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Some harvest options and their consequences for the aspen, birch and associated conifer forest types of the Lake States

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INTRODUCTION

National needs for timber are increasing, along with demands for other uses of forest land. To meet these demands, many forest landowners and managers are attempting to increase wood production and at the same time provide wildlife, water, and recreational opportunities. Public land managers are legally committed to the multiple-use principle, and private owners usually find it to their advantage to manage their land for several resources. Thus, almost all forest landowners face the problem of a limited land base and multiple demands for the resources it can produce. As a consequence, difficult management choices must be made and the trade-offs carefully evaluated, because any change in the management of one resource will invariably affect the others.

This paper focuses on harvest options for eight important forest types of the northern Lake States: aspen, white birch, red pine, white pine, jack pine, black spruce, spruce-fir, and northern white-cedar. It is intended to help landowners and managers identify some recommended harvest options and to aid them in evaluating the consequences (trade-offs) of each. Once a harvest option is decided on, several sources can be consulted for details on *how* to harvest and regenerate specific forest types. For example:

1. Manager's Handbooks are newly available for six of the forest types covered in this paper: aspen (Perala 1977), white birch (Tubbs 1977), jack pine (Benzie 1977a), red pine (Benzie 1977b), black spruce (Johnston 1977a), and northern white-cedar (Johnston 1977b). They can be obtained free of charge from the North Central Forest Experiment Station, 1992 Folwell Avenue, St. Paul, Minnesota 55108.

2. More detailed information for the white birch and spruce-fir forest types is available in management guides published earlier (Marquis *et al.* 1969

and Frank and Bjorkbom 1973, respectively). These guides are based on conditions in the northeastern United States, thus not all the recommendations are applicable to the Lake States. They can be obtained from the Northeastern Forest Experiment Station, 370 Reed Road, Broomall, Pennsylvania 19008.

3. Additional information for the white pine type is available in USDA Handbook No. 445 (Little *et al.* 1973), which can be obtained from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (Price $0.80 domestic postpaid).

4. Specific management information and operating plans are available from private consultants or state extension foresters.

AREA OF APPLICATION

The harvest options and evaluations apply to the aspen, white birch, and associated conifer forest types of Michigan, Minnesota, and Wisconsin. These forests are most prevalent in Upper Michigan and the northern half of Lower Michigan, northeastern and north-central Minnesota, and northern Wisconsin (fig. 1).

The forest types described occupy 27.1 million acres, or 54 percent of the total commercial forest land in the Lake States. Forty-one percent (11.2 million acres) of the area occupied by these types occurs in Minnesota, 34 percent (9.1 million acres) in Michigan, and 25 percent (6.8 million acres) in Wisconsin.

These lands were glaciated during the Wisconsin glacial stage of the Pleistocene epoch. Soils include glacial till, outwash sands and gravels, and organic accumulations in lowlands. They range from poorly drained depressions and peatlands to droughty sands and gravels, and support a large variety of plants and animals. Terrain is flat to gently rolling with occasional outcrop ridges and numerous lakes and streams.

The growth potential of these stands is generally much greater than that currently being

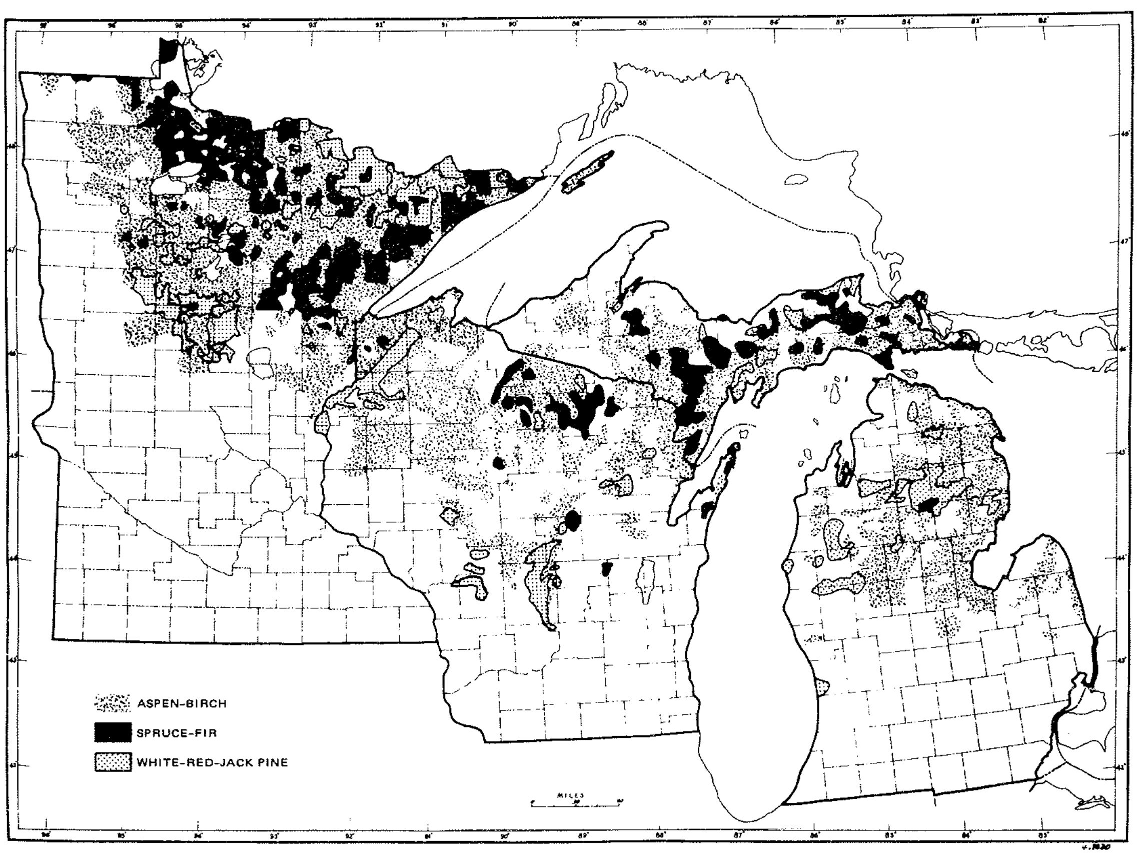

Figure 1.—*Distribution of the aspen-birch, spruce-fir, and white-red-jack pine forest types in Michigan, Minnesota, and Wisconsin. Information from Forest Service Survey data.*

achieved. Growth could be increased markedly by using more intensive silvicultural practices such as thinning, by conversion to faster-growing species, by planting genetically superior seedlings, and possibly by fertilization and irrigation.

RATIONALE FOR HARVEST OPTION RATINGS

Harvest options were rated by evaluating the effects of three common mangement practices on timber investment return, water, wildlife, and visual quality. The practices considered were (1) even-aged management, (2) uneven-aged management, periodic harvesting the same stand of selected trees of different ages, and (3) no management allowing stands to mature, die, and regenerate new stands of the same or different species according to successional trends without harvesting.

The basic information considered in our ratings is summarized below for each resource.

Timber

Lumbering of white pine and red pine sawtimber began about 100 years ago in the Lake States, reaching a peak at the turn of the century. Because of inadequate provision for regeneration and the widespread fires that followed logging, the land once dominated by these pines was converted largely to aspen. Once considered a weed tree, aspen is now the mainstay of a large pulp and paper industry. Thus, although sawtimber production today is less than pulpwood production, the aspen, birch, and associated conifer forest types have contributed significantly to the region's timber needs. Approximately 62 percent of the total Lake States timber harvest is derived from these forest types, although they occupy only 54 percent of the commercial forest land. Aspen and jack pine rate first and second in overall utilization. In terms of value per unit area cut, however, red pine still ranks as the number one species.

Most of the eight forest types are dominated by shade-intolerant species characteristic of early forest succession, and thus lend themselves best to even-aged silvicultural systems. Even-aged management can be simply a clearcut operation at rotation age followed by natural or artificial reproduction, as is commonly done with jack pine, or it can be reproduction through resprouting, as is common in aspen. It can also include a series of thinnings as the stand matures, or sometimes a shelterwood cut near the end of the rotation to provide natural regeneration, followed by removal of shelterwood trees after stand establishment, as is practiced for red pine in parts of the Lake States. Only the spruce-fir forest type, and in some portions of the region, the white pine and northern white-cedar types, can be managed under uneven-aged silvicultural systems. Uneven-aged systems do not provide satisfactory seedbed conditions or adequate light for regenerating and growing most of the eight forest types.

Even-aged silvicultural practices vary from extensive management characterized by a "let-grow" philosophy to more intensive management, including both noncommercial and commercial thinnings prior to final harvest. The intensity of management depends on species composition, stand condition, site quality, markets, and owner objectives. In addition to these constraints and the limitations imposed by management for other resources, our ratings have assumed the best possible implementation of silvicultural practices.

The rating scheme for timber is based on an objective of maximizing investment returns within the different management systems and product objectives. We have assumed an average site, although we recognize that investment returns are greater for timber management on the better sites.

