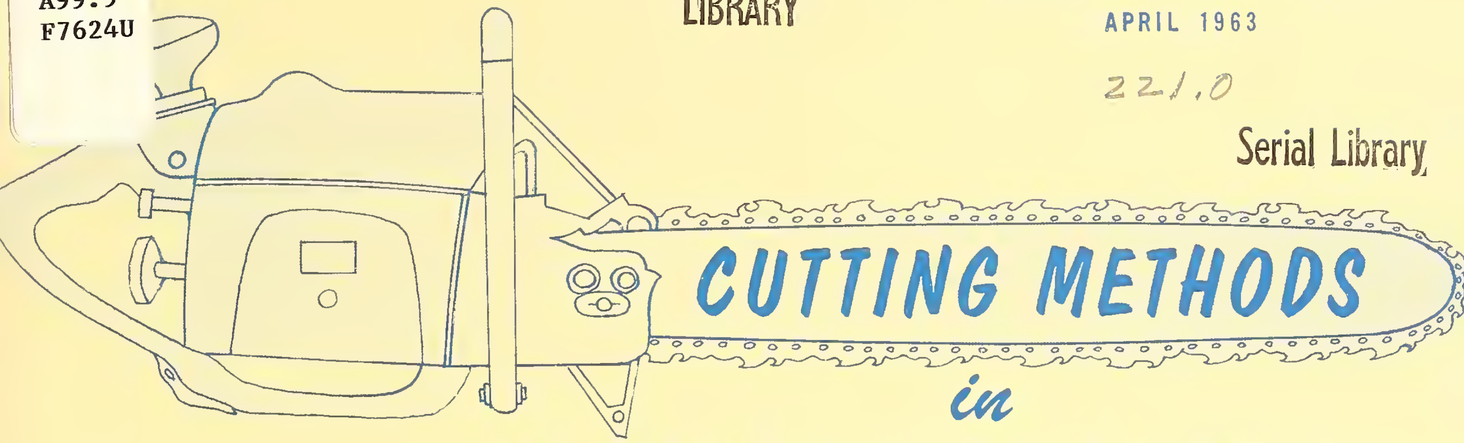
U.S. FOREST SERVICE
RESEARCH PAPER LS-4
APRIL 1963



CUTTING METHODS *in* MIXED CONIFER SWAMPS, Upper Michigan

JOHN W. BENZIE

LAKE STATES FOREST EXPERIMENT STATION
M. B. Dickerman, Director
FOREST SERVICE
U. S. DEPARTMENT OF AGRICULTURE

CONTENTS

ACKNOWLEDGMENT

This report is based on the 5-year results of a cutting methods study in mixed conifer swamps. Tests were installed at several locations in the Upper Peninsula of Michigan. Agencies and private industries cooperating with the Lake States Forest Experiment Station on the installation and collection of data were American Can Company, Marathon Division; Kimberly-Clark Corporation; Mead Corporation, Escanaba Division; Michigan Department of Conservation, Escanaba River State Forest; and the Hiawatha National Forest.

FOR YOUR REFERENCE FILE

Four abstract cards are included at the back of the report for the reader's convenience.

Cutting Methods in Mixed Conifer Swamps, Upper Michigan

By John W. Benzie

INTRODUCTION

Mixed conifer swamp forests produce an assortment of wood products, provide a habitat for many species of wildlife, and furnish a storage basin for ground water. They occupy many of the poorly drained sites in the northern hardwood region. Stands vary from small patches of a few acres to several hundred acres and are made up of several species, any of which may be predominant on a given site.

Management of the mixed conifer swamp type for the production of wood, game, and water is concerned with (1) influencing the amount and kind of regeneration established after harvesting mature trees, (2) reforesting denuded swamps, and (3) increasing the growth and yield of young stands. One of the most important problems is securing prompt and adequate regeneration of the conifer species (Thornton, 1957a).

A survey of reproduction on cutover swamplands in the Upper Peninsula of Michigan was made in 1951 (Zasada, 1952). It showed that new forest stands were usually established after commercial logging. However, the proportion of coniferous reproduction was less than in the original stands, and severe competition from shrub and hardwood species sometimes delayed the development of coniferous reproduction for many years. These results indicated the need for further testing of even-aged and uneven-aged cutting methods to obtain conifer regeneration.

Two detailed studies and three less intensive ones were installed between 1952 and 1955. The first 5-year results from these studies are the basis for this report.

THE MIXED CONIFER SWAMP TYPE

Definition

The mixed conifer swamp type is composed of northern white-cedar (*Thuja occidentalis*), black spruce (*Picea mariana*), white spruce (*Picea glauca*), balsam fir(*Abies balsamea*), and a wide variety of minor species. The proportion of tamarack (*Larix laricina*) has been reduced by heavy infestations of the larch sawfly (*Pristiphora erichsonii*) in many stands where it might otherwise be a significant component. Other associated species may include red maple (*Acer rubrum*), black ash (*Fraxinus nigra*), yellow birch (*Betula alleghaniensis*), paper birch (*Betula papyrifera*), quaking aspen (*Populus tremuloides*), bigtooth aspen (*Populus grandidentata*), and balsam poplar (*Populus balsamifera*). Species that occur less frequently are American elm (*Ulmus americana*), eastern hemlock (*Tsuga canadensis*), sugar maple (*Acer saccharum*), and eastern white pine (*Pinus strobus*).

This complex of species is recognized in "Forest Cover Types of North America" (Society of American Foresters, 1954) as transition forms or variants of the three conifer swamp types; black spruce (no. 12), tamarack (no. 37), and northern white-cedar (no. 38). Since these transition forms are composed of the same species, they are usually considered to be one mixed conifer swamp type in the Lake States. The division between the mixed

NOTE: the author is Research Forester (Forest Management) at the Lake States Forest Experiment Station. The research was done at the Station's Northern Hardwoods Project, Marquette, Mich.

conifer swamp type and one of the pure types is defined as the point when that species predominates (amounts to 50 percent or more of the volume), but this separation is generally not made in practice as long as the other species are well represented in the stand.

Although some stands have nearly equal stocking of cedar, spruce, and balsam, most have a greater proportion of one species. Quite often a stand has relatively high proportions of two species such as cedar and spruce, or spruce and balsam. Almost any combination can be found in the mixed conifer swamp type.

In addition to the variations in proportion of the major species the associated species vary in the different mixed conifer swamps. These species, which are mostly hardwoods, fall in two general groups: (1) red maple, black ash, and yellow birch; and (2) aspen, balsam poplar, and paper birch. The hardwoods associated with the conifers are often the species found in the surrounding forest type. Mixed conifer swamps surrounded by northern hardwoods are most apt to have red maple, black ash, and yellow birch as associated hardwoods; those with an aspen-paper birch type around them will more likely have that species group in mixture. These mixtures are not limited to a transition zone between the surrounding type and the mixed conifer swamp type. They usually occur throughout the entire swamp stand.

Species Characteristics

The silvical habits of the species growing together in the mixed conifer swamps vary considerably. Both long-lived and short-lived, tolerant and intolerant, and fast- and slow-growing species occur. Although all of the major species produce seed in the fall, some of the associated species produce seed in the spring. Some species also regenerate by layers and others by sprouts and suckers. A brief summary of the silvical characteristics of the major species will help to explain their response to various treatments and to evaluate their role in the stand.

Northern white-cedar. — This is a shallow-rooted, slow-growing, small to medium-sized tree, commonly 40 to 60 feet in height at maturity (Godman, 1958). In general, it does best in near-neutral or only slightly acidic swamps with a shallow organic layer of well-decomposed woody peat or muck and moving ground water. It is a tolerant, long-lived tree that reaches ages of 400 years or more. Advanced reproduction of both seedlings and layers is usually present but cannot develop under dense, even-aged swamp stands. In old-growth stands with small openings caused by natural mortality, cedar regeneration must compete with the more tolerant balsam fir and associated hardwood species.

Balsam fir. — This small to medium-sized tree is commonly 40 to 60 feet in height when mature. It is very tolerant and a prolific seed producer (Hart, 1959). Seedling growth is usually slow, but older trees grow quite rapidly under favorable conditions (Roe, 1950). It is a shallow-rooted tree that grows on a wide variety of moist to wet sites. Because balsam fir is a short-lived tree, seldom reaching 100 years of age, it is often less common in the overstory of old, fully-stocked stands than in young ones. However, when small openings are created in old stands balsam fir is likely to increase along with the hardwoods, because of the abundance of tolerant seedlings generally present.

Black spruce. — This is a medium-sized tree, commonly about 60 feet in height at maturity. It is intermediate in longevity between northern white-cedar and balsam fir, reaching ages up to 250 years (Heinselman, 1957). It is usually considered less tolerant than either cedar or balsam fir but more tolerant than tamarack. Although black spruce seedlings and layers will become established under a closed forest canopy, they cannot survive for more than a few years (Heinselman, 1959). In the northern hardwood region, black spruce is largely confined to organic soils ranging from sluggish bogs to seepage areas with good internal drainage. Competition from cedar, balsam fir, and white spruce increases on the better drained sites. There, successional changes are more rapid and black spruce is eventually forced out.

White spruce. — Although this tree makes its best growth on well-drained loams, it is common in many of the mixed conifer swamps where it reaches 80 to 100 feet in height and over 20 inches in diameter at breast height. It is similar to black spruce in both tolerance and longevity. White spruce starts growth 2 weeks earlier in the spring than black spruce and is therefore more susceptible to frost injury. It is also more exacting in its nutrient requirements than is either black spruce or balsam fir (Nienstaedt, 1957).

