\right)+\left(RL-\sqrt{RL^2\left(\frac{HC^1-H1-H2}{HC^1}\right)}\right)\left(RS-\sqrt{RS^2\left(\frac{HC^1-H1-H2}{HC^1}\right)}\right)\right]$	$\frac{\pi HCRSRL}{6}$ 1.7573 .9201512 HCR^2
38	$\frac{H2}{3}$ [Same as 37] If $W > L$, $RL = \frac{W}{2}$ $RS = \frac{L}{2}$; If $W < L$, $RS = \frac{W}{2}$ $RL = \frac{L}{2}$	.3827 HCRSRL

Figure No.	*Frustrum*	*Solid* *
46	$\frac{\pi H2R^2}{2HC}\left[2HC-2H1-H2\right]$	$\frac{\pi R^2HC}{2}$ 1.57079 R^2HC
47	$\frac{\pi H2RSRL}{2HC}\left[2HC-2H1-H2\right]$	$\frac{\pi RSRLHC}{2}$ 1.57079 RSRLHC
48	$\frac{H2WL}{4HC}\left[2HC-2H1-H2\right]$	$\frac{HCLW}{4}$ .25 HCLW
56	$\frac{\pi H2R^2}{3HC^2}\left[3HC^2-12H1^2-12H1H2-4H2^2\right]$	$\frac{2\pi HCR^2}{3}$ 2.09439 R^2HC
57	$\frac{\pi H2RSRL}{3HC^2}\left[3HC^2-12H1^2-12H1H2-4H2^2\right]$	$\frac{2\pi HCRSRL}{3}$ 2.09439 RSRLHC
58	$\frac{H2WL}{6HC^2}\left[3HC^2-12H1^2-12H1H2-4H2^2\right]$	$\frac{2HCWL}{3}$ .6667 HCWL

* Solid is calculated by setting H2 = HC H1 = 0 for "4"

H2 = Hc/2 H1 = 0 for "5"

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U681.3 : 531

Keyword: Crown Volume

Mawson, Joseph C., Jack Ward Thomas, and Richard M. DeGraaf.
1976. **Program HTVOL--The determination of tree crown volume by layers.** Northeast. For. Exp. Sta., Upper Darby, Pa.
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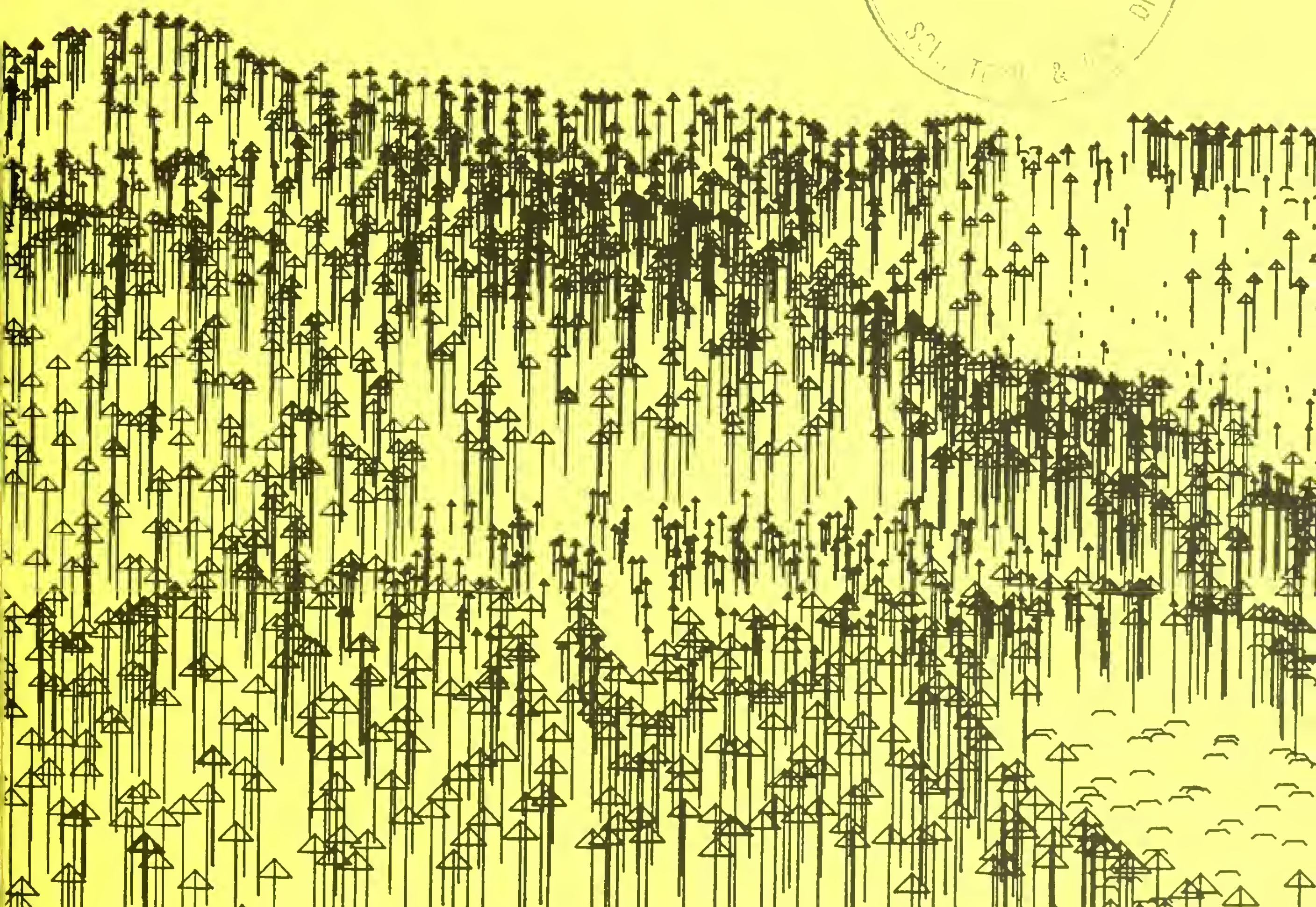
by
Erik Myklestad and J. Alan Wagar

PREVIEW: Computer Assistance for Visual Management of Forested Landscapes



USDA FOREST SERVICE RESEARCH PAPER NE-355
1976

FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
NORTHEASTERN FOREST EXPERIMENT STATION
6816 MARKET STREET, UPPER DARBY PA. 19082

THE AUTHORS

At the time this work was accomplished, Erik Myklestad and J. Alan Wagar were, respectively, research technician and project leader of the Environmental Interpretation Research Project formerly maintained by the USDA Forest Service in cooperation with the College of Forest Resources, University of Washington, Seattle. Wagar is currently leader of the Recreation Research Project maintained by the Forest Service in cooperation with the State University of New York College of Environmental Science and Forestry, Syracuse.

ABSTRACT

The PREVIEW computer program facilitates visual management of forested landscapes by generating perspective drawings that show proposed timber harvesting and regrowth throughout a rotation. Drawings show how changes would appear from selected viewing points and show landscapes as either a grid of distorted squares or by symbols representing trees, clearings, water, rock, etc. PREVIEW can also show roads and other linear features.

PREVIEW requires digitized data for uniformly spaced points in a grid of up to 100 columns and 80 rows. For distorted square drawings, only elevations are needed. For drawings with symbols, data must also include vegetation or surface type codes and, when appropriate, tree heights. At a spacing of 100 feet between adjacent points, the maximum (100 x 80) grid covers approximately 2.9 square miles.

In addition to the cost of preparing data, computer and plotter costs are incurred. These depend on the computer and plotter used, the size of the grid, the number of points visible from the viewing point, and the density of symbols used. Computer (CDC 6400) and plotter (Calcomp 936) costs were approximately $16 for a drawing that plotted vegetation and ground cover symbols for approximately 2,800 visible points from a data grid of 7,200 points embracing 1,653 acres.

PREVIEW is controlled by a series of instruction cards that specify data entries, viewing point(s), angle(s) of view, drawing center point(s), scale of drawing(s), rates of tree growth, normal and shelterwood tree densities, representation as distorted-square or vegetation and surface-type symbols, and year(s) after beginning of rotation.

KEYWORDS: Visual management, Timber management, Land-use planning, Landscape management, Scenery, Computer graphics.

PREVIEW: Computer Assistance for Visual Management of Forested Landscapes

Introduction

BY SHOWING the visual effects of proposed timber harvesting, regrowth, and other landscape changes, computer-generated drawings of groundform and vegetation can greatly assist in the visual management of forested landscapes *(Kojima and Wagar 1972)*. To realize this potential, the PREVIEW computer program was created. In PREVIEW, the earlier groundform and vegetation programs developed by Kojima were combined and rewritten to reduce costs and increase capacity and flexibility. This paper discusses the characteristics, use, costs, and availability of the PREVIEW program.

What PREVIEW Does

PREVIEW lets managers of visual resources convert mapped proposals into perspective drawings that show how proposed landscape changes would appear from selected viewing points. It can represent landscapes by a grid of distorted squares, by vegetation and other ground-cover symbols, or both (compare figs. 1, 2, and 3). It can also plot perspective views of road systems, power lines, boundaries, and other linear features (fig. 3).

In addition to showing landscapes at a single moment, PREVIEW has been designed to handle a series of timber harvesting entries and the regrowth occuring between them. This permits analysis of the visual effects to be expected from alternative timber harvesting schemes throughout an entire rotation (figs. 4 and 5). If this is not done, shaped settings that give good visual results for the first entry may leave awkward visual problems for the second or third entries.

The drawings created by PREVIEW are design aids that must be interpreted in conjunction with maps, photographs, field observations, or other sources of information. Users should understand, for example, that because of the relatively sparse distribution of tree symbols on vegetation drawings, proposed changes may appear less harsh on such drawings than on the ground (fig. 6). In some cases, sketching of additional detail, such as the solid wall of stems surrounding a clearcut, may clarify the visual effects of a proposed change.

TEXT CONTINUES ON PAGE 7.

Figure 1.—Looking west toward Boulder Creek and Boulder sale area from a point 7 miles west-northwest of the summit of Mount Adams, Mount Adams Ranger District, Gifford Pinchot National Forest, Oregon.

Figure 2.—Distorted-square representation of view toward Boulder Creek, Gifford Pinchot National Forest, as drawn by PREVIEW with 100-foot spacing between elevation data points. Original drawing is 27 inches long.

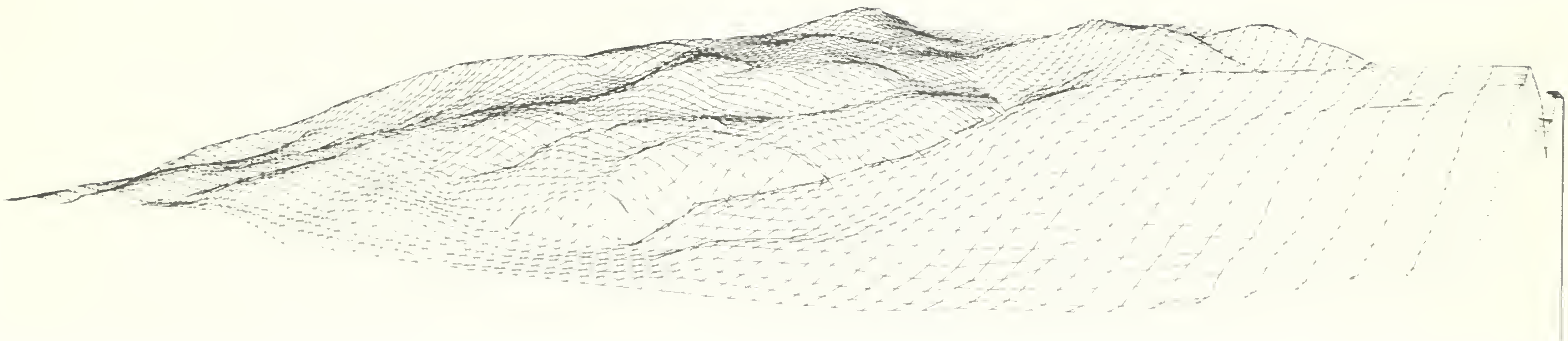


Figure 3.—Vegetation and surface-type representation of view toward Boulder Creek, Gifford Pinchot National Forest, as drawn by PREVIEW. Scale is 100 feet between data points. Road system was drawn by PREVIEW as a separate overlay but has been superimposed here. The symbols that are convex upward represent lava flows.

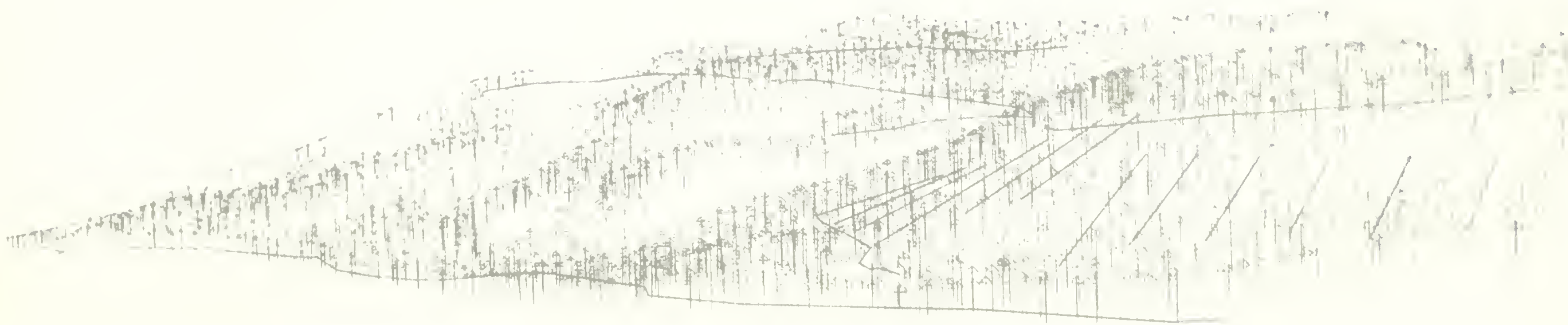


Figure 4.—Preliminary sale layout designed for minimal visual degradation by landscape architect Ronald Tuttle and personnel of the Mount Adams District, Gifford Pinchot National Forest. *Block A:* Eight shelterwood entries and two clearcut entries, all at 20-year intervals. Visual objective is to maintain a timbered texture while increasing textural diversity during a 160-year conversion period. *Block B:* Five clearcut entries at 38-year intervals. Visual objective is to use small clearcuts to repeat the natural openings created by lava-flows.

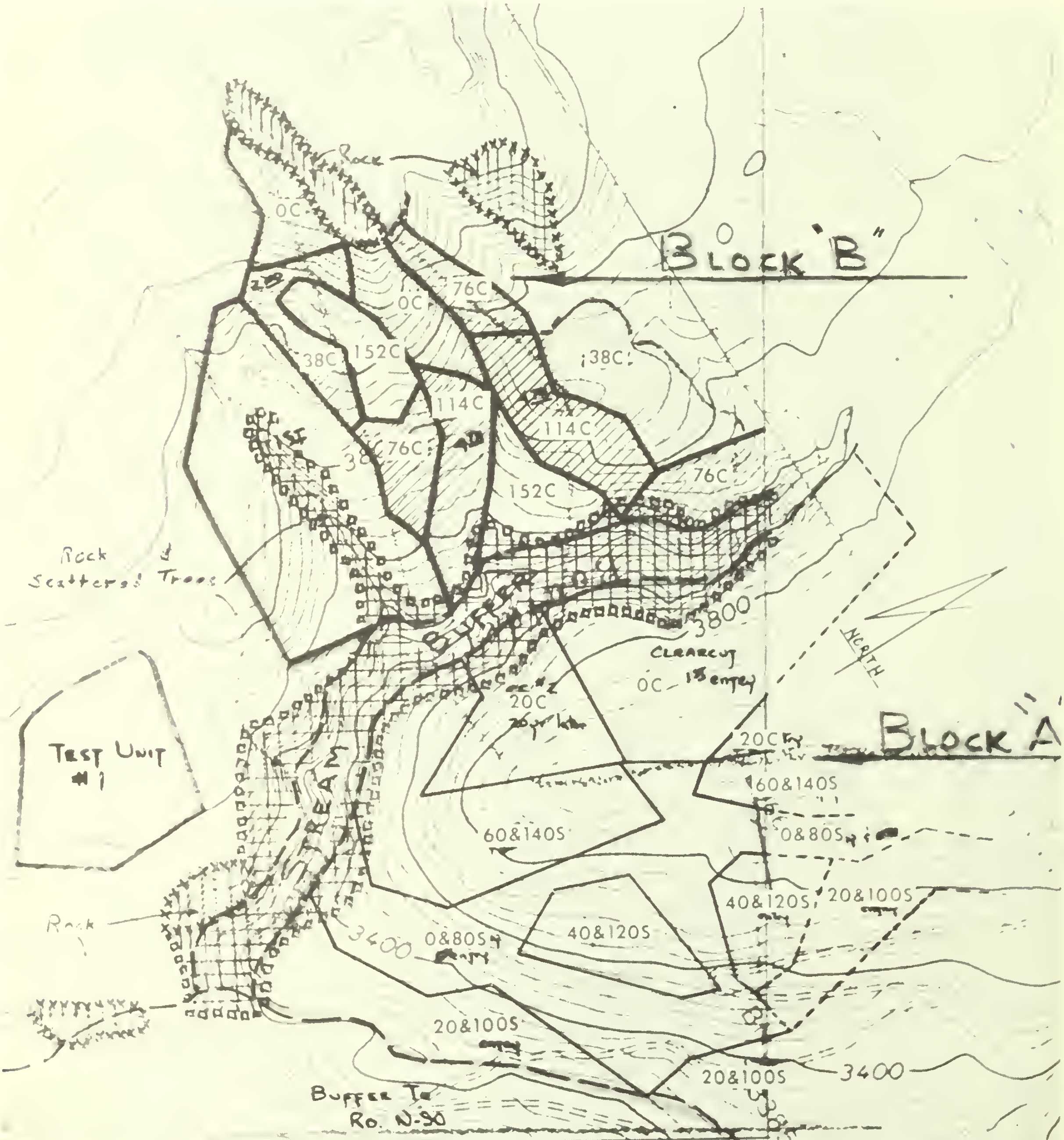
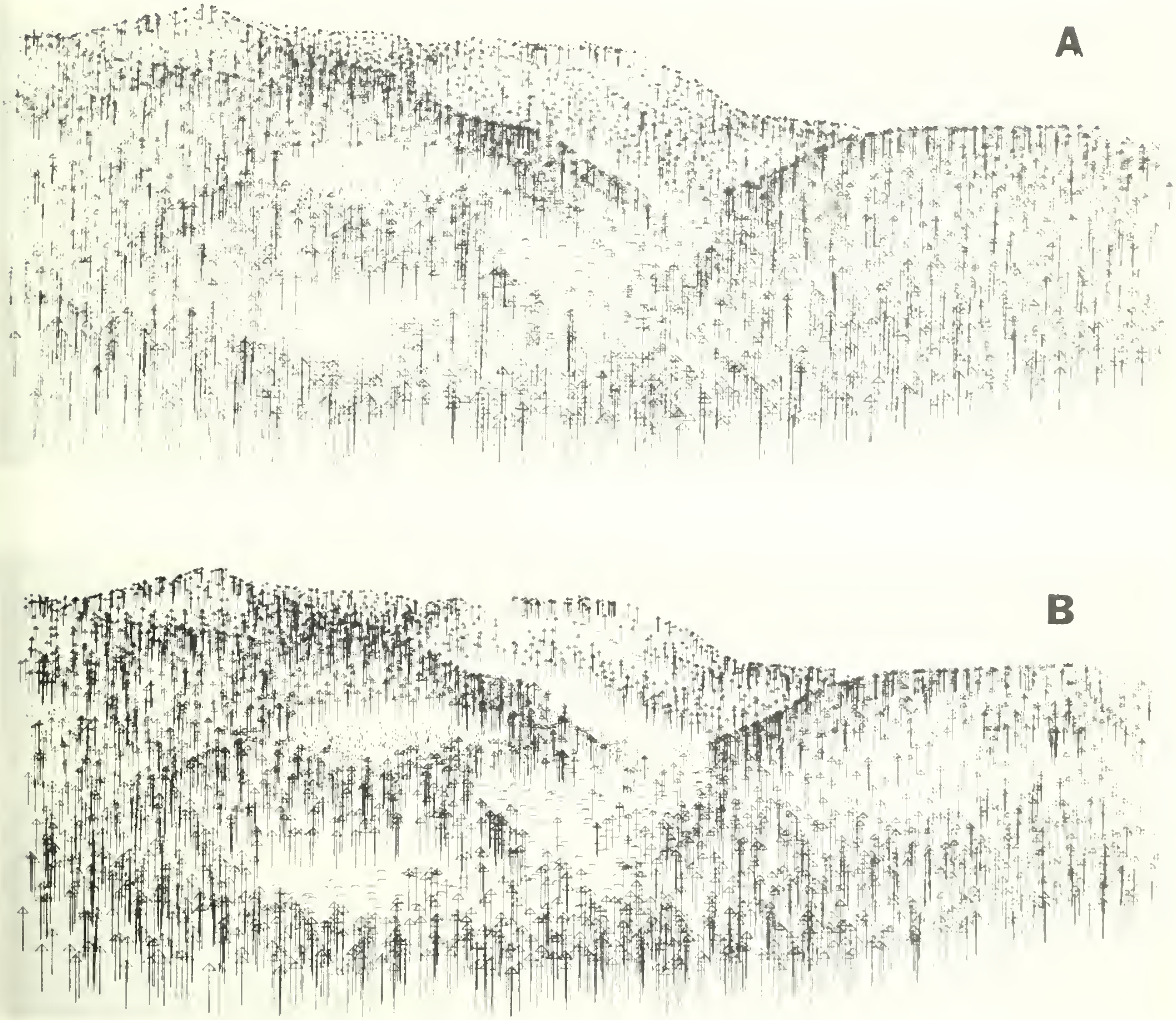


Figure 5.—Computer-generated preview of 152 years of timber harvesting designed for minimal visual degradation, Boulder sale area, Mount Adams District, Gifford Pinchot National Forest. *A*. Year 1 (showing test unit 1 but no other cutting). *B*. Year 1 (1 year after initial clearcut and shelterwood entries). *C*. Year 39 (1 year after second clearcut in Block B and 19 years after second shelterwood entry). *D*. Year 115 (1 year after fourth clearcut in Block B and 15 years after sixth shelterwood entry). *E*. Year 153 (1 year after fifth clearcut in Block B and 13 years after eighth shelterwood entry). Scale is 100 feet between data points.



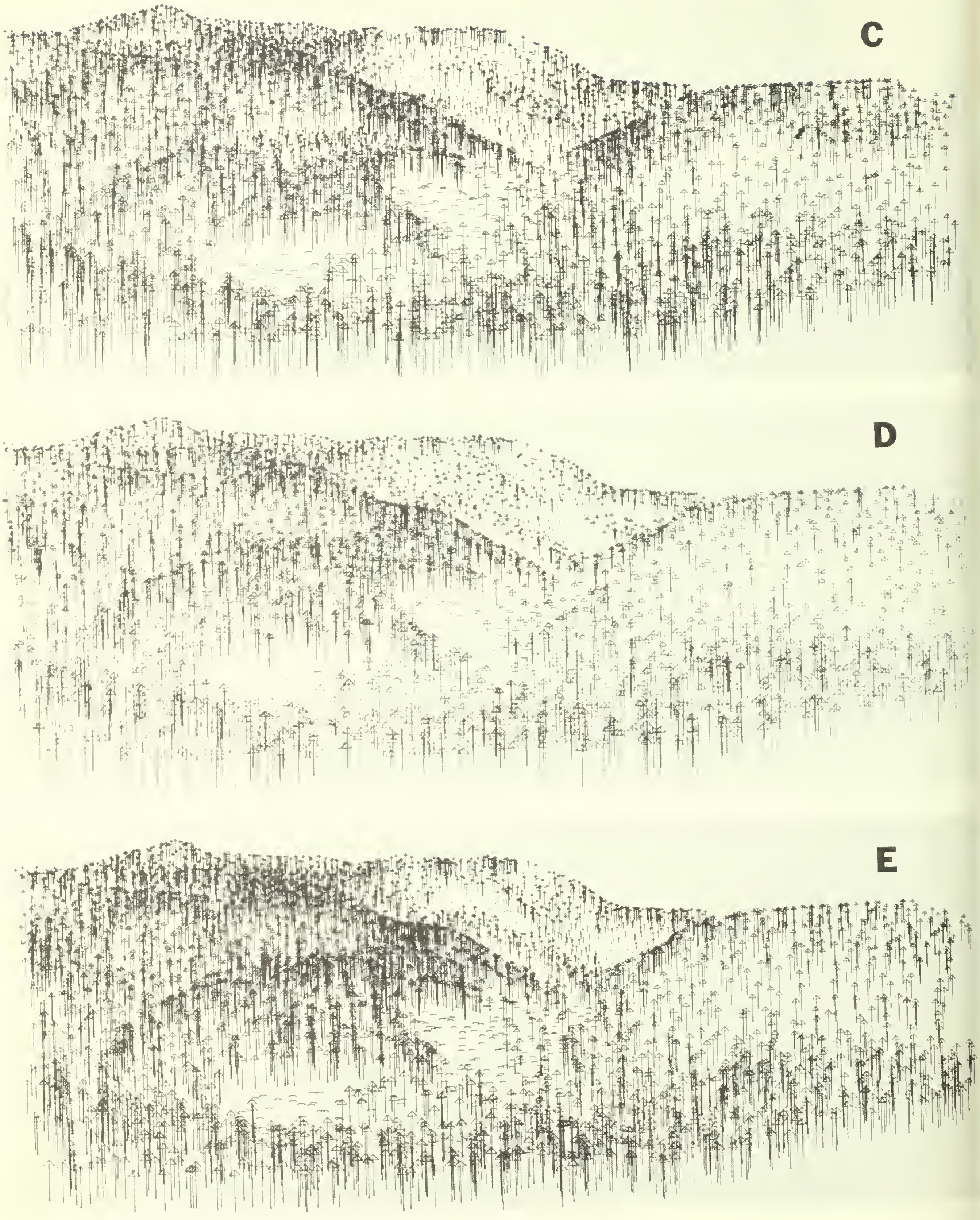

C
D
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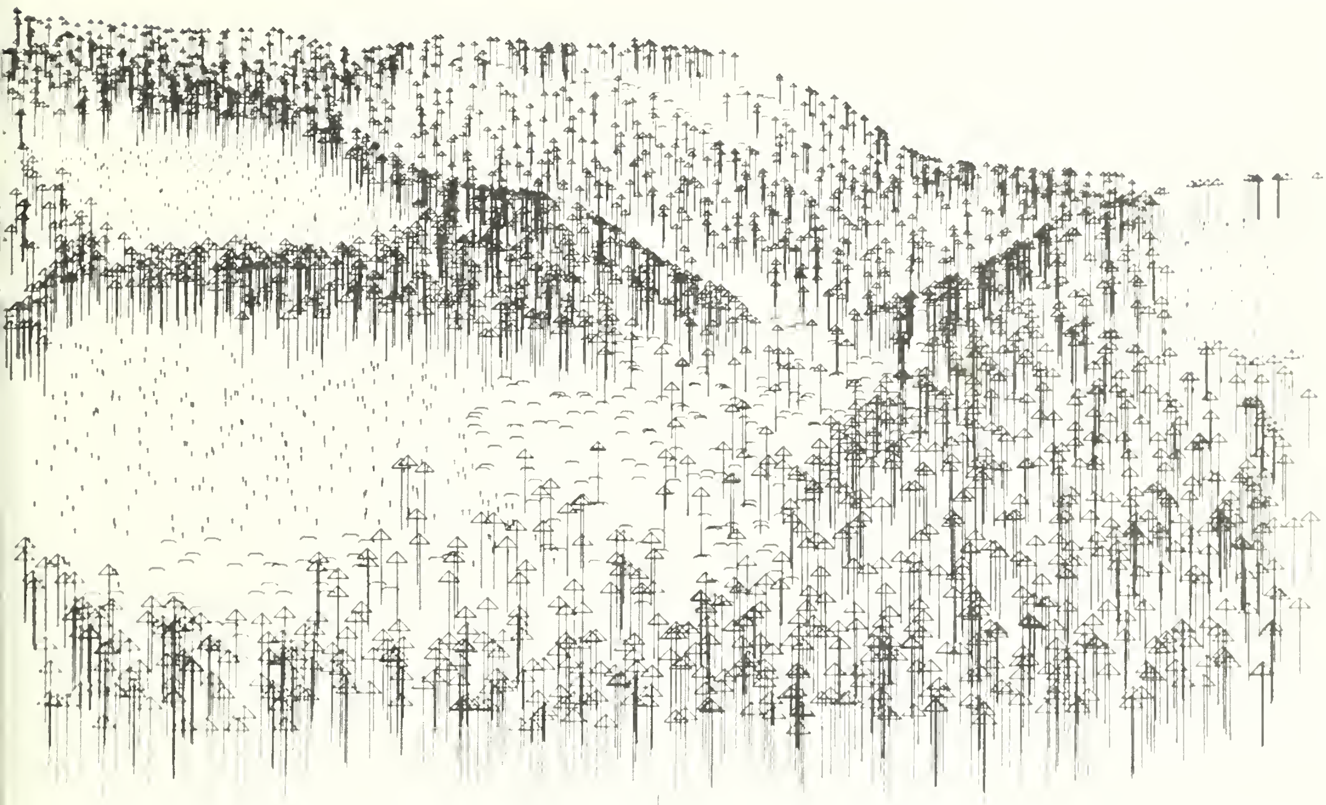
Figure 6.—Hypothetical clearcuts in rectangular blocks. Because PREVIEW represents vegetation by randomly spaced symbols around relatively few grid points, boundaries of clearings may appear less harsh on drawings than on the ground.



Characteristics of PREVIEW

PREVIEW is written in FORTRAN and is currently adapted to a CDC 6400 computer with an off-line Calcomp 936 drum plotter.[1] However, it should be easily adapted to other systems with equivalent capacity.

The program requires digitized data for a grid of up to 8,000 uniformly spaced points (100 columns by 80 rows). For distorted-square drawings, only elevations are needed. For vegetation drawings, data must also include ground-cover types and, in some cases, heights. Currently, a vegetation drawing can include any combination of nine ground surface or cover types (fig. 7). They are:

Code no.	*Surface type or cover*
01	Conifers
02	Hardwoods
03	Fallen timber
04	Water
05	Grass or brush
06	Rock
07	Rock with scattered conifers
08	Rock with scattered hardwoods
09	Coniferous shelterwood

Additional symbols can be developed if needed. Scale is controlled by defining the distance between grid points.

The center point for each drawing must be one of the grid points. However, the viewer's position can be specified anywhere within or outside the grid (fig. 8). Views of any width between 1 and 90 degrees can be plotted.

Drawings are normally plotted as if pro-

[1] PREVIEW has been adapted recently to an IBM 370 computer. Commercial names are used only for identification; their use implies no endorsement by the Department of Agriculture or the Forest Service.

Figure 7.—Ground surface or cover symbols currently used by PREVIEW program. From left to right and top to bottom, symbols are conifers, hardwoods, and felled stems; water surface, grass or brush, and rock outcrop; and rock with scattered conifers, rock with scattered hardwoods, and coniferous shelterwood.