The following general relations formed the basis for the ratings:

1. Larger clearcuts are more profitable than smaller ones, within the range we are considering (economy of scale).
2. Where a variety of product markets are available, multi-product objectives (sawtimber, veneer, pulpwood) are more profitable than single-product objectives.
3. With shade-intolerant species, regeneration is more successful when clearcuts are large enough for full light penetration.
4. For a given product objective, shorter rotations provide higher rates of return on investment. However, landowners and managers

should be aware that even when timber stands are held past optimum financial rotation by 10 to 20 years, loss on rate of return is often minimal.

Water

Supplies of high-quality water are adequate in northern Lake States forests during years of normal precipitation. Such years have about 30 inches of rain and snow and produce about 10 inches of water yield (either streamflow, ground water recharge, or both). Spring flooding usually occurs in years with deep snowpacks, especially when warm spring rains fall on top of the snow. But local flooding can also occur during the warm season when rainfall exceeds 10 inches per month. Long droughts also occur, drying up wetlands and lowering ground water levels. Climate, rather than land management activity, is the major regulator of ground water recharge and streamflow. It alone can account for variations in annual streamflow on the order of −75 to +250 percent of the mean.

There are basically two ways that forest management can affect water yield. First, harvesting the trees can increase streamflow as much as 60 percent the first year after cutting. The amount diminishes over time, but 7 to 10 years may elapse before streamflow returns to the pre-cut level. Annual streamflow peaks (spring flood peaks) may double if the harvested area covers an entire watershed. However, most timber harvests cover only a fraction of a watershed; also, snowmelt occurs earlier in harvested areas than in surrounding areas, tending to reduce peak flows (Verry 1972).

Second, conversion from hardwood to pine can reduce annual streamflow, because pine trees intercept and evaporate about 2.6 inches more of the annual precipitation than do hardwoods. This effect lasts throughout the rotation once crown closure is complete. In addition, pines transpire more water than hardwoods on an annual basis. In wet areas where evapotranspiration is at or very near maximum regardless of vegetative cover, species differences are unimportant (Verry 1976, Urie 1977).

Although clearcutting can cause a drastic change in annual streamflow on a small area, it will not have a great impact on the water yield over a large area. For example, on areas of 250,000-plus acres it is unlikely that forest management will affect the annual flow of rivers by more than 5 percent of the mean. The reason is that only about 1 to 3 percent of the commercial forest area is cut in any one year, and the effects of management are thus spread over a long period. The change in streamflow caused by harvesting is greatest the first year and diminishes with time. And most important, the streamflow from large areas is strongly influenced by ground water inflow to the channel. The rate of ground water inflow depends on the climate over several years and thus overrides impacts of land management on small areas.

Current forest management practices in the Lake States do not significantly affect stream sedimentation because of the relatively flat terrain, the high permeability of soils, and logging limitations on Federal lands near shorelines. Where roads must be built on steeper slopes and on soils with high silt and clay content, action can be taken to prevent or control erosion (Kochenderfer 1970). Rapid revegetation of disturbed areas, common in this climatic region, also relieves the erosion and sediment threat of logging.

Clearcutting aspen on uplands does not change the concentration of nutrients in streamflow (Verry 1972) or in ground water (Richardson and Lund 1975). However, clearcutting of brushy black spruce stands on organic soils will increase the concentrations of iron, manganese, magnesium, potassium, and phosphorus in streamflow by about 2½ times when air temperatures exceed 80° F. These increases in nutrient concentrations on small watersheds do not appear to persist more than 0.25 miles downstream, and phosphorus input to lakes is insignificant. Clearcutting nonbrushy, acid bogs does not significantly change nutrient concentrations in streamflow (Verry 1976).

Stream water temperatures increase if trees shading the channel are removed, but water influence zones require modified or restricted logging near shorelines. However, these strips of trees along waterways must be wide enough to prevent windthrow.

Herbicides are used for tree release and occasionally for site preparation in the Lake States. The correct use of herbicides in the forest will not result in a hazard to people or wildlife assuming concentrated solutions are not spilled directly into watercourses (Norris 1975).

Fertilizers have not been widely used in the Lake States forests. Human sewage effluent and sludge application to forest lands is being done on small areas, and preliminary water monitoring indicates that conservative operations do not endanger water supplies. Application of sewage effluent and sludge on forest land appears to offer an economical tertiary treatment except where large amounts of municipal or industrial waste must be handled and limited land resources are expensive.

Wildlife

The diversity of the aspen, birch, and associated conifer forest types is also reflected in the animal communities they support. For example, Peterson (1975) divided the area covered by the North American Breeding Bird Survey into 56 ecological units in which the northern Lake States region is classified as spruce-hardwood forest. By various measures, this unit ranks among the top five in species diversity. Thus, it is evident that the region is highly important to a large variety of birds, even if only seasonally.

The fact that some areas of the region are remote from permanent settlement and are adjacent to Canada has permitted certain carnivores, such as the timber wolf, to maintain viable populations and thus contribute to the unique diversity of the ecosystem.

In early times, interest in the wildlife of the region focused on the furbearers, and later shifted to the game species (especially white-tailed deer, ruffed grouse, and waterfowl). Accordingly, for many years most wildlife programs revolved around the management of these species. Today, however, society is demanding that all wildlife be considered in land management, and herein lies a problem: knowledge of the impact of management activities is generally limited to the game species. Likewise, the greater the species diversity present, the greater the potential for impacts from each management activity, and the greater the potential for conflicting impacts (i.e., what helps one species may harm another).

Limited knowledge of the habitat requirements for most wildlife also poses a problem in evaluating the impact of harvest options. In these cases the ratings reflect our best estimates, and should be considered tentative until confirmed by future knowledge.

To maintain simplicity and yet take into account the variability in habitat requirements of a large number of species, wildlife was divided into two groups called "edge" and "interior" species (Trimble *et al.* 1974). Edge species are those associated with forest edges, openings, shrubs, and ground vegetation. Examples of this group are the white-tailed deer, black bear, ruffed grouse, snowshoe hare, beaver, and a large number of nongame birds and mammals (Appendix Table 2). Interior species are those associated more with the tree layer of maturing and old growth forest communities. Squirrels, marten, and warblers are typical of this group (Appendix Table 2). In general, the majority of both game and nongame species belongs to the edge group.

The most economical means of altering the habitat on large areas is through the use of silvicultural techniques (including fire). With proper planning silvicultural techniques can serve both timber and wildlife objectives. Specific habitat manipulation measures for wildlife, such as creating openings, seeding old roads and trails, and erecting nest structures, were not considered because they can be applied independent of managing land as a timber resource.

The ratings for wildlife assume the following: (1) options that return habitat to younger successional stages or maintain younger age classes (shorter rotations, thinning, etc.) are generally beneficial to edge species, while longer rotations and few intermediate treatments are more beneficial to interior species. (2) In the case of both edge and interior species, options that alter the vegetation of large acreages in a single area are generally undesirable. (3) Harvest units of 1 acre or less are considered less desirable than units approaching 5 acres, since the ratio of the edge to the size of the harvest unit tend to exceed 1.0 for units of 1 acre or less.

However, even with wildlife production as a primary goal, managers could at times and with good reason select options that are rated low here. Each manager needs to assess not only his objectives and the habitats available on his holdings, but also those of other holdings in the surrounding area. This is especially important for wide-ranging wildlife species whose needs transcend ownership boundaries. Small landowners, whose objectives may be based more on amenities than economic considerations, may want to provide habitats that are in short supply locally or create habitat more specific to certain species.

Visual Quality

Throughout the Lake States there is great potential for timber harvest to affect the visual quality of the landscape, both favorably and unfavorably.

Because the forest types are dominated by pioneer tree species that have evolved even-aged structures, the recommended forest management system is to maintain stands of even-aged trees. The harvesting methods under this system increase the potential for imparing visual quality, but can also open vistas and relieve monotonous landscapes.

Because sharp breaks are not common on the regional landscape, major openings created by land management practices may appear unattractive. However, carefully planned timber harvests, if patterned to blend in with the forest landscape, can be visually apppealing.

The forest landowner must recognize that virtually any forest operation that involves timber removal will temporarily affect on-site visual quality. Professional foresters are available to assist landowners in preparing management plans that will provide wood products, improve wildlife habitat, and yet maintain the visual quality of an area. Noyes (1969) suggests the following harvest controls:

1. Utilize all material possible from harvesting operations.
2. Enhance aesthetic qualities by developing vistas and emphasizing desirable topographic features of the area.
3. Protect seedlings and shrubs by careful skidding and hauling procedures.
4. Replace cut trees by planting seedlings, utilizing natural seedlings, or releasing desirable understory stems alreay established.
5. Protect the site against erosion by well-planned skid and haul road layout, and adequate water drainage facilities.
6. Clean up refuse, tin cans, discarded equipment and parts.
7. Cut up logging slash to lie close to the ground following harvest. Slash can also be disposed of by burning, full-tree logging, or full-tree chipping.

In addition to the degree of control during harvest, the recovery period will also depend on the productivity of the site and the post-logging practices to encourage rapid revegetation (Perala 1977).

Visual quality, both distant and close-up, is enhanced by the presence of large trees. Thus, management options that provide for longer rotations less frequent disturbance will improve visual quality.