Tamarack. — This is a moderately long-lived and very intolerant tree. It is relatively fast growing and occurs as a dominant tree in the overstory of some mixed conifer swamps, but it is practically never found in the understory. When tamarack is able to survive both competition and the larch sawfly, it attains an average size of 60 to 80 feet in height and 14 to 20 inches d.b.h. (Roe, 1957).

Hardwood tree species. — These, when associated with the mixed conifer swamp type, are often defective and poor in quality. They usually comprise a minor portion of the overstory but reproduce vigorously. The aspen-balsam poplar-paper birch group is intolerant, and the red maple-black ash-yellow birch mixture is more tolerant. The two groups generally occur in separate stands, but occasionally they grow together. American elm and sugar maple are also common in some stands. Spring and fall seeders are represented in both groups. The seed of red maple, American elm, quaking aspen, bigtooth aspen, and balsam poplar ripens in the spring, whereas the seed of black ash, sugar maple, yellow birch, and paper birch ripens in the fall. In addition, all of the species except yellow birch are prolific sprouters. The aspens and balsam poplar also regenerate by root suckers. Juvenile height growth of nearly all the hardwood species greatly exceeds that of the conifers, but the swamp sites apparently favor the conifers as the species mature. Advance reproduction of the more tolerant hardwood species is usually present, but the intolerant species do not regenerate unless there is an opening in the overstory.

Nonmerchantable shrub and tree species. — These most frequently include mountain maple (*Acer spicatum*), speckled alder (*Alnus rugosa*), dogwood (*Cornus spp.*), honeysuckle (*Lonicera* spp.), and ribes (*Ribes spp.*).

Ecological Succession

Many of the present mixed conifer swamp stands developed after the widespread tamarack mortality caused by the larch sawfly infestation from 1890 to 1910. Later some of the swamps were cut over for single products such as cedar poles or spruce pulpwood. Other disturbances, such as fire and windthrow, have also altered the succession.

One ecological classification of cover types for northern Michigan includes mixed conifer swamps in Stage Eight of a series of ten stages originating from seepage bogs or marshes (Graham, 1945). The previous stage (Seven) is characterized by highbush cranberry, dogwood, and alder. The next advanced stage (Nine) has red maple, yellow birch, American elm, and white pine. A more detailed discussion of successional changes within this stage is provided by a recent description of the lowland forests in northern Wisconsin (Christensen et al., 1959).

Tamarack is said to be the first tree species to invade the ericaceous shrub stage of the open bog. It is followed by black spruce. These two species may remain a long time in various proportions, but eventually they are replaced by a mixed stand dominated by northern white-cedar and often including balsam fir and black ash. The final stages of succession for these forests are most likely hardwoods with mixtures of eastern hemlock.

Areas Occupied

In the northern Lake States, 2,356,000 acres have been classified as conifer swamp (Cunningham et al., 1958; Findell et al., 1960; Stone and Thorne, 1961). This includes the cedar, black spruce, and tamarack swamps of Michigan and Wisconsin, but only the cedar swamps in Minnesota. The black spruce and tamarack swamps in Minnesota are generally pure types and more typical of the boreal forest region. Although some of the swamps included in the northern hardwood region are pure cedar, black spruce, or tamarack, most of them have a mixture of the conifer species.

The mixed conifer swamp type is found in the wet depressions and drainageways scattered throughout the northern hardwood region. Locally, it may cover only a few acres or several hundred. A large proportion of the individual swamps are less than 100 acres in size, forming pockets or depressions only a few feet lower in elevation than the surrounding topography. Often a ridge or an impervious layer forms the swamp boundary, separating it from the gently rolling or sloping lands that may be at a lower elevation but are better drained.

Soils supporting the mixed conifer swamp type have been grouped in three general classes: (1) peat, (2) muck,[1] and (3) wet or poorly drained

[1] *In this general classification, muck is defined as a well-decomposed organic soil.*

mineral soils (Zasada, 1952). Usually black spruce is the predominant species on the peat soils, and northern white-cedar occupies the muck soils with varying mixtures of the other species. The wet or poorly drained mineral soils often have a more complex mixture, including northern white-cedar, balsam fir, black spruce, white spruce, and several hardwood species.

Stand Conditions

Both single-story and multiple-story stands occur. Single-story stands have a closed canopy and may be composed of one or more age classes. Multiple-story stands usually do not have a closed canopy and always have two or more age classes. Multiple-story stands generally have lower stocking than single-story stands.

Past treatment and site are the two main factors affecting stand condition. A fully stocked stand of regeneration originating after a disturbance that eliminates the entire overstory will form a single-story even-aged stand. On less favorable sites where the regeneration is not adequate for full stocking, multiple-story, uneven-aged stands result. New stands following disturbances that do not completely remove the overstory start out as multiple-story stands, but on the better sites they will develop into single-story stands with a closed canopy consisting of two or more age classes.

Past treatments include not only logging but also disturbances by fire, wind, insects, disease, and animals. These, acting alone or in various combinations, have affected the present stand conditions. One of the most notable effects is the alteration in composition caused by severely reducing or eliminating one or more species. Commercial clearcutting has often removed only one or two species, leaving those for which no market existed at the time. Insects or diseases specific to one species, such as the larch sawfly, also change species composition. Some factors, such as fire and sometimes wind or logging, affect all species in a given area. The influence of these factors on stand condition may be modified by site.

Site indices have been prepared for the major species found in the mixed conifer swamp type (Gevorkiantz, 1956, 1957a, b, c, d) and are at present the best available measure of productivity. However, more information is needed on site quality, especially the identity and influence of factors affecting successional changes, before site character can be used to full advantage in mixed conifer swamp management.

THE STUDY AREAS

The mixed coniferous swamps used in this cutting experiment are located at Amasa, Dukes, Newberry, and Norway, Mich. (fig. 1). Two separate swamps on the Upper Peninsula Experimental Forest at Dukes were used for detailed measurements and observations. Less intensive measurements were taken at three other experimental areas to provide supporting data for the test.

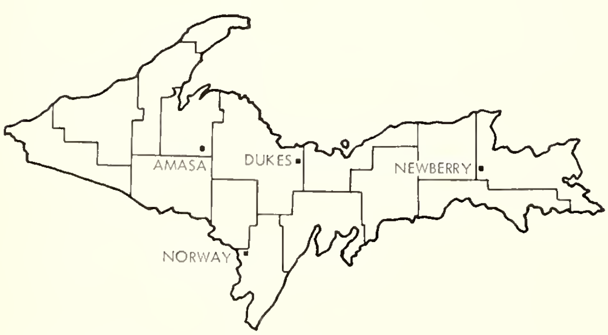


Figure 1. — Mixed coniferous swamp study areas in the Upper Peninsula of Michigan.

There was considerable variation among these study areas typical of that found in the mixed conifer swamp type. The stand at Amasa had a relatively light overstory density averaging only 77 square feet of basal area per acre (table 1). Its multiple-story structure was characteristic of uneven-aged stands. Ages of northern white-cedar exceeded 200 years, spruce ranged up to 100 years, and balsam fir 80 years. All of the other stands were single story with a closed canopy. The two at Dukes had several age classes ranging from 30 to 120 years, but 75 per cent of the trees were in the 60- and 90-year age classes (fig. 2). The stands at Newberry and Norway were primarily one age class originating after a commercial clearcutting 60 years ago.

Only the two study areas at Dukes had more than half of the trees in one species, which was northern white-cedar. Spruce and balsam fir, however, were well represented and together accounted for about one-third of the trees. At Norway, northern white-cedar also comprised the largest proportion of the stand but was less than half of the trees. At Newberry spruce was the largest component of the stand with 46 percent of the trees, followed by cedar with 38 percent. At Amasa the species were more evenly divided, with 36 percent spruce, 29 percent balsam fir, and 28 percent cedar. Tamarack accounted for 8 percent of the trees at Norway but occurred only as scattered trees in the other stands. An occasional white pine or hemlock was also found on the study areas.