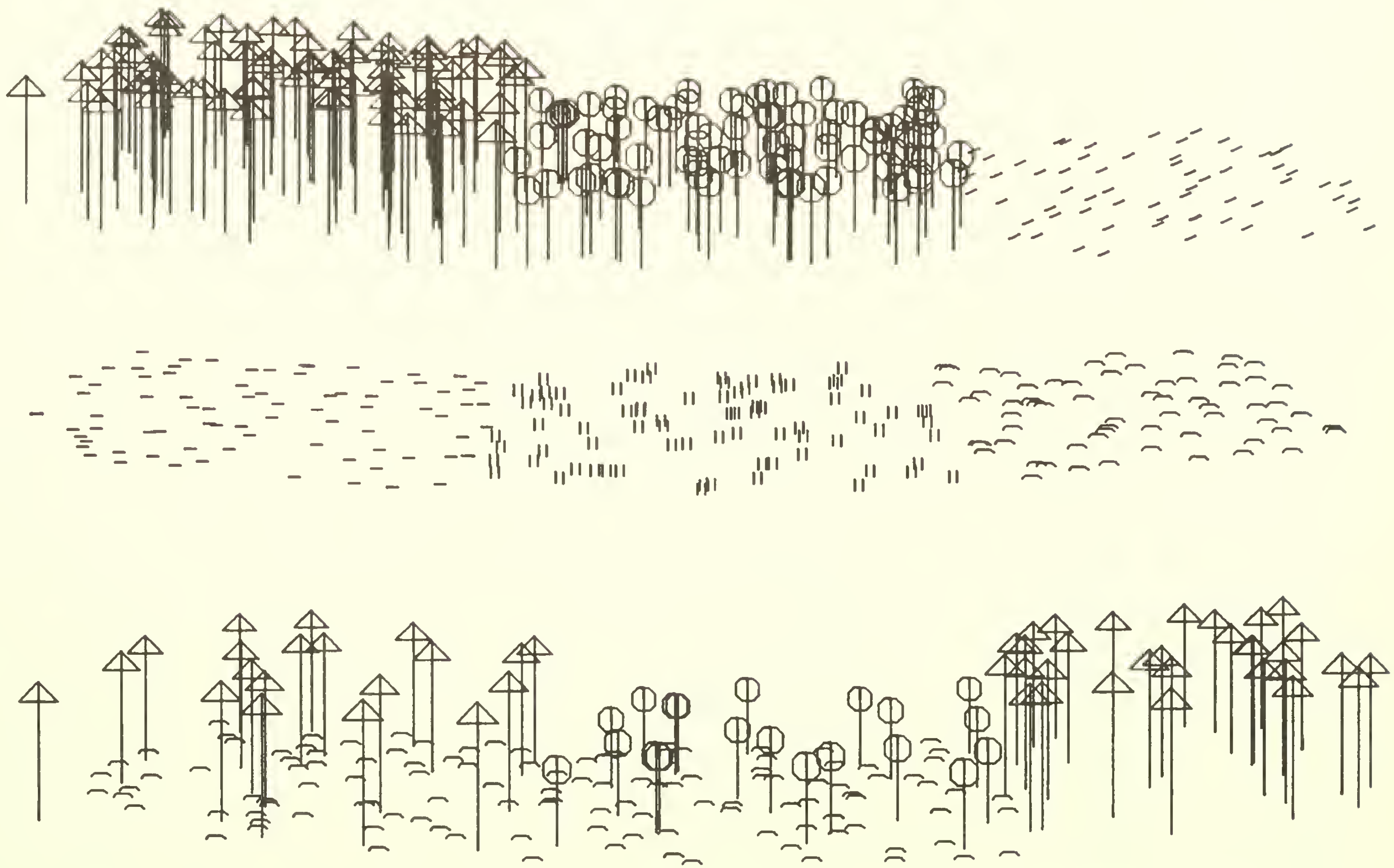
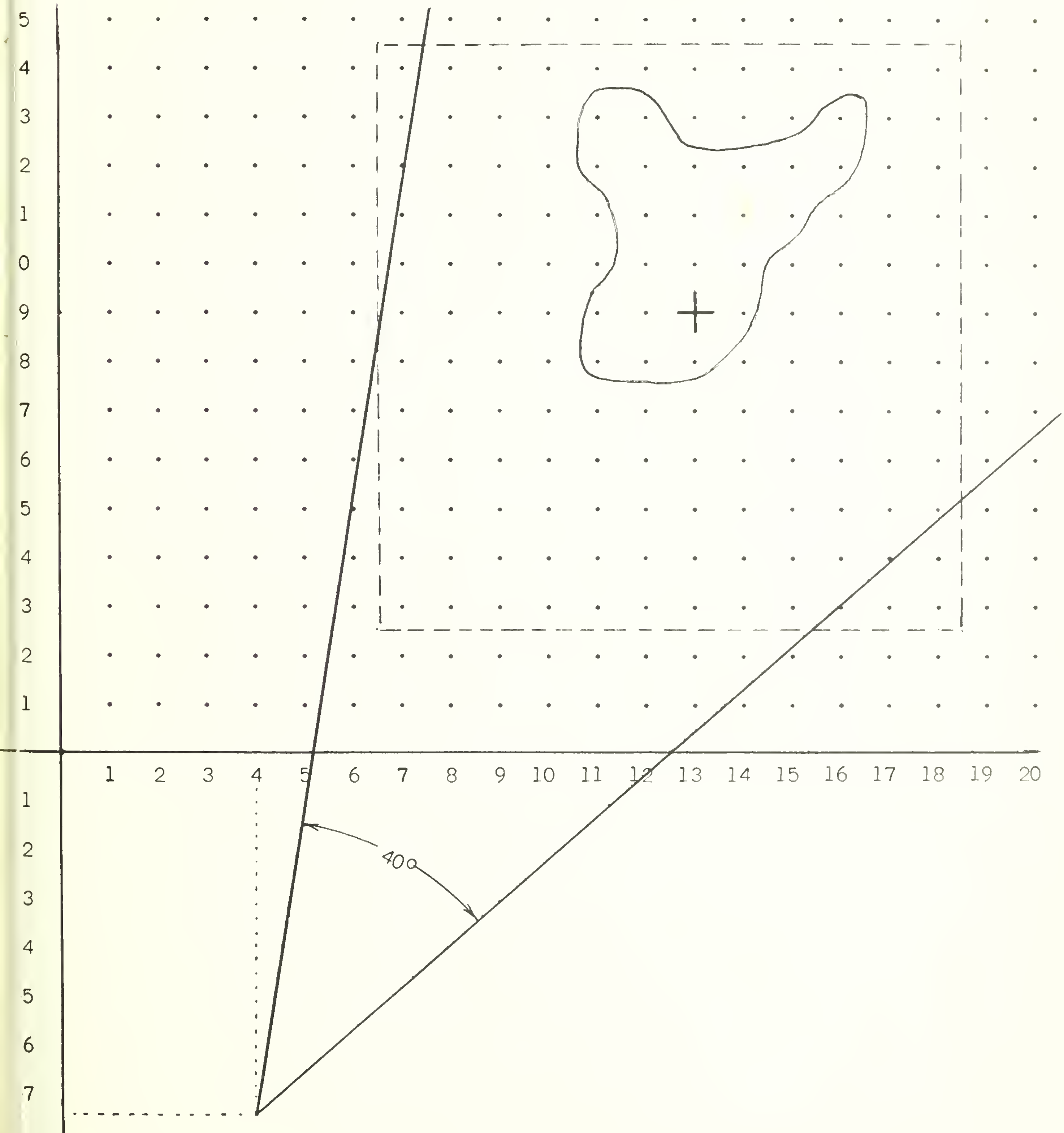


Figure 8.—Grid showing 40-degree angle of view from standpoint (4,-7.5) toward centerpoint (13,9). Data can be entered or plotted for any rectangular portion of the grid—such as the area bounded by dashed lines. Data for freeform areas can be entered by row segments. For the freeform area shown, data would be entered for row 13, x=11-12; row 13, x=16-16; row 12, x=11-16; . . . row 8, x=11-13.



jected on a flat surface 18 inches from the eye of the viewer. However, options are provided to enlarge or reduce either the size of an entire drawing or its vertical dimension.

Symbols on the vegetation drawings are placed around each grid point that, in the absence of vegetation, would be visible from the viewing point. Tree symbols are drawn to correct perspective scale. This is determined by the tree height first defined for each grid point, subsequent height growth, and the distance between the grid point and the viewing point. The density of symbols (i.e., the maximum number for any grid point) is controlled by the user of PREVIEW. Also, the number of symbols around each point decreases with distance from the viewing point, substantially reducing plotting time.

To permit modification and examination of small areas, flexibility has been built into both data entry and plotting (fig. 8). Data can be entered or plotted for any rectangular portion of the 100- by 80-point grid. This avoids handling the entire grid when examining alternatives that involve only part of it. To create irregular shapes, data can also be entered by rows or segments of rows.

Users control the PREVIEW program with a series of instruction cards. These specify:

1. Grid dimensions (number of columns and rows), grid scale (distance between grid points), maximum tree height, and age at which this height is reached. This height and age permit approximate height growth to be plotted for any period specified.

2. Pattern of data entry (i.e., rectangular blocks or segments of individual rows), "common" tree heights and elevations (used to avoid an entry for every grid point for such situations as even-aged stands and large water surfaces), and years after time zero. (The initial data entry is specified as time zero; subsequent data entries are identified by the number of years after it.) Data for uniform ground cover are usually entered in rectangular blocks. Adjustments to these data are normally for the individual row segments that make up the appropriate freeform areas (fig. 8).

3. Viewer position, center point for the perspective drawing(s), and angular width of view.

4. Grid area to be plotted, plotting of distorted squares or vegetation or both, time of plot (years after time zero), and (if appropriate) density of symbols and density of shelterwood. An option is also provided to reuse previous computions when plotting a series of vegetation drawings; this saves substantial amounts of computer time.

5. End of desired computer run. Before this instruction is used, other instructions may be repeated to provide a variety of drawings from as many viewing points as specified.

In addition to the instructions listed above, the following options are provided:

6. List data for grid points in any rectangular area specified.

7. Alter size of drawings.

8. Alter vertical dimension only.

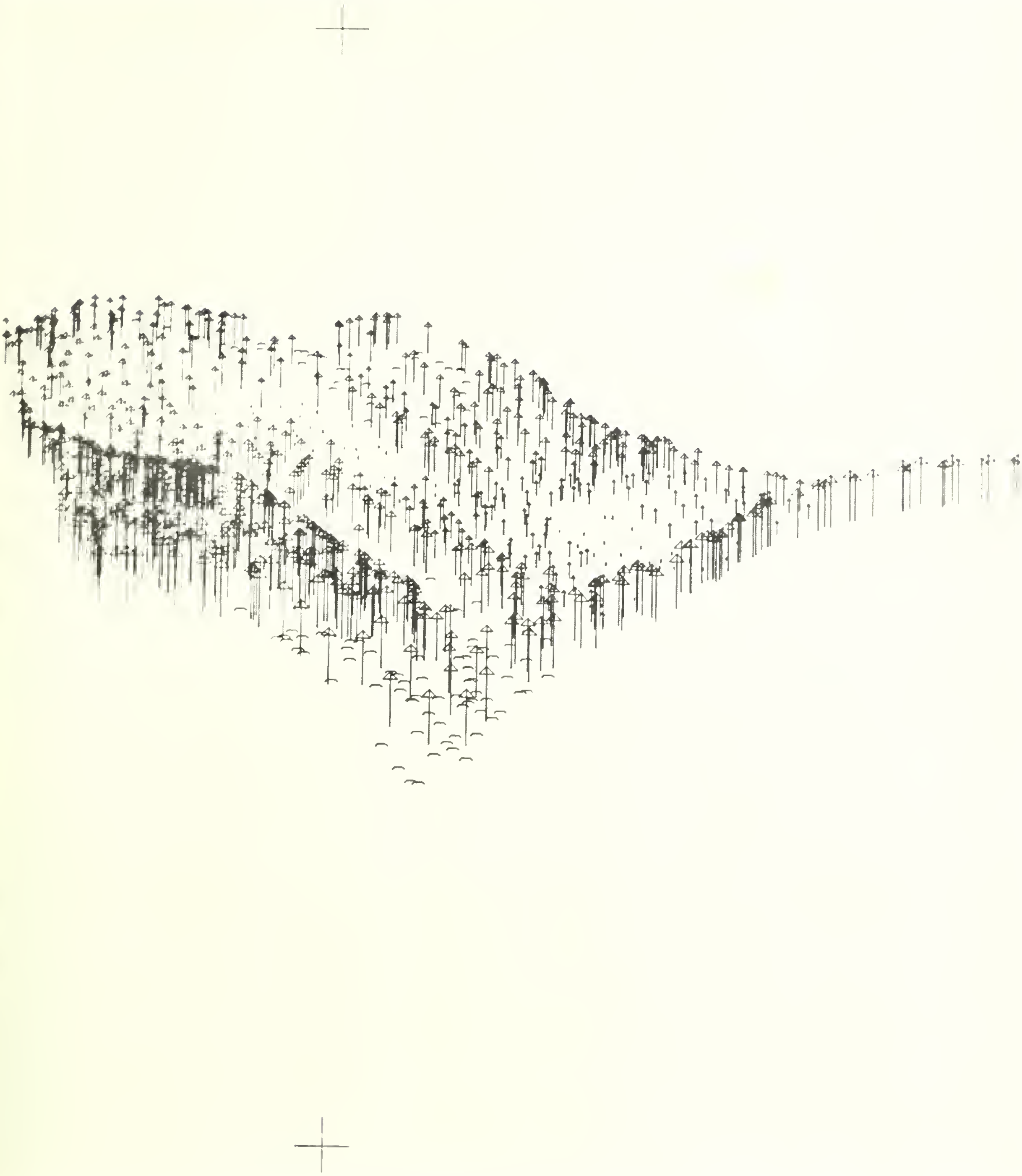
9. Read and plot data for roads or other linear features (up to a maximum of 300 points).

Data Requirements, Costs, and Availability

Digitizing elevation data can be a substantial cost in the application of PREVIEW, and improved procedures may be needed. From a topographic map enlarged to a scale of 400 feet to the inch, elevations were interpolated at 290 points per hour—approximately 25 man-hours for a 7,200-point grid. Keypunching of elevation and ground-cover data for the same grid took approximately 6 hours.

Other "data acquisition" options need to be explored. Digitized elevation data for the entire country are available from the Defense Mapping Agency at a scale of approximately 208 feet between grid points (one point per acre). This is approximately one-fourth the grid density illustrated here, but may be adequate for many situations. Equipment is

Figure 9.—Partial view for year 153 showing only the area affected by proposed clearcuts. Crosses at top and bottom of each view facilitate correct register of overlays on a larger drawing. Scale is 100 feet between data points.



available to digitize elevation data directly from stereo photo pairs, but we did not explore this. Nor did we explore commercial programs for digitizing elevation data. One available program permits tracing of contour lines on digitizer equipment and provides one elevation point per acre *(Travis, Elsner, and Kourtz 1973)*.

If not already available, an efficient program might be developed to interpolate elevation points within rather uniform surfaces bounded, in many cases, by widely separated contour lines. This would avoid the need to trace every contour on digitizing equipment.

Once digitized data are available, the user of PREVIEW incurs computer costs and plotter costs, both of which vary. Computer costs depend on the computer used, the size of the grid, the width of view, and the number of points visible. Because five times as many symbols are plotted for points next to the viewer as for distant points, plotter costs depend greatly on the number of visible points close to the viewer. For the computer-plotter combination mentioned, costs for figures 2 and 3 were approximately \$12 and \$16, respectively. Each of these figures includes approximately 2,800 visible points (640 visible acres) from a data grid of 7,200 points embracing 1,653 acres. The cost for figure 2 includes \$5 for computer time (at \$0.03333 per "resource unit") and \$7 for plotter time (at \$24 per hour). Computer and plotter costs for figure 3 were approximately \$7 and \$9, respectively.

When a view is being modified, as in figure 5, costs can be substantially reduced by plotting only the portion that changes (fig. 9). Combined computer and plotter costs were \$4.32 per view for a series of five partial views. With both visible and hidden points counted, each view included 1,333 grid points (306 acres).

Listings and instructions for using PREVIEW are available from:

Recreation Research Project
Forest Service, USDA
c/o State University of New York
College of Environmental Science & Forestry
Syracuse, New York 13201

Literature Cited

Kojima, Michimasa, and J. Alan Wagar.
1972. COMPUTER GENERATED DRAWINGS OF GROUND FORM AND VEGETATION. J. For. 70(5): 282-285.

Travis, Michael, Gary Elsner, and Peter Kourtz.
1973. A COMPUTER SOFTWARE PACKAGE TO CONVERT DIGITIZED GEOGRAPHIC BOUNDARY AND CONTOUR DATA TO A UNIFORM GRID STRUCTURE. Forest Fire Res. Inst., Ottawa, Ontario, Inform. Rep. FF-X-44, Nov. 1973.

Acknowledgments

The authors acknowledge the work of Forest Landscape Architect Ronald Tuttle and the personnel of the Mount Adams District, Gifford Pinchot National Forest, and Regional Landscape Architect Ronald M. Walters, Pacific Northwest Region, U.S. Forest Service. They located a suitable area, designed harvest patterns and roads, and suggested changes to make PREVIEW more applicable to on-the-ground design problems.

Myklestad, Erik, and J. Alan Wagar
1976. **PREVIEW: Computer assistance for visual management of forested landscapes.** USDA For. Serv. Northeast. For. Exp. Stn., Upper Darby, Pa.
12 p., illus. (USDA For. Serv. Res. Pap. NE-355)

Describes the characteristics, use, costs, and availability of a computer program that generates perspective drawings of landscapes. From any selected point, these drawings can show the visual effects of proposed timber harvesting and regrowth throughout a rotation.

U681.3 : U712.3 : 907 : 61 : 911

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Describes the characteristics, use, costs, and availability of a computer program that generates perspective drawings of landscapes. From any selected point, these drawings can show the visual effects of proposed timber harvesting and regrowth throughout a rotation.

Headquarters of the Northeastern Forest Experiment Station are in Upper Darby, Pa. Field laboratories and research units are maintained at:

- Amherst, Massachusetts, in cooperation with the University of Massachusetts.
- Beltsville, Maryland.
- Berea, Kentucky, in cooperation with Berea College.
- Burlington, Vermont, in cooperation with the University of Vermont.
- Delaware, Ohio.
- Durham, New Hampshire, in cooperation with the University of New Hampshire.
- Hamden, Connecticut, in cooperation with Yale University.
- Kingston, Pennsylvania.
- Morgantown, West Virginia, in cooperation with West Virginia University, Morgantown.
- Orono, Maine, in cooperation with the University of Maine, Orono.
- Parsons, West Virginia.
- Pennington, New Jersey.
- Princeton, West Virginia.
- Syracuse, New York, in cooperation with the State University of New York College of Environmental Sciences and Forestry at Syracuse University, Syracuse.
- Warren, Pennsylvania.

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Acorn Weevils, Rodents, and Deer All Contribute to Oak-Regeneration Difficulties in Pennsylvania

by David A. Marquis
Philip L. Eckert
Benjamin A. Roach

USDA FOREST SERVICE RESEARCH PAPER NE-356
1976

NORTHEASTERN FOREST EXPERIMENT STATION
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
6816 MARKET STREET, UPPER DARBY PA. 19082

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MANUSCRIPT RECEIVED FOR PUBLICATION 16 AUGUST 1976.

Acorn Weevils, Rodents, and Deer All Contribute to Oak-Regeneration Difficulties in Pennsylvania

ABSTRACT

In parts of Pennsylvania, oak regeneration after harvest cutting or natural disturbances has been very poor. Studies on the Tuscarora State Forest suggest that the primary cause of natural regeneration failure may be a lack of viable acorns; on some sites acorn insects and rodents destroy nearly all acorns, even in good seed years. Artificial regeneration is not without difficulties either: rodents were able to reach direct-seeded acorns even through plastic protectors; and planted seedlings have been severely damaged by deer browsing.

KEYWORDS: Oak trees, regeneration, damage by insects, damage by rodents; damage by deer.

OAK REGENERATION after cutting comes mainly from advance seedlings, which are usually present in adequate numbers beneath mature stands over much of the oak range *(Sander and Clark 1971)*. But in parts of Pennsylvania, oak advance seedlings are extremely scarce, and regeneration after harvest cutting or natural disturbances has been very poor. The problem has assumed major significance during the past few years because of severe defoliation by the gypsy moth, oak leaf roller, and other insects, which has left hundreds of thousands of acres with dead overstory trees and little or no regeneration to replace them *(Nichols 1973)*.

Attempts to stimulate the development of additional advance regeneration through shelterwood cuttings have been unsuccessful in these problem areas; so have attempts to plant oak seedlings. Browsing by the unusually large deer herd in Pennsylvania, inadequate acorn crops, destruction of acorns by insects, and consumption of acorns by rodents have all been suggested as possible causes of the regeneration difficulties.

To determine the relative importance of each of these factors, studies were made in central Pennsylvania by the Northeastern Forest Experiment Station and the Pennsylvania Bureau of Forestry in 1973-75. These studies have shown that acorn insects, rodents, and deer all have significant effects, and that, in attempts to secure oak regeneration in this region by either natural or artificial means, all three factors will have to be considered.

Seed Production Experiment

Inadequate seed production is one possible cause of regeneration failure, so an experiment was set up to compare the amount of seed produced in a stand that lacked advance reproduction with the seed produced in a similar stand that had adequate oak advance reproduction.

Two study sites were selected in the Licking Creek Valley on the Tuscarora State Forest near Mifflintown, Pa. The two sites were 1.6 miles apart; both supported stands of mixed oaks, hickory, and red maple (table 1). Area A is an area of 10 to 20 acres that contained abundant oak reproduction (5,250 oak seedlings per acre). Area B is typical of many oak stands in the vicinity in that it contained very little oak advance reproduction (tallies showed only 96 oak seedlings per acre). Although overstory stocking was somewhat lower in the

Table 1.—Overstory and understory on study areas A and B

Area	White oak	Chestnut oak	Red oak	Scarlet oak	Black oak	Hickory	Red maple	Other	Total
				OVERSTORY BASAL AREA[1]					
				Square feet per acre					
Area A	21	2	10	31	8	2	9	3	86
Area B	10	12	10	2	13	31	14	4	96
				UNDERSTORY SEEDLINGS[2]					
				Thousands per acre					
Area A	1.1	0.6	3.3	0.0	0.3	0.2	14.7	2.7	22.7
Area B	(*)	0.0	(*)	0.0	(*)	0.4	6.2	3.9	10.5

[1] Includes all trees 0.5 inch dbh and larger. Tree of average basal area: Area A = 7.6 inches; Area B = 6.2 inches.
[2] Includes all stems less than 0.5 inch dbh.
* Less than 0.05 thousand per acre.

stand with abundant advance reproduction, this did not seem to be the primary reason for presence of advance seedlings; partial cuttings in adjacent stands had failed to stimulate formation of advance regeneration.

Within each of the two areas, six dominant northern red oak trees were selected for seed trapping. All selected trees seemed to have good acorn crops when examined during early August 1973, a year of heavy red oak seed crops in much of Pennsylvania. A large trap was erected beneath the crown of each selected tree. Each trap was 12 to 14 feet wide and 20 to 35 feet long, constructed of sheet plastic supported over galvanized wire supports and arranged with one end and both sides elevated so that acorns falling onto the plastic would roll to the lower end where they fell into a rodent-proof hardware-cloth basket. The total trap areas were equal in the two stands.

Collections of acorns were made weekly throughout the late summer and fall of 1973. Acorns were counted, and samples from each trap and each collection period were tested for soundness and germination. Acorns were removed from their seedcoats to judge soundness. They were considered sound if the embryo seemed intact, even though portions of the meat may have been destroyed by insects. The excised seeds were germinated on moist Kimpack at room temperature for 30 days for estimating viability.

Severe windstorms during the second week in October shattered many of the seed traps, and some of the total acorn crop was lost. The traps were repaired, and additional collections were made in November; but acorns that fell during the last half of October were lost and are not included in the data that follow. In spite of the fact that the data do not represent the entire 1973 crop, the relationships observed are revealing.

There were important differences in seed production between the two study areas. Area A, which had abundant oak advance reproduction, produced more seed than area B (2,815 versus 1,752), and a larger proportion of it was sound (54 percent versus 28 percent). Germination tests showed that germination rates were three times higher for acorns from area A than for those from area B. Thus the number of viable seed trapped on the area with good advance reproduction was about five times higher than that from the area with poor advance reproduction (table 2).

Table 2.—Summary of 1973 collections from seed-trap baskets

Item		Area A	Area B
Total seed collected .	No.	2,815	1,752
Total sound[1]	No.	1,533	498
	Percent	54	28
Total germination . . .	No.	1,027	206
	Percent	36	12

[1] Calculated from the samples on which percent soundness and percent germination were determined.

The damaged and unsound seed found in all acorn collections were the result of feeding by one of several insects *(Nichols 1975)*. The most important of these seemed to be an acorn weevil belonging to the genus *Curculio* and a moth, *Melissopus latiferreanus* (Wlsm.). The adults of both these insects deposit their eggs in the developing acorn, and the resulting larvae consume the nutmeat, usually before the acorn has fallen to the ground. Some of the nuts infested by *Curculio* are not completely eaten and may still be capable of germination. *Curculio* larvae usually emerge from the nut after it falls to the ground, leaving a circular hole in the shell. *Melissopus* larvae usually consume the nutmeat completely and may emerge while the acorn is still on the tree, then infest adjacent nuts before completing their growth. *Melissopus* pupates over winter in the leaves on the forest floor, while *Curculio* overwinters deeper in the soil *(Gibson 1969 and 1972)*.

There seems to be great variation from place to place, even within a relatively small area, in the prevalence of these insects. Additional acorns were collected from the ground in three stands on the Tuscarora State Forest and two stands on the Allegheny National Forest in Warren County, Pennsylvania. In some stands, virtually all acorns were destroyed; in others, very few were affected. Although the number of stands sampled is not adequate for drawing definite conclusions, it seems that insect damage to acorns may contribute significantly to the oak regeneration problem.

Seed Predation and Germination Experiment

The objective of this experiment was to compare the germination of acorns sown under a forest canopy in a stand containing oak advance reproduction with that in a stand lacking oak advance reproduction, and to determine what effect seed consumption by deer or rodents had on seedling establishment under these two stand conditions.

During the fall of 1973, six clusters of three plots each were laid out in each of the two areas previously described for the seed-trapping experiment. Each plot was 3 feet square. Twenty apparently sound undamaged red oak acorns from two seed sources (10 acorns from each source) were sown on each plot by pushing them into the humus until they were ½ to 1 inch below the surface. Laboratory germination tests indicated that viability of the seed sown averaged above 80 percent.

The three plots in each cluster were randomly assigned to one of the following treatments:

1. Protection from both deer and rodents by a ¼-inch-mesh hardware-cloth screen 3 x 3 x 1 foot surrounding the plot on all sides and the top, with the sides buried 4 to 6 inches into the soil.
2. Protected from deer only by a cattle-wire fence approximately 4 feet high and 4 feet in diameter around the plot.
3. Control, unprotected.

Counts of germination and survival were made at monthly intervals throughout the 1974 growing season. They showed that acorn pilferage by rodents was severe in area B, where advance oak reproduction was scarce, but was relatively unimportant in area A, where oak advance reproduction was abundant (table 3). We do not know why rodent pilferage was so much less in area A than in area B.

Table 3.—Total acorn germination in seed predation and germination experiment

[In percent of seed sown]

Area	Control	Protected from deer only	Protected from deer and rodents
Area A	33	28	32
Area B[1]	2	9	53

[1] Differences between treatments were statistically significant in area B, but not in area A.

Direct-Seeding Experiment

Anticipating the possibility that acorn supply may be limiting to oak reproduction, we began a direct-seeding experiment in the fall of 1973 to test the possibilities of sowing acorns in several types of plastic sleeves to protect the acorns from rodent pilferage.

The seeding experiment was laid out in area B (described previously—the stand lacking advance oak reproduction). Eight lines 100 feet long were laid out at random locations in area B, and 40 apparently sound red oak acorns were sown at uniform spacing along each line. Ten acorns at each line were randomly assigned to one of the following four treatments:

1. Plastic protector, ½-inch diameter, 6 inches long.
2. Plastic protector, 1-inch diameter, 6 inches long.
3. Plastic protector, 2-inch diameter, 6 inches long.
4. Control—no protection.

Sowing was accomplished during the first week of November by punching a hole an inch or so deep into the soil, using a soil-sampling tube of appropriate size. The protector was placed in the hole thus created, an acorn was dropped inside the protector, and the plug of soil from the sampling tube was then placed in the protector on top of the acorn so that the acorn was about 1 inch below the surface. A similar procedure was used on the control, except that the protector was omitted. Observations of seed germination and survival were made monthly throughout the 1974 growing season.

Rodent pilferage was extremely high in all four treatments during the late winter and spring months. The plastic tubes offered little or no protection from rodents. Many tubes were pulled out of the ground and the acorn was removed from them. In other cases, the rodents cut their way through the side of the tubes to get at the acorns. Overall germination averaged less than 10 percent, with no statistically significant differences among treatments.

Although the direct-seeding and the plastic protectors both failed, the experiment served to emphasize the extent and impact of rodent pilferage in the study area.

Planting Experiment

As a result of the failure to obtain established seedlings from direct-seeded acorns, it seemed apparent that planting of nursery-grown seedlings offered one way to circumvent acorn depredation. Previous attempts to plant oak seedlings in uncut stands and clearcut openings had not been very successful—presumably because of deer browsing and unfavorable environmental conditions. Therefore an experiment was set up to test planting under three levels of overstory density, using two sizes of nursery stock, both with and without protection from deer browsing.

Two new study areas were selected on the Tuscarora State Forest, one in the Licking Creek Valley and one in the Black Log Valley. Oak advance regeneration was scarce in both areas. Five blocks of three plots each were laid out in the two stands. Each plot was 3 x 3 chains (0.9 acres) and each plot was assigned to one of the following overstory density treatments:

1. Residual stocking 100 percent.
2. Residual stocking 60 percent.
3. Residual stocking 30 percent.

In all cases, stocking levels were based on basal area and average stand diameter, using the stocking charts developed by Roach and Gingrich *(1968)*.

Red oak seedlings were planted in the central 1/10 acre of each plot, in 4 rows of 12 seedlings each. The rows represented subplots and were assigned one of the following four treatments:

1. Large stock, protected against deer browsing by a 4-foot high, 1 foot-diameter chicken-wire fence.
2. Large stock, unprotected.
3. Small stock, protected as in 1 above.
4. Small stock, unprotected.

The small stock was the size normally supplied by the Pennsylvania state nurseries. The small red oak seedlings averaged 0.4 foot in height and 0.10 inch in diameter 2 inches above the root collar. The large stock was obtained from the same source by selection of the largest seedlings available. They averaged 1.3 feet in height and 0.22 inch diameter.

The plots were thinned during April 1975, and seedlings were planted and deer fences erected during the first 3 weeks of May 1975. Tallies of survival, height growth, and numbers of seedlings on which the terminal shoot had been browsed were made once a month during the 1975 growing season.

Several additional years will be required to evaluate the effect of the different residual stocking levels on growth and survival of the planted seedlings. But the impact of deer browsing was clearly apparent after just one season. Most of the unprotected seedlings have already been browsed several times (table 4).

Some of the smaller seedlings, and a few seedlings planted where logs or slash afford some protection, have escaped browsing so far; but it seems apparent that they too will be browsed as soon as they grow a little taller. To date, mortality has been low, but the browsing has been so severe and so frequent that we expect few of the unprotected seedlings to survive for more than a few years.

Growth of many seedlings has been negative: browsing has reduced their height below that at the time of planting. Even a few protected seedlings—whose terminals grew close enough to the chicken-wire mesh to be reached by deer—have been browsed.

Table 4.—Deer browsing on planted seedlings

[In percent browsed]

	Red oak
Fenced:	
Large seedlings	4
Small seedlings	(*)
Both sizes	2
Unfenced:	
Large seedlings	88
Small seedlings	49
Both sizes	69

* Less than 1 percent.

Discussion

The results suggest that the lack of oak advance regeneration in study area B may be due to destruction of seed by acorn insects, plus pilferage of the remaining acorns by rodents. There do not seem to be enough viable acorns surviving the winter to produce new seedlings. No new wild seedlings were observed anywhere in study area B, even though the 1973 acorn crop had been heavy. The seriousness of this situation may be illustrated by the fact that, of the 1,752 acorns trapped in area B, only about 10 could be expected to germinate in the field (498 of the 1,752 acorns trapped were sound, and only 2 percent of the sound unprotected acorns germinated in the field experiment).

The results also suggest that there may be large differences in the amount of insect and rodent depredation in stands located fairly near one another. In study area A, for example, 2,815 acorns were trapped, of which 506 could be expected to germinate in the field—almost 60 times as many as in area B. Of the 2,815 acorns trapped, 1,533 were sound, and 33 percent of the sound unprotected acorns germinated in the field experiment.

That such variations do occur consistently is evidenced by the large differences in the amounts of advance oak regeneration present under these two study stands. Although our studies have been limited to one geographic region in Pennsylvania, the findings of these studies, and observations made in other parts of the problem area, suggest that lack of viable acorns is probably the primary cause of oak advance regeneration failure in Pennsylvania. Because of this, shelterwood cuttings or other cutting methods intended to stimulate natural regeneration are not likely to produce satisfactory results unless some practical methods can be found to control rodent and insect damage to acorns.

Direct-seeding does not seem particularly promising in oak problem areas because of the severe rodent depredations. Unless effective repellents or practical controls are found, planting seems to be the most promising method of regenerating oaks for the immediate future. But even planting does not eliminate all problems. Planted seedlings are severely browsed by deer, and success will be unlikely unless deer populations are reduced or the seedlings are protected from browsing with wire fences, plastic sleeves, or other similar devices.

Thus, oak regeneration problems throughout much of Pennsylvania may be due to the combined action of acorn insects, rodents, and deer, all of which must be taken into account before successful regeneration can be obtained. Much additional research is needed to find practical methods of circumventing these problems.

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Marquis, David A., Philip L. Eckert, and Benjamin A. Roach. 1976. **Acorn weevils, rodents, and deer all contribute to oak-regeneration difficulties in Pennsylvania.** Northeast. For. Exp. Stn., Upper Darby, Pa. 5 p. (USDA For. Serv. Res. Pap. NE-356)

Studies in Pennsylvania suggest that lack of viable acorns is the reason for failure of oaks to regenerate. On some sites insects and rodents destroy nearly all acorns, even in good seed years; rodents destroyed direct-seeded acorns despite plastic protectors; and planted seedlings have been damaged severely by deer browsing.

451 + 453--231--176.1 *Quercus* spp.

Marquis, David A., Philip L. Eckert, and Benjamin A. Roach. 1976. **Acorn weevils, rodents, and deer all contribute to oak-regeneration difficulties in Pennsylvania.** Northeast. For. Exp. Stn., Upper Darby, Pa. 5 p. (USDA For. Serv. Res. Pap. NE-356)

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Determination of HABITAT REQUIREMENTS FOR BIRDS in Suburban Areas

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Determination of HABITAT REQUIREMENTS FOR BIRDS in Suburban Areas

ABSTRACT

Songbird populations can be related to habitat components by a method that allows the simultaneous determination of habitat requirements for a variety of species. Through correlation and multiple-regression analyses, 10 bird species were studied in a suburban habitat, which was stratified according to human density. Variables used to account for bird distribution included aspects of vegetation, human activity, and structures.

KEY WORDS: habitat, birds

CONTENTS

THE FORESTER AND WILDLIFE manager have been traditionally concerned with the production of timber, game, and nongame species in rural areas. But the increasing density of people in cities has brought these professions new responsibilities. Government, concerned citizens, and members of the professions themselves have urged the application of resource management skills to the problems of urban environments.

Until recently, wildlife management in cities dealt mainly with pest control. But a new concern has emerged for the wildlife biologist: to provide wildlife in urban and suburban environments solely for the enjoyment it provides.

Foresters are now looking to trees in cities for more than shade, hardiness, and a minimum of litter. Beyond their visual appeal, trees in urban areas have many amenity values, among them improvement of air and water quality, modification of microclimate, screening of unsightly land uses, and provision of wildlife habitat.

Wildlife exists as a byproduct of vegetation, and thus the manipulation of vegetation for the above purposes affects the diversity and composition of wildlife populations. Wildlife—especially songbirds—adds color, movement, and sound to the landscape, and thus can contribute much to the human habitability of cities. Basic to the management of desired urban wildlife species is our understanding of their habitat requirements. Such knowledge could be used to manipulate vegetation to provide the amenities of wildlife in addition to those of the vegetation alone.

This new concept of the management of wildlife in the city solely for the pleasure it affords probably was first articulated by Bennitt in 1946 when he looked forward "... to the day when we shall hear men discuss the management of songbirds, wildflowers, and the biota of a city." The USDA Forest Service, through the Pinchot Institute for Environmental Forestry Research, is working toward the improvement of the quality of life in our cities through research on the amenity values of forest vegetation and wildlife in urban areas.