A diversity of plant species also enhances visual quality. We considered a forest practice to have a positive influence on the landscape if it (slightly modified from Trimble, *et al.* (1974)):

1. Affects only a relatively small forest area.
2. Complements the shape and form of natural forest openings.
3. Favors rapid vegetative regeneration and growth.
4. Allows larger trees to occupy the site for long periods.
5. Allows for maximum time between cuttings so that forest cover will occupy the site as long as possible.
6. Minimizes physical site damage.
7. Occurs on more fertile sites.

METHOD OF PRESENTATION

We have presented harvest options and information in three forms.

First, we rated each of the forest types according to its production potential for timber, water, wildlife, and visual quality (table 1). These ratings are only relative, and they were determined by different factors for each resource. Productivity, present and future stand conditions, and expected future importance were considered. For example, jack pine on site index 70 is rated low for timber because these stands are usually converted to more productive red pine at the end of the rotation; this is reflected further in the high ratings for red pine. Depending on the viewpoint of the landowner or manager, however, the ratings could be quite different. The wildlife ratings include both "edge"

Table 1.—*Importance of the aspen, birch, and associated conifer forest types for providing timber, water, wildlife, and visual quality on a per-unit basis*[1]

Forest type and site index	Area (million acres)	Resource: Timber	Water	Wildlife: Edge species	Wildlife: Interior species	Visual quality
Aspen	13.2					
Site 80		H	H	H	L	M
Site 65		M	H	H	L	M
Site 50		L	H	H	L	M
White birch	1.8					
Site 70		M	H	H	L	H
Site 60		L	H	H	L	H
Site 50		L	H	H	L	H
Red pine	1.2					
Site 75		H	M	L	H	H
Site 60		H	M	L	H	H
Site 45		H	M	L	H	M
White pine	0.5					
Site 75		H	M	M	H	H
Site 60		H	M	M	H	H
Site 55		M	M	M	H	M
Jack pine	2.5					
Site 70		L	M	M	M	L
Site 55		H	M	M	M	L
Site 40		M	M	M	M	M
Spruce-fir	2.9					
Site 60		H	L	M	M	M
Site 40		M	L	M	M	M
Site 20		L	L	M	M	L
Black spruce	2.1					
Site 45		H	L	M	L	L
Site 35		H	L	L	M	M
Site 25		M	L	L	M	H
Northern white-cedar	1.9					
Site 40		M	L	M	H	M
Site 30		M	L	M	H	M
Site 20		L	L	L	M	L

[1]H = high; M = medium; L = low.

species (those associated with forest edges, openings, shrubs, and ground vegetation), and "interior" species (those associated with maturing and old-growth forest stands) (see Appendix 2).

Second, for each of the forest types, we rated some common harvest options according to their effect on timber investment return, water, wildlife, and visual quality (tables 2-9). The ratings in each table permit the owner or manager to compare— *within the forest type*— the general effects of each harvest option on the various resources. A harvest option was rated "excellent" if its effect on a resource was most desirable for that resource. Conversely, a practice was rated "unfavorable" if it would diminish the resource.

Third, we summarized pertinent information and the consequences of harvest options for each forest type.

When complete information on the consequences of a harvest option was not available, we described the most likely impact of the harvest option on the resource in question.

We used only common names of plants and animals (except for a few diseases) throughout the report; however, scientific names are listed in Appendix Table 1.

ASPEN

Type Description

Aspen is the largest and most widely distributed of the forest types, covering about 13 million acres. The dominant species is quaking aspen, a small to medium-sized tree; it can grow in essentially pure stands, but other species are usually present in varying numbers. Common associates are bigtooth aspen, white birch, northern red oak, red maple, balsam poplar, jack pine, balsam fir, spruce, and northern white-cedar.

Aspen occupies diverse soils and sites, and its growth rate varies with soil fertility and available moisture. Tree heights at age 50 range from 90 feet on deep, fertile, high-calcium loams to 40 feet on dry sands and rock outcrops or water-logged mineral soils and peats (Brinkman and Roe 1975).

Aspen is aptly described as the "phoenix tree"; it has persisted in natural stands largely because of fire. Even where it is a minor component of the stand, aspen's ability to produce abundant root suckers often enables it to become the dominant species after logging or fire. Where aspen is already dominant, it easily reestablishes itself after logging, especially when cutting is followed by fire or similar treatments to kill back other vegetation.

Because aspen cannot reproduce successfully under its own shade, it is replaced by other species when natural ecological succession is not interrupted by fires, logging, or windstorms. On relatively dry sites, aspen is succeeded by red maple or oaks. On moist, fertile soils, aspen is followed by balsam fir, white spruce, or white pine, and on the wetter sites by balsam fir, black spruce, or northern white-cedar. Succession will be to northern hardwoods where that type occurs.

Aspens produce good seed crops every 1 to 5 years, and seedlings can become established only when cutting or burning prepares a suitable seedbed and continuous moisture is provided. However, regeneration is nearly always assured by the abundant root suckers that develop after trees of any age are cut or killed. Vigorous suckers grow fast enough to overtop competing vegetation of comparable age, but they cannot persist under the shade of shrubs or taller reproduction. Although aspen stands continually produce small numbers of suckers, these seldom survive long under a canopy.

Aspen stands typically contain well-developed shrub and herb layers. Plant species diversity is usually greater in this type than in any of the associated conifer forest types.

Evaluation and Discussion (see table 2)

Timber

Because aspen grows on sites ranging widely in productivity, resource objectives should be tailored accordingly. Site index 50 stands are not capable of producing economic quantities of pulpwood to the traditional industry standard of a 4-inch top; but these stands, when fully stocked and managed for whole-tree utilization in 35-year rotations, can produce an equivalent fiber volume of 50 ft 3 /acre/year as chips. For most aspen sites pulpwood should be the main product objective, and the highest investment returns are realized from rotations of about 35 years. On the other hand, a few good aspen sites (exceeding site index 80) mostly in the northern Minnesota counties can be managed for sawtimber and veneer bolts on rotations of 50 to 60 years. Since aspen commonly suffers high losses to heartrot after age 50, intermediate thinnings can be used to shorten rotations and greatly increase yields of large logs (Perala 1977). Good sites may also be managed on a short-rotation basis (30 years) with whole-tree logging and chipping.

Clearcutting to regenerate the stand by suckering is the best means of perpetuating the type. Limiting clearcut size to accommodate other forest uses tends to increase costs, especially in clearcuts smaller than 5 to 10 acres. Aspen growth in extremely small clearcuts (2 acres or less) is strongly retarded by adjacent, older stands.

Table 2.—*Effects of some aspen harvest options on forest resources—a desirability rating*[1] *(timber management objectives: pulpwood, sawtimber, and veneer)*

Forest practice	Rotation length (years)	Size of harvest (acres)	Investment return	Water		Wildlife		Visual quality (landscape and on-site appeal)
				Yield	Quality	Edge species	Interior species	
Even-aged management with clearcutting; no intermediate thinning; Pulpwood objective	35	1	U	0	0	++	U	+
		5	U	++	0	+++	U	+
		20	++	+++	0	++	U	+
		50	+++	+++	0	++	U	+
	45	1	U	0	0	++	U	+
		5	U	+	0	+++	+	+
		20	+	++	0	+	++	+
		50	++	++	0	+	++	+
Even-aged management with clearcutting; no intermediate thinning; sawtimber objective (6" top)	50	1	U	0	0	++	U	++
		5	U	+	0	+++	+	++
		20	++	++	0	+	++	+
		50	+++	++	0	+	++	+
	60	1	U	0	0	+	U	+++
		5	U	+	0	++	++	++
		20	+	++	0	+	+++	+
		50	++	++	0	+	+++	+
Even-aged management with clearcutting; intermediate thinning; Veneer and sawtimber objective (8" top)	50	1	U	0	0	++	U	+++
		5	U	+	0	+++	U	+++
		20	++	++	0	+	++	++
		50	+++	++	0	+	++	+
	60	1	U	0	0	++	U	+++
		5	U	+	0	+++	+	+++
		20	+	++	0	+	++	++
		50	++	++	0	+	++	+
No harvest			0	0	0	U	+	+++

[1]+++ = excellent; ++ = good; + = fair; 0 = no impact; U = unfavorable impact.

Because site index 50 stands are only marginally useful for aspen production, these and poorer sites are more suited to conifers and should be converted where timber production is the prime objective.

Water

Aspen and other hardwood types contribute more water to streamflow or ground water recharge than any other forest cover. Clearcutting this type increases water yield, and harvesting blocks of 20 to 50 acres at shorter intervals will increase water yield more.

As long as water influence-zone restrictions (or equivalent precautions on non-Federal land) are adhered to, and logging roads are constructed with care, no serious erosion hazard results from clearcut logging in aspen, nor do nutrient concentrations in streamflow change significantly (Verry 1972, Richardson and Lund 1975).

Wildlife

The importance of the aspen forest type for game species such as the white-tailed deer, ruffed grouse, and woodcock has long been recognized. However, the type also provides important habitat for a variety of other edge wildlife species. In contrast to "edge species" it generally provides poor habitat for interior species.