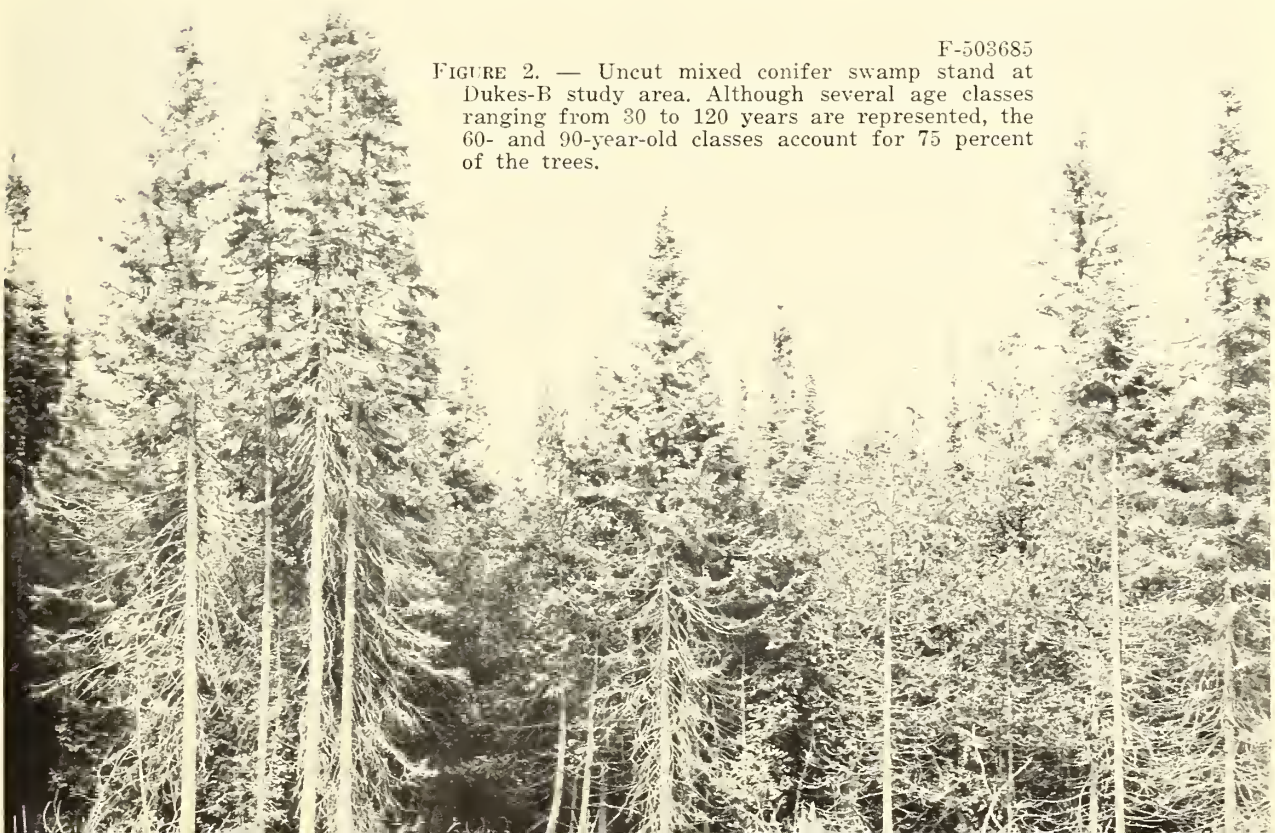
The associated hardwoods, ranging from 5 to 22 percent of the trees, also varied by species composition among the study areas. Red maple and black ash were the most abundant hardwoods in the two study areas at Dukes, with some American elm, yellow birch, and sugar maple occurring throughout the stands. Paper birch was the most numerous at Amasa, with red maple and yellow birch also quite common. The stands at Newberry and Norway had primarily aspen, balsam poplar, and paper birch, with only scattered trees of red maple and black ash.

This variation in species composition and the differences in stand structure among the study areas provide a good representation of the mixed conifer swamp type (fig. 3). Although stand characteristics varied considerably there was apparently less difference between the sites.

TABLE 1. — *Mixed conifer swamp overstory on five study areas; trees 3.6 inches d.b.h. and larger*

Study area	Average d.b.h.	Stand density per acre		Overstory composition based on number of trees per acre			
		Basal area	Trees	Spruce	Balsam fir	Cedar	Hardwood
	Inches	*Sq. ft.*	*Number*	*Percent*	*Percent*	*Percent*	*Percent*
Amasa	7.1	77	277	36	29	28	7
Dukes-A	8.9	219	507	11	16	62	11
Dukes-B	8.8	188	448	25	11	59	5
Newberry	5.8	175	936	46	7	38	9
Norway[1]	6.0	109	554	20	6	44	22

[1] *Besides the species listed here, an additional 8 percent of the trees were tamarack.*



F-503685
FIGURE 2. — Uncut mixed conifer swamp stand at Dukes-B study area. Although several age classes ranging from 30 to 120 years are represented, the 60- and 90-year-old classes account for 75 percent of the trees.

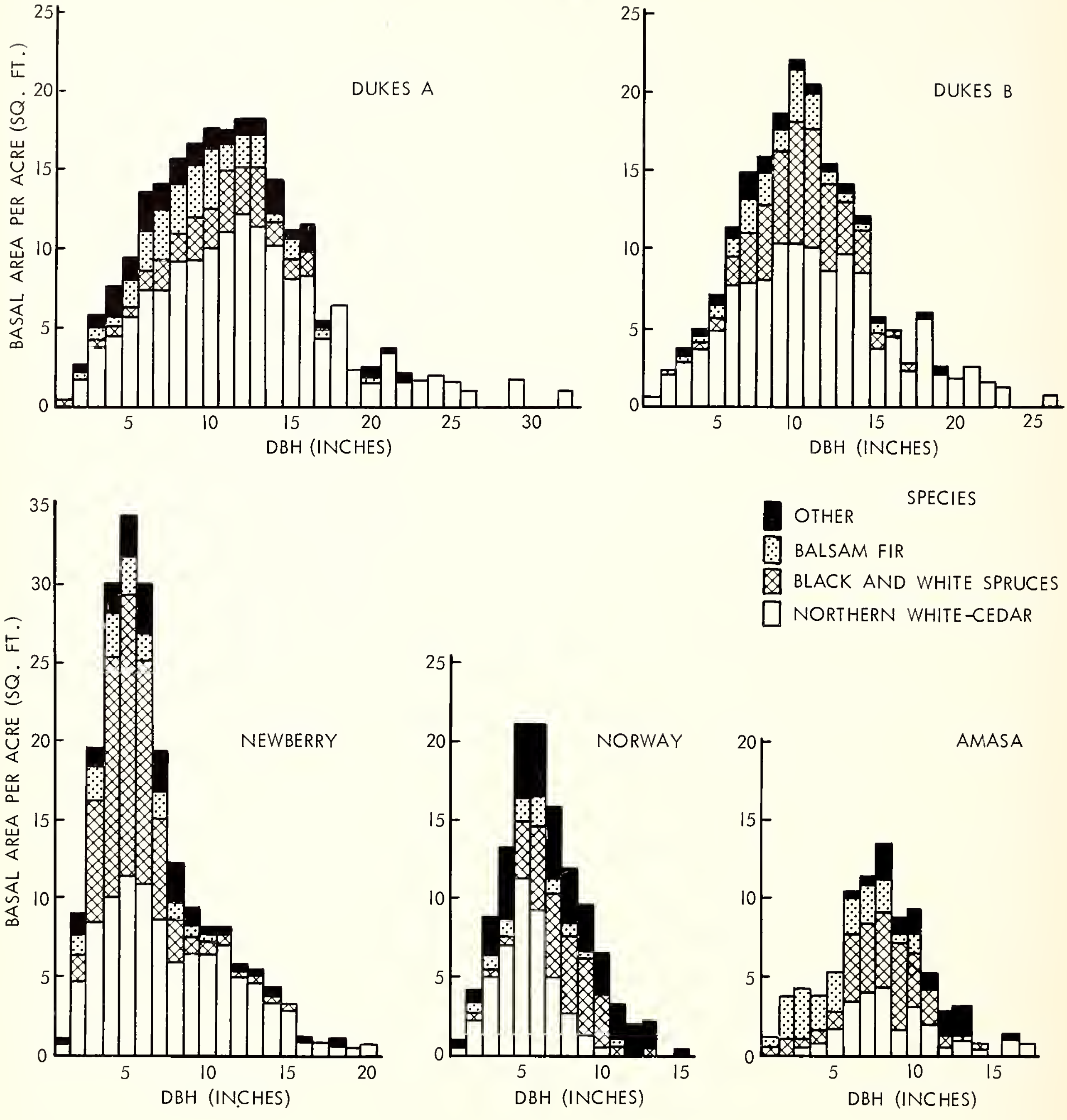


FIGURE 3. — Stand structure and composition at the five study areas. D.b.h. is diameter at breast height.

Site indices were obtained for black spruce, balsam fir, and northern white-cedar at all study areas except Amasa where they could not be determined because of the uneven-aged stand condition. Site indices, expressed as total height at 50 years, were 40 feet for black spruce, 45 feet for balsam fir, and 30 feet for northern white-cedar on the two study areas at Dukes. On the study areas at Newberry they were 40, 40, and 25 feet and at Norway 45, 50, and 30 feet respectively. Water movement was moderate through each of the study areas.

The soil on the two detail study areas at Dukes was classified as Lupton muck. It averaged 3.5 feet deep in study area A and 3.1 feet deep in area B but ranged from 2 to 6 feet in both areas. Reaction of the surface layers was near neutral, with an average pH of 7.5, but below 1 foot it was more alkaline, with a pH of 8.0.

The size of the study areas ranged from 10 to 30 acres. The minimum was 5 acres for each cutting method in the detail studies at Dukes and 2 acres in all other study areas.

CUTTING METHODS

Five cutting methods were tested. Tree selection and designation by diameter limits were used for the all-aged systems. The even-aged systems were a two-cut shelterwood, clearcut strips, and clearcut blocks.

All five methods were included in the studies at the Upper Peninsula Experimental Forest and at Newberry. Clearcutting in blocks was not tested in the studies at Amasa and Norway.

TABLE 2. — *Basal area of residual stands; all trees 4 inches d.b.h. and larger*
(In square feet per acre)

Study area	Cutting method			
	Uncut	Selection	Diameter limit	Shelterwood
Amasa	77	48	60	44
Dukes-A	219	112	38	60
Dukes-B	188	119	106	54
Newberry	175	94	94	89
Norway	109	88	76	49

Uneven-aged Systems

Selection Cutting

Individual tree selection removed between one-fourth and one-half of the basal area by cutting the poor-risk and poor-quality trees in all size classes over 4 inches d.b.h. The residual stands were composed of spruce, cedar, and balsam fir in approximately the same proportions as found prior to cutting. Only a few trees of other species were left scattered throughout the stands. The cutting cycle was undetermined but was expected to vary between 10 and 20 years depending upon the development of regeneration and growth of the residual stands.

The cutting provided small openings and left a relatively uniform spacing in the overstory. The residual overstory ranged from 48 to 119 square feet of basal area per acre, but most of the variation was due to the variation in original stocking (table 2).

Diameter-limit Cutting

The objective of the diameter-limit cutting was similar to that of the selection cut. A diameter limit was set for spruce, cedar, and balsam fir to insure that the residual stand would have about the same proportion of these species as the original stand. All trees above these limits and the merchantable trees of all other species were designated for cutting. Diameter limits used on the five study areas ranged from 6 to 12 inches d.b.h. for spruce, 6 to 10 for cedar, and 6 to 8 for balsam fir.