THE PROBLEM

The traditional approach to the study of wildlife habitat requirements has been to study each species singly and in elaborate detail. In developing management plans for songbirds in urban and suburban areas, we are faced with the problem of determining habitat requirements for more than 100 species. The cost of the traditional species-by-species approach would have been prohibitive. Therefore, we developed a method that would yield statistically reliable estimates of vegetation and bird density and would enable us to identify the habitat components associated with each species.

As suburban communities are ecologically diverse and scarcely studied for wildlife-habitat analysis, it seemed appropriate to utilize such an area for this study. We made four basic assumptions:

1. Birds are nonrandomly distributed *(Preston and Norris 1947, Woolfenden and Rohwer 1969, Hilden 1965)*.
2. Bird distribution is determined by measurable habitat characteristics *(Hilden 1965, Hooper and Crawford 1969)*.
3. The maximum human-bird interaction in a suburban situation takes place along street and roadsides, and such interaction is desirable *(Dagg 1970)*.
4. Identification of the variables affecting bird distribution and density would be valuable for prescribing changes to attract or discourage birds *(Hooper and Crawford 1969)*.

OBJECTIVES

Our objectives were: to develop a technique for identifying and measuring habitat variables important to the occurrence of songbirds during the breeding season, and to test the technique by identifying the key habitat characteristics of 10 bird species during the breeding season in a suburban habitat.

METHODS

Dependent Variables

The dependent variables were the occurrence of 10 locally common breeding songbird species expressed as birds per acre measured on a census plot at 9 sampling dates. The species studied were:

Robin *(Turdus migratorius)*
Gray catbird *(Dumetella carolinensis)*
Blue jay *(Cyanocitta cristata)*
Northern oriole *(Icterus galbula)*
Song sparrow *(Melospiza melodia)*
Chipping sparrow *(Spizella passerina)*
House wren *(Troglodytes aedon)*
Black-capped chickadee *(Parus atricapillus)*
Brown thrasher *(Toxostoma rufum)*
House sparrow *(Passer domesticus)*

Independent Variables

A 1/2-acre circular plot concentric to the bird-census plot was used to measure most of the independent variables. The independent variables are presented in table 1.

Data Collection

The town of Amherst, Massachusetts, was the study area. It contains approximately 100 miles of streets and roads, which we originally stratified into five types on the basis of the density of housing. Ecological-sociological stratifications were suggested by Hooper and Crawford *(1969)*. The need for stratification based on the extent and nature of human activity was also suggested by Bates *(1962)*. However, we later found that stratification was unnecessary, and we limited our analysis to pooled data from three suburban strata.

Pretesting indicated that, within manpower constraints, data could be collected on 80 plots. These were proportionally allocated to the five original strata, and randomly within strata.

Hooper and Crawford *(1969, p. 202)* stated that " . . . it is important to sample bird(s) . . . when the environment and these variables are

Table 1.—Independent variables used to study the habitat associations of 10 songbird species in suburban Amherst, Massachusetts

Variable	Description and measurement
Deciduous tree volume, 0-5 feet, 6-10 feet . . . 96-100 feet, and total; coniferous volume, 0-5 feet . . . 96-100 feet, and total.	The total and discrete layer volumes of deciduous and coniferous tree crowns on a plot. Individual tree crowns were classified as one of 5 profile shapes and 1 of 3 plan view shapes. Height to crown and total height were measured with an altimeter; crown radii were measured with a steel tape.
Deciduous shrub volume, 0-5 feet, . . . 16-20 feet, and total; coniferous shrub volume 0-5 feet. . . 16-20 feet, and total.	The total and discrete layer volumes of deciduous and coniferous shrubs on a plot. Measurement was made by treating each shrub or cluster as a rectangular prism and estimating the length, width, and height with a range pole graduated in feet.
Area of mowed lawn and herbaceous vegetation.	The area in square feet of mowed lawn and weedy growth on a plot, measured as the sum of the areas of convenient rectangles of each vegetation type.
Volume of structures.	The cubic-foot volume of houses on a plot, measured by treating each house as a rectangle and recording its length, width, and height. Only that percentage of a rectangle falling within the plot was recorded.
Building density.	The sum of the distances from plot center to the nearest 5 buildings, measured on aerial photographs of the study area.
Traffic flow.	Vehicles per hour at peak periods, counted for two 15-minute periods between 0730 and 0830; the values were averaged.
Dogs, cats, children, adults, bird feeders, nest boxes.	The number of each variable per plot was obtained from questionnaires sent to all households within 1/16 mile of plot center. After 2 mailings, nonrespondents were assigned the mean values of data received.
Cultivated fields, fallow fields, woodlots, open water.	The distance, in feet, from plot center to the nearest field or woodlot of at least 1 acre, measured from aerial photographs.
Number of gardens, garden area.	The number of garden plots and the sum of their areas in square feet, within 1/16 mile of plot center. Information obtained by questionnaire.

relatively stable." They suggest ". . . breeding, post-breeding, and winter." We chose for study the breeding season as the most stable, because of territorial behavior.

We made nine counts of birds seen and heard from 15 May to 30 June on each of the 80 plots. Our sampling required six counts in 1971 and three in 1972, a total of 720 counts.

We conducted counts only under the following circumstances: During the first 2-1/2 hours after sunrise when the wind speed was less than Beaufort scale 3, when the temperature was between 30° and 80°F, when the overcast was less than 50 percent, and when there was no rain either during or 1 hour before the count. Such constraints are useful, because weather has been shown to affect the rate of bird singing *(McClure 1939, McGowan 1953)*.

The plot size for birds censused by direct observation was calculated by estimating the distance from plot center (up to a maximum of 200 feet) that a bird could be seen in a horizontal view. Six such measurements were taken. The average distance was used as a radius for computing the area of a circular plot. The plot size was variable, depending on the visibility from the center. The plot size for birds censused by song alone differed among species and was the mean distance that song could be heard *(Petraborg et al. 1953)*.

Before making the census counts, we sent a letter soliciting cooperation from persons whose properties were part of a study plot. During the census, the observer drove to the plot and observed for 1 minute from within the vehicle, then stood at the plot center for 4 minutes recording the number of each of the 10 species that was seen or heard.

The visibility up and down the road was usually greater than the plot radius for birds seen. Birds seen there were counted if they were within 200 feet.

Analysis

The simple correlation (r) between variables was calculated by using the actual values and a limited number of scale transformations. The mathematical slicing of the vegetation produced a series of variables that were not truly independent—the volume in a layer was usually related to the volume in an adjacent layer—although the correlations were not significant in many pairs. Since our purpose was insight into songbird habitat, we retained all layers and interpreted the results by a consideration of the significant simple correlation between bird density and vegetation volumes appearing in adjacent positions; and thus groups of adjacent layers with significant correlation coefficients formed "factors".

Factors and remaining significant variables were placed in a model that essentially ranked them by position of emergence from multiple-regression analysis in decreasing contribution to reduction in the unaccounted for variation (R^2).

The statistical technique we used is given in Fryer *(1966)*. We could have developed purely predictive equations from this technique if the number of plots in a stratum had been sufficient.

RESULTS AND DISCUSSION

We found that the data for birds censused solely by sound were not useful. Some species could be heard at great distances. Since all vegetational variables and many other variables were measured on an 83-foot radius plot, the plot may not have been representative of habitat of distant birds. We concluded that only in a very homogenous habitat could birds be censused by sound alone.

After examining the multiple-regression models, we arbitrarily retained only 10 stepwise variables for each species. In all species the increase in R^2 was negligible beyond that point. We retained all variables if fewer than 10 came out in the stepwise procedure.

Evaluation of Independent Variables

Since our aim was the simultaneous determination of habitat relationships of many bird species, using the same habitat data, we evaluated the variables across all bird species rather than for each species separately. This was done to give guidance as to which variables were important and should be included in future studies and which could be eliminated. Importance of the surviving variables to individual species was made as a separate part of the study.

Bird-Population Indices

Indices of the populations of the bird species (table 2) were produced by converting the nine 5-minute counts to density as follows: birds by

Table 2.—Frequency and density of bird species in suburban Amherst, Massachusetts, in 1971

Bird species	Bird population		
	Percentage of plots on which birds were observed	Density of birds per acre	Confidence interval, as percentage of density
Robin *(Turdus migratorius)*	86.7	3.15	17.6
Gray catbird *(Dumetella carolinensis)*	26.7	.43	48.5
Blue jay *(Cyanocitta cristata)*	13.3	.08	67.5
Northern oriole *(Icterus galbula)*	45.0	.84	32.6
Song sparrow *(Melospiza melodia)*	35.0	.42	38.3
Chipping sparrow *(Spizella passerina)*	6.7	.58	125.3
House wren *(Troglodytes aedon)*	15.0	.17	64.5
Black-capped chickadee *(Parus atricapillus)*	88.3	3.31	27.4
Brown thrasher *(Toxostoma rufrum)*	18.3	.52	67.7
House sparrow *(Passer domesticus)*	61.7	2.21	25.7

species observed per visual plot. Results for the nine counts were averaged.

The mean and 90-percent confidence intervals were calculated for each bird species. Confidence intervals ranged from 17.6 to 125.3 percent and averaged 51.5 percent (table 2). These data can be used in estimating required sample sizes for results to be within desired limits.

Relationships of Bird Density to Habitat

We examined the relationship between density indices and habitat variables by stepwise regression and significant correlation coefficients.

The model for each bird species is based on the significant ($\alpha \geq .1$) stepwise variables. However, statistical and practical significance are not necessarily the same. Any variable that increases the R^2 by less than 3 percent is probably not important from a manager's viewpoint.

ROBIN

Robins were found on 86.7 percent of the plots (table 2) at 3.15 birds per acre. Results of the stepwise multiple-regression analysis are given in table 3.

Coniferous height volume between 6 and 10 feet is the most important variable for robins (table 3). However, coniferous height volumes between 0 and 5 feet, 11 and 15 feet, and 16 and 20 feet were also significantly correlated with the 6- to 10-foot layer, as well as the dependent variable. In the stepwise multiple-regression technique, the independent variable having the highest correlation with the dependent variable is removed first. Thus, when the sum of squares attributable to the 6- to 10-foot layer was removed, the other three layers contributed little to the further reduction in total sum of squares and did not emerge in the model. However, it appears that the 0- to 20-foot layer is an important habitat for robins. This logic was used in pooling other series of layers that by themselves have not shown significant additions to R^2.

We believe that the number of gardens and the distance of the nearest fallow field are related to suitable foraging areas. Deciduous height volume between 11 and 15 feet may represent the combination of layers between 6 and 60 feet, all of which showed significant simple correlations (table 12).

Suitable habitat was frequently associated with coniferous volume in the 5- to 20-foot layer and deciduous overstory (11 to 20 feet most important). This habitat description is compatible with the descriptions of other workers. Kendeigh *(1945)* identified the robin as formerly a forest-edge species, but Howell *(1942)* reported that its requirements were best met in suburban areas with lawns for feeding and trees for cover and nesting. Martin *et al. (1951)* noted the relationship of robins to agricultural areas and suburbs and described a preference for lawns, orchard, and clearings rather than woods.

Hester *(1964)* found that nest success was better when the site was associated with human

Table 3.—Habitat variables associated with the occurrence of breeding robins *(Turdus migratorius)* in Amherst, Massachusetts, in 1971.

Independent variable	Multiple R^2	Change in R^2	Simple r [a]
Coniferous tree volume 6-10 feet	0.213	0.213	0.461**
Number of gardens	.428	.215	.421**
Fallow field	.488	.060	.205*
Deciduous tree volume 11-15 feet.	.522	.035	.345**

[a] $^*p < .05$; $^{**}p < .01$

activity. Conversely, Klimstra and Stieglitz (1967) found success better in rural areas and believed that scarcity of cats was a reason.

GRAY CATBIRD

Gray catbirds were observed on 26.7 percent of the plots (table 2) at a density of 0.43 birds per acre. The model of habitat associations is shown in table 4.

Deciduous height volume, 21 to 25 feet, accounted for 39 percent of R^2. Simple correlation coefficients were significant for deciduous layers between 6 and 45 feet (table 4).

The other variables in the model were all measures of vegetation. Preferred gray catbird habitat included a deciduous shrub layer from 6 to 15 feet with a deciduous overstory at 11 to 35 feet.

Kendeigh *(1945)* described the gray catbird's strong association with shrubs, and identified their habitat as one of mixed shrubs and small trees. Nickell *(1965)* and Martin *et al. (1951)* believed that urban expansion increased the amount of suitable habitat, which they described as relatively indiscriminate dense woody plant associations.

BLUE JAY

Blue jays occurred on 13.3 percent of the plots at low density (0.08 birds per acre). The numbers seen per plot varied greatly (table 2). As a result, the stepwise multiple-regression model was not useful for describing the bird's habitat. Only three correlations were significant: fallow fields, number of gardens, and mowed lawn (table 12).

This species occurs in many habitat types, but was observed on few plots in this study (table 2). Kendeigh *(1945)* described the bird as abundant in both coniferous and deciduous forests. Stewart and Robbins *(1958:217)* defined its habitat as: "Various types of forest, wood margins, and hedgerows." Stone *(1926)* believed the species was becoming tamer and better adapted to man's occupied areas.

Bendire *(1895, in Bent 1946)* described its habitat as mixed woods (especially oak and beech), with a nesting preference for dense coniferous thickets. This species is common in suburbs, but for unknown reasons did not occur on enough study plots to allow a statistical analysis of its habitat.

NORTHERN ORIOLE

Northern orioles were found on 45.0 percent (table 2) of the plots and in moderate densities (0.84 birds per acre). The results of the stepwise multiple-regression analysis of its habitat are shown in table 5.

The habitat of the northern oriole contained deciduous shrub cover with mid-canopy volumes of coniferous and deciduous trees (table 5). The bird seems well adapted to suburban areas; but significant negative correlations with children, dogs, mowed lawn, and building density (table 12) indicated that quieter, older, more established neighborhoods may provide better habitat.

Bagg and Eliot *(1937)* described the northern oriole as a bird of the shade-tree community. Graf *(1966)* found that this bird is best adapted to suburbs with mature vegetation.

Stewart and Robbins *(1958:323-324)* described the bird's breeding habitat as: "Shade trees in residential areas, on farms, and in towns and suburbs; also in open stands of flood-plain forests and most forests on the upland." Kendeigh *(1946)* described the nesting habitat as shrubs and small trees in late stages, which agrees well with our results.

SONG SPARROW

Song sparrows were found on 35.0 percent of the plots (table 2) in moderate densities (0.42 birds per acre). The habitat model is shown in table 6. Only one habitat variable, deciduous height volume at 26 to 30 feet, is important; so we consider the model to be of limited utility for predictive purposes.

Examination of the significant coefficients was more revealing (table 12). Sixteen of 19 significant variables had a negative relationship with the dependent variable. Thus there was more information on what made an area unacceptable than on what made it attractive to song sparrows.

Significant negative correlations with deciduous height volume 11 to 50, 96, to 100, and in total, and with coniferous height volume 11 to 30 feet, indicated that open situations are preferable. Positive correlations with deciduous shrub volume 6 to 10 feet and herbaceous vegetation indicated that a relatively open shrub-herbaceous area as best.

Kendeigh *(1945)* reported that shrubs were an important habitat component. Suthers *(1960)*

Table 4.—Habitat variables associated with the occurrence of breeding gray catbirds *(Dumetella carolinensis)* in Amherst, Massachusetts, in 1971

Independent variable	Multiple R^2	Change in R^2	Simple r [a]
Deciduous tree volume, 21-25 feet	0.391	0.391	0.626**
Deciduous shrub volume, 11-15 feet	.436	.045	.021
Deciduous tree volume, 86-90 feet	.481	.045	-.045
Coniferous tree volume, 21-25 feet	.515	.034	-.096

[a] *$p < .05$; **$p < .01$

Table 5.—Habitat variables associated with the occurrence of breeding northern orioles *(Icterus galbula)* in Amherst, Massachusetts, in 1971

Independent variable	Multiple R^2	Change in R^2	Simple r [a]
Deciduous shrub volume, 0-5 feet	0.277	0.277	0.526**
Coniferous tree volume, 26-30 feet	.445	.169	.446**
Deciduous tree volume, 21-25 feet	.527	.082	.509**
Deciduous shrub volume, 6-10 feet	.578	.051	.281*

[a] *$p < .05$; **$p < .01$

Table 6.—Habitat variables associated with the occurrence of breeding song sparrows *(Melospiza melodia)* in Amherst, Massachusetts, in 1971

Independent variable	Multiple R^2	Change in R^2	Simple r [a]
Deciduous tree volume, 26-30 feet	0.082	0.082	-0.286*
Deciduous shrub volume, 6-10 feet	.188	.106	.199
Open water	.236	.048	.099
Volume of structures	.293	.057	-.191

[a] * $p < .05$; ** $p < .01$

Table 7.—Habitat variables associated with the occurrence of breeding chipping sparrows *(Spizella passerina)* in Amherst, Massachusetts, in 1971

Independent variable	Multiple R^2	Change in R^2	Simple r [a]
Coniferous shrub volume, 11-15 feet	0.388	0.388	0.623**
Cats	.501	.113	.467**
Adults	.579	.078	-.070
Coniferous tree volume, 61-65 feet	.631	.052	-.072

[a] * $p < .05$; ** $p < .01$

described absence of overstory to favor development of dense brush with abundant insects as critical.

CHIPPING SPARROW

Chipping sparrows were found on 6.7 percent of the plots, in moderate densities (0.58 birds per acre), but the number of birds seen varied greatly (table 2).

Coniferous shrub volume at 11 to 15 feet was the most important variable, accountng for 38.8 percent of the variation in chipping sparrow occurrence (table 7). Significant correlation coefficients indicated that this layer was more likely 0 to 15 feet (table 12). Deciduous height volume at 41 to 45 feet and coniferous height volumes at 61 to 65 and 66 to 70 feet might retard the shrub layer, but their correlation coefficients were not significant. The negative relationship with people in Amherst conflicted with Stull's *(1968)* report of a general compatibility with man. Positive correlations with cats and dogs were probably due to the coincidental occurrence of species highly adapted to areas of human habitation, correlations not necessarily implying cause and effect.

The correlations added little insight into chipping sparrow habitat requirements, but the habitat is known to be generally characterized by a coniferous shrub volume at 0 to 15 feet, little overstory, and open grassland or lawn. Bull *(1964)* described the habitat as lawns, short grass fields, and bare ground, with nesting in yards, parks, and settled rural country. Forbush *(1927)* called it the most domestic of sparrows. Stull *(1968)* and Martin *et al. (1951)* found the species most common in dooryards, lawns, and orchards. We expected this species to be quite common, and are not sure why we found so few chipping sparrows.

HOUSE WREN

House wrens were found on 15.0 percent of the plots (table 2) in low densities (0.17 birds per acre).

The model contained only four variables; deciduous shrub volume at 16 to 20 feet explained fully three-quarters of the variability in wrens seen (table 8). Examination of the significant coefficients showed that the entire 0- to 20-foot shrub layer was important. The number of gardens added 5.95 percent to R^2, and open water added 3.13. Deciduous height volume at 51 to 55 feet had minor negative effect (table 12). Deciduous height volume at 6 to 25 feet may also be important.

Habitat requirements thus appear to be a dense deciduous shrub layer (0 to 20 feet) combined with a deciduous tree canopy at 6 to 25 feet.

A large body of literature reports that the bird is adapted to dooryards and is found frequently in areas of dense shrubs *(Bent 1948)*. Stewart and Robbins *(1958:231)* described breeding habitat as: "Various edge habitats, including brushland, wood margins, hedgerows, orchards and residential areas."

BLACK-CAPPED CHICKADEE

The black-capped chickadee was found on 88.3 percent of the plots (table 2) at a density of 3.31 birds per acre. Both the frequency and the density are the highest of the 10 bird species studied. The multiple-regression model contains seven habitat components, which together accounted for 72 percent of the variability in chickadee occurrence (table 9).

Coniferous height volume 21 to 25 feet was most important, and examination of the correlations revealed that the layer 6 to 50 feet was important (table 12). The next emergent variable was deciduous height volume at 31 to 35 feet; coefficient examination expanded the layer to 16 to 55 feet. The other coniferous and deciduous height volumes that emerged were included in the expanded layers described above, and they added 16.25 percent to R^2 (table 9).

Deciduous shrub volume at 6 to 10 feet appeared in the model and contributed 3.33 percent to R^2. The simple correlation coefficients showed that the total deciduous shrub volume was important.

Sturman's *(1968)* results indicated that total canopy volume of trees, bushes, and the middle story, considered jointly, showed the greatest predictive power for chickadee abundance, and so were similar to ours. Stewart and Robbins *(1958)* described preferred chickadee habitat as forest edge and woodlands, particularly near weedy fields and pine stands.

BROWN THRASHER

Brown thrashers were found on 18.3 percent (table 2) of the plots in moderate densities (0.52 birds per acre). The model (table 10) contains five habitat variables that together account for

Table 8.—Habitat variables associated with the occurrence of breeding house wrens *(Troglodytes aedon)* in Amherst, Massachusetts, in 1971

Independent variable	Multiple R^2	Change in R^2	Simple r [a]
Deciduous shrub volume, 16-20 feet	0.761	0.761	0.872**
Number of gardens	.820	.060	.252*
Open water	.852	.031	-.095

[a] * $p < .05$; ** $p < .01$

Table 9.—Habitat variables associated with the occurrence of breeding black-capped chickadees *(Parus atricapillus)* in Amherst, Massachusetts, in 1971

Independent variable	Multiple R^2	Change in R^2	Simple r [a]
Coniferous tree volume, 21-25 feet	0.408	0.408	0.638**
Deciduous tree volume, 31-35 feet	.500	.092	.452**
Coniferous tree volume, 61-65 feet	.553	.053	-.144
Number of gardens	.597	.045	.145
Deciduous shrub volume, 6-10 feet	.631	.033	.317**
Deciduous tree volume, 26-30 feet	.675	.045	.335**
Deciduous tree volume, 41-45 feet	.723	.047	.338**

[a] * $p < .05$; ** $p < .01$

Table 10.—Habitat variables associated with the occurrence of breeding brown thrashers *(Toxoxtoma rufrum)* in Amherst, Massachusetts, in 1971

Independent variable	Multiple R^2	Change in R^2	Simple r [a]
Deciduous tree volume, 6-10 feet	0.128	0.128	0.358**
Deciduous tree volume, 0-5 feet	.188	.060	.055
Deciduous tree volume, 21-25 feet	.314	.126	-.025
Number of gardens	.377	.063	-.063
Cultivated fields	.409	.032	.034

[a] * $p < .05$; ** $p < .01$

Table 11.—Habitat variables associated with the occurrence of breeding house sparrows *(Passer domesticus)* in Amherst, Massachusetts, in 1971

Independent variable	Multiple R^2	Change in R^2	Simple r [a]
Cats	0.194	0.194	0.440**
Volume of structures	.308	.114	.432**
Coniferous shrub volume, 11-15 feet	.346	.038	-.131
Coniferous tree volume, 66-70 feet	.407	.061	.190**
Deciduous tree volume, 11-15 feet	.441	.035	.102

[a] * $p < .05$; ** $p < .01$

about 41 percent of the variation in brown thrasher occurrence. Only three simple correlation coefficients were significant (table 12). The habitats that we sampled were marginal for brown thrashers.

There were significant correlations not found in the model: deciduous height volume at 11 to 15 feet and the deciduous shrub volume at 16 to 20 feet (table 12). The most important layer was 0 to 20 feet.

The negatively correlated deciduous height volume at 21 to 25 feet in third position in the model indicates that canopies above 20 feet decrease the habitat's attractiveness to brown thrashers. Requirements were described by Kendeigh *(1946)* as mixed shrub-small tree habitat in middle facies. We agree except to emphasize the importance of a deciduous shrub and small tree layer at 0 to 20 feet.

Bent *(1948)* described the brown thrasher in Massachusetts as a bird of rural and farming districts, living in bushy pastures, sproutlands, briar patches, tangles along fences, dry thickets, brushy hillsides, and the edges of woodland, almost always far from human habitation. However, Sherman *(1912)* noted that the bird was a common dooryard species except in New England. The reason for this difference in the bird's habitat is unclear. Our data did not indicate that human density or cats and dogs had any significant effects.

HOUSE SPARROW

These birds were observed on 61.7 percent (table 2) of the plots at a density of 2.21 birds per acre. The model contains five habitat components, which account for a total of 44 percent of the variation in house sparrow occurrence (table 11).

These results were difficult to analyze because of the affinity of the house sparrow for man's habitat. For example, no cause-and-effect relationship should be implied from correlation between cats and house sparrows. Yet, we do not think this spurious; it probably expressed the concurrent presence of two species dependent on man for habitat. This reliance on man is clearly evident from the emergence of volume of structures in the model. And of the 10 significant simple correlations (table 12), four were measures of man's influence: volume of structures, building density, cats, and adults.

The positive correlations between the distance to the nearest fallow field and woodlot and house sparrow occurrence also indicated that man's living places were suitable habitat. The combined negative relationships to herbaceous vegetation and mowed grass were probably the result of positive correlations with gardens and the presence of pavement and bare ground, which were not measured.

There was a deleterious effect of low shrub and tree volume, both deciduous and coniferous, and a positive influence of high canopy, particularly the coniferous height volume at 56 to 70 feet, although this adaptable species is likely responding to the presence of nest sites in buildings rather than vegetative features.

Woolfenden and Rohwer *(1969)* reported that house sparrows accounted for half of the total breeding bird population in their study of suburban habitats in Florida. Suburban areas provide ideal house sparrow habitat because they contain grassy cover and open ground for feeding, dust-bathing, gathering of nest material, and buildings for nesting.

Importance of Vegetation Layers

Birds respond to environmental features, including vegetative physiognomy *(Lack 1933, Breckenridge 1956, and Klopfer 1969).* Emlen *(1956)* provided a method of describing habitat characteristics of birds, and suggested some variables similar to ours. These included detailed measurements of crown characteristics instead of the relative classes described by Kuchler *(1949).*

Our work was greatly influenced by that of Sturman *(1968),* who developed formulae for computing the volumes occupied by the cone-shaped crowns of conifers and the ellipsoid crowns of hardwoods to describe, with other variables, the habitat of chickadees *(Parus atricapillus* and *P. rufescens)* with multiple-regression techniques.

Birds of temperate North America are intermediate in their degree of layer selection *(Klopfer 1969).* This ability to differentiate between layers, or to recognize more layers, increases the species' diversity of a forested habitat. James *(1971)* and Cody *(1968)* dealt with similar concepts in the discriminate-function habitat analysis of forest birds and grassland birds, respectively.

Layers of vegetation are critical to species diversity *(MacArthur and MacArthur 1961),* but

Table 12.—Correlation coefficients (r) between bird species and habitat variables in Amherst, Massachusetts in 1971

[Significance levels: * = p < .05; ** = p < .01]

Bird species	Deciduous tree volume						
	Total	0-5	6-10	11-15	16-20	21-25	26-30
Robin *(Turdus migratorius)*	.310**		.282*	.345**	.318**	.292*	.308*
Gray catbird *(Dumetella carolinensis)*	.358**		.282*	.535**	.616**	.626**	.555**
Blue jay *(Cyanocitta cristata)*	—		—	—	—	—	—
Northern oriole *(Icterus galbula)*	.269*		—	.338**	.463**	.509**	.504**
Song sparrow *(Melospiza melodia)*	-.264*		—	-.189	-.226*	-.250*	-.286*
Chipping sparrow *(Spizella passerina)*	—		—	—	—	—	—
House wren *(Troglodytes aedon)*	—		.291*	.317**	.243*	.209	—
Black-capped chickadee *(Parus atricapillus)*	.317		—	—	.175	.209	.335**
Brown thrasher *(toxostoma rufrum)*	—		.358**	.231*	—	—	—
House sparrow *(Passer domesticus)*	—		—	—	—	—	—

Bird species	Deciduous tree volume						
	31-35	36-40	41-45	46-50	51-55	56-60	61-65
Robin *(Turdus migratorius)*	.309*	.224*	.185	.199	.232*	.219*	.172
Gray catbird *(Dumetella carolinensis)*	.418**	.259*	.181	—	—	—	—
Blue jay *(Cyanocitta cristata)*	—	—	—	—	—	—	—
Northern oriole *(Icterus galbula)*	.446**	.347**	.243*	—	—	—	—
Song sparrow *(Melospiza melodia)*	-.283*	-.253*	-.221*	-.186*	—	—	—
Chipping sparrow *(Spizella passerina)*	—	—	—	—	—	—	—
House wren *(Troglodytes aedon)*	—	—	—	—	—	—	—
Black-capped chickadee *(Parus atricapillus)*	.452**	.438**	.338**	.227**	.210	—	—
Brown thrasher *(Toxostoma rufrum)*	—	—	—	—	—	—	—
House sparrow *(Passer domesticus)*	—	—	—	—	—	—	—

Bird species	Deciduous tree volume		Coniferous tree volume			
	66-95	96-100	Total	0-5	6-10	11-15
Robin *(Turdus migratorius)*	—	—	—	.242*	.461**	.384**
Gray catbird *(Dumetella carolinensis)*	—	—	—	—	—	—
Blue jay *(Cyanocitta cristata)*	—	—	—	—	—	—
Northern oriole *(Icterus galbula)*	—	—	.348*	.224*	.226*	.278*
Song sparrow *(Melospiza melodia)*	—	-.187	—	—	—	-.176
Chipping sparrow *(Spizella passerina)*	—	—	—	—	—	—
House wren *(Troglodytes aedon)*	—	—	—	—	—	—
Black-capped chickadee *(Parus atricapillus)*	—	—	.364**	—	.413**	.462**
Brown thrasher *(Toxostoma rufrum)*	—	—	—	—	—	—
House sparrow *(Passer domesticus)*	—	—	—	—	—	—

Bird species	Coniferous tree volume 16-20	21-25	26-30	31-35	36-40	41-45	46-50
Robin *(Turdus migratorius)*	* .237	—	—	—	—	—	—
Gray catbird *(Dumetella carolinesis)*	—	—	—	—	—	—	—
Blue jay *(Cyanocitta cristata)*	—	—	—	—	—	—	—
Northern oriole *(Icterus galbula)*	** .333	** .396	** .446	** .394	** .352	** .327	** .309
Song sparrow *(Melospiza melodia)*	-.188	-.180	-.174	—	—	—	—
Chipping sparrow *(Spizella passerina)*	—	—	—	—	—	—	—
House wren *(Troglodytes aedon)*	—	—	—	—	—	—	—
Black-capped chickadee *(Parus atricapillus)*	** .561	** .638	** .615	** .368	** .240	.213	.184
Brown thrasher *(Toxostoma rufrum)*	—	—	—	—	—	—	—
House sparrow *(Passer domesticus)*	—	—	—	—	—	—	—

Bird species	Coniferous tree volume 51-55	56-60	61-65	66-70	71-100	Deciduous shrub volume Total	0-5
Robin *(Turdus migratorius)*	—	—	—	—	—	.189	.170
Gray catbird *(Dumetella carolinensis)*	—	—	—	—	—	—	—
Blue jay *(Cyanocitta cristata)*	—	—	—	—	—	—	—
Northern oriole *(Icterus galbula)*	.197	—	—	—	—	** .438	** .526
Song sparrow *(Melospiza melodia)*	—	—	—	—	—	—	—
Chipping sparrow *(Spizella passerina)*	—	—	—	—	—	—	—
House wren *(Troglodytes aedon)*	—	—	—	—	—	** .423	* .242
Black-capped chickadee *(Parus atricapillus)*	—	—	—	—	—	** .333	** .307
Brown thrasher *(Toxostoma rufrum)*	—	—	—	—	—	—	—
House sparrow *(Passer domesticus)*	—	.200	.188	.190	—	—	—

Bird species	Deciduous shrub volume 6-10	11-15	16-20	Coniferous shrub volume Total	0-5	6-10	11-15
Robin *(Turdus migratorius)*	* .246	—	—	—	.173	—	—
Gray catbird *(Dumetella carolinensis)*	.182	—	—	—	—	—	—
Blue jay *(Cyanocitta cristata)*	—	—	—	—	—	—	—
Northern oriole *(Icterus galbula)*	** .281	—	—	—	—	—	—
Song sparrow *(Melospiza melodia)*	.199	—	—	—	—	—	—
Chipping sparrow *(Spizella passerina)*	—	—	—	** .414	** .306	** .387	** .623
House wren *(Troglodytes aedon)*	* .233	** .522	** .872	—	—	—	—
Black-capped chickadee *(Parus atricapillus)*	** .317	—	—	—	—	—	—
Brown thrasher *(Toxostoma rufrum)*	—	—	* .220	—	—	—	—
House sparrow *(Passer domesticus)*	—	—	—	—	—	—	—

CONTINUED

Table 12.—Continued.

Bird species	Coniferous shrub volume	Habitat variables—			
	16-20	Mowed lawn	Herbaceous vegetation	Volume of structures	Building density
Robin (*Turdus migratorius*)	—	—	-.283*	.252*	-.237*
Gray catbird (*Dumetella carolinensis*)	—	—	—	—	—
Blue jay (*Cyanocitta cristata*)	—	.169	—	—	—
Northern oriole (*Icterus galbula*)	—	-.219*	—	-.198	.305**
Song sparrow (*Melospiza melodia*)	—	—	.169	-.191	—
Chipping sparrow (*Spizella passerina*)	—	—	—	—	—
House wren (*Troglodytes aedon*)	—	—	—	—	.215*
Black-capped chickadee (*Parus atricapillus*)	—	-.319**	—	—	—
Brown thrasher (*Toxostoma rufrum*)	—	—	—	—	—
House sparrow (*Passer domesticus*)	—	—	-.331**	.432**	-.331**

Bird species	Habitat variables—						
	Traffic flow	Dogs	Cats	Children	Adults	Bird feeders	Bird houses
Robin (*Turdus migratorius*)	—	—	—	—	—	.282*	—
Gray catbird (*Dumetella carolinensis*)	—	-.203	—	—	—	—	—
Blue jay (*Cyanocitta cristata*)	—	—	—	—	—	—	—
Northern oriole (*Icterus galbula*)	—	-.199	—	-.184	—	—	—
Song sparrow (*Melospiza melodia*)	—	—	—	—	—	—	.222*
Chipping sparrow (*Spizella passerina*)	—	.399**	.467**	—	—	.269*	—
House wren (*Troglodytes aedon*)	—	—	—	—	—	.396**	—
Black-capped chickadee (*Parus atricapillus*)	—	-.192	—	-.171	—	—	—
Brown thrasher (*Toxostoma rufrum*)	—	—	—	—	—	—	—
House sparrow (*Passer domesticus*)	—	—	.440**	—	.267**	—	—

Bird species	Habitat variables—					
	Cultivated fields	Fallow fields	Open water	Wood lots	Number of gardens	Garden area
Robin (*Turdus migratorius*)	—	-.205	—	.170	.421**	—
Gray catbird (*Dumetella carolinensis*)	—	—	.277*	—	.218	—
Blue jay (*Cyanocitta cristata*)	—	-.170	—	—	-.170	—
Northern oriole (*Icterus galbula*)	—	—	—	-.297*	—	.175
Song sparrow (*Melospiza melodia*)	-.180	—	—	—	—	—
Chipping sparrow (*Spizella passerina*)	—	—	—	—	—	—
House wren (*Troglodytes aedon*)	—	—	—	.252*	—	—
Black-capped chickadee (*Parus atricapillus*)	—	—	—	—	—	—
Brown thrasher (*Toxostoma rufrum*)	—	—	—	—	—	—
House sparrow (*Passer domesticus*)	—	.178	—	.196	—	—

typically only three layers were recognized: herbaceous, shrub, and tree.