Maintaining intolerant types like aspen is important in managing for wide-ranging edge species such as white-tailed deer and moose. For good game habitat, McCaffery (1970) recommended 5 percent upland brush or grass, 10 percent scrub oak, 25 percent aspen, 15 percent conifer cover, and 5 percent lowland brush, or 40 percent combined acreage of grass, upland brush, scrub oak, aspen, and jack pine. However, the area should not have more than 30 percent northern hardwoods or 30 percent pine plantation, or 45 percent combined acreage of northern hardwoods, pine plantation, and white birch. Byelich *et al.* (1972) recommended slightly higher proportions of intolerant types for deer in Michigan: a minimum of 15 percent forest openings and 35 percent aspen, or 60 percent openings, upland brush, aspen, oak, and jack pine combined. For moose, Peek *et al.* (1976) recommended township-sized blocks vegetated with 40 to 50 percent aspen-birch under 20 years old, 35 to 50 percent aspen-birch over 20 years old, and 5 to 15 percent spruce-fir. For species with small home ranges and particularly for those living totally within an aspen stand, the mix of types is not as important, except where broad-scale forest type conversion is contemplated. The foregoing type mixes are idealized objectives, and an owner's soil type or current stand composition may dictate a somewhat different composition.

Because plant composition changes as the stand matures, it may provide for the requirements of a wildlife species during some periods and at others actually be detrimental. This means that the number and distribution of stands of various ages is also important. For example, all age classes are important to ruffed grouse; therefore it is important not only to have aspen stands, but to have them in different age classes (stands up to 10 years old serve as brood habitat, stands 10 to 25 years old serve as over-wintering and breeding habitat, and stands over 25 years old provide nesting cover and winter food). Gullion and Svoboda (1972) recommended that for ruffed grouse, aspen should be clearcut on a 40- to 50-year rotation in a manner such that about 10 acres in a 40-acre unit is cut every 10 years. In so doing, male aspen clones should be preserved for winter food. For other wildlife, only certain age classes may be important. For example, Byelich *et al.* (1972) suggested that 25 percent of the aspen type be maintained in the 0- to 10-year age class as food for deer, especially where it is adjacent to lowland conifers used by deer for winter cover. In fact, since the value of aspen to deer declines with stand age, circumstances may warrant short-rotation management of aspen near wintering areas— i.e., a 25- to 30-year rotation with a cutting interval of 5 to 10 years.

The size of cutting unit is also important. For deer, a harvest unit should preferably be smaller than 40 acres (Ruske 1969). In fact, McCaffery and Creed (1969) found more intense deer use in permanent openings 0.5 to 5 acres in size than in larger openings, and in openings less than 300 feet wide. Similarly, Wetzel *et al.* (1975) found light use in areas farther than 130 feet from cover. This suggests that small patches and strips of different age classes are more beneficial to deer than large openings (Telfer 1974). Peek *et al.* (1976) recommended units of at least 200 acres for moose. Thus, not only do moose tolerate larger cutting units, but they require larger units than deer.

Aspen is also preferred by beaver; stands should be situated within 300 feet of shoreline areas, and preferably within 100 to 200 feet. Knudsen (1962) estimated that about 5 acres of timber should be available at the average colony. At an average distance of 150 feet, this means that 1,500 feet of shoreline aspen would be required to sustain an average colony. Young aspen stands are not only preferred by beaver, but are utilized more thoroughly.

Aspen stands of all age classes are suitable for a large variety of smaller "edge" vertebrates. While the needs of some may be restricted to certain age classes, the needs of most can generally be met with a balanced distribution of age classes in time and space. For cavity nesters, standing dead snags can be left at harvest; these also serve as feeding and perching sites for other birds. For interior species, longer rotations or no cutting at all may be desirable.

Visual Quality

The aspen leaf has an unusual petiole attaching it to the stem, providing its common name "quaking aspen". The rippling of aspen leaves, even in very light wind, has an appealing aesthetic quality, and in spring the pastel foliage provides a pleasing contrast to the darker surroundings. Aspen's autumn foliage is also very attractive; varying blends of golden leaves and whitish bark contrast with the dark green of associated conifers or the bright colors of other hardwood species (Brinkman and Roe 1975).

Because the aspen type is so extensive and because it is usually maintained through clearcutting, management practices have an important effect on visual quality, especially in scenic areas, travel corridors, recreational use areas, and along water bodies. In addition to close control of logging operations, other important factors to be considered in aspen harvest include viewing distance, size, shape and distribution of clearcuts, timing of operations, and establishment of vistas.

The foreground (about 0 to mile) and the middleground (about to 5 miles) viewing zones are most important because they are most readily seen. The background zone about 3-plus miles is important when it is highly visible and when it provides a scenic backdrop.

Foreground landscapes can be enhanced by:

1. Providing vistas that expose and frame scenic features.
2. Utilizing clearcuts to create visual variety by opening up dense stands and breaking up straight lines of timber with curved lines and irregular openings.
3. Leaving attractive and special-interest trees and snags.
4. Providing variety in plant species, age class, tree size, and type.
5. Softening edge layout with transition vegetation.
6. Varying the sizes and shapes of cuttings.
7. Converting to other vegetative types.
8. Treating logging slash.

An aspen regeneration cut presents less visual impact if its size does not dominate and if it is blended with natural or man-made openings that occur in the landscape. The apparent size of cutting units can be reduced by restricting the amount of cut area seen from any one viewing position. Factors such as distance, shape, and screening provided by intervening ridges or other landforms and islands or clumps of vegetation help to limit the apparent size of cutting units.

Irregular, free-form shapes that follow natural projections, indentations, soil boundaries, and topographic features expose smaller areas of clearcut to view. Long, straight, unnatural edges or geometric shapes that clash with natural landscape forms should be avoided.

The outline of an opening that has sharp edge contrast between the clearcut area and surrounding timber can be "feathered" to soften the impact. Existing openings can be used as part of edge, and adjacent stands can be thinned to develop an irregular appearance and spacing. Retaining plant species of various sizes and textures will help to soften edge.

Uniformly spaced clearcuts of nearly the same size and shape are seldom visually pleasing. Dispersal and irregular spacing should be used to avoid a repetitious pattern.

Aspen harvests should be scheduled so that enough time elapses before adjacent new areas are cut to allow dulling and greening of the disturbed areas. Stands immediately adjacent to previous clearcuts should not be scheduled for a regeneration cut until a stand of trees has been established. This manipulation of age classes will create variety and contrast in the sequence of cutover areas.

Where worthwhile opportunities exist, consider cutting carefully selected trees or groups of trees or utilizing clearcuts to open vistas through the timber. This can provide temporary or permanent views of outstanding physical features (rock outcrops, lakes, streams) and panoramas of the forest landscape. Leave clumps of birch and spruce or other conifers to frame and give scale and dimension to the view. Vista openings need not be permanent. As changes occur in the forest scene, new openings can be developed to show the best views. Less attractive views can be allowed to close in.

Harvest options that involve long rotations with intermediate thinnings will have less impact on visual quality than those requiring short rotations. The no-harvest option will result in eventual conversion of the type through natural succession to more tolerant species. As part of this process, the aspen stand frequently breaks up rapidly, revealing dead trees and broken stems that may be unattractive to many viewers.

Diseases

Aspen managed on a 35-year rotation will host a number of diseases that kill very young trees. However, in dense sucker stands none of these diseases will affect future stocking of the mature stand, because they will act as thinning agents.

Shepherd's crook shoot blight sometimes causes terminal shoot dieback during the stand's first few years and often appears capable of wiping out a young stand. However, this disease seldom causes significant mortality. Instead, it reduces growth by killing the current year's terminal shoot, causing a bush-like appearance. Aspen suckers become much less susceptible to shoot blight after they are 5 to 10 years old, and then resume normal height growth.

Hypoxylon canker is one of the principal causes of aspen mortality during a pulpwood rotation. This disease kills an average of 1-2 percent of the aspen trees in a stand yearly, but if a dense sucker stand is obtained after a clearcut, the disease will act primarily as a thinning agent. Susceptibility of aspen to *Hypoxylon* canker varies by genotype. Highly susceptible clones (with 25 percent or more of the stems infected) should not be regenerated to aspen unless a significantly more resistant clone can be encouraged to invade the area occupied by the susceptible clone. One way to avoid regenerating these clones is to leave them uncut. A leaflet on how to identify *Hypoxylon* canker (Schipper and Anderson 1976) is available from the North Central Station on request.

Aspen managed on 50- to 60-year rotations will be subject to the same diseases that affect aspen on shorter rotations. In addition, white trunk rot will begin to be a problem between age 40 and 50, and stands should be checked occasionally to determine whether they must be harvested early to avoid breakup. Trunk rot will have a much greater impact during the last 10 years of a 60-year rotation and may begin to cause significant stand breakup unless the stands are checked regularly and regenerated before rot damage becomes excessive.

Wetwood (caused by bacteria) will become prevalent in older trees. While this disease does not kill trees, it will result in collapse of lumber during kiln drying.

Perennial cankers will render portions of affected trees unsuitable for veneer even though they do not kill trees. Intermediate thinnings to produce veneer-quality trees may cause increased incidence of both *Hypoxylon* canker and white trunk rot. Careless thinning that wounds remaining aspen will increase other heart rots. Therefore, once thinning begins, stands should be checked periodically so that they can be harvested early if either of these diseases begins to cause significant amounts of dead wood.