Except for the study identified as "Dukes-*A*", the diameter-limit cutting left approximately the same average stand density as the selection cutting (table 2). The residual stand density at Dukes *A* was considerably lower than planned because of a severe ice storm during logging. Since the storm occurred at the time of logging, most of the trees were utilized and included in the cut, leaving the residual stand density at 38 square feet of basal area per acre.

In all of the diameter-limit cuttings the residual stand provided less uniform cover than the original stand. This cutting method emphasized lack of uniformity in the original stand instead of minimizing it as the selection cut did. Portions of the stand with lower densities had more trees over the diameter limit than did areas with higher densities; consequently the most open parts of the stand were cut the heaviest.

F-503686

FIGURE 4. — Residual shelterwood stand of cedar, black spruce, white spruce, and balsam fir 2 years after cutting.

Even-aged Systems

Two types of even-aged silviculture were tested. One involved complete removal of the overstory on part of the area, either in narrow strips or small blocks. The other involved partial removal of the overstory over the entire area, leaving the most vigorous and best developed trees as a shelterwood stand for seed production and site protection. Both types presuppose subsequent cuts to remove the shelterwood overstory and the adjacent strips and blocks.

Shelterwood Cutting

In the shelterwood method, spruce, balsam fir, and cedar trees were selected to provide a uniform overstory of one-fourth to one-half the original basal area (fig. 4). The trees in the residual shelterwood stand were selected for quality, vigor, and species. Quality was determined by cull and form. Tree vigor was based on crown class and competition with neighboring trees. The best quality and most vigorous spruce, cedar, and balsam fir in that order of preference were left uniformly spaced over the area. Species composition in terms of basal area averaged 44 percent spruce, 44 percent cedar, 10 percent balsam fir and 2 percent other species in the two study areas at the Upper Peninsula Experimental Forest. On the other study areas, spruce ranged from 10 to 31 percent, cedar from 9 to 73 percent, and balsam fir from 2 to 7 percent of the total basal area.

Clearcutting in Strips and Blocks

Clearcutting methods were included in all of the studies, but only those at Dukes removed the entire overstory (fig. 5). The others were "merchantable" clearcuts and left an overstory of unmerchantable trees ranging from 35 to 65 square feet of basal area per acre. The differences between the merchantable clearcuts and the silvicultural clearcuts, which removed the overstory completely, were so great that they cannot be considered the same treatment. Evaluation of the clearcutting methods is therefore based on the results obtained from the silvicultural clearcuttings in the two stands at Dukes.

Both the strip and block clearcutting methods removed the entire overstory on one-third of the treatment area. Strips were 75 feet wide and oriented in an east-west direction. Blocks were 2 chains square or 0.4 acre in size.

F-471974
FIGURE 5. — The clearcutting methods in the two studies at Dukes removed the entire overstory in 75-foot-wide strips and 2-chain-square blocks.

REGENERATION

Advance Reproduction

The five study areas were each fully stocked with regeneration before cutting if all sizes and all tree species are included. Advance reproduction was present on 96 to 100 percent of the milacre plots. Reproduction less than 6 inches tall was abundant on all areas, but most of it was only 1- or 2-year-old seedlings. They are being continually replaced by new regeneration and can be considered as universally present in mature mixed conifer swamps.

The study areas at Norway and Amasa had regeneration 6 or more inches tall on 65 and 75 percent of the plots respectively. At Newberry, however, only 4 percent of the plots had reproduction this tall. The two detail study areas at Dukes averaged 80 percent stocking with advance reproduction of this size.

Species composition of the advance reproduction 6 or more inches tall was quite variable among the study areas. At Dukes the conifers accounted for only about one-third of the regeneration but on the other study areas they were between 50 and 80 percent of the total, with balsam fir predominant. Spruce had the least stocking in all stands except at Amasa, where hardwoods had the least.

Reduction in stocking by the mechanical effects of logging were kept to a minimum by the protective cover of snow during the winter operations (Thornton, 1957b). Losses of advance regeneration were primarily due to exposure and the accumulation of slash. Both the total area covered with slash and the area covered with deep slash increased with the intensity of the cut (table 3).

The exposure, of course, also increased with the intensity of the cut. The decrease in stocking of advance reproduction after cutting ranged from 12 to 38 percent, being least in the partial cuttings and greatest in the clearcuttings.

Release of advance reproduction was also related to the intensity of the cut. Before cutting, the reproduction on 12 percent of the milacre plots was classified as "free to grow".[2] After cutting, the plots stocked with reproduction free to grow had increased for each of the methods. The increase ranged from 8 percent in the selection cutting method to 23 percent in the clearcut strips.

The total stocking of advance reproduction after cutting ranged from 38 to 56 percent. Reproduction free to grow ranged from 26 to 47 percent. In general, the total stocking decreased with the intensity of the cut, but the area stocked with reproduction free to grow increased.

[2] *Reproduction that had a reasonable chance of reaching the overstory was classified as "free to grow".*

TABLE 3. — *Effects of cutting methods on slash accumulation and advance reproduction in the two study areas at Dukes immediately after cutting*

Cutting method	Overstory basal area[1]		Area covered with-		Milacres of advance reproduction[2]			
	Before cutting	After cutting	Deep slash[3]	Any slash	Des-troyed	Re-leased	Free to grow	Total
	Sq. ft.	*Sq. ft.*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Uncut	189	189	0	0	0	0	12	71
Selection	223	115	19	57	15	8	26	56
Diameter limit	205	70	29	75	12	15	35	48
Shelterwood	200	57	33	75	12	19	44	56
Clearcut strips	199	0	51	86	38	23	47	49
Clearcut blocks	200	0	49	80	29	22	37	38

1 *All trees 3.6 inches d.b.h. and larger.*
2 *Includes all tree species between 6 inches tall and 0.5 inch d.b.h.*
3 *Over 3 feet high.*

Regeneration 5 Years After Cutting

Regeneration established after cutting was not observed separately from the advance reproduction surviving the first 5 years. Thus the total regeneration represents the net effect of the various cutting methods. The fifth-year results include both the decreases in advance reproduction due to logging and subsequent exposure or other causes and the increases due to new regeneration.

Because of the abundant advance reproduction before cutting, the total density of regeneration between 6 inches high and 0.5 inch d.b.h. in the cut stands was only slightly greater than the 7,085 trees per acre present in the uncut stands at Dukes (table 4). However, considering only the conifer species, the density ranged from less than 2,000 to over 5,000 stems per acre. The density of the conifer regeneration was less in the uneven-aged cutting methods (selection, 1,998; and diameter limit, 2,542) than in the even-aged methods (shelterwood, 2,897; clearcut strips, 3,844; and clearcut blocks, 5,135).

Composition of the established regeneration 5 years after cutting was closely related to the intensity of the cut. The proportion of spruce, balsam fir, and northern white-cedar reproduction was greatest where the overstory was completely removed (fig. 6). The proportion of hardwood reproduction decreased as the residual overstory density decreased. The net result was approximately the same total density in all cutting methods, but the cutting methods that were most favorable for conifers were least favorable for hardwoods. Although the density of each conifer species 5 years after cutting increased with the proportion of overstory removed, these increases were not equal. Spruce increased the most and balsam fir the least. Cedar constituted practically half of total conifer reproduction in each cutting method but

TABLE 4. — *Fifth-year regeneration 6 inches or more tall on the two study areas at Dukes*

Cutting methods	Number of stems per acre					Percentage of milacres stocked with-		
	Spruce	Balsam fir	Cedar	Hard-wood	Total	Coni-fers	Hard-wood	Any tree
Uncut	14	390	1,877	4,804	7,085	30	88	92
Selection	37	977	984	5,456	7,454	51	80	87
Diameter limit	42	1,183	1,317	5,846	8,388	61	84	88
Shelterwood	196	1,327	1,374	4,953	7,850	71	92	98
Clearcut strip	223	1,716	1,905	4,405	8,249	75	78	91
Clearcut block	467	2,092	2,576	3,509	8,644	75	75	89

F-503687

FIGURE 6. — Conifer reproduction in clearcut blocks and clearcut strips had a better opportunity to compete with shrubs and hardwood species than that in partially cut stands.
F-503688

was 82 percent of that in the uncut stand. The number of stems of cedar reproduction in the uncut stand was less than in the clearcut strips and blocks but more than in the partially cut stands.

The distribution of the reproduction must also be considered in evaluating the effect of the cutting methods. Although the actual requirement for satisfactory stocking is not known, an arbitrary minimum of 60 percent of the milacres stocked with at least one stem, which is commonly used, was established for this study. Using this standard, all cuttings except the selection method resulted in satisfactory stocking of conifers alone (table 4). The selection cutting, with only 51 percent stocking of conifers, might also be considered satisfactory since it is scheduled to receive additional selective cuts which may increase the conifer stocking. However, all of the partially cut areas (selection, diameter limit, and shelterwood) are more heavily stocked with hardwood reproduction than are the clearcut areas (figs. 7 and 8). The competition of this hardwood reproduction could

FIGURE 7. — Competition from shrubs and hardwood reproduction was the most severe in partially cut stands. The conifer regeneration in this shelterwood stand at Dukes was well established 5 years after cutting but it was overtopped with shrubs and hardwood reproduction up to 8 feet tall as shown by the 6-foot range pole.

F-503689

FIGURE 8. — Competition from shrubs and hardwood reproduction in the clearcut areas was not as severe as in the partially cut stands, but it will still delay the growth of conifers unless it is controlled.

well limit the development of established conifer reproduction and prevent the establishment of additional conifers following future cuts in these stands.