We dealt with 5-foot layers of woody vegetation, divided into trees and shrubs, and subdivided into coniferous and deciduous. We did this to better relate bird populations to measurable habitat characteristics. This builds on the ideas of R.H. MacArthur, but describes the habitat requirements of birds in more detail. We made preliminary examination of the effects of vegetation layers with deciduous and coniferous trees and shrubs combined. This resulted in significant declines in total R^2 values.

The 5-foot layers are arbitrary. It should be possible to vary the width or deal with various nonstandard widths by species to derive the best fits. However, this would involve numerous computer runs. A 5-foot layer was selected as the minimum meaningful layer for management, but the inverse was tested. Multiple-regression analyses of 10-foot layers were made, which resulted in a sharp decrease in R^2 values for all 10 bird species.

More layers of less depth add progressively more independent variables. Because of the requirement for plot numbers to equal or exceed the number of independent variables, we did not feel we could deal with layers of less than 5 feet.

Different bird species are significantly correlated with different coniferous and deciduous vegetation layers (table 12). There was little difference in the pattern of correlations for deciduous shrubs and trees combined, or for coniferous trees and shrubs combined. No species except the song sparrow differentiated between tree and shrub forms. Song sparrows were significantly and negatively correlated with coniferous shrubs and with deciduous overstory layers up to 45 feet, and with no other vegetation variables.

Bird Species Compatibility

The densities of several of the bird species studied were significantly correlated with each other:

Species correlated	r^a
Robin—gray catbird	0.340**
Robin—black-capped chickadee	.380**
Gray catbird—northern oriole	.457**
Gray catbird—house sparrow	.267*
Northern oriole—black-capped chickadee	.395**

[a] *p<.05;**p>.01.

All significant correlations were positive, which perhaps indicates that these bird species had similar habitat associations. The converse would be true with negative correlations. In making management decisions, it could be assumed that significant routine correlations mean that management for one species would have a similar effect on another. In fact, examination of the habitat associations of positively correlated species reveals a similarity of associations.

Comments on Study Design

Our design specified 10 species in the belief that observers could not accurately census more without confusion. We found this to be incorrect; in future similar studies we intend to include all species encountered. This should increase the efficiency of studies, because information on more species is gathered from the same amount of field work.

Unless an inventory of vegetation by species is needed for other purposes, we suggest recording vegetation data only as deciduous or coniferous. Time would be saved, and botanically expert field personnel would not be needed.

Our census plots were of variable size, while 0.5-acre plots were used for sampling vegetation. Such an arrangement adds a source of variability that can be avoided by having a standard plot size for the measurement of all variables. Unless the vegetation plot is representative of the surrounding habitat, birds could be counted in a different habitat than that on the 1/2-acre circular vegetation plot. Thus, a standard plot for all field measurements is recommended.

Our bird-population estimates are, actually, measures of bird use of plots or are indices to bird numbers. The correlations with habitat features were no less valid—but care should be taken when utilizing such data for other purposes, such as measuring bird-population trends.

Many of the independent variables proved of little value in describing habitat. The variables (which were expensive to measure) concerning human populations, dogs and cats, and auto and pedestrian traffic, accounted for little in the results. Careful consideration of these variables led to a reduced list for use in continuing studies.

This study was a pilot for the development and testing of a habitat-evaluation technique for birds in urban-suburban situations. The approach is flexible and could be altered to fit different circumstances, because independent and dependent variables, sampling schemes, plot sizes and shapes, and statistical levels of significance can be manipulated.

The study area was chosen to provide the complexity present in man-dominated environments. We visualize suburban areas, ecologically, as essentially extended variable "edge". While ecologists have long recognized "edge effect" *(Dice 1931, Leopold 1933:131)*, those who have made habitat analyses have generally avoided studying such complex habitats. We believe our technique and its results show that meaningful results can be obtained in such circumstances, and this approach should be even more effective in less complex situations.

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PERFORMANCE OF PONDEROSA PINE ON BITUMINOUS MINE SPOILS IN PENNSYLVANIA

by Walter H. Davidson

USDA FOREST SERVICE RESEARCH PAPER NE-358
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FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
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ABSTRACT

Seedlings from 40 seed sources of ponderosa pine (*Pinus ponderosa* Laws.) were planted on a strip-mine spoil in central Pennsylvania in 1969. Survival of seedlings from different sources ranged from 23 to 90 percent after six growing seasons. The average height of the seedlings ranged from 67 to 140 cm for the same period. Eight sources produced seedlings that were average or above in both height growth and survival.

Keywords: ponderosa pine, surface mine, reclamation, ecotype, provenance

INTRODUCTION

DIFFICULT PLANTING CONDITIONS and poor survival have encouraged the testing of new species for reclamation of strip-mine spoil banks. Ponderosa pine *(Pinus ponderosa* Laws.) was included in early species trials *(Hart and Byrnes 1960)* but it performed poorly and was not recommended. A chance planting of ponderosa pine in 1955 produced much better results *(Jones 1970).* In light of this contradiction, I welcomed the opportunity to participate in field tests of seedlings from ponderosa pine provenances during a study conducted by the Rocky Mountain Forest and Range Experiment Station. In the spring of 1969, I received 2,780 test seedlings from 49 seed sources. The seedlings were 2-1-1 stock which had been grown at the Bessey Nursery in Halsey, Nebraska.

PLANTING SITE

An old strip mine in Clearfield County, Pennsylvania, was selected as the planting site; it is at 41°N latitude and 78°12′W longitude, and has an elevation of about 1,600 feet. Precipitation at the site averages about 45 inches per year, and about 24 inches during the growing season (April through September). The normal growing season is just over 100 days.

The area had been planted at least twice before the ponderosa pine was planted, but only a few scattered trees had become established. An analysis of a composite soil sample showed these characteristics: pH: 3.4; Me H^+/100 gm: 6.7; M.mhos (cm conductance): 0.44; SO_4: 1,062 ppm; P: 0.4 ppm. Particle size distribution was: greater than 2 inches, 8 percent; ¼ inch to 2 inches, 47 percent; 2 mm to ¼ inch, 19 percent; less than 2 mm, 26 percent.

PLANTATION ESTABLISHMENT AND LAYOUT

The seedlings were shipped by air to the planting site; they were stored for 1 week in an unheated basement before being planted in mid-April, 1969. The seedlings were in excellent condition; they were planted by a two-man crew in 3 consecutive days. Mattocks were used to prepare the planting holes. The stony, compacted soil and the large size of the 2-1-1 seedlings made planting extremely difficult.

The study design was a randomized complete-block; a row of 10 trees from each provenance was in each of six blocks. Seedlings were planted at 6- × 6-foot spacings. All seedlings were planted, but there were only enough seedlings from 40 of the 49 sources for six complete replications; so only the 40 sources were compared (table 1).

Table 1.—Climatological data for sources of ponderosa pine planted on bituminous strip-mine spoils[a]

Ecotype and source	State	Latitude north	Longitude west	Elevation	Annual precipitation	Growing[b] season precipitation	Growing season
				Feet	*Inches*		*Days*
Transition zone							
754	MT	47°05′	110°50′	4,550	13.73	10.64	116
Central Montana							
815	MT	47°04′	109°15′	4,800	16.52	12.02	108
814[c]	MT	47°03′	108°59′	3,700	16.52	12.02	108
813	MT	47°53′	108°33′	4,700	11.27	8.51	112
812	MT	47°30′	109°30′	3,400	12.85	9.15	131
823[c]	MT	46°05′	107°23′	2,900	14.44	9.32	135
829	WY	44°48′	107°20′	5,100	15.91	10.57	130
Central Rockies							
830	WY	44°37′	107°05′	7,000	15.91	10.57	130
831[c]	WY	44°11′	106°50′	5,800	13.07	9.47	117
848	WY	42°35′	105°40′	6,900	13.74	9.76	124
847[c]	WY	42°13′	105°15′	5,500	12.44	9.61	141
845	NE	41°30′	103°57′	5,100	14.37	11.01	127
760	CO	40°12′	105°32′	8,400	16.07	11.20	98
761	CO	39°59′	105°25′	8,000	18.57	12.30	125
763	CO	39°06′	105°06′	7,800	18.32	14.13	119
Black Hills and high plains							
822[c]	MT	46°15′	108°27′	3,800	10.93	8.22	141
824	MT	45°55′	106°36′	3,400	15.13	10.48	132
825	MT	45°41′	106°00′	3,600	15.13	10.48	132
827	MT	45°50′	104°28′	3,800	13.22	10.32	127
702	ND	46°56′	103°30′	2,500	15.42	12.11	111
701	ND	46°35′	103°27′	2,600	15.42	12.11	122
703	SD	45°51′	103°30′	3,200	13.52	11.11	135
704	SD	45°34′	103°11′	3,450	12.77	9.99	129
832[c]	WY	44°53′	105°33′	3,900	17.61	11.92	128
833	WY	44°39′	104°16′	4,000	16.32	11.56	120
834	WY	44°27′	104°26′	5,500	16.32	11.56	120
835	WY	43°54′	104°11′	5,080	13.58	10.00	134
836	WY	43°40′	104°05′	4,080	13.67	10.23	134
837	SD	44°17′	103°50′	6,300	23.81	16.28	129
838	SD	43°55′	103°38′	5,680	17.07	13.56	117
839	SD	44°10′	103°35′	5,400	22.23	14.85	93
854	SD	43°13′	101°43′	3,300	16.11	12.66	128
853	NE	42°56′	102°30′	3,600	16.11	12.66	128
852	NE	42°31′	102°29′	3,800	19.31	13.95	132
722[c]	NE	42°39′	103°05′	4,300	19.31	13.95	132
851	NE	42°42′	103°35′	4,200	17.49	13.47	128
723	NE	41°46′	103°50′	4,600	14.37	11.01	127
Low-elevation east plains							
757	SD	43°14′	100°58′	2,600	18.80	13.46	134
720[c]	NE	42°41′	99°46′	2,300	20.31	15.72	149
856[c]	NE	41°26′	100°01′	2,900	19.79	15.28	154
Colorado Plains and foothills							
759	NE	41°27′	103°05′	4,300	17.09	13.21	135
758	NE	41°13′	103°15′	4,500	17.35	13.33	137
858	CO	40°32′	105°08′	5,300	14.19	10.37	145
724	CO	39°06′	104°37′	7,400	19.41	14.27	119
860	CO	38°35′	104°56′	6,500	11.79	8.84	168
861	CO	37°55′	104°55′	6,600	14.93	9.73	131
Southern Rockies, NE. New Mexico							
765	CO	37°19′	104°43′	7,000	16.20	11.32	167
862	NM	36°57′	104°18′	7,350	17.43	13.99	147
863	NM	35°50′	104°58′	6,400	16.56	12.99	155

[a] Supplied by R. A. Read, Rocky Mtn. For. Range Exp. Stn., Lincoln, Nebr.
[b] April through September.
[c] Not included in the analysis.

Table 2.—Average survival[a] and total height after four and six growing seasons, by seed source

Ecotype and source	State	Survival	Height 4 years	Height 6 years	6-year height as percentage of mean[b]
		Percent	*Centimeters*		*Pct.*
Transition zone					
754	MT	58	35	67	74
Central Montana					
815	MT	52	48	90	99
813	MT	79	45	77	85
812	MT	85	50	90	99
829	WY	50	45	79	87
Central Rockies					
830	WY	50	40	72	79
848	WY	68	48	85	93
845	NE	62	42	77	85
760	CO	70	46	79	87
761	CO	80	45	81	89
763	CO	87	45	78	86
Black Hills and high plains					
824	MT	58	63	107	118
825	MT	85	63	113	124
827	MT	68	53	94	103
702	ND	67	46	80	88
701	ND	35	52	96	105
703	SD	73	45	77	85
704	SD	90	64	113	124
833	WY	60	53	88	97
834	WY	77	55	97	107
835	WY	66	56	95	104
836	WY	47	55	93	102
837	SD	77	54	92	101
838	SD	73	43	73	80
839	SD	54	49	90	99
854	SD	43	52	92	101
853	NE	38	63	114	125
852	NE	58	51	89	98
851	NE	32	55	92	101
723	NE	57	46	84	92
Low-elevation east plains					
757	SD	78	73	140	153
Colorado Plains and foothills					
759	NE	63	44	79	87
758	NE	48	44	79	87
858	CO	48	52	89	98
724	CO	43	52	98	108
860	CO	23	47	89	98
861	CO	72	47	80	88
Southern Rockies, NE. New Mexico					
765	CO	43	63	114	125
862	NM	33	61	104	114
863	NM	60	67	122	134

[a] No mortality in fifth and sixth growing seasons.
[b] Average height at 6 years as percentage of mean for entire plantation.

RESULTS

By the end of the first growing season, the average survival for seedlings by seed source ranged from 30 to 93 percent. The average survival for all seedlings was 66 percent. After 1 full year, average survival by source ranged from 23 to 90 percent; overall, average survival dropped to 61 percent. Few seedlings died after that time, so the ranges were the same after six growing seasons (table 2).

There was some dieback during the first year; this made early height comparisons difficult. However, by the end of the second growing season, there were significant differences in the average height of seedlings from different sources. The shortest source averaged 19 cm; the tallest, 37 cm. The average height for all sources was 30 cm.

At the end of the fourth growing season, the average height for all sources was 51 cm. The shortest source, 754, averaged 35 cm; the tallest, 73 cm. Included in the tallest source, 757, was the tallest individual seedling at 108 cm. In the shortest source was the smallest seedling at 15 cm.

At the end of the sixth growing season, the average height for all sources was 91 cm. Source 757 averaged 140 cm; source 754 averaged 67 cm (table 2 and figs. 1 and 2).

With three exceptions, there were only minor changes in the rank of sources by height from the second to the sixth growing season. The height of seedlings from source 815 was below average after 2 years, but above average at 6 years. The height of seedlings from sources 833 and 852 was above average after 2 years and below average at 6 years.

Statistical analysis at the sixth year showed that there were highly significant differences in survival between sources, and significant differences in average height.

Seedlings from 8 sources were average or above in both height and survival; 10 sources produced seedlings that were above average in height but below average in survival; 12 sources produced seedlings that were above average in survival but that were below average in height; and seedlings from 10 sources were below average in both height and survival.

Figure 1.—A 170-cm tree from South Dakota (seed source 757).

Figure 2.—A 70-cm tree from Montana (seed source 754).

The eight sources that were above average in both height and survival offer the highest potential for reclaiming bituminous strip-mine spoils (table 3). The average height of seedlings from these sources was 108 cm compared to 91 cm for all sources; average survival was 75 percent, versus 60 percent for all seedlings planted.

There are no strong trends associated with the sources that produced the best seedlings. Six were in the Black Hills and high plains ecotype, but other sources in this ecotype produced seedlings that performed poorly. The fastest growing seedlings came from the easternmost extent of the range. This was the only source (757) in the low-elevation east plains ecotype that was compared in my study.

Three of the nine sources that were not compared because of limited data produced seedlings with superior characteristics (table 3). Two were from the central Montana ecotype. There were four other sources from this ecotype in my study; all performed fairly well and nearly met the requirements for inclusion with the superior sources. Superior seedlings from the third source for which data are limited came from the Black Hills and high plains ecotype.

Table 3.—Superior provenances [a] for plantings on bituminous strip-mine spoils

Ecotype and source	State	Average survival	Average height	Seedlings planted
		Percent	*Centimeters*	*No.*
Central Montana				
814 [b]	MT	84	95	50
823 [b]	MT	80	111	20
Black Hills and high plains				
825	MT	85	113	60
827	MT	68	94	60
704	SD	90	113	60
832 [b]	WY	76	105	20
834	WY	77	97	60
835	WY	66	95	60
837	SD	77	92	60
Low-elevation east plains				
757	SD	78	140	60
Southern Rockies, NE. New Mexico				
863	NM	60	122	60

[a] Both survival and height average or above for all origins tested.

[b] Not included in analysis but showed superior characteristics.

Of the remaining six sources not compared, five produced seedlings that performed fairly well. Only source 856 in Nebraska produced poor seedlings. The 6-year average height of these seedlings was 85 cm, and only 25 percent survived.

The results indicate that ponderosa pine seedlings from some sources will perform satisfactorily on bituminous mine spoils. The growth rates and survival of these seedlings compare favorably with those of red pine (*Pinus resinosa,* Ait.), a favored species for reclamation in Pennsylvania. Davis *(1973)* reported that first-year survival was 80 percent for red pine planted in spring on an acid spoil (pH 3.6). Average height after five growing seasons was 64 cm. The fatest growing ponderosa pine seedlings (source 757) averaged 100 cm after 5 years. Seedlings from the eight superior sources averaged 80 cm.

CONCLUSIONS

On the basis of data obtained from this study, seed from selected sources of ponderosa pine can be recommended for planting on bituminous strip-mine spoils in Pennsylvania (fig. 3). Additional testing of these

Figure 3.—Ponderosa pine test planting on Pennsylvania strip-mine spoil.

seedlings and those from other sources on a variety of spoils would be beneficial. The data also showed that there were only minor changes in relative performance after the second growing season. Therefore, it is possible to predict the performance of seedlings from each source with fairly good accuracy after only 2 years.

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- Pennington, New Jersey.
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- Syracuse, New York, in cooperation with the State University of New York College of Environmental Sciences and Forestry at Syracuse University, Syracuse.
- Warren, Pennsylvania.

Davidson, Walter H.
1977. **Performance of ponderosa pine on bituminous mine spoils in Pennsylvania.** Northeast. For. Exp. Stn., Upper Darby, Pa. 6 p., illus. (USDA For. Serv. Res. Pap. NE-358)

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232.12: 114.449.8

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CHANGES IN THE LOGGING LABOR FORCE

by Charles H. Wolf and Jean W. Nolley

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1977
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
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6816 MARKET STREET, UPPER DARBY, PA. 19082

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ABSTRACT

Employment in the logging industry dropped 28 percent between 1950 and 1970, while output of industrial roundwood increased 31 percent Today's loggers are older, better educated, and more skilled. A large proportion are self-employed, many work less than a full year, and a substantial number have incomes below the poverty level. Mechanization of timber harvesting will continue to affect the size and makeup of the labor force.

KEYWORDS: forest labor, employment, mechanization

THE LOGGING LABOR FORCE in the United States has changed during the last two decades—drastically in some ways and to a lesser degree in others. The logger of the 1970s is a little older, better educated, more skilled, and earns more than his 1950 counterpart. While total employment in logging has declined, the number of women and skilled workers has actually increased.

Compared to other manufacturing industries, logging has the lowest proportion of female workers, the highest proportion of Negroes, and an exceptionally large number of workers with limited schooling. In addition, a large proportion of the labor force is self-employed, many work less than a full year, and a substantial number have incomes at or near the poverty level.

One of the few sources of data on persons associated with the logging industry is the Census of Population *(U.S. Bureau of Census 1973)*. It provides not only a detailed description of today's logger, but an opportunity to find out how he is changing and to compare him with other workers. In this paper we use the Census to examine the logging labor force with the intent of improving our knowledge of the industry's past and providing a basis for foretelling its future.

Output up and employment down.—To supply America's need for wood products in 1970, the logging industry harvested 11.1 billion cubic feet of industrial roundwood *(USDA Forest Service 1973)*. This was a 31 percent increase over the 8.5 billion cubic feet harvested in 1950. The key to achieving this dramatic increase in output was the mechanization of nearly all phases of timber harvesting. The chainsaw, hydraulic shear, rubber-tired skidder, portable steel spar, and the multi-functional machines that fell, delimb, bunch, and skid are a few examples of logging equipment that the industry has adopted in its search for better and cheaper ways to harvest timber.

This increased mechanization has affected both the quantity and type of labor needed by the industry. According to the 1970 Census of Population, 123,829 persons were employed in logging, about 48,000 less than in 1950[1] (fig. 1). For every seven loggers who were employed at the time of the Census (in March) there was one who was not working.[2] These individuals had previous experience in logging and were actively searching for work. Many were temporarily out of work because of a seasonal slowdown and were likely to be recalled. Others were probably older workers approaching retirement age or young people with few skills and limited formal education.

In addition to the unemployed, there was a large group of individuals whose last job was in logging, but who were no longer actively seeking employment. Some of these people were workers who had stopped looking for work because they believed their chance of finding a job was nil. Others who had withdrawn from the logging labor force were students, retired workers, housewives, inmates of institutions, and persons doing incidental unpaid family work.

There were over 20,000 of these people who had last worked in the logging industry between 1968 and 1970. Half of them were in the prime working age group, 16 to 44. All together they form a pool of experienced workers that the logging industry might draw from during a time of national emergency.

[1]The Census of Population estimate of logging employment for 1970 is 63 percent higher than the estimate published by the Annual Survey of Manufacturers, even though both define the logging industry in terms of SIC code 241. The ASM's practice of surveying only establishments with 10 or more employees and the classification of some woods operations as secondary processing industries account for most of the difference in employment statistics.

[2]Nationally, the unemployment rate for men was 4.4 percent in 1970 and 5.1 percent in 1950.

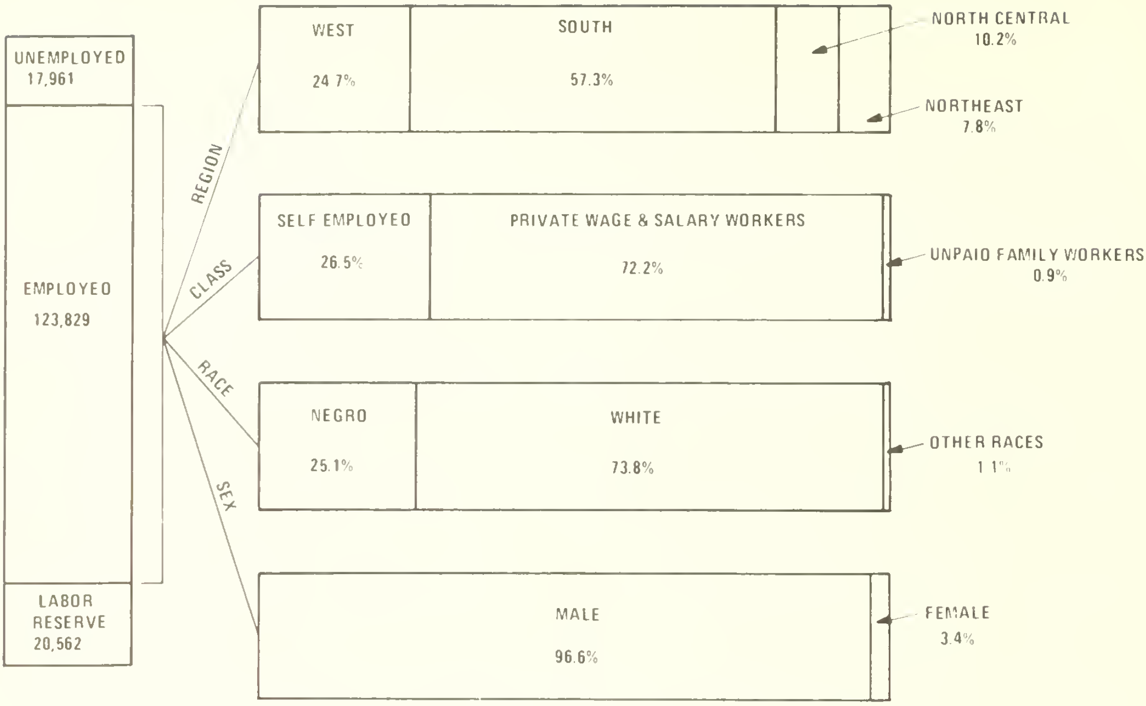


Figure 1.—Distribution of persons associated with the logging industry, 1970.

The surprisingly large number of loggers who were either unemployed or who had stopped looking for jobs and become part of the labor reserve can be attributed mainly to the increased mechanization of timber harvesting. From 1950 to 1970, the output of industrial roundwood increased by 31 percent while logging employment dropped by 28 percent. Fewer workers were needed by the industry to satisfy the increasing demand for roundwood.

The existence of nearly 18,000 unemployed experienced loggers may appear to contradict reports that there is a shortage of forest workers. However, it should be recognized that such reports are usually limited to specific geographic areas and to specific occupations. As the following discussion will show, some regions were affected less than others by the decline in employment, and there was an increasing demand for workers in the skilled occupations. Shortages, therefore, could have developed because the unemployed workers did not possess the skills that were in demand, or because they were not living in the region where the jobs were available.

All major regions of the United States showed a drop in logging employment between 1950 and 1970. The greatest decline occurred in the Northeast and West, where the number of loggers fell by more than 40 percent. In the South, employment increased between 1950 and 1960 but declined thereafter for an overall drop of only 10 percent. Presently, the South ranks first in employment, with 57 percent of all loggers residing in the region (fig. 1).

The sharpest decline in employment occurred among the occupational groups with the least skill (fig. 2). According to the system of classification used by the Bureau of Census, there were 60,000 fewer laborers in 1970 than in 1950. Included in this broad category are chokermen, chasers, fellers, buckers, and teamsters using horses or mules. The number of service workers, who include camp cooks, watchmen, and janitors, also showed a big decline.

All other occupational groups had an increase in employment. The number of foremen, log scalers, mechanics, skidder operators, and other workers in the craftsman group increased by 74 percent. Operatives, who include truck drivers and loader operators, showed an increase of 36 percent. The professional, technical, and managerial group also increased, but not as much as the other occupations. Thus while mechanization has reduced the need for laborers and service workers, it has increased the industry's requirements for supervisors, equipment operators, maintenance workers, and other skilled personnel.

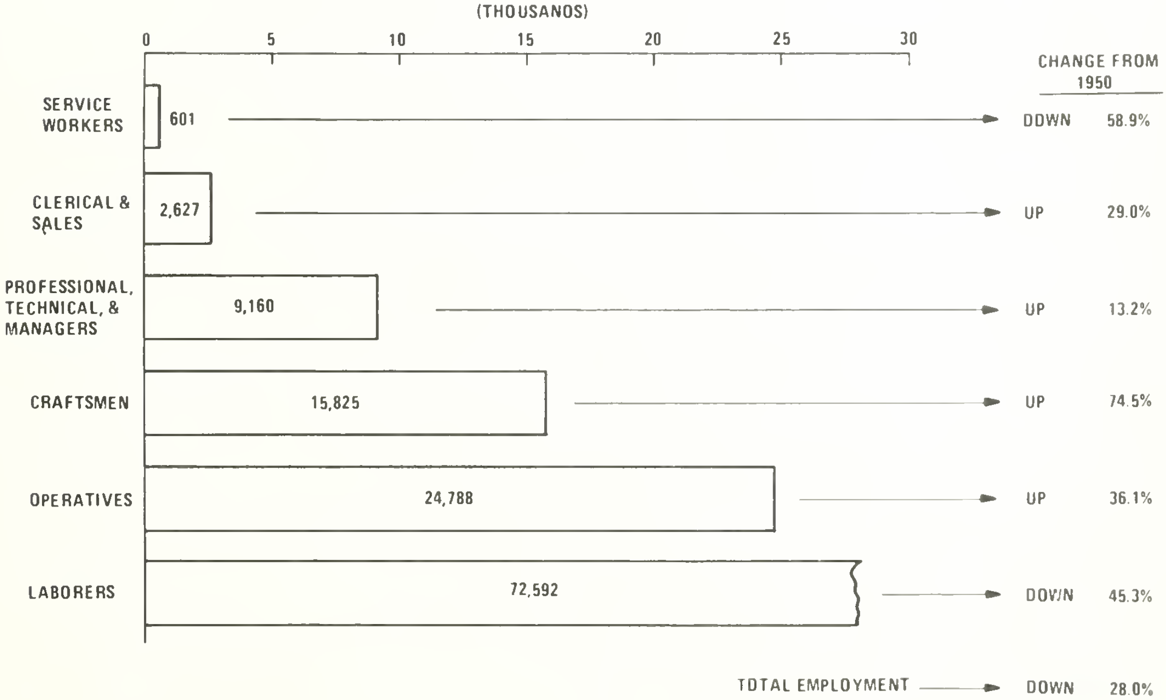
Another change that seems to be linked to mechanization is the increasing number of loggers who operated their own logging crews. From 1950 to 1970, the proportion of self-employed loggers rose from 14.9 to 26.5 percent. To some extent, this may reflect a reduction in optimum crew size and the efforts of paper companies to help loggers become independent businessmen.

Few women and many blacks.—Although the number of women in the logging industry has more than doubled during the last two decades, women still comprise only 3.4 percent of the total work force—the smallest percentage of female workers in any manufacturing industry. Nearly half of these women occupy white collar jobs such as secretaries, bookkeepers, and office managers. The remainder are employed as truck drivers, log scalers, loader operators, and in other jobs that traditionally have been held by men.

Nationally, one out of every four loggers is black. But almost all of them are in the South, where they account for nearly half of the logging labor force. Because the South has undergone a smaller decline in logging employment than other regions, the number of Negroes in the industry fell by only 10 percent between 1950 and 1970, while white employment dropped by 34 percent.

Young but getting older—A distinguishing feature of loggers is that as a group they are slightly younger than workers in other sectors of the wood industry and in most other manufacturing. This is true today as it was in the past. It probably reflects the industry's lower educational requirements and the preference of older workers for jobs that are less demanding physically and afford greater protection from extremes of weather.

Figure 2.—Occupational structure of the employed logging labor force, 1970.



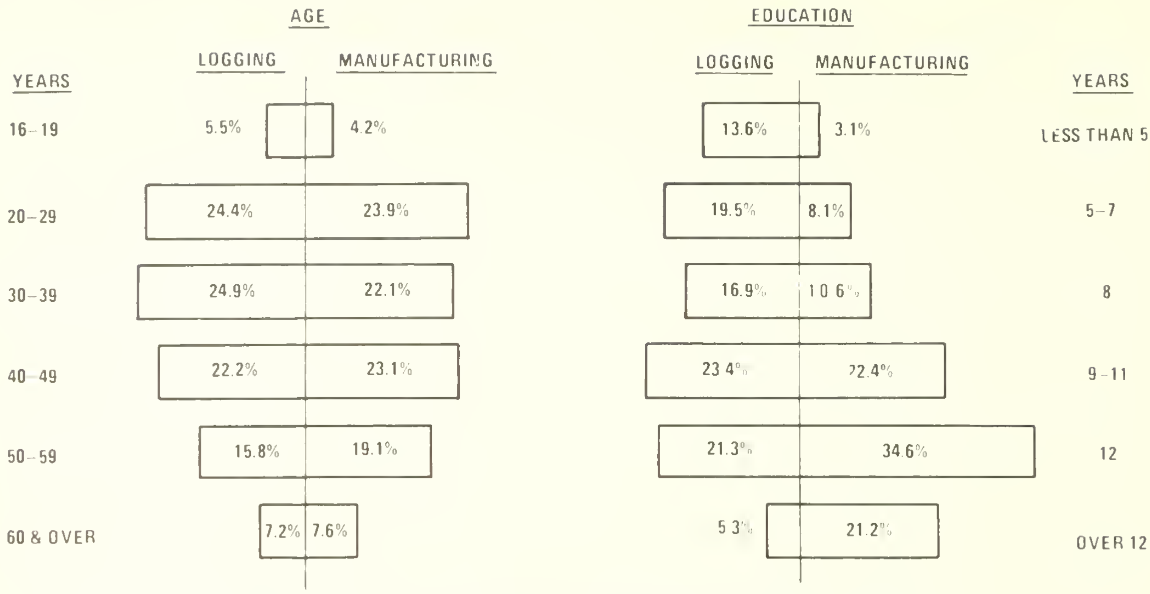


Figure 3.—Age and education distribution of males in logging compared to manufacturing, 1970.

Even though loggers are younger than other manufacturing workers, their median age has been steadily increasing.[3] The median age of men in logging in 1970 was 38—an increase of 2 years since 1950. The fact that there were fewer new job openings than retirements has caused the median to creep upward over time (fig. 3).

There has been a noticeable decline in the proportion of loggers under 20 and over 65 years of age. The first of these changes reflects the current trend toward longer school attendance and the existence of child labor laws that restrict employment of persons under the age of 18. The earlier retirements have been encouraged by more liberal social security benefits and the growth of private pension plans.

Education lags.—In the past, logging did not require much formal education. A worker's greatest assets were a strong back and a willingness to learn through on-the-job training. It is therefore understandable that loggers as a group lag behind other workers in schooling.

In 1970, one out of every two men in logging had less than 9 years of formal education. One out of every three had less than 8 years. Loggers have less formal education than any other group of manufacturing workers.

During recent years, education levels have not increased in logging to the same extent as in other industries. While male workers in manufacturing showed an increase from 1960 to 1970 of over a year in median school years completed, the corresponding increase in logging was only 0.8 years. Women in logging showed an equal change, but their median education level was already 2.8 years greater than that of men.

Earnings up but still low.—The increased use of skilled labor by the logging industry is one of the major reasons why the annual earnings of loggers have risen faster than the average for all manufacturing. However, even though earnings have more than doubled since 1950, loggers still have lower incomes than workers in any other manufacturing industry. The median for men during 1969 was $4,488, or slightly more than half that of all men employed in manufacturing.

In general, the more formal education a logger had, the higher his earnings were likely to be. The earnings for loggers with 4 years of high school were twice those of loggers with 8 years or less of schooling. Men in the 25- to 34-year age group tended to have higher earnings than those who were either younger or older.