Although viruses of aspen have not been studied extensively, there is some evidence that they may account for clone deterioration in some areas when aspen is repeatedly regenerated from root suckers (Berbee and Castello 1976).

Insects

Although more than 300 species of insects feed on aspen (Davidson and Prentice 1968, Batzer 1972), only a few are important. Juvenile aspen can be heavily attacked by stem borers, but if regeneration is dense, sufficient stems usually escape damage to provide a well-stocked stand. If suckers are excessively dense these attacks may provide a natural thinning.

The most spectacular insect defoliator of aspen is the forest tent caterpillar. Widespread infestations of this insect defoliate aspen stands at 6- to 16-year intervals, but cause noticeable mortality only on excessively wet or excessively dry sites. Infestations do cause reduced growth, accelerated nutrient cycling, and temporary release of understory herbs, shrubs, and tree reproduction, however. The forest tent caterpillar is likely to cause significant economic impact only when aspen is grown for sawtimber and veneer.

The large aspen tortrix is another defoliator that has violent but short-lived population upsurges. Little tree growth is lost, however, because heavy infestations seldom last more than 1 or 2 years.

The poplar borer causes damage primarily in open-grown stands. Trees can break when weakened by tunneling of the large larvae. Sawtimber and veneer management options would be affected most. Treatment for the borer with insecticide is not feasible.

WHITE (PAPER) BIRCH
Type Description

The white birch type is estimated to occupy about 1 million acres in the Lake States (Quigley and Babcock 1969). White birch seldom develops into a large or high-quality sawtimber tree, and most of it is harvested as boltwood and used for sawed specialty products or pulpwood (Quigley and Babcock 1969).

White birch is an intolerant tree, more so than its common associates white spruce and balsam fir, but it may persist in successionally advanced stands through its ability to fill the canopy gaps created by death of surrounding trees.

White birch is a short-lived, fast-growing tree. Trees of seedling origin reach maturity as early as 60 years of age, and maximum age is about 140 years. Sprouts are shorter-lived and usually mature at 50 to 60 years, with a maximum age of 70 to 90 years. In mature stands, the trees attain an average height of 70 to 80 feet and an average diameter of 10 to 12 inches.

While white birch occupies all elevations, slopes, and aspects in this region (Fowells 1965), site quality— at least in northern Wisconsin— is closely related to topography (probably as a reflection of soil moisture conditions). Poorer sites occur on steeper slopes and on ridgetops, while better sites occur on flats and rolling terrain. Site quality also increases with increased soil silt and clay and with mottling in the upper 48 inches of soil (Cooley 1962).

White birch resembles aspen in many respects and frequently grows along with aspen in similar secondary successions (Curtis 1959). Its importance as wildlife habitat and as an aesthetic resource may exceed its value for wood fiber.

Like the aspen type, white birch stands typically support a well-developed tall shrub and herbaceous layer; many species are common to both types.

Evaluation and Discussion (see table 3)

Timber

Where white birch is grown for pulpwood, maximum annual yields are realized on rotations of 45 years on the best sites, and 70 years on the poorest commercial sites. Financial maturity is generally reached 5 to 10 years earlier. However, when white birch is grown in mixture with other pulpwood species (the usual case), it is best to apply the same rotation used for the other species and harvest the entire forest crop at the same time. Only site indexes of 60 and better should be considered for growing white birch for sawtimber or boltwood. Early tending of stands (weedings, cleanings) and intermediate thinnings (if very carefully done) will improve quality, increase yields, and shorten rotations by about 10 to 20 years, depending on site and desired product size.

Using scarification along with a shelterwood system or a progressive 1-chain-wide strip clearcutting is probably the best way to regenerate the birch type from seed in the Lake States. Trees less than 60 years old reproduce well by stump sprouting. Where uneven-aged management is used, white birch will be steadily replaced by more tolerant species.

Water

Comments for the aspen type (page 9) apply equally well to the white birch type; both aspen and white birch are deciduous hardwoods with relatively short rotation ages, and they frequently occur together.

Wildlife

The relatively high value of white birch to edge wildlife species is probably related to the variety of tall shrub and herbs in this type. Although white birch itself is less preferable than aspen, the components of the white birch type are otherwise very similar to those of the aspen type. Likewise, the wildlife community is similar in both, except, for example, the additional attraction white birch offers to the yellow-bellied sapsucker. A leaflet on how to identify sapsucker injury to trees (Ostry and Nicholls 1976a) is available on request. As with aspen, white birch also provides poor habitat for interior species of wildlife.

Recommendations for wildlife discussed under aspen management (pages 9-10) generally apply to the white birch type as well. However, in certain areas, the higher monetary value of white birch may permit the cautious use of intermediate thinnings. For many edge wildlife species, this practice would be beneficial because release cutting stimulates ground vegetation and seed production on the remaining trees for about 10 years (Shaw 1969). For example, Shaw and Ripley (1965) found that the number of woody twigs on browse plants doubled when the basal area of the overstory was reduced from 110 to 80 square feet per acre. Thus, for wildlife purposes Shaw (1969) recommended making intermediate cuts in white birch stands at 10-year intervals and keeping 25 percent of the stand in the seedling-sapling age class.

Visual quality

White birch is one of the most striking native North American trees. The bark of young trees is reddish brown and not particularly attractive, but it becomes white as the tree matures and tends to peel about the trunk in curled strips. Foliage colors are pleasing to the eye in spring and summer, but especially in fall when the leaves turn a vivid yellow. Clumps of trees are often formed from stump sprouts, making white birch easy to see and adding contrast and variety to the landscape (Noyes 1969).

Table 3.—*Effects of some white birch harvest options on forest resources—a desirability rating*[1] *(timber management objectives: pulpwood, sawtimber, and veneer)*

Forest practice	Rotation length (years)	Size of harvest (acres)	Investment return	Water		Wildlife		Visual quality (landscape and on-site appeal)
				Yield	Quality	Edge species	Interior species	
Even-aged management with clear-cutting; no intermediate thinning	50	1	U	0	0	+	U	++
		5	U	+	0	++	U	++
		20	U	++	0	+	++	++
		50	+	++	0	+	++	+
	70	1	U	0	0	+	U	++
		5	U	+	0	++	+	++
		20	++	++	0	+	++	+
		50	+++	++	0	+	++	+
	90	1	U	0	0	+	U	+++
		5	U	+	0	++	++	++
		20	+	++	0	+	+++	+
		50	++	++	0	+	+++	+
Even-aged management with clear-cutting; intermediate thinning	30	1	U	0	0	++	U	++
		5	U	++	0	+++	U	++
		20	U	+++	0	++	U	++
		50	+	+++	0	++	U	+
	50	1	U	0	0	++	U	+++
		5	U	+	0	+++	U	+++
		20	++	++	0	++	+	++
		50	+++	++	0	++	+	+
	70	1	U	0	0	++	U	+++
		5	U	+	0	+++	U	+++
		20	+	++	0	+	+	++
		50	++	++	0	+	+	+
No harvest			0	0	0	U	+	+++

[1]+++ = excellent; ++ = good; + = fair; 0 = no impact; U = unfavorable impact.

White birch is attractive as a single stem, in clumps, in pure stands, or in mixed stands. Associated species, such as balsam fir, spruce, or white pine, also add to its visual appeal. These associates, when not dominating the stand, add a visually pleasing dark green contrast to the birch (Noyes 1969).

Cultural practices can enhance the visual quality of white birch stands. Even-aged management with clearcutting and careful thinning is recommended, but large clearcuts should be avoided. The harvest practices suggested for aspen, pages 10-11 apply to the white birch type as well. Managers should especially take advantage of the ability of birch to develop clumps of stems from stump sprouts (Noyes 1969).

The no-harvest option would result in conversion of the white birch type to more tolerant species through natural succession. Thus, under this option stands would provide maximum visual quality for a relatively short period— from maturity to onset of stand break-up.

Diseases

Phellinus trunk rot is the principal agent responsible for white birch cull. This heart rot is most important in the older stands.

Poria causes a canker and heart rot in older white birch stands. Affected portions of *Poria*-cankered stems will be unsuitable for veneer.

Birch dieback may be important for all birch harvest options because it can kill entire birch stands. The cause of birch dieback is unknown. Intermediate thinnings, if too severe, can cause reduced growth of the remaining trees and break-up of the stand.

Insects

Many insects feed on white birch, but the one capable of the most widespread infestations in the Lake States is the birch skeletonizer. Because defoliation occurs late in the growing season, little mortality results.

An eastern pest, the birch leaf miner, is moving west and may now be found hollowing out leaves in Lake States birch stands. Weakened trees become susceptible to infestations of the bronze birch borer, which can kill them (Baker 1972). Long rotations would expose stands to recurrent outbreaks of all three insects.

RED PINE
Type Description

Red pine was an important component of the extensive Lake States pine forests that were cut about the turn of the century. Logging was generally followed by slash fires, either accidental or intentional, to reduce the risk of wildfires. The widespread fires increased aspen and jack pine at the expense of red pine and white pine. Although the area of natural red pine forest today is small, the type has been expanded considerably by planting; it now occupies a total area of about 1 million acres.