The results at Amasa, Newberry, and Norway differed from those at Dukes in some respects. Stocking of conifer regeneration 6 or more inches tall showed the same general trend for the various cutting methods in all study areas. But compared to Dukes, the percentage of milacres stocked was higher at Amasa, lower at Newberry, and approximately the same at Norway. Part of these differences is undoubtedly related to the composition of the overstory at the study areas. Amasa had the highest proportion of balsam fir, which is a very tolerant species and regenerates more abundantly than the other conifers, whereas Newberry had the highest proportion of spruce, which is the least tolerant, except for tamarack, and the most difficult to regenerate.

Competition from hardwood species was much more variable among the study areas. There was more hardwood reproduction at Dukes than at any of the other study areas, and the cutting methods did not have the same trends in all areas. Composition of the overstory hardwood species was quite different among the study areas as described earlier. This probably explains much of the variation, but the application of the cutting methods also contributed to it. Commercial clearcuttings left a residual stand of unmerchantable trees, making conditions more nearly like those in the partial cuttings than those in the silvicultural clearcuttings where the entire overstory was removed.

Considering all the information available from these study areas the general conclusions agree with the findings at Dukes. Conifer reproduction fared best in the open, where it was more abundant and had the least competition from hardwoods.

● ENVIRONMENT FOR SEEDLING GROWTH ●

The amount and kind of competing vegetation and use by animals as well as some measures of the micro-environment were recorded for each of the cutting methods on the two study areas at Dukes. These data were used to compare the treatments in terms of overhead shade, air temperature, and seedbed moisture conditions. The differences in conifer regeneration and competition were related to these factors.

Physical Factors

The effects of shade, temperature, and seedbed moisture on regeneration cannot be evaluated directly from this study, but a general description of the conditions created by the cutting methods can be obtained. Briefly, the clearcuttings had less overhead shade, lower minimum temperatures, and fewer "dry" seedbeds than did the partial cuttings. Details are discussed at some length below.

Overhead shade

Classification of the milacre seedbeds by overhead shade conditions shows that the proportion of the area shaded was related to the residual basal area as would be expected. Overhead shade was classified as none, moderate, or heavy based upon the crown cover directly over the plot and the estimated proportion of the day that sunlight would fall on the seedbed.

Conifer regeneration 6 or more inches tall was most abundant and most uniformly distributed where the overhead shade was the least (table 5). As the amount of overhead shade increased, conifer regeneration decreased. Moderate shade was most favorable for hardwoods.

TABLE 5. — *Stocking and density of regeneration between 6 inches tall and 0.5 inch d.b.h. related to overhead shade on study areas at Dukes 5 years after cutting*

Overhead shade	Conifers		Hardwoods	
	Stocking	Density	Stocking	Density
	Percent	*Number*	*Percent*	*Number*
None	70	3,100	84	4,600
Moderate	53	2,100	89	5,400
Heavy	41	2,100	79	4,400

Temperatures

Frost was observed on the ground 2 weeks earlier in the clearcut areas than in any of the cutting methods with a residual overstory. This observation prompted the recording of air temperatures in the clearcut blocks, the shelterwood, and the uncut stand during the growing season. Two years' records show that maximum temperatures under the shelterwood stand averaged 5 degrees higher than under the uncut stand, but minimum temperatures were approximately the same in both stands. In the clearcut blocks minimum temperatures averaged 6 degrees lower than in either the shelterwood cutting or the uncut stand, and maximum temperatures averaged 6 degrees higher than in the uncut stand or nearly the same as in the shelterwood cutting.

The significance of these findings is not fully understood, but perhaps the combination of both higher and lower temperatures in clearcut blocks and strips favors the swamp conifers in competition with shrub and hardwood species. High daytime temperatures early in the season stimulate bud bursting, and the succulent tissues are then subjected to frost injury from low nighttime temperatures. Phenological records at the Upper Peninsula Experimental Forest show that growth starts about May 15 for most of the competing shrub and hardwood tree species except black ash. The average date that growth starts for black ash, balsam fir, and northern white-cedar is 10 days later on May 25, and for black spruce it is not until June 6.

Moisture

Because the ground water level is usually near the surface in mixed conifer swamps, moisture is one of the most important factors affecting the vegetation. The fluctuations of the ground water levels were recorded during the growing season in an uncut portion of study area *B* at Dukes (fig. 9). Except for two short periods during August 1957 the ground water was not more than 1 foot below the average ground surface and most of the time it was less than 0.5 foot.

The combination of high water table and uneven ground surface or microtopography results in some seedbeds that are periodically under water and some that get very dry in the summer. In an attempt to establish a relationship between stand treatment and surface moisture conditions, each milacre plot was classified as "wet", "average", or "dry" based primarily on its elevation in relation to the water table. The smallest proportion of average seedbeds was on the uncut areas, and the largest proportion on the clearcut areas (table 6). A smaller proportion of the area was classified as wet in the cut stands than in the uncut stands. The proportion classified as dry was least in the clearcut areas and about the same in uncut and partially cut stands. Thus the proportion of wet seedbeds decreased with all methods of cutting, but the proportion of dry seedbeds did not decrease until the complete overstory was removed.

TABLE 6. — *Classification of milacre seedbeds by moisture condition 5 years after cutting on study areas at Dukes*

(*in percent*)

Cutting method	Moisture condition on seedbed		
	Wet	Average	Dry
Uncut	26	47	27
Selection	19	55	26
Diameter limit	16	57	27
Shelterwood	17	56	27
Clearcut strips	17	72	11
Clearcut blocks	12	71	17

These differences in seedbed moisture conditions may have been caused by changes in both the ground surface and water table. The ground surface was modified to some extent by the logging equipment even though the operations were carried out during the winter months. No direct measurements were taken, but the disturbance was observed to increase with the intensity of cutting. The cutting methods may have influenced the water table also by their effect on precipitation reaching the ground and by possible changes in evapotranspiration.

One-third of the total precipitation in the central part of the Upper Peninsula of Michigan falls as snow. There is very little snowmelt during the winter months; consequently most of this moisture

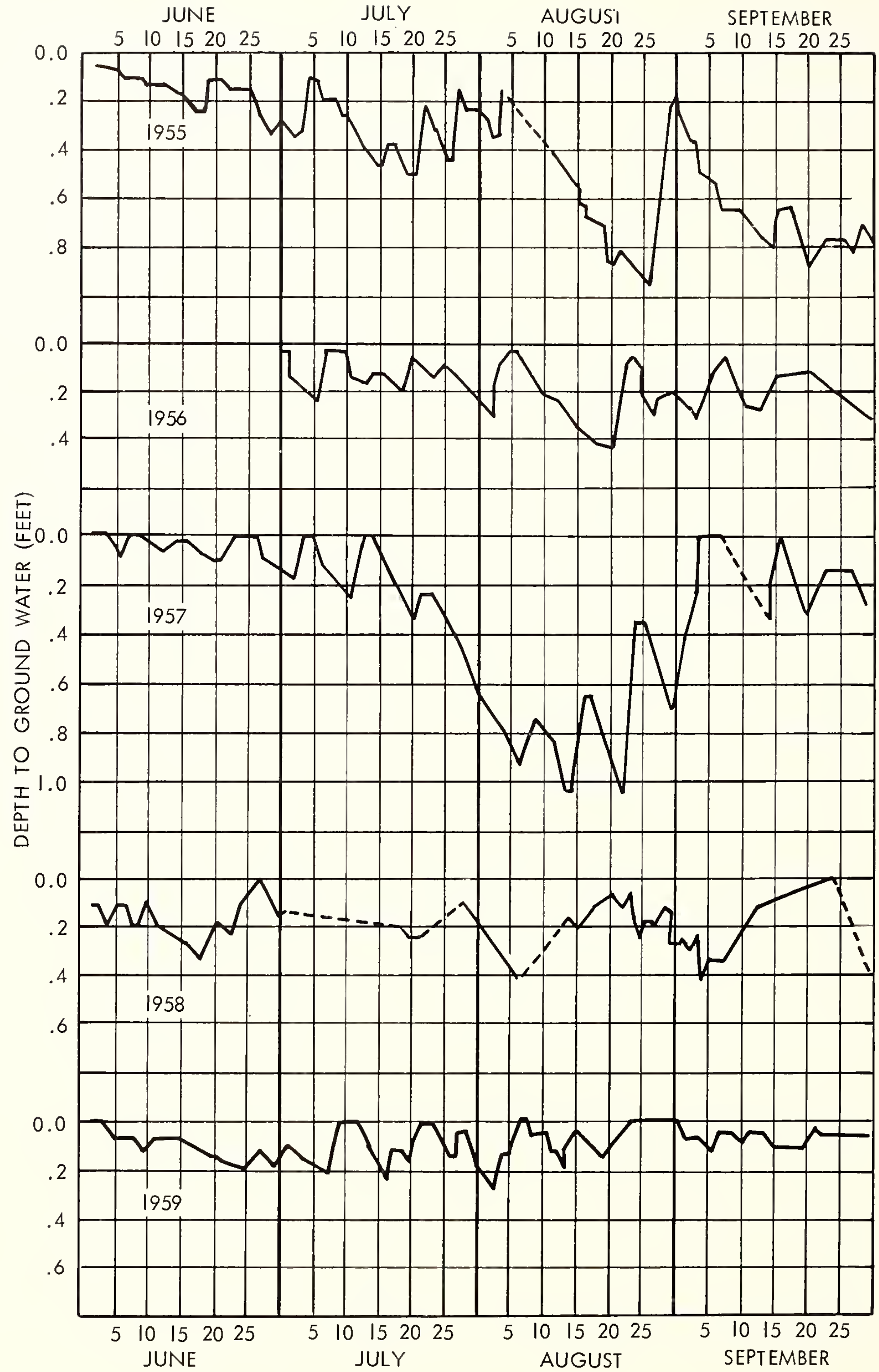


FIGURE 9. — Patterns of ground water levels in uncut mixed conifer swamp, Dukes study area *B*.

is held in the snowpack until spring break-up and becomes available just before the start of growth (fig. 10). This is an important source of soil moisture recharge.