[3]The median is the middle value in a group of values that are arrayed from low to high or high to low. Its principal advantage over the mean is that it is not unduly influenced by unusually high or low values.

Whites had much higher earnings than Negroes, and men were better paid than women.

Total family income is another indicator of how well loggers are doing financially. This measure takes into account the earnings of all family members, plus income from such sources as dividends, interest, rentals, unemployment insurance, and public assistance. A poverty index can be devised by adjusting total family income for such factors as family size, age and sex of the family head, number of children, and farm or nonfarm residence. The official "poverty level" for a nonfarm family of four was $3,743 in 1969.

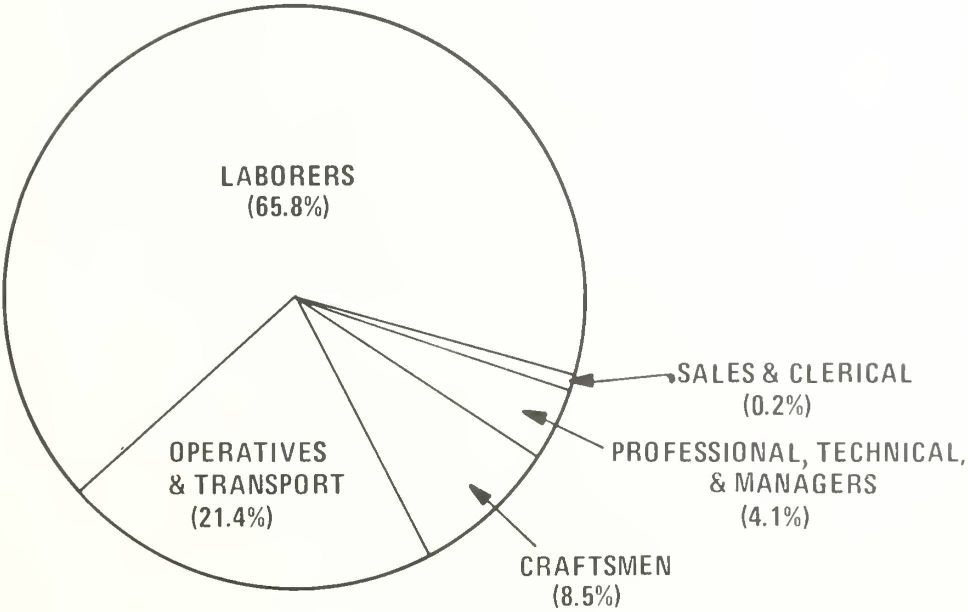
A look at these income statistics shows that 25.1 percent of the men and 29.7 percent of the women who were part of the logging work force headed families with a total income that was below the poverty level. In comparison, only 3.6 percent of the male and 15.2 percent of the female family heads employed in manufacturing were in the poverty group.

Poverty was much more common among black loggers than among whites. Fifty-five percent of the male Negro loggers headed families with incomes in the poverty range, while only 16.8 percent of the whites were in the same category. As might be expected, most of the loggers of both races who had family incomes below the poverty level were employed as laborers (fig. 4).

One reason why earnings are low is that many loggers do not work year-round. According to the Census Bureau, only 45 percent of the men in logging worked 50 to 52 weeks in 1969, as compared to 77 percent in all manufacturing (fig. 5). Another 44 percent of the logging work force was employed only 27 to 49 weeks out of the year. These percentages may appear to be quite low, but they do represent progress toward more year-round employment. In 1949, only one out of every three loggers worked 50 to 52 weeks.

There is still a large gap between the earnings of loggers and those of other workers, even when only full-time workers are considered. In 1969, the median earnings for loggers who worked 50 to 52 weeks and more than 30 hours each week were $5,648, or only 64 percent of the earnings of the comparable group in manufacturing. When earnings are compared by occupation, differences between workers in the wood industry and other manufacturing are largest for operatives, craftsmen, and managers, and smallest for laborers, sales, and clerical workers.

Figure 4.—Occupations of workers in the logging labor force who head families with incomes below the poverty level, 1969.



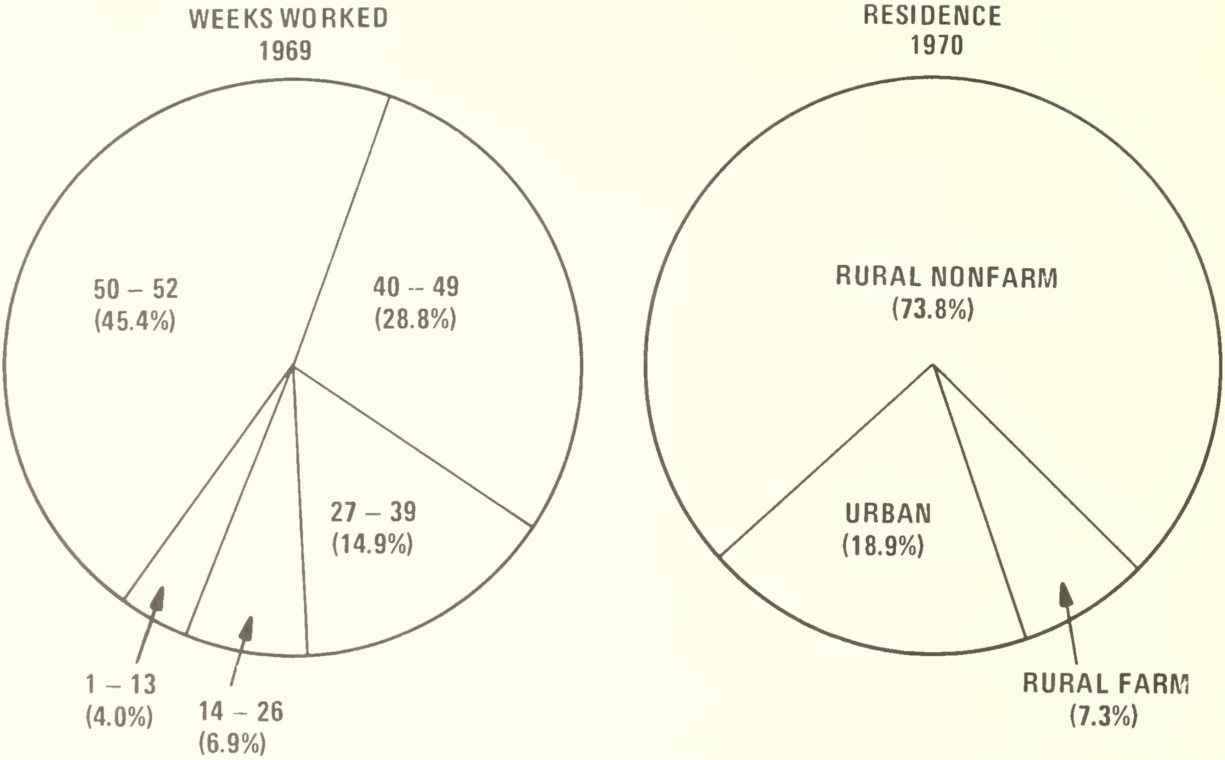


Figure 5.—Number of weeks worked and residence of persons employed in the logging industry.

In the past, many loggers were actually farmers who supplemented their farm income by working in the woods during the winter months. This seasonal movement of workers from farms to woods appears to have just about ended.

During 1970, only 7.3 percent of the persons employed in logging lived on farms, as compared to 13.9 percent in 1960 and 28.5 percent in 1950 (fig. 5). Most loggers still live in rural areas, even though they no longer operate farms. A significant number (18.9 percent) live in small towns of over 2,500 people and on the fringes of metropolitan areas.

Future outlook.—In assessing the future, it is convenient to view the logging labor force as comprising two components or groups. The first group consists of loggers who are the true professionals of the industry. They are highly efficient, well-trained workers who are employed year-round, earn a good living, and use the most modern timber-harvesting equipment.

In contrast, the second group, which we shall call the "part-timers", is involved in logging because it is often their only employment alternative. These individuals may be small farmers or workers who have lost their regular jobs and are waiting for employers to begin hiring again. Still others in this group are either unable or unwilling to find permanent jobs because they have limited formal education and an overriding desire to work when and how they wish. These "in and outers" have no permanent attachment to the logging industry. They look upon logging not as a lifetime occupation but as a temporary job that will supplement their incomes from public assistance, unemployment insurance, farming, and miscellaneous jobs.

The "part-timers" are the marginal workers of the logging industry. They are mainly responsible for the industry's bleak statistics on weeks worked, earnings, and families living below the poverty level. They work intermittently, have limited tools and equipment, and earn much less than professional loggers. Although there is no way of telling how many of these part-time loggers there are, I would estimate that they account for one-fourth of total industry employment.

In the future, I foresee timber harvesting becoming increasingly more mechanized with the development of new equipment and the more widespread use of what is currently available. The latest statistics show that in 1972 the logging industry purchased $157 million worth of new capital equipment, or about twice as much as it did during the early 1960s *(U.S. Bureau of the Census 1975)*. This continuing substitution of capital for labor will have a pronounced effect upon the logging labor force.

First of all, it is likely to further reduce industry employment even with the projected increase in the demand for roundwood. The decline in employment will occur primarily among the part-time loggers because they are less suited for the type of jobs that will dominate the logging industry in the future.

Many part-time loggers do not possess the training potential or the temperament required to operate and maintain sophisticated timber-harvesting equipment. And many of the part-time loggers who are self-employed have neither the financing to purchase nor the business skills to efficiently utilize modern logging equipment. As a result, the productivity of the professional logger will increase while the productivity of the part-time logger will remain about the same. The wider this gap in productivity between the two groups becomes, the more difficult it will be for the part-time logger to exist alongside the professional.

Large investments in equipment will become more and more necessary for success in the logging business. However, this does not mean that the part-time logger will totally disappear. There will always be some who will be able to operate successfully on small timber tracts, in rough terrain, and in other situations where the usefulness of sophisticated mechanized equipment is limited.

In addition to the decline in the number of part-time loggers, there will be many other changes that will accompany the increased mechanization of timber harvesting. For investments in mechanized equipment to be profitable, logging must be conducted with as little downtime as possible. Therefore, more loggers will have an opportunity to work on a full-time, year-round basis. The operation and maintenance of this mechanized equipment will demand a more skilled and better educated labor force. Large numbers of the industry's new employees will be graduates of vocational-technical schools and company training programs as greater emphasis is given to formal education and off-the-job training. The relative earnings of loggers should improve, reflecting their greater skills and steadier employment.

One can only guess at what some of the other changes may be that will affect the logger and his industry. Will the companies that now purchase roundwood be forced to do more of their own logging as the escalating prices of equipment make it more difficult for the independent contractor to stay in business? Can the piece rate system survive in an industry with costly machines and skilled labor? And finally, how will recent legal developments that permit the organization of loggers affect the structure of the industry?

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1973. THE OUTLOOK FOR TIMBER IN THE UNITED STATES. USDA For. Serv., Resour. Rep. 20, p. 361 (table 30).

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- Berea, Kentucky, in cooperation with Berea College.
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- Warren, Pennsylvania.

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Economic Analysis of the Gypsy Moth Problem in the Northeast

III. Impacts on Homeowners and Managers of Recreation Areas

by
George H. Moeller
Raymond L. Marler
Roger E. McCay and
William B. White

USDA FOREST SERVICE RESEARCH PAPER NE-360
1977
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
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PREFACE

This is the third in a series of papers on economic impacts of the gypsy moth in the Northeast. The first two papers *(McCay and White 1973; Payne et al. 1973)* dealt with the economic impacts of the gypsy moth on commercial forest production and on residential property values, respectively. Here, we deal with nonmarket impacts of a gypsy moth infestation on residential and on recreation properties. No method for obtaining information about such impacts has yet gained wide acceptance. This paper is intended to provide perspective for those who administer and implement gypsy moth control programs and to add to the state of the art for those who conduct related research on nonmarket impacts of forest pests.

Economic Analysis of the Gypsy Moth Problem in the Northeast

III. Impacts on Homeowners and Managers of Recreation Areas

ABSTRACT

The economic impacts of a gypsy moth infestation on homeowners and on managers of recreation areas (commercial, public, and quasi-public) were determined from data collected via interviews with 540 homeowners and 170 managers of recreation areas in New York and Pennsylvania. The approach to measuring the impact of gypsy moth was to determine the interaction of a specific effect of an infestation (tree defoliation, tree mortality, nuisance) with a specific ownership objective (the reason a person has for owning or managing a property). Data were also collected on costs of controlling the gypsy moth, on financial losses resulting from infestation, and on person-days of recreational use of property lost by ownership class.

ACKNOWLEDGMENTS

Our thanks go to David P. Worley, principal economist, USDA Forest Service, Insect and Disease Laboratory, Delaware, Ohio, for his team leadership in organizing the economic analysis of gypsy moth impacts contained in this and previous papers in this series.

Credit is also given to the state, federal and private agencies that supplied sampling lists used in this study. These agencies include the New York State Department of Environmental Conservation, the Pennsylvania Department of Environmental Resources, the USDA Animal and Plant Health Inspection Service, and local gypsy moth control offices. Finally, we thank the homeowners and managers of recreation areas who provided the detailed information used in this study.

This report was funded in part through a U.S. Department of Agriculture program entitled "The Expanded Gypsy Moth Research and Development Program."

THE GYPSY MOTH has spread slowly throughout many sections of the northeastern United States since it was accidentally introduced into Massachusetts in 1869. Various actions have been taken by state and federal governmental agencies to control its occurrence.

An intensive biological investigation of the gypsy moth is now in progress. Efforts to determine the impacts of a gypsy moth infestation on forest production and property values have succeeded *(McCay and White 1973; Payne et al. 1973)*. These impacts are now understood and can be predicted within acceptable limits. But only limited research has been done on other impacts of gypsy moth: the impacts of nuisance, defoliation, and tree mortality on the recreational and esthetic values of forest land. The impacts of a gypsy moth infestation on these values are immediate, particularly in cases where tree cover contributes significantly to the recreational and esthetic components of property value. Thus, understanding the true magnitude of the gypsy moth problem requires accurate determinations of the impacts of a gypsy moth infestation, not only on timber production but on all other values associated with forested land.

The present study sought to identify and quantify the impacts of a gypsy moth infestation on forested land values other than timber.

STUDY METHODS

Homeowners and managers of recreation areas in Pennsylvania and New York were interviewed between September and November 1973. This period was selected to afford respondents ample opportunity to observe the spring and summer effects of gypsy moths on their properties.

The person interviewed was, whenever possible, one who was directly involved in deciding whether to take gypsy moth control action. For private properties, this person was the individual property owner. For recreation areas, the person responsible for managing the property was interviewed. If three successive attempts to obtain an interview failed, a specific property was dropped from our sample.

The study questionnaire elicited information about the effects and impacts of a gypsy moth infestation (including dates of earliest infestation and control measures), related costs, evaluation of control programs, and satisfaction with past control efforts.[1] All information solicited during the interview related to the respondent's recollection of his first experience with the effects of a gypsy moth infestation. Thus, gypsy moth effects and impacts could be evaluated independent of subsequent control efforts.

Ownership Classes

Four types of properties were included in the survey: private homes, located in areas usually containing 1 to 50 homes per 50 acres, and differing from urban properties primarily in their size and forested character; commercial campgrounds located in forest settings and ranging in area from a few acres to several hundred acres; public recreation areas, forested properties publicly owned and operated for public recreational use; and quasi-public recreation areas, forested properties operated for institutional groups like the Boy Scouts of America and church organizations.

Some homeowners had paid commercial operators to control the gypsy moth. The remaining homeowners, as well as all managers of recreation areas, had participated in cooperative public control programs. Five ownership classes were thus established: 1) homeowners - public control; 2) homeowners - commercial control; 3) commercial campgrounds; 4) public recreation areas; and 5) quasi-public recreation areas.

Sampling

The survey was conducted in a 35-county area in which gypsy moth defoliation had been severe during the year prior to the study: the area included portions of southeastern New York State, all of Long Island, and portions of northeastern Pennsylvania.

[1]A copy of the study questionnaire may be obtained from the USDA Forest Service, Forest Insect and Disease Laboratory, Hamden, Conn.

Sampling lists included all properties in the survey area that had been included in the 1973 cooperative public gypsy moth control program. In addition, a list of homeowners who had paid for their own gypsy moth control was developed from the records of commercial spray operators in the survey region.

The sample, drawn from a total of 8,165 properties, consisted of 590 homeowners and 201 managers of recreation areas. Interviews were completed at 710 out of the 791 sampled properties. Because of differences in relative availability of control records and unequal sizes of ownership classes, it was not possible to obtain a uniform distribution of respondents from the three geographic regions or from the five ownership classes (table 1).

DATA ANALYSIS

The interview of each respondent provided data on: ownership objectives and their relative importance; the effects of gypsy moth infestation and their relative importance; financial losses resulting from infestation; costs of gypsy moth control measures; and losses in the recreational use of properties.

Profiles of Ownership Objectives

The specific impacts that a gypsy moth infestation have on a particular property will depend, in part, on the property owner's objectives, i.e., his reasons for owning or managing a property. A profile of objectives, consisting of six objectives, was determined for each respondent. The need for a place of residence was assumed to be common to all ownership classes and was not listed as an objective. Possible ownership objectives included:

1. Enjoyment of natural beauty
2. Backyard recreation
3. Maximizing recreation use
4. Maximizing recreation revenue
5. Property value (maintenance or enhancement thereof)
6. Other (as specified by respondents)

Each respondent was asked to indicate the significance of each objective by assigning it a percentage rating for its relative importance. On each questionnaire, the ratings for all objectives totaled 100 percent. Individual profile ratings were used to determine an average profile of ownership objectives for each ownership class.

Quantifying Effects of Gypsy Moth

The four principal effects of a gypsy moth infestation on a property were defined as: the presence of insects, insect droppings, and egg masses, constituting an offense to the senses (Nuisance); the defoliation of trees or shrubs, resulting in loss of shade and in an unsightly appearance (Defoliation); the presence of dead trees (Mortality); and any additional effects specified by the respondent, e.g., allergic response to gypsy moth (Others). Each respondent was asked to indicate the significance of

Table 1.—Respondents by ownership class and geographic area

Ownership class	Number on sampling list	Sample size	Number of complete responses	Location of respondents: Southeastern New York	Long Island	Northeastern Pennsylvania
Homeowners						
Public control	7,888	523	481	55	214	212
Commercial control	76	67	59	0	14	45
All homeowners	7,964	590	540	55	228	257
Managers of recreation areas						
Commercial campgrounds	156	156	134	42	0	92
Public recreation areas	16	16	16	9	3	4
Quasi-public recreation areas	29	29	20	3	3	14
All managers	201	201	170	54	6	110
Total	8,165	791	710	109	234	367

each effect by assigning to it a percentage rating for its relative importance. On each questionnaire, the ratings for all effects totaled 100 percent. Individual effect ratings were used to determine an average effects profile for each ownership class.

Rating Impacts of Gypsy Moth Effects on Ownership Objectives

Each respondent was asked to estimate the relative impact that each effect of gypsy moth had had on his set of ownership objectives by assigning to each objective a percentage of total impact rating. On each questionnaire, the ratings for all impacts totaled 100 percent. Average impacts on objectives profiles were determined for each ownership class.

Importance Indices

A forecasting technique called PATTERN[2] can be used to isolate the interactions of elements involved in a particular decision *(Esch 1969)*. The technique can be applied to almost any situation in which the importance of such interactions must be gauged.

By use of PATTERN, we developed a table of importance indices for each ownership class (tables 2-6). Each importance index is the product of an Effect Rating and the Importance Rating of an Impact on an Ownership Objective. For example, for homeowners-public control, (table 2) the importance index for the impact of nuisance on enjoyment of natural beauty (23.85 as expressed as a percentage) was determined by multiplying the average effect rating for nuisance (.53) by the average impact for the enjoyment of natural beauty ownership objective (.45). The importance index provides a measure of the relative importance of the impact of a particular effect of gypsy moth on a particular ownership objective. The four or five largest index values comprise an Importance Index Profile which identifies the most important aspects of the gypsy moth problem for each ownership class (tables 2-6).

Control Costs and Financial Losses

The amount of money that people are willing to spend is often equated with the importance they attach to a particular good or service. The usual economic yardstick for measuring the financial magnitude of the gypsy moth problem is the homeowner's or property manager's demonstrated willingness to pay for control measures. Data on financial magnitudes of gypsy moth impacts were obtained from the respondent. Each respondent was asked to estimate the time spent in controlling gypsy moths and the total cost of equipment, materials and services. In estimating control costs, the respondent's own time was valued at $2 per hour. Average control costs were determined for each ownership class. The average financial loss sustained by each ownership class was determined in an analogous manner.

Average annual costs of control measures and financial losses resulting from gypsy moth infestation were calculated for all ownership classes except managers of public recreation areas (tables 7-8).

Reductions in Recreational Use

The average number of person-days per year that were lost in the recreational use of properties was calculated for each ownership class (table 9).

First Occurrence and First Gypsy Moth Control Measures

Table 10 shows, for each ownership class, the distribution of respondents with respect to the first calendar year of gypsy moth infestation and the first calendar year in which control measures were taken.

RESULTS

Impacts on Objectives

The importance index profiles (tables 2-6) reveal that the nuisance and defoliation effects of gypsy moth infestation were the prime concerns of all ownership classes. For homeowners, the principal impacts of these two effects were on backyard recreation and on the enjoyment of natural beauty (tables 2-3). Managers of commercial campgrounds were concerned with the impacts of nuisance, defoliation, and tree mortality on the enjoyment of natural beauty. In addition, they were concerned with the impact of

[2]PATTERN = Planning Assistance Through Technical Evaluation of Relevance Numbers.

TEXT CONTINUES ON PAGE 8.

Table 2.—Importance indices for homeowners (public control)

Item	Ownership objectives					Total	Average effect rating
	Enjoy natural beauty	Backyard recreation	Property value	Maximize recreation use	Other [a]		
	Percent					*Percent*	*Percent*
Average ranking of ownership objectives	41	29	15	2	13	100	—
Average gypsy moth impact on ownership objectives	45	42	6	2	5	100	—
Gypsy moth effects							
Nuisance	**23.85** [b]	**22.26**	3.18	1.06	2.65	—	53
Defoliation	**18.90**	**17.64**	2.52	0.84	2.10	—	42
Mortality	1.80	1.68	.24	.08	.20	—	4
Other [a]	.45	.42	.06	.02	.05	—	1
						Total	100

[a] As specified by respondents.

[b] Indices in boldface comprise the importance index profile. They summarize the most important aspects of the gypsy moth problem for this ownership class.

Table 3.—Importance indices for homeowners (commercial control)

Item	Ownership objectives					Total	Average effect rating
	Enjoy natural beauty	Backyard recreation	Property value	Maximize recreation use	Other [a]		
	Percent					*Percent*	*Percent*
Average ranking of ownership objectives	39	23	17	0	21	100	—
Average gypsy moth impact on ownership objectives	49	28	13	2	8	100	—
Gypsy moth effects							
Nuisance	**24.01** [b]	**13.72**	6.37	0.98	3.92	—	49
Defoliation	**22.05**	**12.60**	5.85	.90	3.60	—	45
Mortality	2.45	1.40	.65	.10	.40	—	5
Other [a]	.49	.28	.13	.02	.08	—	1
						Total	100

[a] As specified by respondents.

[b] Indices in boldface comprise the importance index profile. They summarize the most important aspects of the gypsy moth problem for this ownership class.

Table 4.—Importance indices for managers of commercial campgrounds

Item	Management objectives: Maximize recreation revenue	Property value	Enjoy natural beauty	Maximize recreation use	Other [a]	Total	Average effect rating
	Percent					*Percent*	*Percent*
Average ranking of management objectives	30	22	20	19	9	100	—
Average gypsy moth impact on management objectives	10	15	46	15	14	100	—
Gypsy moth effects							
Nuisance	4.30	**6.45** [b]	**19.78**	**6.45**	6.02	—	43
Defoliation	3.20	4.80	**14.72**	4.80	4.48	—	32
Mortality	1.90	2.85	**8.74**	2.85	2.66	—	19
Other [a]	.60	.90	2.76	.90	.84	—	6
						Total	100

[a] As specified by respondents.

[b] Indices in boldface comprise the importance index profile. They summarize the most important aspects of the gypsy moth problem for this ownership class.

Table 5.—Importance indices for managers of public recreation areas

Item	Management objectives: Maximize recreation use	Enjoy natural beauty	Maximize recreation revenue	Property value	Other [a]	Total	Average effect rating
	Percent					*Percent*	*Percent*
Average ranking of management objectives	53	30	4	4	9	100	—
Average gypsy moth impact on management objectives	42	37	2	9	10	100	—
Gypsy moth effects							
Nuisance	**21.84** [b]	**19.24**	1.04	4.68	5.20	—	52
Defoliation	**17.22**	**15.17**	.82	3.69	4.10	—	41
Mortality	2.94	2.59	.14	.63	.70	—	7
						Total	100

[a] As specified by respondents.

[b] Indices in boldface comprise the importance index profile. They summarize the most important aspects of the gypsy moth problem for this ownership class.

Table 6.—Importance indices for managers of quasi-public recreation areas

Item	Management objectives: Maximize recreation use	Enjoy natural beauty	Property value	Maximize recreation revenue	Other [a]	Total	Average effect rating
	Percent					*Percent*	*Percent*
Average ranking of management objectives	36	22	7	4	31	100	—
Average gypsy moth impact on management objectives	30	45	9	2	14	100	—
Gypsy moth effects							
Nuisance	**12.00** [b]	**18.00**	3.60	0.80	5.60	—	40
Defoliation	**14.70**	**22.05**	4.41	.98	6.86	—	49
Mortality	3.00	4.50	.90	.20	1.40	—	10
Other [a]	.30	.45	.09	.02	.14	—	1
						Total	100

[a] As specified by respondents.

[b] Indices in boldface comprise the importance index profile. They summarize the most important aspects of the gypsy moth problem for this ownership class.

Table 7.—Average control cost for owners who employed a gypsy moth control measure in addition to public control measures

Ownership class	Respondents within class	Cost of equipment, materials, services	Labor cost [a]	Total cost
	Percent	*Dollars*		
Homeowners				
Public control	52	16	46	62
Commercial control	54	120	26	146
Managers of recreation areas				
Commercial campgrounds	5	77	192	269
Quasi-public recreation areas	5	40	400	440

[a] At $2 per hour.

Table 8.—Average financial loss due to a gypsy moth infestation [a]

Ownership class	Respondents within class	Cost of equipment, materials, services	Labor cost [b]	Total loss
	Percent	*Dollars*		
Homeowners				
Public control	42	56	20	76
Commercial control	41	257	35	292
Managers of recreation areas				
Commercial campgrounds	22	116	36	152
Quasi-public recreation areas	35	521	86	607

[a] Capital cost reduction in property value, increase in maintenance cost, and loss of revenue.

[b] At $2 per hour.

Table 9.—Person-days of recreation loss due to a gypsy moth infestation

Ownership class	Respondents	Respondents experiencing recreation impact	Recreation lost by respondents who experienced a recreation impact
	Number	*Percent*	*Person-days*
Homeowners			
Public control	481	51	108
Commercial control	59	44	133
Managers of recreation areas			
Commercial campgrounds	134	4	161
Public recreation areas	16	25	36,660
Quasi-public recreation areas	20	12	240

Table 10.—Distribution of respondents by ownership class, by first year they experienced an infestation, and by year of first control measure, in percent

Year	Homeowners (public control)		Homeowners (commercial control)		Commercial campground managers		Public recreation area managers		Quasi-public recreation area managers	
	First experience	First control	First experience	First control	First experience	First control	First experience	First control	First experience	First control
1969 or earlier	11.5	4.0	7.1	1.7	10.3	0.8	25.0	12.4	21.1	10.5
1970	12.8	5.2	5.7	.0	18.1	5.6	6.2	.0	5.3	5.3
1971	34.1	10.6	31.5	11.8	26.7	17.5	25.0	18.8	26.3	.0
1972	32.5	33.8	37.1	39.0	30.2	32.5	37.6	25.0	42.0	26.3
1973	9.1	46.4	18.6	47.5	14.7	13.6	6.2	13.8	5.3	57.9

nuisance on property value and on maximizing recreational use (table 4). The managers of both public and quasi-public recreation areas were most concerned with the impacts of nuisance and defoliation on enjoyment of natural beauty and on maximizing recreation use (tables 5-6).

Control Costs

Homeowners who participated in a cooperative public control program (250 respondents) spent an average of $62, of which only $16 went for expenses other than their own time. In contrast, homeowners who paid for commercial control measures (32 respondents) spent an average of $146, of which $120 went for expenses other than their own time. Managers of commercial campgrounds (7 respondents) who had participated in a cooperative public control program, spent an average of $269, of which $77 went for expenses other than their own time. The manager of a quasi-public recreation area, the sole respondent in this ownership class who paid for control in addition to participating in a cooperative public control program, spent $440, only $40 of which went for expenses other than his own time (table 7). No control cost data were available from managers of public recreation areas.

Financial Losses due to Infestation

The financial losses attributed to gypsy moth consisted of capital costs incurred in coping with the infestation plus increases in maintenance costs, reduction in property values and, where applicable reduction in revenues (table 8).

Homeowner-commercial control (24 respondents) sustained an average financial loss of $292, in contrast to the average loss of $76 sustained by homeowner-public control (202 respondents). Managers of commercial campgrounds (29 respondents) sustained an average loss of $152. Managers of quasi-public recreation areas (7 respondents) sustained an average loss of $607.

Recreation Losses due to Infestation

Of 59 respondents in the class, 44 percent of homeowners-commercial control lost annually an average of 133 person-days of recreational use of their property because of gypsy moth infestation. Of 481 homeowners-public control, 51 percent lost annually an average of 108 person-days of recreational use of their property. Four percent of managers of commercial campgrounds suffered a recreation loss due to infestation. This loss amounted to an average of 161 person-days of recreational use of their facilities annually. Of 16 managers of public recreation areas, 25 percent lost annually an average of 36,660 person-days of use of their facilities. Of 20 managers of quasi-public recreation areas, 12 percent lost annually an average of 240 peron-days of use of their facilities (table 9).

DISCUSSION

The purpose of this study was to identify and, whenever possible, quantify the impacts of gypsy moth on non-commercial forest owner objectives. The information is intended to assist public decision makers who are responsible for design, implementation, and coordination of gypsy moth control programs.

The information contained here is not available elsewhere. The information should provide a basis for beginning to incorporate financial and other non-market gypsy moth impact data into the decisionmaking processes—particularly for high value forest properties where commercial timber production is not a major objective of ownership. It is in such high value forest properties that control programs can prove immediately beneficial.

For all ownership groups it was demonstrated that specific ownership or management objectives were seriously affected by a gypsy moth outbreak.

Loss of recreational use of private home properties ranged from 180 person days per year for homeowners—public control to 54 days for homeowners—commercial control. Impacted commercial recreation areas averaged 161 person-days of recreation loss annually. These public recreation areas and quasi-public areas that were impacted lost an average of 36,300 person-days and 240 days of recreation use, respectively.

The financial information on gypsy moth impacts—control costs and financial impacts—provide some insight into the financial magnitude of the gypsy moth problem. However, more research will be needed to refine these figures. The data on financial implications should be used with caution. Under no circumstances should total financial impacts for an ownership class be derived by adding average control cost and average financial impact. This is because owners who sustained a control cost are not necessarily the same as those who sustained a financial impact and vice versa.

In approaching the study problem, difficult problems were encountered with regard to study design. The PATTERN technique for identifying the interactions between effects of gypsy moth and impacts on owner objectives had not been previously applied to the problem. Although results do point out the relative magnitude of impacts on owner objectives, other techniques should be applied to the problem. Results of the PATTERN analysis can be used to design control programs that are directed to the most important aspects of the gypsy moth problem.

Sampling also presented a problem. We used more than one ownership class because we felt that impacts of gypsy moth would vary depending on objectives of ownership. Results showed that this was correct. But definition of ownership classes presented a difficult problem. Three criteria had to be met: 1) owners within a class must have experienced a gypsy moth infestation; 2) they should have fallen into a clearly defined ownership class; and 3) they should have been able to recall with some accuracy their experience with the gypsy moth. Because of the study design, responses were based on the first year of experience with the gypsy moth. This is because a continual program of control would have reduced the impacts we wanted to measure. The year for which people responded varied and consequently recall errors could be present. Further studies can be designed to reduce these sources of sampling error, but they will be more expensive than the present study. Preparation of sampling frames will be costly. It is uncertain whether useful information can be gathered through the mail questionnaire survey technique.

In future research, alternative techniques could be used to evaluate gypsy moth impacts. We feel our technique works. Major problems in conducting any such research are preparation of sampling lists, interviewer training, and cost. Additional research should also be done in other geographic areas and under different conditions of infestation.

The above limitations should be taken into account when using the information contained in this study. However, we feel the information is sufficiently accurate to begin the process of incorporating non-market impacts of gypsy moth into the decisionmaking process and to serve as a basis for designing control programs directed toward the most important aspects of the gypsy moth problem.

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Headquarters of the Northeastern Forest Experiment Station are in Upper Darby, Pa. Field laboratories and research units are maintained at:

- Amherst, Massachusetts, in cooperation with the University of Massachusetts.
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- Berea, Kentucky, in cooperation with Berea College.
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1977. **Economic analysis of the gypsy moth problem in the Northeast. III Impacts on homeowners and managers of recreation areas.** Northeast. For. Exp. Stn., Upper Darby, Pa.
9.p. (USDA For. Serv. Res. Pap. NE-360)

The economic impacts of a gypsy moth infestation on homeowners and on managers of recreation areas (commercial, public, and quasi-public) were determined from data collected via interviews with 540 homeowners and 170 managers of recreation areas in New York and Pennsylvania. The approach to measuring the impact of gypsy moth was to determine the interaction of a specific effect of an infestation (tree defoliation, tree mortality, nuisance) with a specific ownership objective (the reason a person has for owning or managing a property). Gypsy moth impact data were also collected on costs of controlling the gypsy moth, on financial losses resulting from infestation, and on person-days of recreational use of property lost by ownership class.