Red pine is most common on level to gently rolling topography underlain by fine to loamy sands, or on low ridges adjacent to lakes and swamps. It grows best on moist, well-drained soils, but can withstand moderate drought. Nearly all red pine stands in Minnesota are found on site indexes between 45 and 75. Average site index is 55 at 50 years of age.

Red pine grows in both pure and mixed stands. Associated species on the coarser, drier soils are jack pine, aspen, white birch, and northern pin oak. On the fine to loamy sands, associates include eastern white pine, red maple, northern red oak, and white spruce-balsam fir mixtures.

Because of its longer lifespan, red pine often succeeds its less tolerant associates. In the absence of a major disturbance, it is succeeded by its more tolerant associates because they can regenerate in the understory more easily. The rate of succession is more rapid on the better sites.

Under natural conditions, wildfires commonly interrupt ecological succession in red pine. Pure red pine stands sometimes regenerate following fire, but a mixture of intolerant species often results. Fire easily kills young trees, but older ones usually survive ground fires because of their thick bark. Fire scars on old-growth trees attest to the common historical occurrence of fire in this type.

Red pine stands seldom survive more than 200 to 250 years, but a few live to 350 and some to about 400 years.

Common shrubs include hazel, blueberry, sweet-fern, willow, cherry and bush-honeysuckle. Common herbaceous species include aster, bracken fern, wintergreen and false lily-of-the-valley.

Evaluation and Discussion (see table 4)

Timber

Red pine is unique in the Lake States in that it is the only type managed to a major extent as an intensively cultured plantation crop. This is due to its relatively fast growth rate and productivity, markets for thinnings and its high economic value over a wide range of sites. Common product objectives are pulpwood, posts, poles, and pilings from intermediate thinnings, and sawtimber from the final crop, even on site indexes as low as 45 (which, for example, would be noncommercial for aspen).

Although it is possible to grow red pine using an uneven-aged system, even-aged management provides optimum timber production because the species grows best in full sunlight. Basal area densities of 90 to 180 ft^2/acre, depending on site and tree size desired, should be maintained by intermediate thinnings. A basal area of not more than 90 ft^2 /acre appears optimum for obtaining the highest investment return (Lundgren 1965). Where markets support thinnings, rotations for highest investment returns can vary from 65 to 95 years. The decline in financial return is gradual from 95 to 125 years.

Investment returns from growing red pine in the Lake States are thoroughly detailed in North Central Forest Experiment Station Research Papers LS-18 and NC-2 (Lundgren 1965, Lundgren 1966).

Clearcutting followed by planting is recommended unless continuous tree cover is needed. In esthetically sensitive areas, strip-shelterwood systems with planting allow a gradual transition from mature stands to new forest.

Water

Evaporation and transpiration losses are higher in pure pine stands than in hardwood stands. Thus, pine stands yield less streamflow than hardwood stands. A quick estimate of differences in streamflow between hardwoood and pine stands can be calculated using North Central's Research Paper NC-128 (Verry 1976). Thinning dense pine stands can increase water yield if water production is a primary goal (Urie 1971, Van Der Zel 1970).

Many young plantations require herbicide applications to control competing broadleaf species. There are, however, no serious water quality hazards associated with forest applications of herbicide, unless there are accidental spills of concentrated herbicide in a stream. Direct delivery of herbicide to surface waters should also be avoided.

Wildlife

The lack of variety in species and stand structure and the long life of the red pine type creates conditions generally unfavorable to edge wildlife, but favorable to interior wildlife. Red pine provides the best habitat for edge wildlife during the early stages of regeneration. However, this period is brief, especially in extensive plantations. During the rest of the life of homogeneous stands, the

Table 4.—*Effects of some red pine harvest options on forest resources—a desirability rating*[1] *(timber management objectives: pulpwood, poles, and piling from periodic thinnings; sawtimber final crop)*

Forest practice	Rotation length (years)	Size of harvest (acres)	Investment return	Water: Yield	Water: Quality	Wildlife: Edge species	Wildlife: Interior species	Visual quality (landscape and on-site appeal)
		1	U	0	0	++	U	++
		5	+	+	0	+++	U	++
	75	20	++	++	0	+	+	+
		50	+++	++	0	+	+	+
Even-aged management with intermediate thinnings and clearcutting		1	U	0	0	++	U	+++
		5	+	+	0	+++	+	+++
	110	20	+	++	0	U	++	++
		50	++	++	0	U	++	++
		1	U	0	0	+	U	+++
		5	U	+	0	++	++	+++
	145	20	+	++	0	U	+++	++
		50	++	++	0	U	+++	++
No harvest			0	0	0	U	++	+++

[1]+++ = excellent; ++ = good; + = fair; 0 = no impact; U = unfavorable impact.

value to edge wildlife remains low. In contrast, the primary value to interior species occurs during the period of stand maturity.

Certain management practices can be applied to enhance the value of the red pine type for edge wildlife. Because red pine can provide cover for a number of species, plantations can be established in areas short of coniferous cover. However, to be beneficial to edge wildlife, red pine should not occupy more than 30 percent of the area (McCaffery 1970).

Plantation size is also important. Bailey and Alexander (1960) recommended that conifer plantations not exceed 7 acres. They should preferably be as small as 1 to 5 acres if well interspersed with hardwood types (Smith 1958). If these small sizes are not suitable to overall objectives, Rutske (1969) recommended that plantations be surrounded by 60-foot-wide unplanted strips, and in plantations nearing 10 acres or larger, he suggested alternating 60-foot-wide unplanted strips with 250- to 400-foot-wide planted strips. Other practices that can benefit edge wildlife include (1) 10-foot rather than 6-foot spacing where Christmas trees are not an objective, (2) several rows of spruce around the perimeter to reduce interior wind velocities, (3) mixing the species composition by alternating 20 rows of red pine with 10 more widely spaced rows of other conifers, and (4) maintaining small openings and hardwood inclusions (Smith 1958). The main objective of these measures is to avoid extensive, dense stands with little or no ground vegetation. As the stand matures, intermediate cuttings to minimum recommended stocking levels can help to maintain a ground vegetation layer beneficial to edge wildlife.

With one exception, none of the preceding measures recommended for edge species should affect the suitability of red pine for interior species. This exception is the creation of small, isolated patches of red pine that may not be as favorable as larger stands in closer proximity to one another. The other measures would tend to be beneficial by increasing vegetation diversity, crown vigor of the overstory, and seed production. Bald eagles and ospreys require live and dead old-growth red and white pine near water, and it is prudent to reserve from cutting an area of about 7 acres surrounding existing and potential nest sites.

Visual Quality

Red pine trees, especially large ones along lakes or streams, are very attractive. Red pine stands are most pleasing when managed near the upper limits of basal area, which reduces the amount of understory vegetation.

To maintain visual quality, careful silvicultural operations and implementation of those items discussed under the aspen type (pages 10-11) should be encouraged. Maximum visual quality will be maintained by selecting management options that provide high stand basal areas over long rotations. If visual quality is a major consideration, understory vegetation can be controlled to enhance the park-like appearance, especially in younger or thinned stands, including plantations.

The no-harvest option will maximize visual appeal for any single area because of the longevity of the species, although without thinning it will take longer to reach large diameters. In the long run, however, the type will normally undergo conversion to more tolerant species through natural succession.

Diseases

The most important disease of red pine in the Lake States at present is *Scleroderris* canker. A leaflet explaining how to identify this disease is available from the North Central Station on request (Skilling and O'Brien 1973). The disease is most important in young plantations, where it causes shoot dieback and canker, and can kill all the trees in a plantation. Once the trees have become taller than about 6 feet, they generally are not affected by *Scleroderris* canker in the Lake States. Recently a new form of *Scleroderris* canker has been encountered in New York state that is killing much older trees.

Red pine shoot blight is an important disease of red pine reproduction when seed trees or shelterwood trees are left. The disease kills the current year's needles, and if severe, will kill the entire tree. A leaflet telling how to identify this disease is available from the North Central Station on request (Skilling and O'Brien 1973).

Lophodermium needlecast disease can infect red pine of all ages, but is most important in seedlings and saplings. The disease can kill young trees if severe and will stunt the growth of less severely infected trees. *Scleroderris* canker, shoot blight, and needlecast are the only diseases that reduce visual quality of affected stands under any of the management options.

Red pine root and butt rot *(Armillaria)* can infect red pine when the trees have been under stress from environmental or pathological conditions. The disease is most severe when red pine plantations are established in areas where hardwoods were grown previously, but can be important in areas occupied by conifers for many years.

Polyporus schweinitzii also causes a root and butt rot; it enters through wounds caused by fire or logging. Therefore it can be important in stands that are periodically thinned.

Fomes root rot can infect red pine of all ages, but it is not important in this region at present.

Fomes red pine heart rot infection usually enters through dead branch stubs, while wounds rarely become infected.

Recently *Diplodia* has become an important disease of red pine. This fungus kills new shoots and branches, and in some situations girdling cankers will kill trees.