Measurements in the study area over 4 winters showed maximum snow depths during the second or third week of March. The snowpack in the clearcut areas averaged 5 to 10 inches deeper than in the partial-cut areas and 13 to 16 inches deeper than in the uncut stand (table 7). Snow melted earliest on the north side of the clearcut areas and latest in the uncut stand. During the period covered by these measurements, an appreciable amount of ground in the clearcut areas was free of snow cover by April 15, and snow had completely disappeared from the uncut stands and the south edges of openings by the middle of May. This same trend has been reported for black spruce swamp cuttings in northern Minnesota (Weitzman and Bay, 1959).

TABLE 7. — *Average depth of maximum snowpack at Dukes*

(in inches)

Cutting method	Date				Average
	3-13-58	3-9-59	3-17-60	3-9-61	
Uncut	28	34	42	31	34
Selection	38	40	46	34	40
Diameter limit	38	42	52	38	42
Shelterwood	42	42	48	35	42
Clearcut strip	45	51	57	45	50
Clearcut block	45	47	54	40	47

The data on seedbed moisture conditions show that hardwoods were dominant on a larger proportion of the dry seedbeds (70 percent) than on wet ones (60 percent), but the reverse was true for conifers, the figures being 23 and 27 percent respectively. The smaller proportion of dry seedbeds in the clearcut methods might help account for

F-503690

FIGURE 10. — Snow pole in a shelterwood stand at Dukes showing 50 inches of snowpack (the 5-foot pole is marked at 3-inch intervals). A series of 60 poles observed for 4 winters showed that the average maximum snow depth increased 6 to 8 inches when the overstory was partially cut and 13 to 16 inches when it was completely removed in strips or blocks.

their slight advantage over partial cuts in conifer abundance and distribution.

Biological Factors

Competing Vegetation

Although conifer regeneration may become established within the first year after cutting, it is often suppressed by hardwood and brush competition for many years.[3] An evaluation of this competition showed it was present in 75 to 80 percent of the milacre quadrats and 30 percent were over 3 feet tall 5 years after cutting. There were no differences in stocking among the cutting methods studied.

Mountain maple was the most widely distributed species of brush competition in the uncut stand and was still the most widespread in all cutting methods after 5 years (table 8). None of the

[3] *The term "brush" as used here includes both woody shrubs and unmerchantable hardwood tree species as shown in table 8.*

TABLE 8. — *Percent of milacres stocked with brush species at Dukes 5 years after cutting*

Species	Cutting methods					
	Uncut	Selection	Diameter limit	Shelterwood	Clearcut strip	Clearcut block
Mountain maple	73	52	59	61	34	30
Speckled alder	17	8	6	17	23	20
Ribes	13	18	21	15	14	18
Dogwood	7	8	6	12	24	16
Honeysuckle	12	8	8	4	1	4
Rubus	0	3	16	1	7	16
Willow	0	7	7	3	8	5
Cherry	0	0	1	0	1	1
Hazel-nut	1	1	1	1	0	1

other species was found on more than 25 percent of the area in any of the cuttings. Speckled alder was the second most frequent species in the even-aged cutting methods and ribes in the uneven-aged methods. Dogwood was more prevalent in the even-aged cutting methods than in the uneven-aged methods and honeysuckle was more common in the uncut stand. Brambles (*Rubus* spp.) and willow were scattered throughout all cutting methods but were not found in the uncut stand.

Growth of established conifer regeneration can be increased by releasing it from overtopping brush and hardwood competition. In another study at the Upper Peninsula Experimental Forest, the average height growth of seedlings during the first 5 years after release was 32 to 93 percent more than that of the seedlings that were not released (table 9). Balsam fir showed the greatest response and northern white-cedar the least. Black spruce was intermediate, with 68 percent increase in height growth. Before release, black spruce and balsam fir averaged 3.0 feet and northern white-cedar 4.5 feet in height. They were overtopped with speckled alder and mountain maple.

TABLE 9. — *Average growth of trees during first 5 years after release compared to growth of overtopped trees*

Species	Average annual height growth		
	Overtopped	Released	Increase
	Feet	*Feet*	*Percent*
Balsam fir	0.22	0.43	93
Black spruce	0.22	0.37	68
Cedar	0.22	0.29	32

With the amount of shrub and hardwood tree species present in all of the cutting methods tested and the favorable results obtained by releasing conifers from overtopping competition, the possibility of release as a regular management practice should be considered. Cutting the overtopping shrubs and hardwoods would involve a large number of stems in most cases. A more economical way might be with the use of a silvicide.

Animals

Mixed conifer swamps in the Lake States often support large populations of whitetail deer and snowshoe hare (Thornton, 1957a). In some stands the populations exceed the carrying capacity, and over-browsing severely restricts or eliminates the reproduction, especially that of northern white-cedar. In study area *A* at Dukes, however, no difference was observed between the reproduction protected and that unprotected from deer and hare. The population of deer on the Experimental Forest in 1959 was 15 animals per square mile as determined by a pellet survey. No estimate of the hare population on the study area is available, but it can be asserted that neither the snowshoe hare nor the whitetail deer had an appreciable effect on the overall regeneration. No data were collected on the protected and unprotected reproduction at the other study areas, but observations indicate that the effects of browsing were no greater than those found on study area *A*.

Krefting (1962) studied the relative deer use among the cutting methods in the two stands at Dukes and found that in the partial cuttings it increased with the intensity of the cut. The clearcut blocks had the least evidence of deer use. The results in the strip cuttings were variable; use was high in the uncut strips and low in the clearcut strips.

Other animals also find both food and shelter in mixed conifer swamps, but their influence on the stand is more difficult to evaluate. Two examples illustrate some detrimental effects of the beaver and squirrel. Beavers dammed one of the streams draining the Amasa study and flooded the shelterwood cutting area. At the Dukes studies, squirrels clipped a large amount of the spruce cones before they ripened in 1956 when the seed crop was rated as good. Good seed crops were also recorded in 1958 and 1960; but losses caused by squirrels were minor.

Classification of Residual Trees

A comparison of the basal area per acre by diameters before and after cutting shows the changes in stand structures caused by the three partial cutting methods at Dukes (fig. 11). The differences in growth and mortality among the cutting methods were caused by the differences in both the density of the residual stand and the type of trees left.

Trees in the three partial cutting methods (selection, diameter limit, and shelterwood) and in the uncut stand were classified prior to cutting by the Lake States tree vigor classification system, which is based on crown position and development (Gevorkiantz et al., 1943). Three classes are recognized: progressive, provisional, and regressive.[4]

The number of residual trees per acre in each of the three classes varied with the cutting method (table 10). The selection and diameter-limit cuttings left the same number of regressive trees per acre, but the selection method left a larger number of progressive and provisional trees. The shelterwood cutting method left about the same number of progressive and provisional trees per acre as the diameter-limit cutting but only about one-third as many regressive trees.

Growth

The net growth during the first 5 years after cutting was less in cut stands than in the uncut stand. Part of this was due to the reduction in the growing stock and part was due to higher mortality in the cut stands (table 11). Both the diameter-limit and shelterwood cutting methods had negative net growth. The selection cutting had the most gross growth, but net growth was only three-fourths of that in the uncut stand because of increased mortality after cutting.

Although this study indicates that partial cutting in mixed conifer swamps is not justified from the standpoint of growth, younger stands have shown favorable results. A 45-year-old stand in the eastern end of the Upper Peninsula had 320 trees per acre over 5 inches d.b.h. 10 years after a heavy thinning compared to only 80 trees that large in the unthinned plot (Roe, 1947). However, a similar thinning in a 60-year-old stand was not beneficial, but the reason for this was thought to be poor drainage. In northern Wisconsin, growth per acre was greatest in the densest plots in a 65-year-old mixed conifer swamp stand, but diameter growth of individual trees responded to a 10-year-old improvement cutting to such an extent that good growth was recorded for all stand densities from 90 square feet of basal area per acre to over 200 (Skilling, 1959).

Differences between the growth obtained in this study and that reported elsewhere may be partially due to stand ages, conditions, sites, and the shorter growth period (5 years) used. The growth may well increase in some of these cutting methods after the trees are fully adjusted to their new growing space. A reduction in mortality might also be expected, which would increase the net growth.

Mortality

An average of 23 trees per acre was lost by mortality during the first 5 years after cutting (table 12). Mortality ranged from 13 trees per acre in the uncut stand to 33 trees per acre in the diameter-limit cutting.

More than 40 percent of the mortality (number of trees) in the uncut stand as well as in each of the partial cutting methods was the result of windthrow and breakage (fig. 12). Other types of mortality included logging injury and exposure.