453- -145.7 x 18.77 *Lymantria dispar* L. : 652.54 : 907.2- -(74)

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Use of Computer Simulation in Designing and Evaluating a Proposed Rough Mill for Furniture Interior Parts

by
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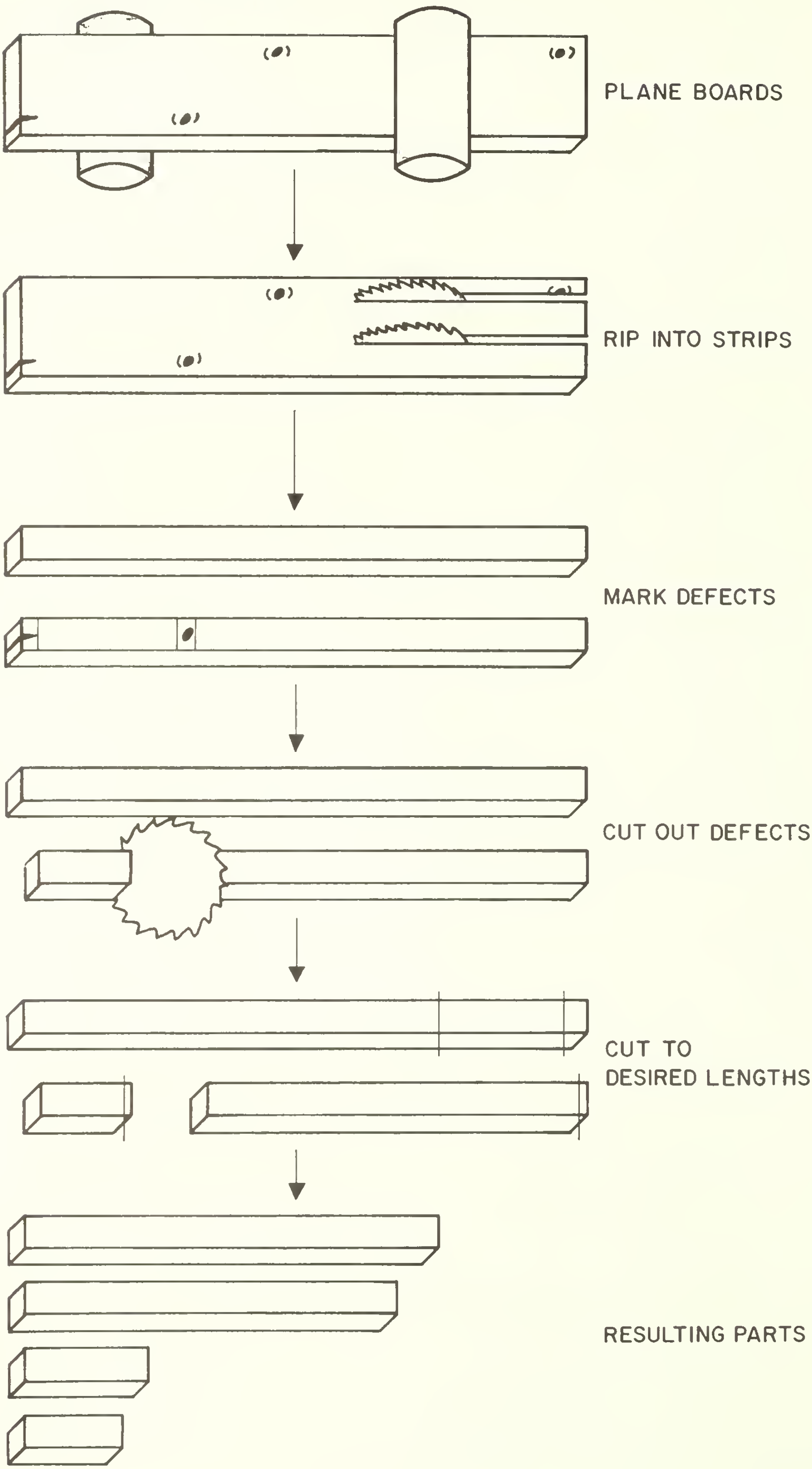
Use of Computer Simulation in Designing and Evaluating a Proposed Rough Mill for Furniture Interior Parts

ABSTRACT

The design of a rough mill for the production of interior furniture parts is used to illustrate a simulation technique for analyzing and evaluating established and proposed sequential production systems. Distributions representing the real-world random characteristics of lumber, equipment feed speeds and delay times are programmed into the simulation. An example is given of how bottlenecks are found and removed in order to design on paper a layout that will meet a set of goals before a single piece of equipment has been purchased. GPSS (a General Purpose Simulation System language) was used.

Keywords: models, simulation, operations research, systems analysis, plant layout, computer programs

Figure 1.—Sequence of operations used to produce interior parts from lumber



INTRODUCTION

THE TASK OF DESIGN and layout for many wood-processing systems can present very complex problems, especially where random events or elements have important effects on production. Converting rough lumber into furniture and dimension parts is a case in point. Because of the random occurrence of defects in rough lumber, it is usually not possible to predict exactly how much time it will take to complete each step in the manufacturing process. Other elements are also at work: the desired output changes from order to order; workers don't always work at the same speed; the capabilities of various machines differ; production rules can have unexpected or even bizarre effects on output; and different grades of lumber will also affect output.

This paper describes the use of a computer simulation technique for solving a design and layout problem of this type. The technique is widely applicable in the evaluation of proposed or existing systems. The development of a proposed automated rough mill for producing furniture interior parts is used as an illustration. Interior parts are frame parts used in the construction of furniture. Typically, they are cut to one thickness, but vary in length. Although made of sound material, they may contain defects.

WHY SIMULATION?

Simulation is the general process of developing and testing a model of a real system. There are a number of advantages to using the computer simulation approach to build and evaluate a hypothetical model of a rough mill. Simulation permits the designer to observe the model's performance before any equipment has been purchased and installed, thus reducing greatly the possibility of costly errors. Another advantage is flexibility. The model of the rough mill can be changed easily. Different equipment, different grades of lumber, and different cutting bills can be tested separately or in combination.

Simulation can generate test data that will show the effects on the whole system of any change in part of the system. Conclusions and decisions do not have to be based solely on data about productivity. Information about utilization, e.g., percent use (use time ÷ total time x 100) of manpower and equipment can be determined. Such information can be used to discover and eliminate production bottlenecks. In general, with computer-simulation techniques, one can see at once things that will occur over a period of time.

THE PROBLEM

Several possible manufacturing sequences for making interior parts from 4/4 yellow-poplar lumber were tested at the Forest Products Marketing Laboratory *(Lucas and Araman 1975, Araman and Lucas 1975)*. The sequences showed no differences in yield of parts, so the sequence considered best from a standpoint of automation and production control was selected for further development.

The manufacturing sequence was divided into four major segments (fig. 1): 1. Planing kiln-dried lumber to a uniform thickness; 2. Producing strips of standard width by gang-ripping the lumber; 3. Removing objectionable defects from the strips by crosscutting; and 4. Crosscutting the defect-free strips into several lengths, with the longest obtainable desired length being cut first. We needed to develop a layout for the sequence that would be capable of producing a specified amount of parts. And we needed to know what effect different grades of input lumber would have on the parts production per shift. Our objective was to design an efficient manufacturing system for interior parts that was capable of producing from either No. 1 or No. 2A Common 4/4 yellow-poplar lumber approximately 4,000 board feet of finished parts per 8-hour shift.

SIMULATION - THREE BASIC PARTS

There are three basic parts to any simulation: the model of the system being simulated; the required input information; and the interpretation of the output information.

THE SYSTEM

The initial system for the interior parts rough mill to be simulated contains the following sequence of operations (fig. 2):

1. *Lumber infeed*
   Rough, kiln-dried 4/4 yellow-poplar lumber, in random widths and in random lengths up to 16 feet, starts into the mill on a tilted breakdown hoist (1).
2. *Conveyor*
   The lumber is unstacked one layer at a time onto a cross conveyor (2).
3. *Infeed station*
   Worker A feeds the boards one at a time onto the planer infeed belt (3).
4. *Planer*
   The planer or facer and planer (4) skip planes the boards on both sides to a standard thickness.
5. *Canted infeed rolls*
   Coming out of the planer, the boards go onto a canted roller conveyor (5) that aligns the boards against a fence for feeding into the gang ripsaw.
6. *Gang ripsaw*
   The gang ripsaw (6) cuts the boards into standard-width strips.
7. *Offbearer station*
   Worker B tails the ripsaw and moves the edgings off and out of the way.
8. *Cross conveyor*
   From the tail of the ripsaw, the strips pass onto a cross conveyor (7) that takes the strips over to the marking station.
9. *Marking station conveyor*
   The strips move one at a time onto the marking station conveyor (8).
10. *Defect-marking station*
    Worker C inspects each strip on the conveyor and quickly marks it where it is to be cut to remove defects. If a strip has a defect at the end, such as a split or a knot, he makes a single mark to show where the bad end is to be cut off. Otherwise, the strip is marked on both sides of the defect. Marks are made with a conducting electrolytic solution.
11. *Automated defect saw*
    As the strip moves into the defect saw (9), an electronic sensing device locates the marks that worker C has made and trips a circuit that activates the automatic saw.
12. *Conveyor*
    Once the defects have been cut out, the resulting strips are of random lengths. A conveyor (10) carries them to another automated saw where they will be cut to the various lengths of interior furniture parts.
13. *Automatic cut-to-length saw*
    An automatic cut-to-length saw (11) can be controlled by a mini-computer or electronic circuit. Before a production run starts, information about the number of parts required of each desired length is fed into the controlling device. No operator is required to operate the saw. Cutting to length is done automatically as follows:
    a. The strip is advanced and is measured for the longest obtainable desired length,
    b. The strip is stopped and crosscut, producing a part,
    c. After the first cut has been made, the remaining section of strip is measured and cut to the next longest obtainable desired length. This procedure is continued until the piece remaining is shorter than the shortest desired part,
    d. After each part has been cut, the computer deducts one unit from the quantity required for that length,
    e. When no more cuttings are required, the counter for that length goes to zero,
    f. When all cutting requirements have been satisfied, the system stops and is reset for the next run.

After the strips have been cut to the desired lengths, they are moved on to an automatic sorter (not shown in figure 2). Then the parts are cut to final dimensions by molding and tenoning.

Figure 2.—Flow chart of the interior parts mill, initial layout.

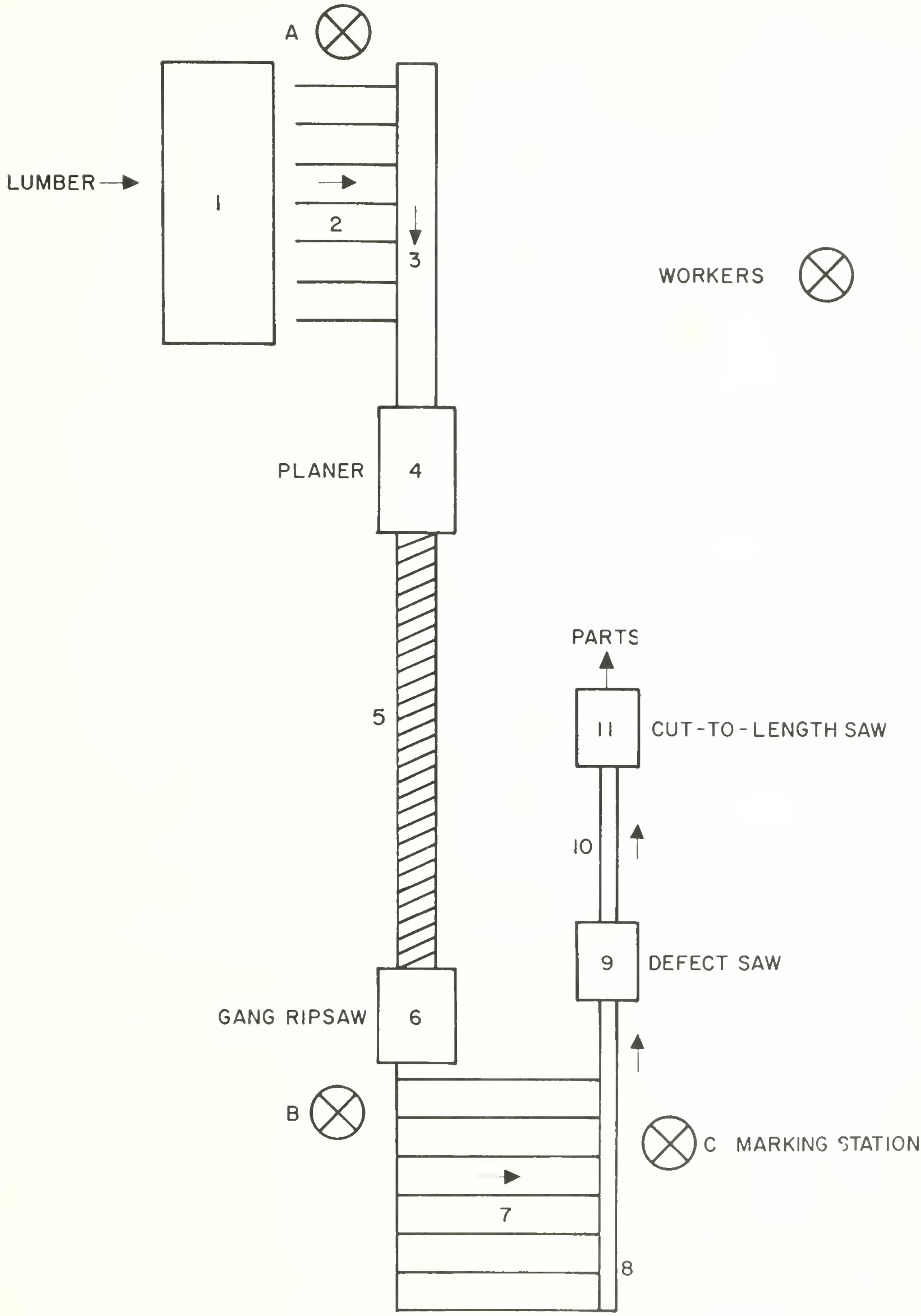


Table 1.—Cutting bills

A		B		C	
Cutting length	Number required	Cutting length	Number required	Cutting length	Number required
inches		*inches*		*inches*	
73	118	70	118	70	236
62	165	60	165	60	330
56	47	54	47	54	94
37	329	40	329	40	658
30	71	30	71	30	142
24	400	24	400	24	800
22	71	22	71	22	142
16	1081	16	1081	16	2162
13	71	13	71	13	142

The width of all parts is 1-11/16 inches.

THE INPUT

The information needed to simulate the system includes cutting bills, lumber-yield information for various grades of lumber, and instructions for operating the system.

Cutting Bills

The cutting bills, which list the parts required, must be typical of the system being studied. For our evaluation, we used three cutting bills (table 1). Each cutting bill contains nine cutting lengths and the number of each needed. The width for all parts was 1-11/16 inches and the lengths were changed from cutting bill A to develop cutting bill B and the quantities required were doubled to create cutting bill C.

Lumber-yield information

The raw material must be defined in terms of grade of lumber and the yield of parts for the system being evaluated. A description of the input lumber and the material left after each step in the manufacturing sequence must be developed by yield studies. This information is used in the simulation program to describe the material entering each operation in the sequence.

Our analysis of the production of interior parts from No. 1 and No. 2A Common 4/4 yellow-poplar lumber gave us the following lumber-input information for each grade, which was required to run the simulation:

1. A frequency distribution of the lengths of boards as they enter the system. The same distribution also describes the lengths of the strips

Table 2.—Distribution of board lengths

Length	No. 1 Common	No. 2A Common
ft.	*no.*	*no.*
5	1	0
6	0	2
7	0	1
8	15	5
10	5	16
12	25	20
13	1	1
14	18	23
15	1	0
16	10	7

Table 3.—Distribution of numbers of strips (1-11/16 inches wide) cut from each board

Number of strips per board	Number of boards	
	No. 1 Common	No. 2A Common
1	0	1
2	20	17
3	25	25
4	26	25
5	4	3
6	1	4

Table 4.—Distribution of numbers of defects per strip

Objectionable defects per strip	Number of strips	
	No. 1 Common	No. 2A Common
0	171	149
1	49	50
2	25	37
3	0	13

Table 5.—Lengths (in inches) of pieces remaining after removal of objectionable defects in the strips (assuming that defects are spaced equally along the strip)

Length of strips	Number of defects			
	0	1	2	3
60	60	27	18	13
72	72	33	22	16
84	84	39	26	19
96	96	44	30	22
120	120	56	37	28
144	144	67	44	33
156	156	72	48	36
168	168	77	51	39
180	180	83	55	42
192	192	89	59	44
Number of strips	1	2	3	4

cut from these boards by gang ripping (length is not affected by gang-ripping; table 2).

2. A frequency distribution of the number of strips produced by gang-ripping each board (table 3).

3. A frequency distribution of defects per strip describing the number of defects that have to be marked and cut out by the mark-sensing defect saw (table 4). This distribution depends on the quality of parts desired. For our study, defects that impaired the strength of a part or occurred on the ends of parts were objectionable.

4. A distribution of the usable lengths of the defect-free strips remain after defects have been cut out (table 5). For this simulation I assumed that the defects were spaced equally along the strips.

Operating instructions

Operating instructions and information needed to simulate the rough mill setup included a lumber-infeed rate, equipment speeds, belt speeds, time delays for marking strips, time delays for crosscutting, and travel distances. All of these are shown in table 6.

A lumber-infeed rate of five boards per minute was used. Worker A controls the flow by placing the boards on the planer infeed belt one at a time. To prevent overflows on the cross conveyor after the gang ripsaw, worker A stops feeding lumber into the system for 10 minutes when 100 or more strips are on the transfer belt.

Feed speeds for the planer-infeed belt, lumber planer, gang-rip-canted-infeed rolls, and gang ripsaw were all set at 100 feet per minute. Worker B is at the rear of the gang ripsaw to remove edgings. The cross conveyor has a feed speed of 25 feet per minute.

The time per strip required by the marker depends on the number of objectionable defects per strip, plus a fixed inspection time.

The two crosscut saw infeed belts are set for 60 feet per minute, and we used a 1-second delay for each crosscut.

In addition to the time delays, feed speeds, and distances, there was a constraint on the productivity of the marker: To insure the proper flow of materials through the defect and cut-to-length saws, the marker must wait for each

Table 6.—Information needed to simulate the rough mill setup

Equipment or operation	Length	Feed speed	Comments
	ft.	ft./min.	
Lumber infeed	7		Operator = controlled release rate = 5 boards/minute
Planer infeed belt	20	100	
Planer	8	100	
Canted infeed roll converyor	25	100	
Gang ripsaw	6	100	
Cross conveyor	18	25	
Defect marking	4	60	1 second delay for inspection plus time delay for marking defects
Automated defect saw	4	60	1 second delay for each cut
Conveyor	8	60	
Automatic cut-to-length saw	4	60	1 second delay for each cut

strip to clear the defect saw before he marks the next strip. This delay at the marking station was measured to see if it was creating a bottleneck in the system.

THE OUTPUT

Production statistics provided by the simulation include equipment and worker-utilization summaries and system-production rates. The equipment-use summaries will tell us if we need additional equipment where there are bottlenecks in the process. It could tell us that we have an inefficient operation, with too much equipment. The system-production rates will tell us if we have achieved the goal of designing a plant that will produce at least a minimum number of parts per 8-hour shift.

SIMULATING AND DESIGNING

Simulating and designing is a trial and error approach used to create a manufacturing layout that will satisfy a set of goals (fig. 3). For example, results from the initial layout simulation may show that the production rate is low. Then the bottleneck that is holding back production must be located and removed by redesigning the layout. Simulation with the redesigned layout may show adequate production rates, but also some inefficiencies in design. These can be removed, and the new design tested. The input raw material can be changed and the effect of this change can be studied.

The first step is to develop a program for simulating the initial design that includes all of the operating characteristics, the lumber-supply characteristics, and the desired product distributions. Once the simulation program has been written, you can begin testing and redesigning the layout (fig. 3).

RESULTS FROM THE INITIAL LAYOUT

We simulated operation of the system with No. 2A and then No. 1 Common yellow-poplar lumber as the input material. Production rates per 8-hour shift achieved for each grade were as follows:

	Rough lumber	*Finished parts*
	------ *bd. ft.* ------	
No. 1 Common	3100	2400
No. 2A Common	3100	2200

The difference in finished-parts footage is due to the lower yield of parts from the No. 2A Common lumber.

The production rates achieved did not meet the goal of approximately 4,000 board feet of finished parts per 8-hour shift. Therefore, the system was checked for bottlenecks by evaluating equipment use.

Table 7.—Percentage of time equipment was in use in initial layout

Item	Lumber grade	
	No. 1 Common	No. 2A Common
Planner	21	19
Gang ripsaw	24	21
Lumber delay	68	72
Marking station	100	100
Marker	25	26
Defecting saw	71	72
Cut-to-length saw	81	74

This analysis (table 7) showed that the marking station, which consists of the marker and the defecting saw, was the bottleneck in the system; it was 100 percent utilized. The percentage of use was low for the planer and gang ripsaw; each of these machines is capable of four times the present production. The lumber feed was delayed 68 and 72 percent of the production time. The defecting saw was used about 71 percent of the time with either grade.

The cut-to-length saw was used 81 percent of the production time for No. 1 Common lumber, but only 74 percent for No. 2A Common lumber. This difference was caused by two factors:

1. More material was removed from a No. 2A Common lumber before it reached the cut-to-length saw; and

2. Although the total time the cut-to-length saw was used was the same for both grades, the total production time was longer when No. 2A Common lumber was used, and this reduced the percentage utilization.

The equipment-use summary shows that the marker is working only 25 percent of the time, but he must wait for each strip to clear the defecting saw before he can feed the next strip.

The solution we chose for removing the hindrance at the marking station was to add a second defecting and cut-to-length saw combination after the marker. Each saw would have to

Figure 3.—Flow chart of design process using systems simulation to design a mill layout for specific needs.

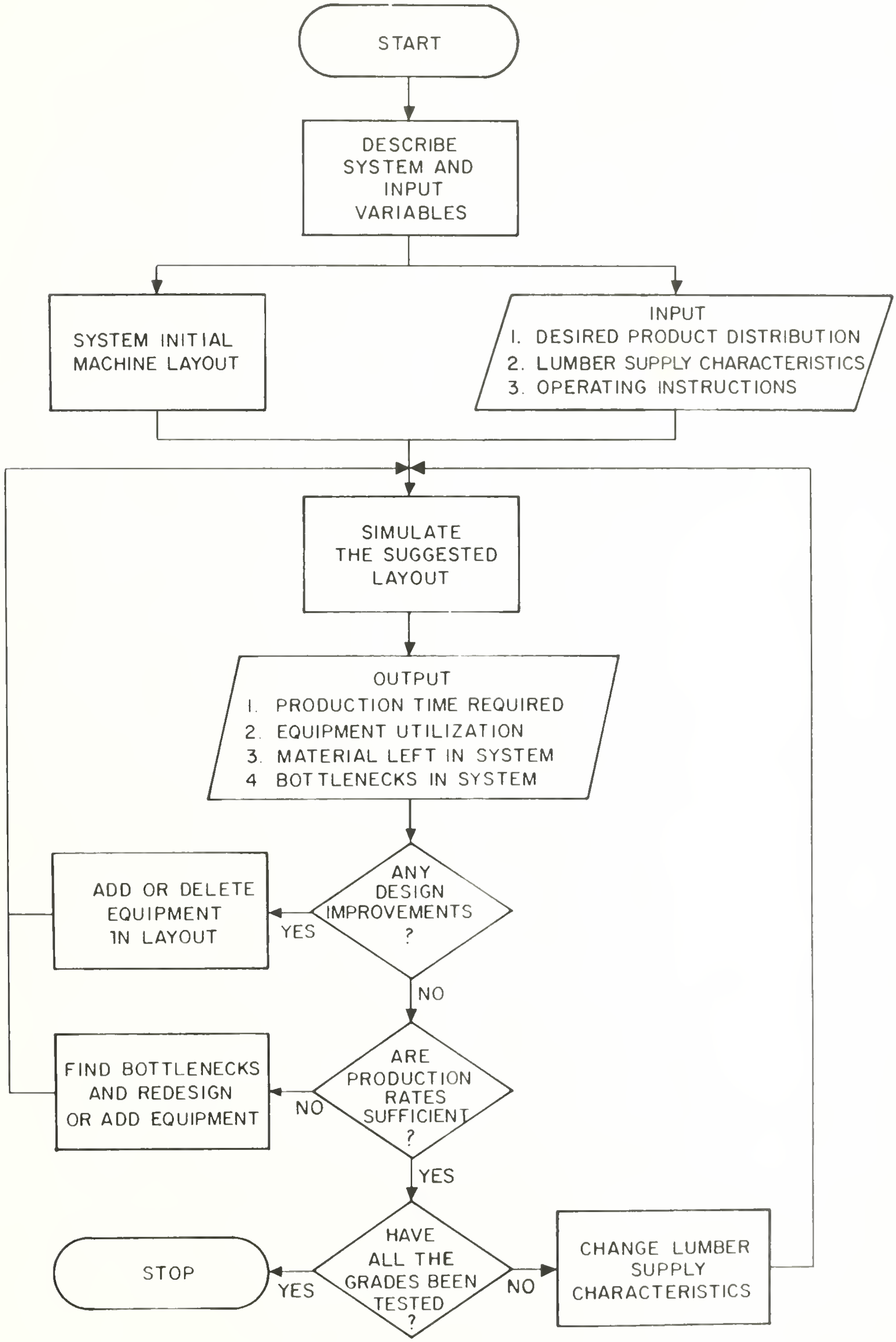
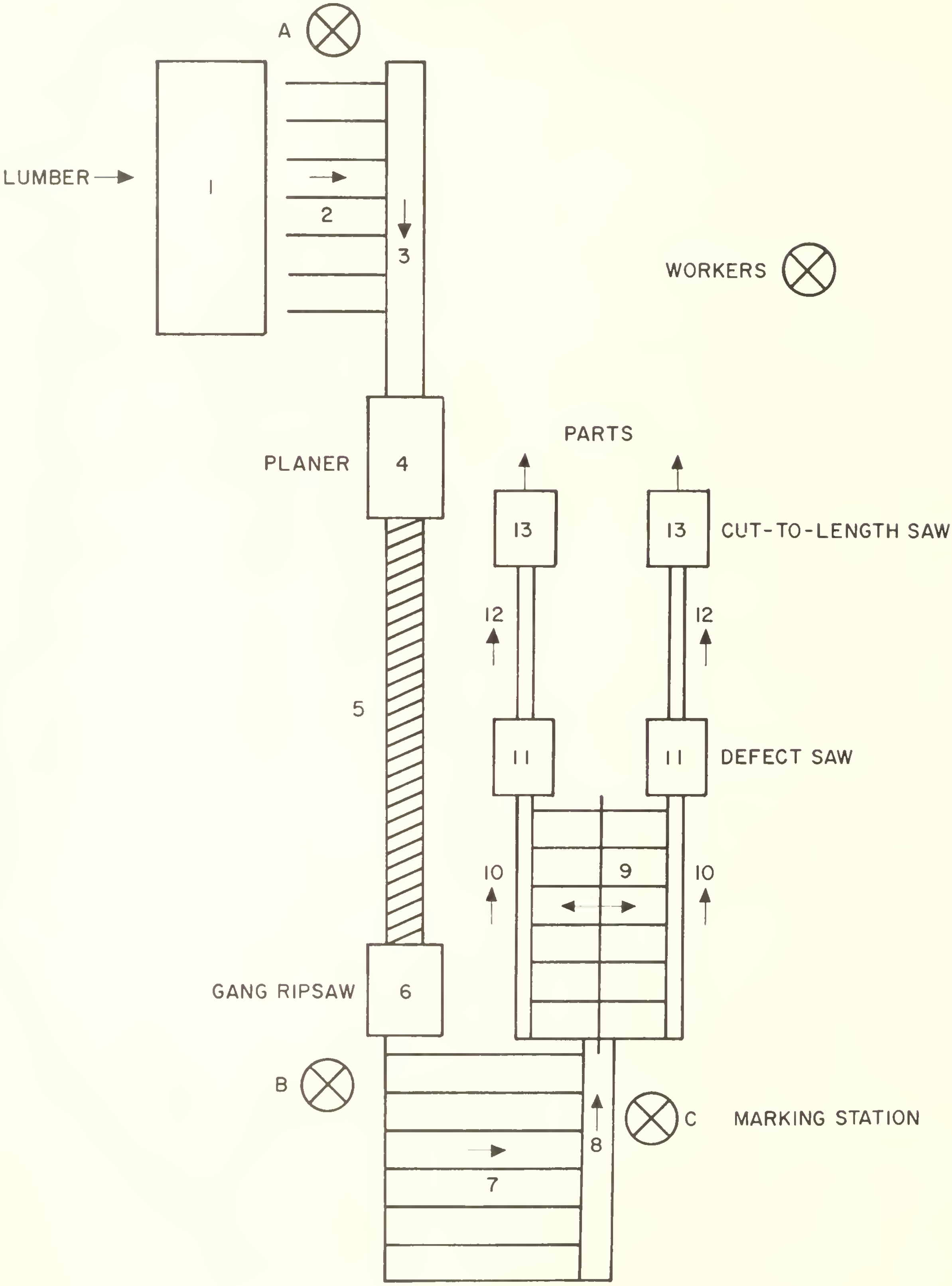


Figure 4.—Flow chart of the interior parts mill, modified layout.



remove defects only from every other strip. This modified layout is shown in figure 4.

RESULTS FROM THE MODIFIED LAYOUT

Simulations with the modified layout gave these production rates:

	Rough lumber	*Finished parts*
	------ *bd. ft.* ------	
No. 1 Common	5700	4400
No. 2A Common	5500	3900

We have achieved the objective of obtaining approximately 4,000 board feet of finished parts per 8-hour shift.

The use summary for the modified plant is presented in table 8. The effective use of the marker has almost doubled, although there is still a bottleneck at the marking station. But because production has been almost doubled by the addition of the second crosscutting line, the objective has been satisfied.

THE SIMULATION LANGUAGE

The simulation language we used was GPSS (General Purpose Simulation System), a package program available from IBM.

Listings of the programs used to evaluate and design the interior parts plant can be obtained from the author. Information about the language and its use is available in the literature *(Gordon 1969, IBM 1969, IBM 1971, IBM 1971b, Schriber 1974).*

Table 8.—Percentage of time equipment was in use in modified layout

Item	Lumber grade	
	No. 1 Common	No. 2A Common
Planner	29	27
Gang ripsaw	36	30
Lumber delay	59	56
Marking station	100	100
Marker	46	47
Line No. 1		
Defecting saw	65	66
Cut-to-length saw	74	67
Line No. 2		
Defecting saw	67	62
Cut-to-length saw	76	64

SUMMARY

Simulation has allowed us to design an interior parts plant that will meet a production goal set at 4,000 board feet of interior parts produced in an 8-hour shift. It has also allowed us to compare the effects of the use of No. 1 Common and No. 2A Common lumber on production rate and equipment utilization.

This technique is applicable to many systems, but is especially valuable in the analysis of random-input processes, such as the interior parts plant in this case. Similar problems, such as designing furniture-finishing lines or sawmill setups, could be investigated through computer simulation. However, there are several requirements for simulating a system:

1. The problem to be solved must be clearly stated;
2. The model should contain only pertinent activities of the system. Minor details in the system that do not influence production should be omitted;
3. The model should show the interactions of manpower and equipment as a function of time;
4. The model should be flexible, allowing for changes; and
5. Good quality input and description data must be used. The results are only as good as the input information provided.

In general, simulation permits a designer to observe the system's performance before any equipment is purchased and installed, thus reducing greatly the possibility of costly design errors.

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Headquarters of the Northeastern Forest Experiment Station are in Upper Darby, Pa. Field laboratories and research units are maintained at:

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Araman, Philip A.
1977. **Use of computer simulation in designing and evaluating a proposed rough mill for furniture interior parts.** Northeast. For. Exp. Stn., Upper Darby, Pa.
9 p., illus. (USDA For. Serv. Res. Pap. NE-361)

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The Influence of Stand Density and Structure on Growth of Northern Hardwoods in New England

by
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The Influence of Stand Density and Structure on Growth of Northern Hardwoods in New England

ABSTRACT

Growth of northern hardwoods over a 10-year period was studied in plots that were treated to produce residual densities of 40, 60, 80, and 100 square feet of basal area per acre with stand structures of 30, 45, and 60 percent sawtimber. Both diameter and basal area growth are tabulated by treatment and species.

THERE IS increased emphasis by landowners on intensive forest management, but the ability of a forest manager to make decisions for any stand of timber depends upon the growth information available to him. Regardless of the objectives—timber, aesthetics, recreation, water, or wildlife—the response of the residual stand depends on the treatment the stand receives. The residual density of a forest stand is the basis of silvicultural treatment, since density influences growth per acre. Therefore, management decisions that will result in maintaining the stand for different objectives can be made using residual stand density as a means of controlling growth response.

A study was established in a second-growth northern hardwood stand on the Bartlett Experimental Forest, Bartlett, N. H., to determine what average level of residual density will produce the best growth response. The stand originated from clearcutting 70 to 90 years ago and is composed primarily of beech, red maple, and paper birch, with some sugar maple and yellow birch, and a few white ash and miscellanous trees of other species.

METHODS

A total of 48 square 1/3-acre plots were laid out on a relatively uniform site. Each plot was surrounded by a 50-foot wide treated isolation strip.

Four levels of residual stand density were assigned at random to these plots: 100, 80, 60, and 40 square feet of basal area per acre in trees 4.5 inches dbh and larger. Within each level of residual stand density, three levels of residual stand structure were randomly assigned: 30, 45, and 60 percent sawtimber (trees 10.5 inches dbh and larger). The plot layout consisted of four plots with each of these 12 combinations, in a completely randomized design.