Insects

Insect damage to red pine is most prevalent during the establishment period. In plantations, white grubs, the red-headed pine sawfly, and the Saratoga spittlebug are probably the most serious. Also, in the eastern and southern parts of the red pine range, the European pine shoot moth can cause damage to leaders, although wood fiber growth loss may be recovered in succeeding years (Miller *et al.* 1978). No serious problems from insects occur once the trees reach pole size. However, cone crops are frequently destroyed by insects (Mattson 1971). A leaflet on how to control the red pine cone beetle is available on request (Miller and Taylor 1968).

WHITE PINE

Type Description

Eastern white pine, the mainstay of the early logging era in the Lake States, is now of minor importance as a timber species. Throughout most of the region today, it is threatened by white pine blister rust. Thus, white pine is infrequently planted, and planting will not likely increase until rust-resistant stock becomes readily available. White pine occurs in scattered natural stands throughout the region, or more frequently as a component of other types—either as a super-canopy or scattered individuals, or as a dominant or codominant component of red pine stands.

White pine grows on a wide variety of sites. Optimum development is on moist, deep loams or on sandy loams of lower slopes, but it also is able to compete on upper slopes and ridgetops.

Within densely stocked pure or nearly pure stands of white pine, the tall shrub layer is poorly developed, except for hazel; a low shrub layer of bush-honeysuckle, sweet-fern, and blueberry predominates over a sparse herbaceous ground cover.

Evaluation and Discussion (see table 5)

Timber

Although no longer the giant in the timber industry that it once was, white pine still commands economic respect where significant amounts of it are available in large stands. It is prized for its high-quality lumber and rapid growth rate, sometimes even in the face of high risk from biological hazards such as blister rust (Schlaegel 1971). White pine is not well suited for pulpwood or poles, and sawtimber is the major product objective (other than Christmas trees).

Although uneven-aged management is possible for white pine, it has not proven very satisfactory for regeneration; thus we recommend even-aged management. Clearcutting during good seed years or in small patches or strips when seed is available from adjacent stands is moderately successful. If no regeneration develops, mechanical site preparation and planting are required. Spreading shelterwood cuttings over a period of years is probably the most reliable method for natural regeneration.

Rotations vary but 80 years is sufficient to produce large saw logs.

Water

Comments under red pine (page 15) apply equally well to white pine. In addition, some good

Table 5.—*Effects of some white pine harvest options on forest resources—a desirability rating*[1] *(timber management objectives: sawtimber)*

Forest practice	Rotation length (years)	Size of harvest (acres)	Investment return	Water		Wildlife		Visual quality (landscape and on-site appeal)
				Yield	Quality	Edge species	Interior species	
		1	U	0	0	++	U	++
Even-aged		5	+	+	0	+++	+	++
management	80	20	++	++	0	+	++	+
with clear-		50	+++	++	0	+	++	+
cutting								
		1	U	0	0	+	U	+++
		5	+	+	0	++	+	+++
	120	20	+	++	0	+	+++	++
		50	++	++	0	+	+++	+
No harvest			0	0	0	0	++	+++

[1]+++ = excellent; ++ = good; + = fair; 0 = no impact; U = unfavorable impact.

white pine stands occur on lower slopes in moist stream bottoms. Water influence zone restrictions on Federal land should be adhered to (with equivalent precautions elsewhere), and erosion from roads should be avoided by placing roads away from seepage areas or by providing adequate drainage.

Wildlife

In comparison with the red pine type, the white pine type (if not in pure, dense stands) tends to have better-developed tall shrub and herb layers. This consideration and the more mesic soil conditions tend to give the white pine type higher value than red pine for edge wildlife species, while still maintaining considerable value for interior wildlife. As with red pine, the white pine type also provides the best habitat for edge wildlife during the early stages of regeneration.

Management recommendations for wildlife follow those previously described for red pine (pages 15-16). However, in view of the small amount of reforestation with white pine, management opportunities consist primarily of maintaining tall shrub and herb layers by thinning, and preserving 7 acres around existing and potential nest sites for bald eagles and ospreys.

Visual Quality

Mature white pine, with its plume-like branches, is visually attractive along waterways, in small groves, or as single trees. Because white pine is generally found on mesic sites, it does not often exhibit the open, park-like understory of old-growth red pine stands.

Management options that call for harvest of smaller areas and longer rotations will maintain the greatest visual quality, and special care must be taken in newly regenerated stands.

Dead portions of white pine crowns infected with blister rust are not necessarily unattractive for all viewers, but the life of individual trees can be prolonged by pruning infected or dead branches (Hansen *et al.* 1974).

The no-harvest option will provide high visual quality for a long period in the absence of blister rust. Eventually, however, the type will be lost under this option because of natural succession to more tolerant species.

Diseases

White pine blister rust is by far the most important disease of eastern white pine, limiting its management to areas of low blister rust hazard (VanArsdel 1964), at least until resistant varieties are developed.

Fomes pine heart rot is responsible for about 90 percent of the cull in eastern white pine. The disease enters through dead branch stubs and weevil-killed shoots.

Armillaria pine root and butt rot will be important only in white pine plantations established in areas where hardwood stumps are left from the previous harvest.

Under the no-harvest option, white pine blister rust and *Armillaria* pine root rot will be important from a visual standpoint because they kill trees.

Insects

The two most significant insects in white pine management are the white pine weevil and the introduced pine sawfly. The weevil damages leaders, resulting in deformed stems. The incidence of weevil attack is reduced where there is an overstory of broadleaf trees. The sawfly defoliates trees of all ages and can reduce growth and kill the tops of mature trees.

JACK PINE

Type Description

The jack pine type covers about 2.5 million acres in the Lake States. Jack pine grows in both pure and mixed stands; common associates in mixed stands are red and eastern white pine, the aspens, white birch, several oaks (mainly northern red oak and northern pin oak), and spruce-balsam fir mixtures. The type is usually found on level to gently rolling sand plains, mainly of glacial outwash, fluvial, or lacustrine origin. It also grows on eskers, sand dunes, rock outcrops, ridges, and glacial lake beds and beaches.

Jack pine is a rather small, short-lived species that establishes readily on recently burned areas, especially on exposed sand sites. It is less shade-tolerant than any of its principal associates except quaking aspen and white birch. Thus, jack pine is a temporary type that on better sites is replaced by more shade-tolerant species when natural succession is not interrupted by fire. Fire encourages reproduction of jack pine at the expense of the more shade-tolerant species, except for oak and aspen, which sprout vigorously. On poor sites, such as light sandy soils where other commercial species do poorly, jack pine is more permanent. Here it tends to grow in pure stands but sometimes is mixed with northern pin oak. The poorest jack pine sites are largely free of shrubs; medium sites are characterized by low shrubs such as blueberry, sweet-fern, and dwarf-honeysuckle; and the better sites often have a dense undergrowth of American and/or beaked hazel, green alder, red-osier dogwood, and willows.

Evaluation and Discussion (see table 6)

Timber

Jack pine is one of the few species that is generally not re-established where it grows best. From a timber standpoint, it is desirable to convert good jack pine sites to the more productive red pine. Thus, the trend is to establish jack pine on dry soils where no other species fares as well.

The primary product objective for jack pine is to grow pulpwood, except on the better sites where intermediate thinnings are sometimes used to increase production of poles and small saw logs. Badly overstocked seedling and sapling stands may need thinning or cleaning to reduce the risk of stagnation.

Jack pine requires even-aged management; clearcutting followed by scarification or burning is best. Seedlings can be established by scattering

Table 6.—*Effects of some jack pine harvest options on forest resources—a desirability rating*[1] *(timber management objectives: pulpwood to a 3-inch top)*

Forest practice	Rotation length (years)	Size of harvest (acres)	Investment return	Water: Yield	Water: Quality	Wildlife: Edge species	Wildlife: Interior species	Visual quality (landscape and on-site appeal)
		1	U	0	0	+	U	+
		5	U	+	0	++	+	+
	40	20	++	+++	0	+	++	+
		50	+++	+++	0	+	++	+
Even-aged		1	U	0	0	+	U	++
management		5	U	+	0	++	+	++
with	55	20	+	++	0	+	+++	+
clearcutting		50	++	++	0	+	+++	+
		1	U	0	0	++	U	+++
		5	U	+	0	+++	U	+++
	70	20	+	++	0	++	+	++
		50	+	++	0	++	+	+
No harvest			0	0	0	U	+	+++

[1]+++ = excellent; ++ = good; + = fair; 0 = no impact; U = unfavorable impact.

cone-bearing branches, direct seeding, or planting. Shelterwood cutting is limited to stands that bear nonserotinous cones and where landscape and wildlife values are especially important.

Rotation lengths that maximize pulpwood yield range from 40 to 70 years, depending on stand density and risk from insects, disease, and weather. Generally, return on investment is greater with shorter rotations. Sawtimber and poles may require 70-year rotations.

Water

Comments for water in the red pine discussion (page 15) apply equally well to jack pine.