More mortality occurred in each of the partially cut stands than in the uncut stand. Although the

---

[4]		
Progressive	*1. Head dominants*	*Dominating surrounding trees.*
	2. Strong dominants	*Competing with trees of same crown class but poorer development.*
Provisional	*3. Conditional dominants and codominants*	*Competing with trees of same crown class on equal footing.*
Regressive	*4. Weak dominants and codominants*	*Competing with trees of same crown class but better developed.*
	5. Intermediate	*Competing with trees of higher crown class.*
	6. Suppressed	*Overtopped.*

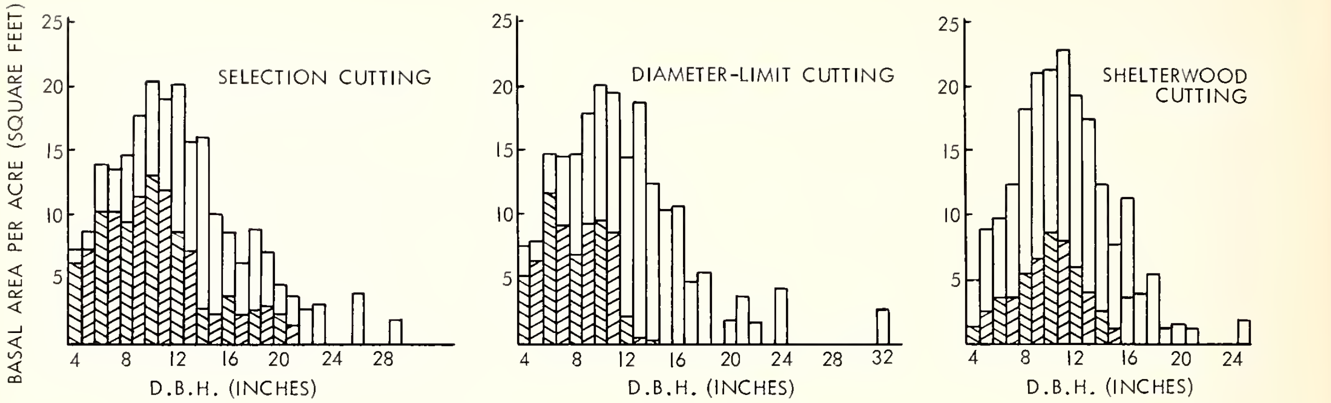


FIGURE 11. — Effects of partial cutting methods on stand structure in the study areas at Dukes. Shaded portions of graphs represent the residual stand.

F-503691

FIGURE 12. — The shallow roots of black spruce and brittle wood of balsam fir were factors in the two types of mortality caused by wind-uprooting and breaking. About 40 percent of the mortality during the first 5 years was caused by wind.

TABLE 10. — *Number and percentage of residual trees 3.6 inches d.b.h. and larger per acre by tree class, Dukes study area*

Class	Cutting method: Uncut		Selection		Diameter limit		Shelterwood	
	No.	*Percent*	*No.*	*Percent*	*No.*	*Percent*	*No.*	*Percent*
Progressive	128	29	71	21	47	17	44	31
Provisional	68	15	75	23	40	15	37	26
Regressive	251	56	188	56	188	68	60	43
Total	447	100	334	100	275	100	141	100

TABLE 11. — *Effect of cutting methods on basal area of residual stands during first 5-year period, Dukes study area*[1]

(*In square feet*)

Cutting method	Overstory basal area per acre[2]			Annual change per acre		
	Before	After	5th year	Net	Mortality	Gross[3]
Uncut	189.2	189.2	194.0	.96	1.06	2.02
Selection	223.2	115.4	119.0	.72	1.65	2.37
Diameter limit	205.3	71.2	69.6	—.32	1.53	1.21
Shelterwood	199.9	57.1	56.7	—.08	1.30	1.22

1 *Clearcut blocks and strips are excluded since they had no residual stand.*
2 *Includes all trees 3.6 inches d.b.h. and over.*
3 *This column shows the annual change that would have occurred if no trees had died.*

TABLE 12. — *Summary of mortality per acre during first 5 years after cutting, by cutting method and tree class*

(*Number of trees*)

Class	Cause of mortality	Cutting method: Uncut	Selection	Diameter limit	Shelterwood	Average
Progressive	Wind	1.5	1.5	2.2	3.0	2.0
	Other	2.0	1.4	2.2	3.5	2.3
	Total	3.5	2.9	4.4	6.5	4.3
Provisional	Wind	0.0	4.4	4.3	1.5	2.6
	Other	0.5	3.2	0.4	0.5	1.1
	Total	0.5	7.6	4.7	2.0	3.7
Regressive	Wind	4.8	5.3	8.5	4.0	5.6
	Other	4.4	13.1	15.7	5.0	9.6
	Total	9.2	18.4	24.2	9.0	15.2
Total	Wind	6.3	11.2	15.0	8.5	10.2
	Other	6.9	17.7	18.3	9.0	13.0
	Total	13.2	28.9	33.3	17.5	23.2

number of trees lost per acre was the greatest in the diameter-limit cutting, the greatest loss in basal area was in the selection cutting (table 11). The estimated volumes lost by mortality during the 5-year period were 0.33 cord per acre in the selection cutting, 0.31 cord in the diameter limit, 0.26 cord in the shelterwood, and 0.21 cord in the uncut stand.

The average mortality for all stands by tree class was 4 progressive, 4 provisional, and 15 regressive trees per acre during the 5-year period. The fact that regressive trees made up the greatest proportion of the mortality explains some of the differences between the cutting methods. In the uncut and selectively cut stands, 56 percent of the residual trees were regressive; after the diameter-limit cut, 68 percent were regressive; and after the shelterwood cut, 43 percent. In general the shelterwood cutting method removed the greatest proportion of regressive trees, the diameter-limit cutting left the most, and the selection cutting method removed trees in about the same proportion as they occurred in the original stand.

RECOMMENDATIONS

The results observed during the first 5 years in this study have established some basic relationships that are useful in the development of silvicultural prescriptions for mixed conifer swamps. As described earlier in this report, the type is composed of a complex mixture of species and shows a strong tendency toward ecological change. Assuming that it is desirable to keep a high proportion of conifers on these sites, the natural succession must be held somewhere between the shrubs and the hardwood tree species. The even-aged cutting methods were the most successful in this respect. Conifer regeneration made the best development and competing hardwoods the poorest development on the clearcut blocks and strips. The shelterwood method was also more favorable for the conifers than either of the uneven-aged methods tested, but hardwood competition was greater than on the clearcut blocks or strips.

It is apparent, then, that even-aged management holds the most promise for regenerating conifers in the mixed conifer swamp type.

Determination of rotation age is a major problem in the application of even-aged systems in this type because some species reach maturity at a much earlier age than others. Stands with a high proportion of balsam fir must be cut at a relatively young age compared to stands consisting mostly of spruce or cedar. In stands where balsam fir is a significant component in mixture with spruce and cedar a compromise must be made between harvesting the balsam before losses become excessive and keeping spruce and cedar through their most productive growth period. A compromised managerial rotation age of 80 years has been suggested in a cutting guide prepared by the Forest Service for these stands (Stout, 1961).

This guide, based primarily on early results of this study, recommends strip cutting. Narrow strips not exceeding one tree height in width are to be clearcut. Wider strips up to two tree heights are permissible providing 30 square feet of basal area per acre in dominant conifers of good genetic characteristics are left as a shelterwood overstory.

These recommendations were generally borne out by later analysis of the study. The major point not discussed in the guide is the possibility of clearcutting in blocks or irregular patches instead of strips. Since the results in terms of conifer establishment and growth were as good on blocks as on strips, it would appear that these two methods are equally applicable. The choice of method should depend on the condition of the stand. In uniform stands it will usually be more advantageous to clearcut strips. In many stands, however, natural mortality or past stand treatment has already created a number of age classes in irregular patches. Block or patch cuttings could take better advantage of this natural age distribution than could regularly spaced strips.

Clearcut openings should be small. Observations of numerous cuttings in this type indicate that clearcutting large areas usually results in extensive brush invasion. Considerable time is often required before the conifer species again occupy these sites. The size of openings used in this study provides a guide until more information is available. Blocks are 2 chains square, and strips are 75 feet wide.

Observations of regeneration and measurements of the environmental factors suggest that a northerly exposure is the most favorable for swamp conifer regeneration. This can be accomplished by cutting east-west strips with subsequent strip cuttings progressing toward the south. Similarly block cuttings should progress from north to south in each stand.

Shelterwood cutting is recommended for small areas of swamp where it is impractical to use clearcut blocks or strips. A residual stand of 60 square feet of basal area per acre should be left after the initial cut. Well-developed dominant and codominant trees uniformly spaced over the area should be selected on the basis of windfirmness, seed production, and tree quality. They should remain until a good stand of conifer regeneration is established, approximately 10 years.

Although the recommended cutting practices create the most favorable conditions for the establishment and growth of conifer regeneration, hardwood competition if not controlled is likely to retard growth, especially in the shelterwood method. Release of established conifer seedlings from 5 to 10 years after cutting will ensure satisfactory development. Competition is generally not limiting until the fifth year, but after the tenth year conifer growth may be reduced considerably. Techniques for releasing the swamp conifers have not been studied, but chemical control methods seem to offer the best possibility for reducing the large number of hardwood stems present in the swamps at minimum cost.

These recommendations are based on observations and experience in conjunction with the results of this study. Most of the evidence supports the recommendation for even-aged management. A lesser amount of evidence is available for the specific applications discussed, and they will undoubtedly be modified when more detailed information is acquired on the effects of opening size, shape, and orientation, and the density and composition of the shelterwood overstory.

● SUMMARY ●

The mixed conifer swamp forests occupy the wet depressions and drainageways in the northern hardwood forest region. They vary in species composition, but one or more of the conifers, northern white-cedar, black spruce, white spruce, balsam fir, or tamarack, are always predominant. The species in the surrounding types are generally scattered throughout the swamp. The strong tendency toward a change in species composition is one of the major problems in regenerating the swamp forests. The hardwood species growing in the swamps are usually very aggressive but highly defective and poor in quality. Conifers are generally more desirable than hardwoods, but do not regenerate as prolifically nor grow as fast in their juvenile years.