To bring stand structure to the level assigned to each plot, unwanted trees were frilled and treated chemically in the fall of 1963. Trees that were diseased or dying were removed first, and then trees were removed at random to meet the plot treatment specifications. Most plots were similar in species composition, but on a few plots some effort was made to make species composition similar to that of the total area (table 1). Trees that did not die were re-treated

Table 1.—Initial species composition on study plots (in percent)

Treatment		Species								
Residual basal area	Percent Sawtimber	Beech	Yellow birch	Sugar maple	Red maple	Paper birch	White ash	Red spruce	Hemlock	Other
ft²/acre										
	30	25.6	10.0	—	32.3	23.7	.8	—	7.6	—
40	45	24.3	3.4	4.5	26.0	21.4	7.5	—	12.9	—
	60	39.0	7.8	5.5	21.8	19.1	1.0	—	5.5	.3
	All	29.6	7.1	3.3	26.7	21.4	3.1	—	8.7	.1
	30	51.7	12.5	6.0	6.5	10.4	7.5	1.0	4.4	—
60	45	37.5	11.1	3.7	21.3	19.0	.7	—	6.7	—
	60	14.7	3.8	5.5	37.7	28.9	—	—	9.4	—
	All	34.7	9.2	5.1	21.7	19.4	2.7	.4	6.8	—
	30	23.0	9.3	6.6	35.4	14.0	2.0	—	9.4	.3
80	45	36.5	6.4	8.6	16.0	27.3	.9	1.1	3.2	—
	60	35.2	12.0	11.6	16.3	12.6	5.3	1.7	5.3	—
	All	31.6	9.2	8.9	22.6	18.0	2.7	.9	6.0	.1
	30	8.4	4.1	3.5	45.3	23.5	1.2	.4	10.1	3.5
100	45	36.4	13.7	1.0	22.8	17.8	—	.2	8.1	—
	60	21.7	9.4	11.1	34.4	14.7	1.8	.5	6.4	—
	All	22.1	9.1	5.2	34.2	18.6	1.0	.4	8.2	1.2

in the spring of 1964. Initial diameter measurements and marking were done after the growing season of 1964, and a few frilled trees that remained alive were cut to complete the treatments.

All trees on the 1/3-acre plot were recorded by species and measured to the nearest 0.1 inch; each tree was numbered and the point of diameter measurement (usually 4.5 feet) was marked with paint. Plots were reinventoried 3, 5, 8, and 10 growing seasons after installation. Reproduction information was taken after 9 growing seasons *(Leak and Solomon 1975)*.

Basal area growth was averaged for the four plots that received each treatment and then placed on an annual basis for comparison with gross growth, production, accretion, ingrowth, and mortality. A stepwise regression analysis was used to develop relationships between these dependent growth measures and the residual basal area and percentage of sawtimber in the stand. The independent variables were residual basal area, residual basal area squared, percent sawtimber, percent sawtimber squared, and the interaction of residual basal area and percent sawtimber. The interaction of basal area and percent sawtimber is the same as the residual basal area in sawtimber. It is given because the residual basal area in sawtimber was not used as an independent variable.

Both diameter growth and basal area growth were analyzed by species and size class for the different treatments. The diameter growth per tree was computed on an annual basis by species for each treatment. The diameter growth per tree was then computed separately for survivor trees, ingrowth trees, and trees that died during the study.

BASAL AREA GROWTH

The terms used in this paper have been previously defined by others *(Erdmann and Oberg 1973; Forbes 1955; Blum and Filip 1963; Gilbert 1954; Beers 1962; Marquis and Beers 1969; Frayer 1967)*.

Survivor growth—Increase in basal area of trees present at both inventories.

Accretion—Increase in the basal area of all trees present at the initial inventory, plus ingrowth accretion. This includes accretion on trees in the survivor, ingrowth, and mortality groups *(Frayer 1967)*.

Ingrowth—Trees that grew larger than the threshold size (4.5 inches) between inventories.

Mortality—Trees that died during the period (including ingrowth).

Production—(Net increase)—The net change in basal area between two inventories (accretion + ingrowth - mortality).

Gross growth—Total basal area produced by all trees during the period (production + mortality).

Gross Growth

Average annual gross growth in basal area remained relatively constant over a range of treatments based on residual basal area and size class (table 2). This was true also in other studies of northern hardwoods, both in the Northeast *(Blum and Filip 1963; Solomon and Leak 1969; MacMoller 1947)* and in the Lake States *(Church 1960; Erdmann and Oberg 1973; Eyre and Zilligitt 1953)*.

There is a slight decline in gross growth as both residual basal area and the percentage of sawtimber increase. More open stands of smaller trees apparently produce higher rates of gross basal area growth than more densely stocked stands of larger trees. This additional growth may occur because stands in the lower residual densitites do not fully utilize the site, and thus leave space for greater annual growth. Or the greater basal area growth of poletimber may not mean greater growth in volume.

Production

The average annual basal area production per acre for the total stand decreased as residual basal area per acre increased and as the percentage of sawtimber in the stand increased (table 2). Studies in both New England and the Lake States have indicated that production decreases as residual basal area increases. The total production of an approximately balanced stand of pole and sawtimber is 1.2 square feet annually for 100 square feet of basal area. This agrees with work by Church *(1960)* and with work by Leak *(1961)* in younger stands. However, Jensen *(1941)* and Blum and Filip *(1963)*, working in slightly older stands, found production to be 2.3 square feet annually. Blum and Filip *(1963)* and Church *(1960)* show an increase in production as residual basal area increases; Leak *(1961)* shows an increase to 2.3 square feet for the lowest den-

Table 2.—Average annual gross growth, production, accretion, ingrowth, and mortality by size class and treatment (in square feet of basal area per acre)

Residual basal area	Percent saw-timber [a]	Gross growth	Production			Accretion			Ingrowth		Mortality		
			Pole-timber	Saw-timber	Stand Total	Pole-timber	Saw-timber	Stand Total	Pole-timber	Saw-timber	Pole-timber	Saw-timber	Stand Total
40	30	2.73	0.79	1.43	2.22	1.39	0.51	1.90	0.83	1.17	0.26	0.25	0.51
	45	2.58	.67	1.33	2.00	1.10	.68	1.78	.80	.90	.33	.25	.58
	60	2.59	1.33	.51	1.84	1.10	.69	1.79	.80	.40	.16	.59	.75
60	30	2.38	.40	1.31	1.71	1.35	.55	1.90	.48	1.04	.39	.28	.67
	45	2.51	.63	1.66	2.29	1.16	.76	1.92	.59	.90	.22	—	.22
	60	2.33	.40	1.61	2.01	.88	.88	1.76	.57	.86	.20	.12	.32
80	30	2.18	-.26	1.95	1.69	1.31	.64	1.95	.23	1.31	.49	—	.49
	45	2.13	.05	1.62	1.67	1.11	.71	1.82	.31	1.13	.24	.22	.46
	60	1.94	.20	.95	1.15	.70	.92	1.62	.32	.59	.24	.55	.79
100	30	2.45	-.11	1.85	1.74	1.32	.70	2.02	.43	1.40	.46	.25	.71
	45	2.16	-.36	1.57	1.21	1.01	.83	1.84	.32	1.22	.47	.48	.95
	60	1.86	-.19	1.10	0.91	.62	1.07	1.69	.17	.50	.48	.47	.95

[a] Trees from 4.5 inches to 10.5 inches dbh were classified as poletimber; trees more than 10.5 inches dbh were classified as sawtimber.

Table 3.—Annual accretion by species, size class, and treatment (in square feet of basal area per acre)

Species	Size	Treatment											
		40			60			80			100		
		30	45	60	30	45	60	30	45	60	30	45	60
Beech	Poletimber	.42	.37	.37	.65	.48	.22	.36	.48	.28	.24	.45	.23
	Sawtimber	.10	.09	.19	.29	.27	.10	.09	.28	.32	.01	.27	.20
Sugar maple	Poletimber	—	.07	.04	.10	.04	.03	.05	.04	.06	.03	.01	.05
	Sawtimber	—	.01	.08	.03	.01	.06	.02	.03	.05	.01	.00	07
Yellow birch	Poletimber	.05	.05	.05	.13	.09	.01	.07	.06	.09	.03	.12	.09
	Sawtimber	.03	.01	.03	.05	.03	.03	.04	.01	.06	.02	.04	.01
Paper birch	Poletimber	.07	.04	.01	.05	.08	.04	.07	.15	.03	.11	.05	.01
	Sawtimber	.11	.09	.14	.04	.15	.19	.10	.18	.12	.18	.14	.15
Red maple	Poletimber	.44	.28	.17	.18	.17	.34	.43	.14	.20	.44	.15	.22
	Sawtimber	.19	.18	.21	.03	.20	.33	.22	.20	.16	.36	.23	.38
White ash	Poletimber	.00	.02	.04	.05	.01	—	.02	.03	.01	.01	—	.01
	Sawtimber	—	.11	—	.06	—	—	.03	—	.06	.01	—	.04
Hemlock	Poletimber	.41	.27	.41	.16	.30	.24	.28	.21	.02	.40	.24	.03
	Sawtimber	.07	.20	.05	.05	.11	.17	.15	.00	.15	.11	.16	.19
Red spruce and other	Poletimber	.00	.01	.00	.02	—	.00	.01	.00	.00	.07	.00	—
	Sawtimber	—	—	—	—	—	—	—	.02	.01	.02	—	.02

sity class. Some of these differences may be attributable to the range in basal area and size classes.

Annual sawtimber production showed no relation to residual basal area but decreased as the percentage of sawtimber increased (tables 2 and 3). Although Church *(1960)* showed a similar increase and then decrease in average annual sawtimber production, his results were not over a range of residual percentages of sawtimber. Sawtimber production was highest where only 25 to 30 square feet of sawtimber remained in the residual stand, and there was a high percentage of poletimber. Apparently, a high rate of sawtimber growth depends on a high rate of ingrowth into the smaller sawtimber sizes.

Annual poletimber production decreased as residual basal area increased (table 2). However, the change in percentage of sawtimber up to 60 percent did not have a significant influence on poletimber production. The production remains positive up to approximately 80 square feet and then becomes negative. The negative or zero poletimber production in the higher basal areas is not necessarily detrimental; it could mean that the density of smaller trees in the stand is declining slightly or remaining constant.

The basal area growth for the four measurement periods is indicated in figure 1. When the period growth rate is compared with the production increases in table 2, it becomes apparent that 60 square feet of basal area with 45 percent or more sawtimber maintains the best growth response over all the measurement periods. Growth has slowed after 8 years in plots with 80 and 100 square feet of basal area. The high response maintained in plots with 40 square feet is due mainly to the high ingrowth. However, such a stand is understocked for optimum growth *(Solomon and Leak 1969).*

Accretion

The average annual accretion was approximately the same for the four levels of residual basal area but decreased slightly with increases in percentage of sawtimber (table 2).

Although other work also indicates a small change in accretion as residual basal area increases *(Leak 1961; Blum and Filip 1963; Gilbert et al. 1955),* the change in accretion in this study is less than the others reported. This is probably due to the differences in the percentage of sawtimber, especially since the sawtimber has a lower annual accretion.

The accretion of poletimber decreased as the percentage of sawtimber increased for all levels of basal area (table 2). The decrease in poletimber growing stock may be the major reason for the decline.

The sawtimber accretion not only increased as the percentage of sawtimber increased; it increased slightly as the basal area per acre increased (table 2). Apparently, sawtimber accretion increases as trees grow from poletimber to sawtimber size.

Ingrowth

As expected, poletimber ingrowth for the stand decreased as the basal area increased (table 2). Although the ingrowth at most of the density levels was almost the same for the three percentages of sawtimber, there was a marked decrease as the percentage of sawtimber increased at the 100-square-foot level. The percentage of sawtimber did not appear to influence the ingrowth unless more than half of the stand was in sawtimber-size trees, although the sapling size distribution is unknown. Ingrowth should decrease as the density of the stand increases.

Leak *(1961)* found that ingrowth in 60-year-old northern hardwoods decreased as residual basal area increased. Other work in slightly older northern hardwoods showed more ingrowth than this study *(Blum and Filip 1963).* This may be attributed to the more extensive cutting of large trees and the different stand ages.

Over the 10-year period, the basal area growth of trees that grew from poletimber to sawtimber size is shown as sawtimber ingrowth in table 2. Sawtimber ingrowth was less where the percentage of sawtimber in the residual stand was higher at each density level because the sawtimber ingrowth trees were fewer and their growth was slower where the percentage of sawtimber was higher. The sawtimber ingrowth was slightly higher where the residual basal area was higher.

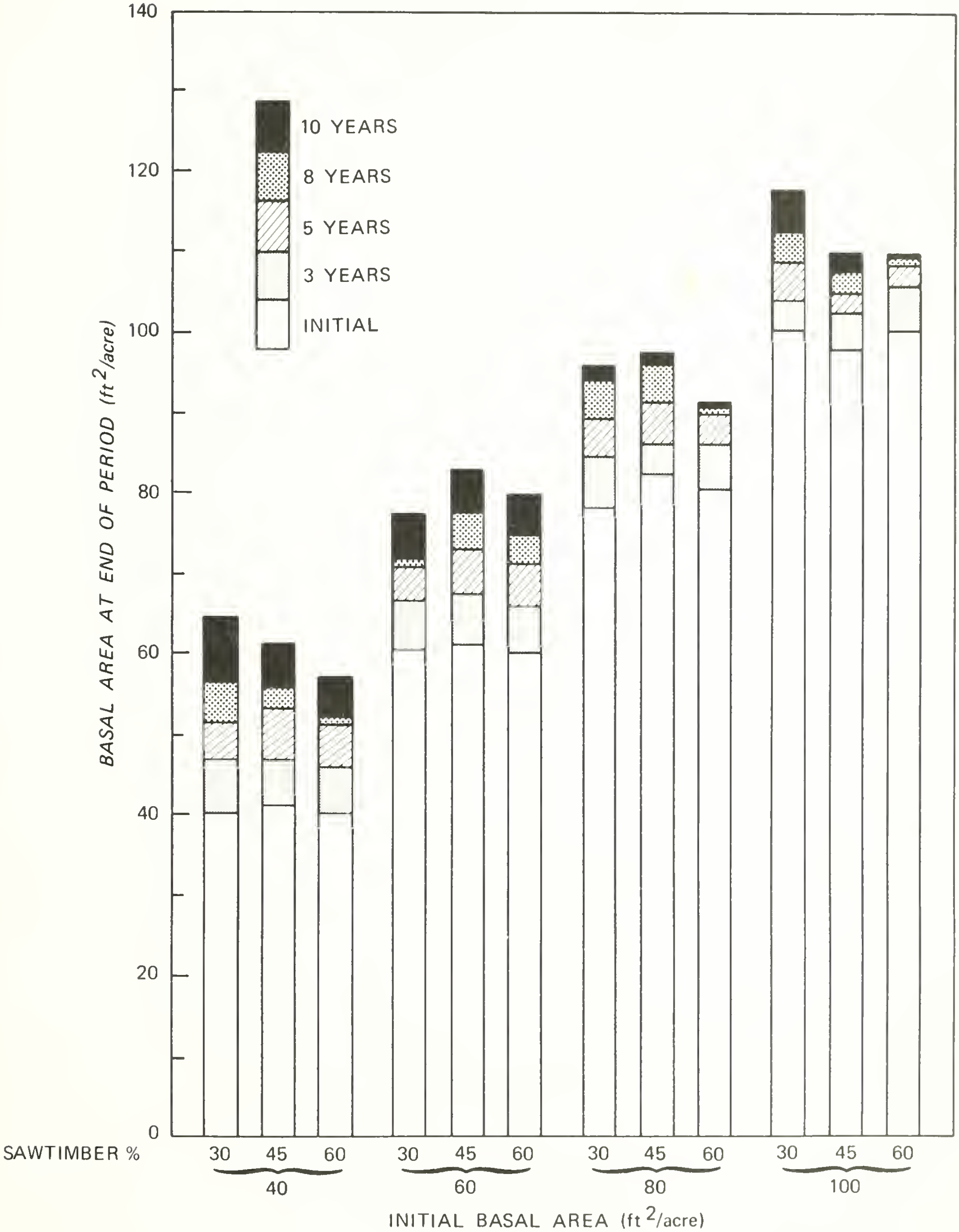
Mortality

The average annual mortality for the entire stand was not clearly related to residual basal area or percentage of sawtimber (tables 2 and 3), although mortality approximately doubled when the residual basal area was increased from 40 to 100 square feet and the percentage of sawtimber increased.

Mortality was similar to that found by Leak *(1961)* but was less than that found by Blum and Filip *(1963).* The sugar maple stands of the Lake States have lower mortality than the hardwood stands of New England *(Church 1960; Eyre and Longwood 1951; Erdmann and Oberg 1973).*

Although separate equations were not developed, mortality of poletimber increased as density increased and as percentage of sawtimber decreased. Mortality of sawtimber tends

Figure 1.—Basal area at the ends of consecutive growth periods for the 12 different treatments (poletimber and sawtimber combined).



to be lower when there is a lower percentage of sawtimber in the residual stand. However, the relatively high mortality of sawtimber in the stands with low residual basal areas may be due to the beech scale-nectria complex on beech, since most of it was in beech.

BASAL AREA GROWTH RATES BY SPECIES

The average annual accretion by species showed that hemlock, beech, and red maple responded the most to different levels of residual basal area (table 3). Accretion of all three species decreased as the residual basal area increased and as the percentage of sawtimber increased. Some of this may be due to the decrease in the amount of poletimber in the residual stand.

To compare the basal area accretion of different species, I expressed the annual accretion as a percentage of the initial basal area (table 4). Overall, poletimber outgrew sawtimber up to approximately 80 square feet of basal area. In the higher basal area classes, sawtimber makes better use of the growing space than poletimber. The percentage of annual accretion for sawtimber decreased as the percentage of sawtimber in the stand increased. The higher the stocking level of larger trees, the less the accretion percentage. Poletimber accretion does not follow a set pattern as the percentage of sawtimber in the stand increases.

Beech, hemlock, and red maple had a higher percentage of annual accretion than the totals for all species combined. The percentages for hemlock were the highest of all species, approximately double those of the second highest, beech. The two high percentages at 40 square feet of basal area with 60 percent sawtimber and the high percentage of 80 square feet with 60 percent sawtimber were due to the low initial basal area and high annual growth. Sugar maple, yellow birch, and paper birch were the same with all treatments, with some decrease as basal area increased and percentage of basal area increased.

The mortality of poletimber was highest for beech, and was not closely related to density or to percentage of sawtimber (table 5). However, beech mortality tended to be highest with 40 square feet of basal area. Most of the mortality was in beech because of the beech scale-nectria complex. The mortality for the other species was

Table 4.—Annual accretion, by species, size class, and treatment (in percent of initial basal area)

Species	Size	Treatment											
		40			60			80			100		
		30	45	60	30	45	60	30	45	60	30	45	60
Beech	Poletimber	7.06	5.79	7.41	3.02	3.83	4.36	2.61	2.68	2.60	3.14	2.26	2.23
	Sawtimber	2.32	2.55	1.80	3.00	2.63	2.67	2.06	2.45	1.83	1.27	1.69	1.74
Sugar maple	Poletimber	—	3.85	3.48	3.44	2.48	1.90	1.10	0.90	1.29	1.01	2.04	1.02
	Sawtimber	—	.00	7.62	4.11	1.59	3.55	3.08	1.21	1.09	2.17	.00	1.13
Yellow birch	Poletimber	2.17	3.65	3.09	2.23	2.15	1.96	1.18	1.34	1.64	1.11	1.19	1.16
	Sawtimber	1.75	.00	2.04	2.87	1.19	1.71	2.86	1.59	1.45	1.41	1.18	.62
Paper birch	Poletimber	1.18	1.62	0.79	1.64	1.67	1.03	1.48	1.84	1.23	1.11	0.82	0.78
	Sawtimber	3.08	1.44	2.21	1.23	2.22	1.42	1.57	1.32	1.57	1.32	1.22	1.11
Red maple	Poletimber	4.43	3.44	5.20	5.40	3.17	2.60	2.20	2.43	2.72	1.44	1.33	1.69
	Sawtimber	6.31	8.26	3.90	5.36	2.65	3.53	2.66	2.82	2.79	2.41	2.06	1.76
White ash	Poletimber	0.00	9.09	10.53	2.20	2.44	—	1.83	4.35	3.85	1.82	—	6.25
	Sawtimber	—	3.85	—	2.68	—	—	6.67	—	1.51	1.45	—	2.38
Hemlock	Poletimber	16.30	14.83	53.25	14.68	12.24	15.48	5.96	8.11	25.00	4.58	4.54	2.00
	Sawtimber	14.00	5.80	3.55	3.18	6.87	4.17	5.60	0.00	3.58	8.27	6.06	3.03
Red spruce & other	Poletimber	0.00	0.00	0.00	3.23	—	0.00	4.76	0.00	—	1.77	0.00	—
	Sawtimber	—	—	—	—	—	—	—	.00	0.00	.00	—	0.00
Total	Poletimber	5.15	4.88	8.11	3.30	3.70	3.42	2.40	2.51	2.26	1.97	1.89	1.65
	Sawtimber	3.89	3.72	2.67	2.78	2.59	2.59	2.65	1.97	1.87	2.10	1.84	1.70

so small that the maples were combined into one category and all others into a third. Sawtimber follows a pattern similar to that of poletimber.

Although most of the mortality that occurred was in beech, the greatest basal area ingrowth was also in beech (table 6). Hemlock was second in the amount of ingrowth, followed by red maple.

Red maple produced the most ingrowth into the sawtimber class (table 7). Beech, yellow birch, and paper birch also had substantial sawtimber ingrowth. Although hemlock did well where it was growing, the larger sizes were not well represented in all treatments. For all species, the 80- and 100-square-foot residual basal area treatments seemed to provide

Table 5.—Annual mortality, by species and treatment (in square feet of basal area per acre and percentage of initial basal area)

Species	Unit	Treatment											
		40			60			80			100		
		30	45	60	30	45	60	30	45	60	30	45	60
		POLETIMBER											
Beech	Ft²/acre	0.10	0.24	0.16	0.25	0.22	0.15	0.24	0.14	0.12	0.13	0.22	0.22
	percent	1.68	3.76	3.21	1.16	1.76	2.97	1.74	.78	1.12	1.70	1.10	2.14
Maples	Ft²/acre	0.07	0.06	—	—	0.01	0.05	0.17	0.05	0.10	0.22	0.14	0.13
	percent	.71	.60	—	—	.14	.34	.71	.49	.83	.66	1.19	.73
Others	Ft²/acre	0.09	0.03	—	0.13	—	—	0.08	0.04	0.03	0.11	0.10	0.13
	percent	.81	.51	—	1.01	—	—	.48	.25	.36	.43	.46	1.39
		SAWTIMBER											
Beech	Ft²/acre	0.18	0.20	0.55	0.22	—	0.06	—	0.14	0.37	0.08	0.43	0.37
	percent	4.18	5.67	5.22	2.28	—	1.60	—	1.23	2.11	10.00	2.70	3.23
Maples	Ft²/acre	0.08	0.06	—	—	—	—	—	—	—	—	—	0.10
	percent	2.66	2.75	—	—	—	—	—	—	—	—	—	0.36
Others	Ft²/acre	—	—	0.05	0.06	—	0.06	—	0.08	0.18	0.17	0.05	-
	percent	—	—	.54	.68	—	.31	—	.54	.84	1.00	.29	—

Table 6.—Average annual ingrowth of poletimber by species and treatment (in square feet of basal area per acre)

Residual basal area	Percent sawtimber	Species							
		Beech	Sugar maple	Yellow birch	Paper birch	Red maple	Hemlock	White Ash Red spruce Other	Total
	30	.23	—	.02	.02	.30	.25	.01	.83
40	45	.37	—	.04	—	.16	.19	.04	.80
	60	.36	.03	.02	—	.08	.29	.02	.80
	30	.22	.01	.04	—	.02	.19	—	.48
60	45	.29	—	.04	.01	.03	.22	—	.59
	60	.26	.03	.01	.01	.07	.18	.01	.57
	30	.11	.01	—	—	.04	.07	—	.23
80	45	.15	.02	—	.02	.02	.10	—	.31
	60	.12	.02	.02	—	.07	.08	.01	.32
	30	.17	.01	.01	—	.06	.16	.02	.43
100	45	.18	.02	.01	—	—	.11	—	.32
	60	.09	—	.01	—	.04	.03	—	17

Table 7.—Average annual ingrowth of sawtimber by species and treatment (in square feet of basal area per acre)

Residual basal area	Percent sawtimber	Species							
		Beech	Sugar maple	Yellow birch	Paper birch	Red maple	Hemlock	White Ash Red spruce Other	Total
	30	—	—	.22	.32	.54	.09	—	1.17
40	45	.18	.09	.04	—	.45	.14	—	.90
	60	.04	.04	.04	.09	.18	—	—	.40
	30	.54	.09	.14	.05	.09	.04	.09	1.04
60	45	.27	—	.14	.22	.18	.09	—	.90
	60	.09	.04	—	.14	.59	—	—	.86
	30	.18	.04	.14	.04	.59	.22	.09	1.31
80	45	.54	.09	.04	.18	.23	.05	—	1.13
	60	.32	—	—	.09	.18	—	—	.59
	30	.09	—	.04	.23	.63	.23	.18	1.40
100	45	.32	—	.27	.18	.27	.18	—	1.22
	60	.09	.04	—	.14	.23	—	—	.50

favorable conditions for sawtimber ingrowth. Also, as might be expected, the lower percentages of sawtimber in the initial stand for all density levels allowed greater amounts of sawtimber ingrowth.

STRUCTURE

Changes in stand structure for the 10-year growth period are shown in figure 2; the average numbers of trees per acre are plotted over the average diameter for the four plots of each treatment. An increase in ingrowth can be seen in the 5- and 6-inch classes for the 40- and 60-square foot basal area levels; the poletimber sizes also increased over the 10-year period and the size distribution quickly regained a reverse J-shape. At the denser treatment level of 80 square feet, the distribution was maintained in the poletimber class and the number of trees crossing into sawtimber class increased. At the 100-square-foot level there was little or no increase in the poletimber size classes and the sawtimber was maintained. Thus the stand structure at the 80-square foot level remained approximately the same; at the 100-square-foot level there was some decrease in trees, indicated by the mortality increase at the 100-square foot level.

Changes in stand structure occurred mostly in the smaller diameter classes for the lower basal areas and in the larger diameters in the larger basal areas over the 10-year period. The increase in size served to be more uniform for the larger trees than for the poletimber-size trees.

Changes in percentage of sawtimber had no noticeable effect on size distribution.

DIAMETER GROWTH RESULTS

Within density treatments, the average annual diameter growth did not differ among the four remeasurement intervals in the 10-year growth period (table 8). Only the growth of poletimber at the 100-square-foot level declined in average annual rate as the inventory period lengthened. There was a slight decline in the average diameter growth of sawtimber as the period increased, but the annual rates remained similar over most time periods.

Poletimber diameter growth decreased as the level of density increased. The annual diameter growth ranged from 0.06 inches to 0.20 inches. However, there was a decline in the annual rate as the percentage of sawtimber increased at the 80- and 100-square-foot density levels.

The relationship between annual poletimber diameter growth per tree and residual density for the 10-year period may be expressed by:

Poletimber diameter growth $= .2361 - .0018\,(x_1)$
here x_1 = residual basal area in square feet.

This equation is significant at the 5 percent level with $r = .90$ and standard error of mean $y = .0029$.

Figure 2.—Distribution of diameters at initial inventory and 10 years later, for each of the 12 treatments.

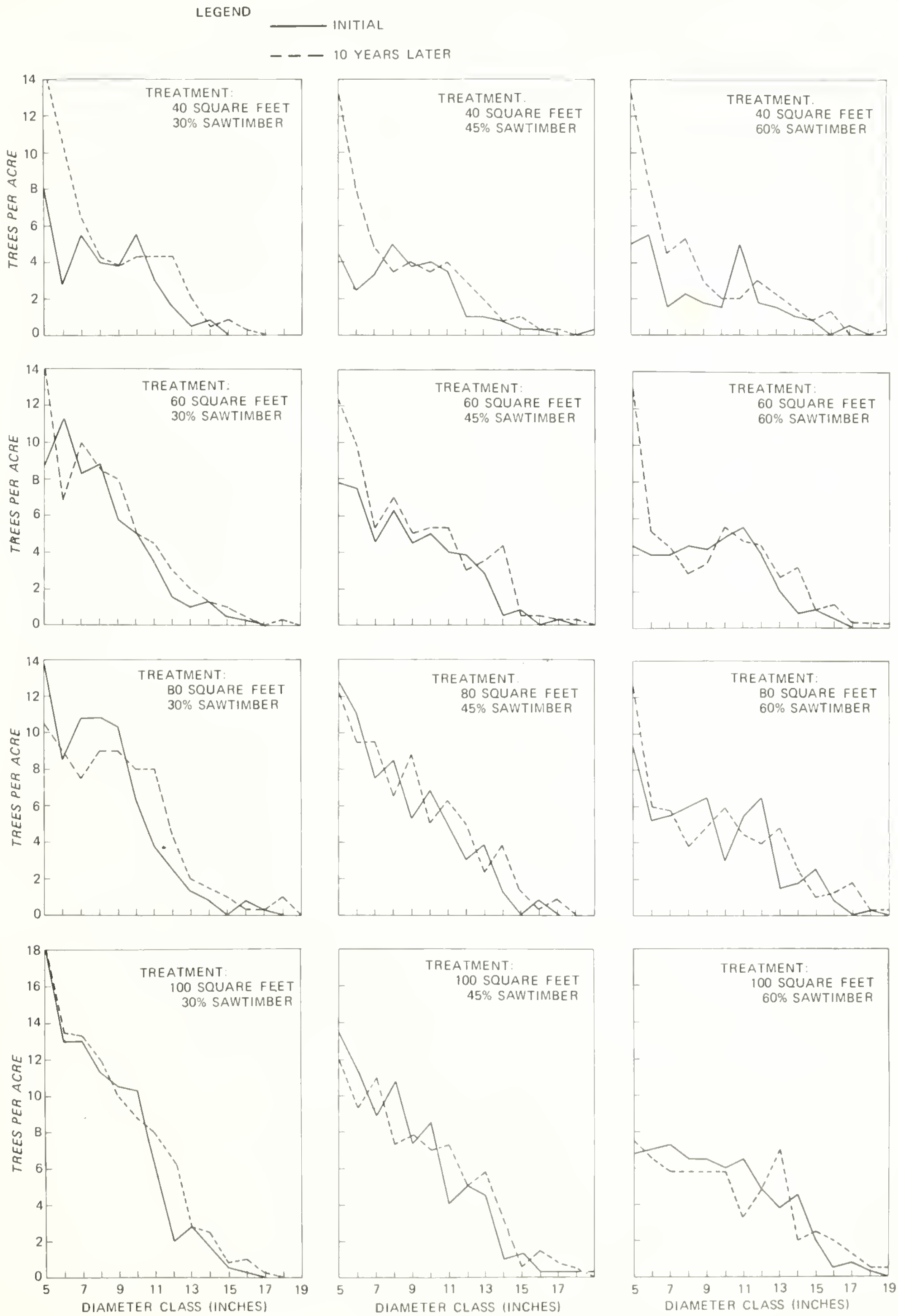


Table 8.—Average annual diameter growth by treatment and size class for different growth periods (in inches)

Residual basal area	Percent sawtimber	Period in years 0–3	0–5	0–8	0–10
		POLETIMBER			
40	30	.16	.17	.16	.17
	45	.15	.17	.16	.16
	60	.19	.20	.19	.20
60	30	.12	.13	.11	.12
	45	.13	.13	.12	.13
	60	.12	.13	.12	.12
80	30	.09	.09	.09	.09
	45	.11	.10	.09	.09
	60	.09	.09	.08	.08
100	30	.08	.08	.07	.07
	45	.09	.08	.07	.08
	60	.08	.07	.06	.06
		SAWTIMBER			
40	30	.16	.16	.15	.15
	45	.15	.15	.16	.17
	60	.17	.16	.15	.15
60	30	.12	.14	.12	.13
	45	.15	.14	.13	.13
	60	.13	.14	.13	.13
80	30	.13	.13	.12	.13
	45	.12	.11	.10	.10
	60	.12	.11	.10	.11
100	30	.10	.12	.10	.10
	45	.11	.10	.09	.10
	60	.10	.10	.10	.10

Annual sawtimber diameter growth per tree ranged from a low of .09 inch to .17 inch for the range in basal area levels. Diameter growth of sawtimber was greater than that of poletimber at the higher density levels. The annual sawtimber diameter growth per tree may be expressed by:

Sawtimber diameter growth = .1881 - .0009 (x_1) where x_1 = residual basal area in square feet.

This equation is significant at the 5 percent level with r = .72 and standard error of mean y = .0029.

The annual diameter growth per tree for the total stand may be expressed by:

Stand diameter growth = .2121 - .0013 (x_1) where x_1 = residual basal area in square feet.

This equation is significant at the 5 percent level with r = .901 and standard error of mean y = .0022.

For comparable residual stand densities, diameter growth rates were slightly higher for both pole and sawtimber stands in the Lake States *(Eyre and Zilligitt 1953; Erdmann and Oberg 1973)*. However, in northern hardwood stands in New England, both pole and sawtimber reached their optimum levels of diameter growth between 60 and 80 square feet of basal area, when diameter growth is still high and site is fully utilized.

SPECIES DIAMETER GROWTH

When separated by species, diameter growth decreased as basal area increased for both pole and sawtimber (table 9). For both size classes, diameter growth either stayed the same or increased slightly as the percentage of sawtimber increased. However, there is tendency for the sawtimber (overstory) to grow slightly faster than the poletimber.

As expected, hemlock of all sizes grew the fastest at all levels of density. But some species, such as paper birch, showed little difference in diameter growth among treatment levels, possibly because the trees present were close to maturity. While beech and red maple made up the largest percentage of the stand, they followed hemlock in growth even though both of them had high mortality. The more tolerant species, such as beech, sugar maple, and yellow birch, showed a more gradual decline in annual diameter growth. Although the growth of the intolerant species, such as paper birch, did not differ much among the different levels of treatment, the growth of intermediate species such as red maple, white ash, and tolerant hemlock decreased with an increase in residual basal area. Except for sugar maple, which had good diameter growth in the low-basal-area classes, hemlock and beech had the fastest growth rates of species considered northern hardwoods in other studies *(Wilson 1953; Gilbert et al. 1955)*. Sugar maple and beech grew as fast in diameter as the Lake States hardwoods *(Eyre and Zilligitt 1953)*.

The diameter growth of trees that later died was highest for beech (table 10). Most of the other species showed minimal growth before death. The relatively good growth of nearly-dead beech may be due to the beech scale-nectria complex, which can cause the tree's bark to swell just before death.