A survey of the regeneration on cutover swamplands in the Upper Peninsula of Michigan made in 1951 showed that under existing logging practices, the proportion of conifers in the reproduction stand was less than that in the original stand. This indicated that these practices were inadequate to ensure continuous high production in swamplands. Therefore between 1952 and 1955 several experimental cuttings, including both even-aged and uneven-aged methods, were made on five study areas. The even-aged methods tested were clearcutting in small blocks, clearcutting in narrow strips, and a two-cut shelterwood. The uneven-aged methods were selection and diameter-limit cuttings.

Advance reproduction was generally present in all study areas, but most of it was small and not well established. The two clearcutting methods resulted in the greatest losses of advanced reproduction because of logging, exposure, and slash accumulation. However, they also released more advanced reproduction from overtopping trees than did any of the other cutting methods.

Five years after cutting, the distribution, density, and composition of conifer regeneration were best in the clearcut blocks. Clearcutting in strips was the next most successful followed in order by shelterwood, diameter limit, and selection. All cutover areas except those cut by the selection method were over 60-percent stocked with conifer regeneration. The area cut selectively was 51-percent stocked with conifers, which is probably adequate for this type of cutting if subsequent cuts have similar results.

All cutting methods tested encouraged the invasion of hardwoods, but partial cutting over the entire stand increased their abundance and size

more than did clearcutting portions of the stand. A study of the environment associated with the cutting methods showed differences in overhead shade, temperatures, and moisture, which explains some of the variation in early development of the reproduction.

Competition from shrub species also retards the development of conifer regeneration. Methods for dealing with this problem have not yet been tested, but growth studies have shown that release can increase the height growth of white-cedar by 32 percent, black spruce by 68 percent, and balsam fir by 93 percent. Use of silvicides to control both brush and hardwood competition should be considered.

The partially cut stands in this study made very little growth during the first 5 years after the cut. All but the selectively cut stands showed a net loss in basal area because of post-cutting mortality. Forty percent of this mortality in all cutting methods was caused by wind. Losses were greatest in the residual stands that had a high proportion of trees with suppressed and poorly developed crowns and least where the proportion of dominant and well developed crowns was highest.

Cutting recommendations to obtain conifer regeneration based on these results would generally favor clearcutting in small blocks or narrow strips. The shelterwood method, however, may be more appropriate in small areas of the swamp type. It will probably still be necessary to control shrubs and hardwoods in some areas to ensure a conifer stand.

LITERATURE CITED

Christensen, E. M., Clausen, J. J. (Jones), and Curtis, J. T.
1959. Phytosociology of the lowland forests of northern Wisconsin. Amer. Midland Nat. 62(1): 232-247.

Cunningham, R. N., Horn, A. G., and Quinney, D. N.
1958. Minnesota's forest resources. U.S. Forest Serv. Resource Rpt. 13, 52 pp., illus.

Findell, Virgil E., Pfeifer, Ray E., Horn, Arthur G., and Tubbs, Carl H.
1960. Michigan's forest resources. U.S. Forest Serv., Lake States Forest Expt. Sta., Sta. Paper 82, 46 pp., illus.

Gevorkiantz, S. R.
1956. Site index curves for balsam fir in the Lake States. U.S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 465, 2 pp., illus.

Gevorkiantz, S. R.
1957a. Site index curves for white-cedar in the Lake States. U.S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 472, 2 pp., illus.

Gevorkiantz, S. R.
1957b. Site index curves for black spruce in the Lake States. U.S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 473, 2 pp., illus.

Gevorkiantz, S. R.
1957c. Site index curves for white spruce in the Lake States. U.S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 474, 2 pp., illus.

Gevorkiantz, S. R.
1957d. Site index curves for tamarack in the Lake States. U.S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 498, 2 pp., illus.

Gevorkiantz, S. R., Rudolf, Paul O., and Zehngraff, Paul J.
1943. A tree classification for aspen, jack pine, and second-growth red pine. Jour. Forestry 41: 268-274.

Godman, R. M.
1958. Silvical characteristics of northern white-cedar. U.S. Forest Serv., Lake States Forest Expt. Sta., Sta. Paper 67, 17 pp., illus.

Graham, Samuel A.
1945. Ecological classification of cover types. Jour. Wildlife Mangt. 9: 182-190, illus.

Hart, Arthur C.
1959. Silvical characteristics of balsam fir. U.S. Forest Serv., Northeast. Forest Expt. Sta., Sta. Paper 122, 22 pp., illus.

Heinselman, M. L.
1957. Silvical characteristics of black spruce. U.S. Forest Serv., Lake States Forest Expt. Sta., Sta. Paper 45, 30 pp., illus.

Heinselman, M. L.
1959. Natural regeneration of swamp black spruce in Minnesota under various cutting systems. U.S. Dept. Agr. Prod. Res. Rpt. 32, 21 pp., illus.

Krefting, Laurits W.
1962. Use of silvicultural techniques for improving deer habitat in the Lake States. Jour. Forestry 60: 40-42.

Nienstaedt, Hans.
1957. Silvical characteristics of white spruce. U.S. Forest Serv., Lake States Forest Expt. Sta., Sta. Paper 55, 23 pp., illus.

Roe, Eugene I.
1947. Thinning in cedar swamps. U.S. Forest Serv., Lake States Forest Expt. Sta. Tech. Note 279, 1 p.

Roe, Eugene I.
1950. Balsam fir in Minnesota — a summary of present knowledge. U.S. Forest Serv., Lake States Forest Expt. Sta. Misc. Rpt. 13, 25 pp.

Roe, Eugene I.
1957. Silvical characteristics of tamarack. U.S. Forest Serv., Lake States Forest Expt. Sta., Sta. Paper 52, 22 pp., illus.

Skilling, D. D.
1959. Growth of swamp conifers following an improvement cut. U.S. Forest Serv., Lake States Forest Expt. Sta., Sta. Paper 71, 10 pp., illus.

Society of American Foresters.
1954. Forest cover types of North America. 67 pp., illus. Soc. Amer. Foresters, Washington, D. C.

Stone, Robert N., and Thorne, Harry W.
1961. Wisconsin's forest resources. U.S. Forest Serv., Lake States Forest Expt. Sta., Sta. Paper 90, 52 pp., illus.

Stout, Bernard M.
1961. Timber management guide for the national forests of the north central states — mixed conifer swamp type. U.S. Forest Serv. 14 pp., illus. Milwaukee, Wis.

Thornton, Philip L.
1957a. Problems of managing Upper Michigan's coniferous swamps. Jour. Forestry 55: 192-197.

Thornton, Philip L.
1957b. Effects of cutting methods on advance reproduction in two mature mixed coniferous swamps in Upper Michigan. Jour. Forestry 55: 448-451.

Weitzman, Sidney, and Bay, Roger R.
1959. Snow behavior in forests of northern Minnesota and its management implications. U.S. Forest Serv., Lake States Forest Expt. Sta., Sta. Paper 69, 18 pp., illus.

Zasada, Z. A.
1952. Reproduction on cutover swamplands in the Upper Peninsula of Michigan. U.S. Forest Serv., Lake States Forest Expt. Sta., Sta. Paper 27, 15 pp., illus.

SOME RECENT PAPERS

IN THE LAKE STATES STATION SERIES

Station Papers:

Farm Lumber Consumption and Use Data: Needs and Methods of Estimating. by Allen L. Lundgren and Ronald I. Beazley. Sta. Paper 93, 20 pp., illus. 1961.

Small Private Forest Landowners in Michigan's Upper Peninsula — Characteristics, Ownership Attitudes, and Forestry Practices, by Dean N. Quinney. Sta. Paper 95, 20 pp., illus. 1962.

Contracting for Forest Aerial Photography in the United States, by Gene Avery and Merle P. Meyer. Sta.Paper 96, 37 pp., illus. 1962.

Three Pine Release Experiments in Northern Minnesota, by Robert E. Buckman and Allen L. Lundgren. Sta. Paper 97, 9 pp., illus. 1962.

Proceedings of the Fifth Lake States Forest Tree Improvement Conference. Sta. Paper 98, 42 pp. 1962.

Three Growing Stock Density Experiments in Minnesota Red Pine — A Progress Report by Robert E. Buckman. Sta. Paper 99, 10 pp., illus. 1962.

Identification of Conifer Insects by Type of Tree Injury, Lake States, by H. J. MacAloney and D. C. Schmiege. Sta. Paper 100, 41 pp., illus. 1962.

Forest Insects and Diseases in the Northern Great Plains — A Survey, by Louis F. Wilson. Sta. Paper 101, 28 pp., illus. 1962.

Forest Plantations of Northern Lower Michigan, by Robert N. Stone and Clarence D. Chase. Sta. Paper 102, 31 pp., illus. 1962.

Private Forest Landownership in the Urban Fringe Area of Michigan, by Con H Schallau. Sta. Paper 103, 17 pp., illus. 1962.

The Market for Wood Pallets in the Auto Industry — A Case Study of Ford Motor Company, by Charles F. Sutherland, Jr. Sta. Paper 104, 10 pp., illus. 1962.

Site Requirements and Yield of Paper Birch in Northern Wisconsin, by John H. Cooley. Sta. Paper 105, 11 pp., illus. 1962.

Pulpwood Production in Lake States Counties, 1961, by Arthur G. Horn. Sta. Paper 106, 18 pp., illus. 1962.

Research Papers:

Seed Stored in Cones of Some Jack Pine Stands, Northern Minnesota, by Eugene I. Roe. U.S. Forest Serv. Res. Paper LS-1, 14 pp., illus. 1963.

Forest Soil Freezing and the Influence of Management Practices, Northern Minnesota, by Sidney Weitzman and Roger R. Bay. U.S. Forest Serv. Res. Paper LS-2, 8 pp., illus. 1963.

WOOD · WATER · FORAGE · WILDLIFE · RECREATION

FOREST SERVICE
U S
DEPARTMENT OF AGRICULTURE