Table 9.—Average annual diameter growth by treatment and species (in inches)

Species	Size class	Treatment 40			60			80			100		
		30	45	60	30	45	60	30	45	60	30	45	60
Beech	Poletimber	0.15	0.14	0.15	0.11	0.12	0.10	0.09	0.10	0.09	0.08	0.08	0.08
	Sawtimber	.15	.12	.13	.13	.14	.13	.11	.11	.11	.08	.11	.11
	All	.15	.14	.15	.11	.12	.11	.09	.10	.09	.08	.08	.08
Sugar maple	Poletimber	—	0.12	0.17	0.13	0.08	0.10	0.04	0.03	0.05	0.03	0.04	0.03
	Sawtimber	—	.36	.26	.12	.05	.19	.13	.05	.06	.06	.02	.07
	All	—	.13	.21	.13	.07	.13	.05	.04	.05	.04	.04	.05
Yellow birch	Poletimber	0.13	0.18	0.12	0.09	0.09	0.07	0.05	0.05	0.06	0.04	0.05	0.04
	Sawtimber	.08	.08	.09	.12	.06	.10	.11	.06	.08	.07	.05	.05
	All	.10	.16	.11	.10	.08	.09	.06	.05	.06	.04	.05	.04
Paper birch	Poletimber	0.07	0.07	0.08	0.07	0.08	0.05	0.06	0.08	0.06	0.05	0.04	0.07
	Sawtimber	.11	.08	.11	.07	.10	.08	.09	.07	.08	.07	.07	.06
	All	.09	.07	.10	.07	.09	.07	.07	.07	.08	.06	.06	.06
Red maple	Poletimber	0.17	0.15	0.18	0.16	0.12	0.11	0.08	0.09	0.10	0.06	0.06	0.07
	Poletimber	.18	.22	.20	.18	.14	.15	.13	.13	.14	.12	.10	.10
	All	.17	.17	.19	.16	.13	.12	.09	.11	.11	.07	.07	.08
White ash	Poletimber	0.03	0.17	0.26	0.10	0.08	—	0.15	0.14	0.15	0.07	—	0.11
	Sawtimber	—	.23	—	.15	—	—	.16	—	.10	.07	—	.17
	All	.03	.21	.26	.12	.08	—	.16	.14	.11	.07	—	.15
Hemlock	Poletimber	0.22	0.30	0.36	0.24	0.24	0.24	0.20	0.18	0.19	0.14	0.15	0.18
	Sawtimber	.32	.31	.22	.21	.28	.19	.23	.19	.21	.20	.22	.19
	All	.23	.30	.35	.24	.24	.23	.20	.18	.20	.14	.16	.19
Red spruce	Poletimber	0.30	—	0.01	0.10	0.21	0.17	—	0.04	—	0.05	0.04	—
	Sawtimber	—	—	—	—	—	—	—	.14	0.05	.08	—	0.17
	All	.30	—	.01	.10	.21	.17	—	.09	.05	.05	.04	.17
Other	Poletimber	—	0.12	0.09	—	—	—	0.16	—	0.07	0.11	—	—
	Sawtimber	—	—	—	—	—	—	—	—	—	.17	—	—
	All	—	.12	.09	—	—	—	.16	—	.07	.12	—	—

Table 10.—Average annual diameter growth of trees that died, by treatment and species (in inches)

Species	Size	Treatment 40			60			80			100		
		30	45	60	30	45	60	30	45	60	30	45	60
Beech	Poletimber	0.16	0.18	0.16	0.08	0.11	0.09	0.09	0.07	0.08	0.08	0.09	0.10
	Sawtimber	.12	.15	.12	.15	—	.11	—	.13	.08	—	.05	.09
	All	.14	.17	.14	.12	.11	.10	.09	.10	.08	.08	.07	.10
Sugar maple	Poletimber	—	0.08	0.20	—	—	0.08	0.01	0.01	0.02	—	0.00	0.01
	Sawtimber	—	—	—	—	—	—	—	—	.04	—	—	—
	All	—	.08	.20	—	—	.08	.01	.01	.03	—	.00	.01
Yellow birch	Poletimber	—	0.06	0.08	0.06	—	—	—	—	0.05	—	0.07	0.08
	Sawtimber	—	—	.08	—	—	—	—	—	—	—	.07	—
	All	—	.06	.08	.06	—	—	—	—	.05	—	.07	.08
Paper birch	Poletimber	0.02	—	—	—	—	—	0.05	0.02	—	—	0.02	—
	Sawtimber	—	—	—	0.12	—	—	—	.01	—	0.03	—	—
	All	.02	—	—	.12	—	—	.05	.02	—	.03	.02	—
Red maple	Poletimber	0.06	—	—	—	0.06	0.02	0.03	—	—	0.02	0.01	0.03
	Sawtimber	.01	0.18	—	—	—	—	—	—	—	—	—	.04
	All	.04	.18	—	—	.06	.02	.03	—	—	.02	.01	.04
White ash, Hemlock, Red spruce, Other	Poletimber	—	—	—	0.00	—	—	—	—	—	0.09	—	—
	Sawtimber	—	—	—	—	—	0.09	—	—	0.00	.08	—	—
	All	—	—	—	.00	—	.09	—	—	.00	.09	—	—

Table 11.—Average annual diameter growth of ingrowth trees by treatment and species (in inches)

Species	Treatment 40			60			80			100		
	30	45	60	30	45	60	30	45	60	30	45	60
Beech	0.13	0.11	0.13	0.09	0.12	0.09	0.08	0.15	0.08	0.06	0.08	0.08
Sugar maple	—	—	.13	.12	—	.27	.12	.10	—	—	.20	—
Yellow birch	.16	.25	.16	.15	.12	.50	—	—	.30	—	.00	.06
Paper birch	.08	—	—	—	.22	.03	.00	.01	—	—	—	—
Red maple	.21	.24	.20	.20	.20	.15	.08	.03	.09	.08	—	.19
White ash	—	.19	.26	—	—	—	—	—	—	—	—	—
Hemlock	.28	.31	.37	.27	.28	.25	.20	.20	.23	.11	.19	.15
Red spruce	.30	—	—	—	—	.17	—	—	—	.09	—	—
Other	—	.12	—	—	—	—	—	—	.07	—	—	—

Like the other rates of average diameter growth, the annual growth rate of ingrowth trees decreased as the density increased and remained constant with different percentages of sawtimber (table 11). The species with most rapid growth were hemlock, yellow birch, and red maple, followed by sugar maple and beech. All of the species except hemlock were very close to the overall average shown in table 10. Hemlock ingrowth grew faster than the overall average, indicating the rapid response of hemlock to thinning. It grew approximately twice as much at the lower densities as at the higher densities. Red maple and beech ingrowth followed similar diameter-growth patterns, with a high growth rate at the lower densities that declined rapidly as density increased. The only other species with an ingrowth response to most treatments was yellow birch.

CONCLUSION

In even-aged stands, the main objective is to encourage maximum growth of overstory trees; regeneration, ingrowth, and understory response are of little importance except for their possible influence on the regeneration of the new stand. Notice, in table 2, that maximum sawtimber accretion is obtained by maintaining stocking in sawtimber trees of 60 square feet or more (100 square feet with 60 percent sawtimber). This finding is in line with the recommendations of available stocking guides for northern hardwoods *(Solomon and Leak 1969)*. However, mortality can be high at high sawtimber densities when beech with the beech scale-complex is a significant part of the stand. Therefore it is important to make sure that residual sawtimber trees are vigorous enough to last until the next harvest.

The situation is more complicated in uneven-aged stands. Although high sawtimber accretion is still desirable, we must take care that sawtimber production is maintained by adequate ingrowth into the sawtimber sizes. The treatment that produced the highest sawtimber accretion (100 square feet and 60 percent sawtimber, or 60 square feet of sawtimber) produced quite low sawtimber production (table 2), simply because ingrowth into the sawtimber sizes was not maintained. Furthermore, in the 100-square-foot treatments the poletimber capital is shrinking.

The ideal treatment for an uneven-aged stand to be managed for quality sawtimber is one that maintains high sawtimber production, acceptable sawtimber accretion, and poletimber capital—i.e. it does not reduce the available poletimber. The 60-square-foot density with 45 and 60 percent sawtimber and the 80-square-foot density with 30 or 45 percent sawtimber all produced at least 1.6 square feet of sawtimber production. These treatments produced .7 to .9 square feet of sawtimber accretion, except for the 80-30 treatment which, with only 24 square feet of sawtimber density, produced .64 square feet of accretion (approximately full accretion required 35 to 40 square feet of sawtimber or more). The 60-square-foot treatments (with 45 and 60 percent sawtimber) produced positive poletimber productions, which means that poletimber trees would have to be removed during the next cutting to reestablish the treatment. Since ingrowth slightly exceeds mortality, the 80-square-foot treatments (with 30 and 45 percent sawtimber) produced slightly negative to very slightly positive poletimber production rates, which indicate that a treatment of about 80 square feet with 40 to 45 percent sawtimber would require minimal work in the poletimber sizes to reestablish the treatment.

In summary, a 60-square-foot treatment with about 45 to 60 percent sawtimber seem reasonable for fairly intensive uneven-age management where some cultural or marginal work could be done in the poletimber to improve quality and species composition. A treatment of 80 square feet with about 45 percent sawtimber should be appropriate for less intensive even-age management where little work will be done in the poletimber size. The q-ratio for 45 percent sawtimber is about 1.7 or a little higher while the q for 60 percent sawtimber is about 1.5. These growth data should be useful in making specific predictions of stand response to various levels of density and structure, and they provide some general guidelines for management to achieve optimum basal area growth. Notice that stand growth response will depend upon species composition, since certain species such as hemlock grow much faster in diameter and maintain ingrowth rates better than other species. Since these data were taken from a 70- to 90-year-old stand, caution should be used in applying these results to younger or older stands.

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Growth of northern hardwoods over a 10-year period was studied in plots that were treated to produce residual densities of 40, 60, 80, and 100 square feet of basal area per acre with stand structures of 30, 45, and 60 percent sawtimber. Both diameter and basal area growth are tabulated by treatment and species.

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Use and Users of the Cranberry Backcountry in West Virginia: insights for eastern backcountry management

by Herbert E. Echelberger
and George H. Moeller

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Use and Users of the Cranberry Backcountry in West Virginia: insights for eastern backcountry management

ABSTRACT

Management of backcountry recreation areas in the eastern United States should be based in part on information about the identity of backcountry users and what they seek in their backcountry experiences. Because little of this kind of information is now available, managers may be adopting some strategies with inadequate knowledge of the consequences of their decisions. Results of a study of users of the Cranberry Backcountry in West Virginia describe the potential impact of several management alternatives. Cranberry Backcountry visitors and western Wilderness Area visitors are compared.

Keywords: Dispersed recreation, visitor survey, wilderness areas, backcountry management

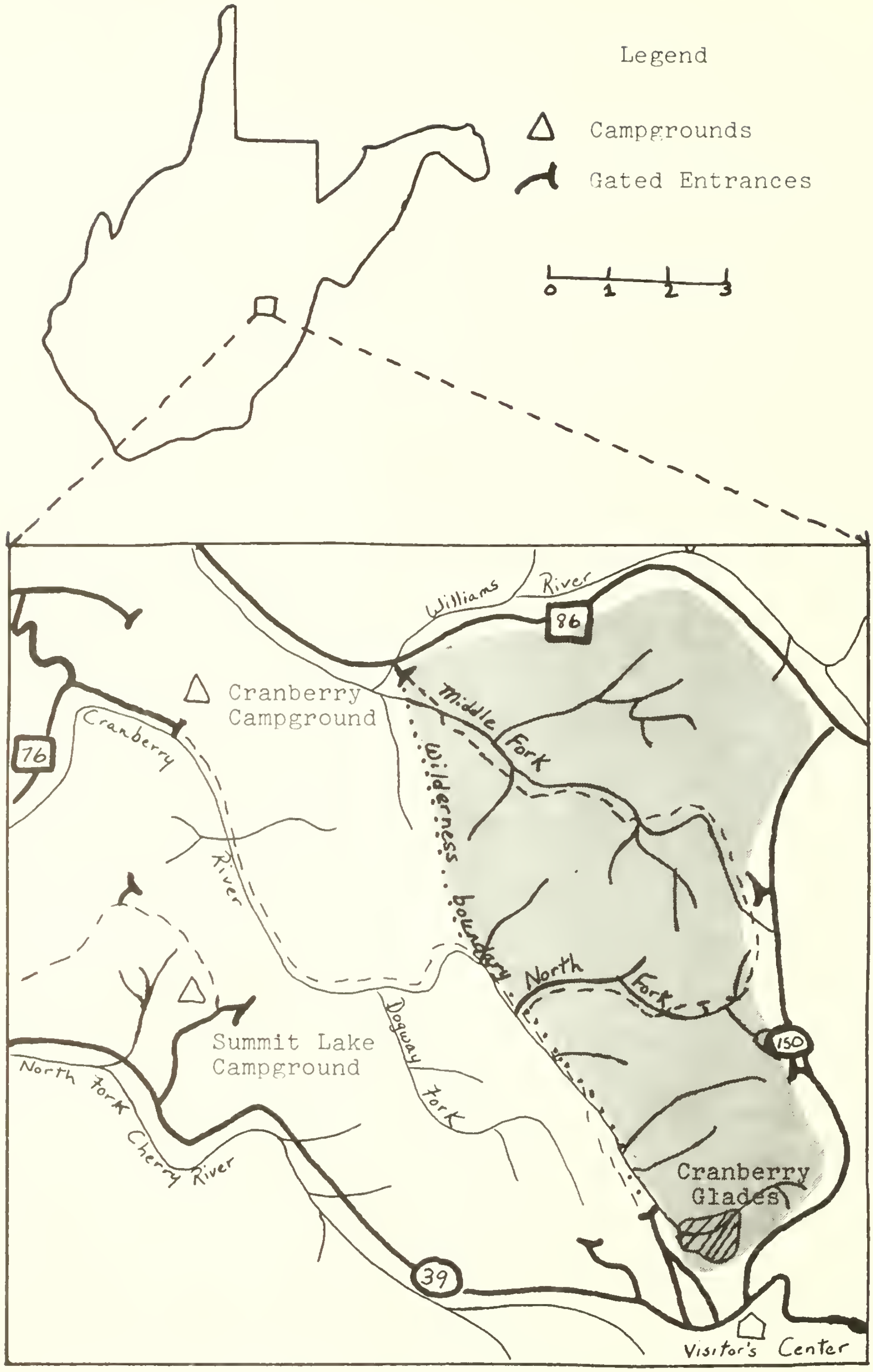

Figure 1.—Cranberry Backcountry.

INTRODUCTION

AMONG THE MANY goods and services provided by National Forests in the eastern United States is the opportunity for a backcountry recreation experience. This experience might be characterized as one of solitude, exploration, and challenge in a setting that has little evidence of man's impact. Few studies have been done to describe the recreationists who seek this kind of experience on eastern National Forests. Such information is badly needed to develop backcountry management alternatives. This paper seeks to provide descriptive information about visitors to a specific backcountry area and to summarize their opinions about management of the area.

The Study Area

The Cranberry Backcountry is a 53,000-acre parcel of the Monongahela National Forest in West Virginia (fig. 1). The topography is hilly to mountainous, with elevations ranging from less than 2500 feet to more than 4500 feet. The Backcountry contains the headwaters of the Cranberry River and provides some of the finest trout fishing in West Virginia. Primitive camping, hiking, nature study, and hunting are also favored recreational activities.

The "Back Country" was established in 1936 when roads through the area were gated and officially closed to all entry as a fire-prevention measure. This closure was terminated in 1945, and from then until 1975 the area was under the Forest Service's multiple-use/sustained-yield forest management. On January 3, 1975, the Cranberry Wilderness Study Area was established under Public Law 93-622. This law set aside 36,300 acres in the eastern portion of the Cranberry Backcountry to be studied for possible inclusion in the National Wilderness Preservation System.

Although there is a secondary road system within the Cranberry Backcountry, it is used only for administrative purposes. Public access is provided through nine gated entrances that are evenly distributed around the boundary. There is a fairly well-developed trail system throughout the Backcountry. Recreational travel is restricted to hiking, bicycling, and horseback riding. Recreational use of the Cranberry Backcountry was estimated at about 40,000 visitor-days in 1972.

The Visitor Survey

In response to a need for information about dispersed recreation in the Backcountry, the Forest Service developed the Cranberry Backcountry Visitor Survey. This survey took place between April 1 and December 15, 1972. Self-registration boxes were set up at each gated entrance point and all visitors 16 years or older were asked to register (fig. 2). Every 18th registered visitor was mailed a questionnaire that asked the visitor's opinions of his Backcountry experience and of present Backcountry management, about possible solutions to recognized problems, about the level of facility development in and adjacent to the Backcountry, and about himself.

On randomly selected days, a person was stationed inside the Cranberry Campground entrance gate to check registration rates. This one gate has traditionally contributed about 60 percent of the total use of the Backcountry. Whenever someone did not register at the self-registration box, the checker would ask him to register. Reasons given for not registering at the box were: in a hurry; will register on way out;

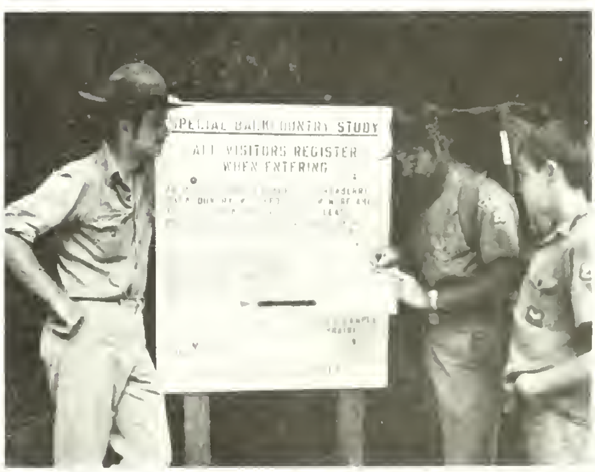

Figure 2.—Visitors were asked to register each time they entered the Backcountry.

too wet; too lazy; etc. No one refused to register when asked to do so. A separate list of these "non-volunteer registrants" was compiled and every fourth non-volunteer registrant was mailed a questionnaire.

More than 550 questionnaires were mailed. After two reminders had been sent, 413 of the questionnaires were returned. Response rates were 80 percent for volunteer registrants and 70 percent for non-volunteer registrants. A comparison of questionnaires from the two groups showed no significant differences in responses, except that a greater percentage of the non-volunteer registrants listed as their major reason for visiting the Cranberry Backcountry fishing, and fewer listed hiking, nature study, or camping.

SURVEY RESULTS

Results of the survey are descriptive. Reported percentages generally had a deviation of ± 10 percent; measurement error was considered where appropriate. Chi-square tests were utilized in some cases in which results might otherwise have been ambiguous. Confidence levels are reported in these instances.

The Cranberry Backcountry Visitor

A trout fisherman under 30 years old from West Virginia is a description of nearly 60 percent of the Cranberry Backcountry visitors. About one-quarter of all users were female. Most visitors came with one to three friends or family members and stayed either a few hours or a couple of days. Just over half the respondents indicated less than a day's stay; 45 percent stayed between 1 and 3 days. The remaining 4 percent stayed 4 to 15 days.

About a quarter of the respondents indicated that they had not previously visited the Cranberry Backcountry. Of those who had visited the area, 3 in 10 had been coming to the Cranberry Backcountry for 10 years or more; 2 in 10 for 6 to 9 years; and nearly 4 in 10 for 2 to 5 years.

Only one respondent in four was a member of an outdoor organization. Hunting and fishing organizations accounted for 45 percent of those who had such organizational affiliations, whereas youth groups (i.e., scouts, 4-H, etc.) accounted for 32 percent. Conservation and outing clubs accounted for the remaining 23 percent of the affiliations. About a quarter of these affiliated respondents belonged to more than one organization.

Results of past wilderness surveys have characterized western wilderness users as highly educated. Hendee et al. (*1968*) reported the distribution of educational attainment among western wilderness users; about one-third had less than 13 years education, about one-third had a college degree or some college education, and almost one-third had done postgraduate work. Cranberry Backcountry users were different; 64 percent had less than 13 years education, 26 percent had some college or had finished college, and only 11 percent had done postgraduate work. The differences in these distributions may be due, in part, to differences in the ages of respondents in the two studies. Hendee reports that 22 percent of the respondents in his study were under 24 years old, whereas 30 percent of the respondents in the Cranberry Backcountry Survey were under 24 years old. In spite of the differences in the two distributions, the educational levels for Cranberry Backcountry respondents still compare very favorably with U.S. educational levels. Table 1 shows a comparison of these two distributions. Note, again, the age discrepancy.

Although the distribution of educational attainment among Cranberry Backcountry visitors is not the same as Hendee's distribution, Cranberry Backcountry visitors do appear to be more highly educated than the U.S. population as a whole. Educational attainment and occupation were highly correlated. White-collar occupations were reported by 36 percent of the Cranberry Backcountry respondents and blue-collar occupations by 40 percent; 23 percent of the respondents were students, housewives, or retirees. One percent were unemployed.

Nearly 90 percent of the respondents answered the question about total family income. The distribution of incomes is shown in table 1, along with data for the U.S. and for West Virginia. The income distributions indicate that Cranberry Backcountry visitors are slightly more affluent than the U.S. population in general and considerably more affluent than most residents of West Virginia. These observations are similar to those at western Wilderness Areas (*Stankey 1971*).

Table 1.—Respondents in Cranberry Backcountry study compared with national and state averages on education and income (in percent of respondents)

Category	Cranberry (age 16 and over)	U.S. (age 25 and over)	W. Va.
	EDUCATION (years)		
Less than 12	22	45 [a]	—
12	41	34	—
13 to 15	15	10	—
16 or more	22	11	—
	TOTAL FAMILY INCOME (dollars)		
Less than 3,000	4 [b]	9 [c]	17 [d]
3,000 to 6,999	16	22	29
7,000 to 9,999	24	20	24
10,000 to 14,999	35	27	20
15,000 or more	21	22	10

[a] Source: U.S. Bureau of the Census 1972.
[b] Although the study was done in 1972, replies probably reflect 1971 income.
[c] Source: U. S. Bureau of the Census 1975 (reflects incomes in 1970)
[d] Source: U.S. Bureau of the Census 1970

The Cranberry Backcountry Experience

Knowledge of user characteristics and past experiences is necessary to forecast future Backcountry use. But administrators also need information about how visitors feel toward present management. Backcountry visitors were asked if the area was overused in relation to their primary reason for visiting it. More than half believed it was, and 15 percent felt the area was greatly overused for their primary activity.

Recreational facilities in the Cranberry Backcountry consist of pit toilets, a few open-faced shelters (figure 3), and maintained trails. This level of development tends to insure a primitive type of recreation experience. We were interested in whether visitors felt they had had a wilderness experience. Nearly three-quarters of the respondents felt that the Backcountry had provided them with a wilderness experience. Furthermore, the overall quality of the recreation experience was rated as pleasant or very pleasant by 9 of 10 respondents.

When asked to comment on what they liked about their Cranberry Backcountry visit, respondents most often specified the solitude, peace, and quietness of the area and its natural scenic beauty (table 2). On the negative side, overcrowding and lack of camping facilities were mentioned most often. About 12 percent of the respondents specifically mentioned that evidence of logging and related activities had detracted from their Backcountry experience. Four of ten respondents offered no negative comments, which suggests that decisions to change existing facilities or management of the Cranberry Backcountry may meet with considerable public resistance.

Respondents were also asked to rate the in-

Figure 3.—Facility development in the Cranberry Backcountry promotes primitive recreational experiences.

Table 2.—Most and least liked characteristics of the Cranberry Backcountry (in percent of respondents)

Characteristic	Percentage of respondents
MOST LIKED	
Solitude and natural scenic beauty	63
Fishing and hunting	20
Exclusion of motor vehicles	7
Other	2
No response	8
LEAST LIKED	
Overcrowding	16
Logging	12
Littering	11
Poor fishing	10
Dusty, rough roads	5
Other	2
No dislikes or no response to question	44

fluence of 10 current conditions in the Backcountry on their overall experience (table 3). The condition that detracted most from the quality of their experience was evidence of logging (38 percent), but an even larger number (43 percent) said they had not encountered evidence of logging or that it had not affected them.

Overcrowding was cited as the second most important condition detracting from Backcountry visits, but more half the respondents did not encounter overcrowding or were not affected by it. Other conditions that detracted from the enjoyment of some respondents were vehicular traffic, stocking of fish in the Cranberry River (although 27 percent of respondents said fish stocking enhanced the quality of their visits), and the lack of facilities.

User Reactions to Management Alternatives

Planning for the management of public land and water recreation resources is a dynamic process. To respond to changing public demands, planning must involve input from many "publics." To learn how users felt, we asked them to react to several possible changes in Cranberry Backcountry management.

Table 4 summarizes responses toward facility development alternatives. More interpretive signs, picnic tables, shelters along the Cranberry River, and parking areas at entrance gates were desired by as many as half the respondents. However, half the respondents or more expressed no opinion or were opposed to adding more of these facilities.

About one-third of the respondents wanted more small water impoundments, shelters along hiking trails, walk-in primitive campgrounds, foot trails, and bridges over rivers. Two-thirds expressed no opinions or were opposed to adding more of these facilities.

Table 3.—Influence of conditions on the overall quality of visit (in percent of respondents)

Condition	Detracted from experience	Enhanced experience	No effect	Did not encounter	No opinion
Logging	38	2	7	36	17
Overcrowding	29	2	15	37	17
Vehicular traffic	18	4	17	41	20
Fish stocking	16	27	10	25	22
Lack of facilities	14	17	20	28	21
Mining	10	1	3	68	18
Noise	9	2	15	56	18
Inadequate access	7	21	14	32	26
Lack of law enforcement	6	5	19	48	22
Hunting	2	6	8	57	27

Table 4.—Percentage of respondents with certain opinions about adding facilities to the Cranberry Backcountry

Possible addition	Add more	Don't change	Reduce existing number	Remove existing number	No opinion
Interpretive signs	50	25	1	1	23
Picnic tables	48	30	1	3	18
Shelters along Cranberry River	47	37	1	3	12
Parking areas at entrance points	46	39	1	1	13
Small water impoundments	36	29	1	2	32
Shelters along hiking trails	35	29	1	2	33
Walk-in primitive campgrounds	34	32	1	2	31
Foot trails	33	39	1	1	26
Bridges over rivers	30	45	2	3	20
Foot bridges along trails	23	37	1	2	37
Areas with no trails	18	40	3	1	38

At least half the respondents did not favor adding more facilities to the Cranberry Backcountry. These results, coupled with the finding that 44 percent of the respondents had no dislikes about the Cranberry Backcountry or did not respond to the question (table 2), suggest that any additional facilities, although increasing the durability of the site, may tend to reduce the satisfaction of individual users or even the total satisfaction of all users. Such additions are apparently desired by less than a majority of current Backcountry users. They are especially not wanted by those whose expectations were "solitude and natural scenic beauty of the area."

The second set of alternatives dealt with opinions about suggested changes in management policy (table 5). A majority of respondents felt that 6 of the 12 suggested policy changes would reduce the overall quality of their Backcountry experience. Payment of an entrance fee, camping only in designated areas, and restricting the use of certain areas by issuing trip permits would reduce the quality of experience for nearly half the visitors. Rangers regularly patrolling the Backcountry and mandatory registration would improve the quality of experience for most visitors. A little over one-third of the visitors would like to see a portion of the Cranberry River set aside for fly fishing.

Our overall impression from reactions to the two sets of management alternatives is that the current level of facility development and the existing management policies provide most Backcountry visitors with the kind of recreation experience they desire.

A MANAGEMENT PREFERENCE PROFILE

A management preference profile of respondents was developed to provide a better data base of visitor expectations and desires. This information may be of value in decisions about management or operating policies. The profile was developed to determine what proportion of respondents would prefer (a) a more primitive backcountry experience, (b) a less primitive backcountry experience, and (c) to keep the present level of primitive backcountry experience available in the Cranberry Backcountry.

Table 5.—Expected effects of changes in management policies on quality of experience (in percent of respondents)

Suggested change in policy	Reduce quality	Improve quality	No effect	No opinion
Allow public use of motorized vehicles in backcountry	84	4	2	10
Allow deep mining	82	1	2	15
Provide vehicle access points closer to Cranberry River	71	12	4	13
Allow public vehicle access only during deer season	64	11	5	20
Allow snowmobiles in Backcountry during winter	63	11	5	21
Allow bear hunting in Backcountry	56	11	6	27
Collect an entrance fee	45	15	15	25
Allow camping only in designated areas	42	33	9	16
Issue trip permits to restrict number of visitors in an area	42	21	11	26
Set aside portion of Cranberry River for fly fishing only	22	35	15	28
Have Forest Ranger regularly patrol the Backcountry	6	63	15	16
Require all visitors to register when entering the Backcountry	6	54	26	14

Profiles were based on respondents' answers to 22 questions about present conditions encountered in the Backcountry, preferred level of facility development, and preferred operating policies. Responses for each of the questions were assigned a score from 1 to 3, with 1 representing an interest in less primitive conditions, and 3 representing an interest in more primitive conditions. A "no opinion" or "nonresponse" was scored as 2. Total scores could range from 22 to 66.

Actual scores ranged from 34 to 58, and the distribution within these limits approximated a normal (bell-shaped) curve. Respondents whose scores were within one standard deviation (4 points) of the actual midpoint of the distribution (46) were considered to have mid-range preferences. A total of 70 percent of the respondents fell in this category; 14 percent had scores less than 42 and were designated as preferring less primitive conditions, and 16 percent had scores of 51 or more and were designated as preferring more primitive conditions.

It is possible that the number of respondents who preferred more primitive conditions is slightly inflated when compared with the total number of Cranberry Backcountry users. Of the 413 responses to the questionnaire, 243 were from visitors who had registered voluntarily at the gated entrances. Twenty-one percent of these volunteer registrants preferred more primitive conditions (table 6). Only 9 percent of the respondents who did not register voluntarily but were asked to register preferred more primitive conditions. Although more visitors registered voluntarily than did not, those who preferred more primitive conditions were significantly more likely to register voluntarily than those who preferred less primitive conditions ($p < .05$).

Preference scores for volunteer registrants were also analyzed by season (table 6). More summer visitors preferred more primitive conditions than did spring or fall visitors ($p < .05$). Spring and fall visitors to the Cranberry Backcountry are more likely to arrive with specific activities in mind (fishing and hunting, respectively) and are, consequently, likely to be less concerned with the other primitive recreation opportunities available in the area. A greater proportion of summer visitors arrive with hopes of finding a wildernesslike experience and they are more likely to desire facilities and management that foster this kind of experience.

Table 6.—Management preferences of groups of visitors

Group	More primitive conditions	Present conditions	Less primitive conditions	N
Voluntary registrants	21.2	64.4	14.4	243
Involuntary registrants	9.4	76.5	14.1	170
				413
Spring visitors	16.8	67.2	16.0	131
Summer visitors	29.7	60.4	9.9	91
Fall visitors	14.3	61.9	23.8	21
				243
Fishing-gate entrants	23.4	60.4	16.2	192
Nonfishing-gate entrants	13.7	78.5	7.8	51
				243

In our analysis of visitors who entered the Backcountry through gates that provided access to the fishing opportunities, we expected that fishing-gate entrants would prefer less primitive conditions and that nonfishing-gate entrants would prefer more primitive conditions. The preferences shown in table 6, however, lead to rejection of this hypothesis.

Another purpose of categorizing users was to identify differences in group characteristics. A discriminant analysis comparing visitors who preferred more primitive conditions with those who preferred less primitive conditions showed that the latter were often younger and lived in larger cities and were more likely to be white-collar workers than blue-collar workers. This finding is probably correlated with the slightly higher educational and annual income levels of the visitors who preferred more primitive conditions ($p < .01$). We describe the visitor with this constellation of characteristics as "cosmopolitan."

The information from the management preference profile should be useful in deciding on the future management of the Cranberry Backcountry. For example, if residents of the eastern United States become more "cosmopolitan," management might expect the proportion of Backcountry visitors who prefer more primitive recreation experiences to increase. On the other hand, if a greater number of less "cosmopolitan" users should visit the Backcountry, management might expect to experience greater demand for site development and policies that promote less primitive recreation experiences.

CONCLUSIONS

Most visitors to the Cranberry Backcountry are well satisfied with present levels of facility development and present operating policies. Any increase in the area's physical capability to accommodate more visitors may attract more visitors than the present users want to encounter. A decision to alter the present operating policy to one that excludes any of the present uses of the Backcountry may upset the present balance of visitor expectations and satisfactions.

The present mix of satisfied visitors, those who want more primitive conditions and those who want less primitive conditions, may not be stable. What is likely to disturb its proportions is a change in user characteristics. In time, users may become more urbanized and educated; this would result in a greater proportion of visitors who would prefer a more primitive backcountry experience.

When our information is compared with that about western Wilderness Area users *(Hendee et al. 1968, Merriam and Ammons 1967, Stankey 1971)*, questions arise about similarities and differences between eastern and western backcountry users. Although visitors to the Cranberry Backcountry represent a very limited sample of all eastern backcountry visitors, their characteristics, expectations, and satisfactions do not differ much from those found in the West. In both cases, many backcountry recreationists come in small groups, stay for short periods, and make several trips per year. In both cases, they may fairly be characterized as young to middle-aged adults with slightly more education and income than the population from which they come. And in both regions, less than a third of the respondents to the surveys belong to organized conservation groups.

Most Cranberry Backcountry fishermen, campers, hikers, etc. anticipated a set of experiences before they entered the Backcountry, and came away satisfied. What remains unknown is how these expectations and satisfactions compare with those of visitors to western Wilderness Areas. Although user desires for facility development and management policies may be universal throughout the National Wilderness Preservation System, we lack sufficient knowledge of what motivates visitors to visit specific wilderness areas and what benefits they derive from a trip to a Wilderness Area, especially in the East. Managers don't know what user expectations are or whether they can be met by eastern Wilderness. The Cranberry Backcountry provided a "wilderness experience" for nearly three-quarters of our respondents, but the Cranberry Backcountry is only 53,000 acres. Is a wilderness experience in the Cranberry Backcountry equivalent to a wilderness experience in the Glacier Peaks of Washington? And how would the experience of the Glacier Peak Wilderness (452,020 acres) compare with that provided by the 2,570-acre Gee Creek Wilderness in Tennessee, or the 1,500-acre Wambaw Swamp in South Carolina? For some, these acreage differences are irrelevant, for others, they may be paramount.

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