Wildlife

The jack pine type is generally beneficial to both edge and interior wildlife species. Its overall value to edge wildlife is less than that provided by the aspen or birch types, because jack pine itself is generally not as palatable and shrubs are not as prevalent. However, it is more valuable than the other conifer types, whose canopies intercept more light and thus lessen the development of lower vegetation layers. For wildlife sensitive to excessive snow depths, however, jack pine ranks lower than other conifers. The habitat provided by jack pine stands during the regeneration phase are most beneficial to edge wildlife, whereas older, more fully stocked stands tend to be more beneficial to interior species.

In general, management should favor maintenance of this type with a balanced distribution of age classes among stands (Ruske 1969). Most recommendations previously discussed for established red pine (pages 15-16) also apply to jack pine, except that, because jack pine is a short-rotation, intolerant type, a larger percentage of jack pine than red pine would be acceptable where intolerant types are in short supply.

The Kirtland's Warbler is an endangered species that nests in north-central Lower Michigan and requires breeding habitat that would not be met by following the general recommendations for red or jack pine. It breeds in young jack pine stands, usually of fire origin, which grow on the Grayling sand soil type. For nesting, stands should be 6 to 15 feet tall, well interspersed with small openings, and preferably larger than 200 acres. The requirement for small openings becomes more important with increasing stand age and density.

Visual Quality

Extensive areas of jack pine are considered by many people to be rather unattractive. Less extensive stands that lend diversity to the landscape or occur on rock outcrop ridges have high visual appeal.

Harvest options that include longer rotations or thinning and cleaning of excessively overstocked seedling and sapling stands will add to visual quality. Attention to size, close control of harvest, and use of appropriate techniques discussed in earlier sections will enhance the visual appeal of the type.

The no-harvest option will provide maximum visual quality from early maturity to stand break-up. On all but the poorest sites the no-harvest option will result in conversion to more tolerant species that may be even less visually attractive.

Diseases

Scleroderris canker causes a shoot dieback and stem canker on young jack pine. While the disease may act as a thinning agent in dense stands of reproduction, it can kill entire stands when severe. Older jack pine is also susceptible to the New York strain of *Scleroderris* canker mentioned for older red pine.

Eastern gall rust, sweet-fern rust, comandra blister, and stalactiform rust can damage jack pine of any age. The rusts are particularly capable of killing young trees. Older trees become badly malformed and are often not harvested. The cankers caused by these rusts can also allow entry of heart rot fungi.

Fomes pini and *F. pinicola* cause heart rot of mature and overmature jack pine. However, cull caused by these heart rots is seldom a problem for rotations as short as 70 years.

Armillaria pine rot and butt rot will infect jack pine, especially when the trees are established where hardwoods have been grown previously.

Davisomycella needle blight kills all but the current year's needles on infected jack pine. Severely infected trees might be killed, especially when young, but generally the disease only causes growth loss. Jack pine is also susceptible to *Diplodia* attack as mentioned for red pine.

Scleroderris canker and *Davisomycella* needle blight will reduce the visual quality of affected stands under the no-harvest option. The other diseases may actually be interesting to casual observers.

Insects

Although jack pine hosts a variety of insects that attack developing leaders during the establishment period, height growth is not seriously reduced and stem form, which is normally irregular, is not greatly affected. Saratoga spittle bug, however, can be a serious pest during the establishment period.

The most significant damage occurs during the pole stage when severe defoliation by the jack pine budworm and jack pine sawflies can kill suppressed trees and the tops of others. Budworm injury can be minimized by harvesting at a rotation age of about 40 years. Open-grown as well as very dense stands produce heavy crops of male cones, which enhance survival of jack pine budworm larvae.

SPRUCE-FIR

Type Description

The spruce-fir type occupies nearly 3 million acres in the Lake States. Despite the type name, balsam fir is typically more abundant within the type than is white spruce.

Spruce-fir is considered the climax forest type over a major part of the area occupied by aspen, birch, and associated conifer forests (Cooper 1913, Ohmann and Ream 1971). Old-growth stands have varying mixtures of balsam fir, white birch, and white spruce, with some black spruce, aspen, northern white-cedar, and occasional stems of black ash, red maple, and balsam poplar. Where succession is less advanced, white, red, and jack pine may be associated with the type. The type is sometimes represented by small (usually less than 10 acres), scattered stands of pure fir originating after fire, windstorm, or epidemics of spruce budworm (Roe 1950).

Over much of the Lake States balsam fir occurs as an understory within aspen, white birch, jack pine, white pine, and occasionally red pine types. In the natural course of succession, these types will eventually become spruce-fir as the overstory dies. Much of the spruce-fir type within the region originated in this manner, particularly areas that escaped disturbance for many years.

Spruce-fir stands will typically have a tall shrub layer composed of mountain-maple, hazel, and honeysuckle, and a poor low shrub layer, with mosses predominating over herbs as ground cover.

Evaluation and Discussion (see table 7)

Timber

From a silvicultural standpoint, spruce-fir is the most flexible of the eight types. It can be managed through either even-aged or uneven-aged systems, and in pure or mixed stands with aspen and birch. Even the crudest silvicultural prescriptions can provide good regeneration of balsam fir if a seed source is nearby. The only difficult and recurrent problem with the type is how to increase the proportion of white spruce, which has more value for high-quality paper and sawtimber.

Table 7.—*Effects of some spruce-fir harvest options on forest resources—a desirability rating*[1] *(timber management objectives: balsam fir pulpwood to a 3-inch top, and a white spruce sawtimber)*

Forest practice	Rotation length (years)	Size of harvest (acres)	Investment return	Water		Wildlife		Visual quality (landscape and on-site appeal)
				Yield	Quality	Edge species	Interior species	
Uneven-aged management with selection cutting	70	1	U	0	0	++	U	+++
		5	U	0	0	+++	U	+++
		20	+	0	0	+	+	++
		50	+	0	0	+	+	++
Even-aged management with clearcutting[2]	70	1	U	0	0	+	U	++
		5	U	+	0	++	+	++
		20	++	++	0	+	+++	+
		50	+++	++	0	+	+++	U
No harvest			0	0	0	U	++	+++

[1]+++ = excellent; ++ = good; + = fair; 0 = no impact; U = unfavorable impact.
[2]Clearcut width should not exceed 200 feet for natural regeneration.

Product objectives for this type are balsam fir pulpwood and white spruce pulpwood and sawtimber, with occasional yields of balsam fir sawtimber. Rotation ages should be approximately 70 years for fir and up to 90 for spruce where sawtimber is the objective. Little economic information is available for the spruce-fir type.

Even-aged management is particularly well-suited for mature or overmature even-aged stands. Clearcutting in narrow strips or small patches is best so that natural seeding can come from adjacent uncut stands. Large clearcuts should be avoided because they generally offer too harsh an environment for seeding establishment and the clearcut interior receives too little seed. Shelterwood cuttings also work well if a series of light cuts are conducted over a period of several years. Opening these old stands too quickly puts them in danger of windthrow. Once seedlings are established, the shelterwood can be removed completely. The shelterwood also allows larger areas to be regenerated at one time.

Uneven-aged management can be used in uneven-aged stands, or in young even-aged stands where the objective is to achieve uneven-aged structure. Single trees or groups of trees should be removed on 5- to 20-year cutting cycles as they mature, or in even-aged stands when the trees reach marketable size. Stands should be thinned at the same time to promote a good distribution of age and size classes. Uneven-aged management provides ideal regeneration conditions for the spruce-fir type.

Balsam fir often establishes in the understory of aspen and can be managed with it, either as an alternate crop in an even-aged system or as a concurrent crop in an uneven-aged system. In the even-aged system, the aspen is harvested when mature while the fir is still sapling or small pole size. Openings in the fir canopy will usually be large and numerous enough to allow scattered clumps of aspen suckers to be established. The fir is grown to maturity and the whole stand, fir *and* aspen, is clearcut. Aspen suckers will dominate the site, but in 10 to 20 years fir will re-establish in the understory. The success of this system depends on an adjacent fir seed source.

The uneven-aged aspen-fir system is much like the uneven-aged system for fir alone. Group selection of aspen and single-tree or group selection of fir will favor good regeneration of both.

Water

Comments under red pine (page 15) apply equally well to the spruce-fir type. In addition, since dense spruce-fir stands intercept more precipitation than pines (Helvey 1971), water yields from dense spruce-fir stands will be slightly less than from pine stands.

Wildlife

The spruce-fir community is generally beneficial to both edge and interior wildlife species. The generally dense tree canopy provides good winter cover. In stands with light to medium stocking and in those with an aspen component, the lower vegetative layer can be moderately well-developed and beneficial to edge wildlife. However, this layer is usually poorly developed and generally less valuable to edge wildlife than it is in the jack pine type.

As explained under the aspen type (page 9), McCaffery (1970) recommended that an area contain about 15 percent conifer cover to maximize wildlife production. Assuming that a management area contains about 15 percent spruce-fir, two silvicultural options could be pursued to maintain this proportion and enhance the type's value for edge wildlife. One would be to apply uneven-aged management through selection cutting on a cycle of 30 years or less to open the canopy and stimulate understory vegetation, while at the same time leaving portions uncut or lightly cut to retain some canopy cover. The other option would be to apply even-aged management that will balance age class distribution. Although Rutske (1969) recommended cutting in strips 65 to 100 feet wide or in small patches of about 0.5 acres for deer, strips up to 200 feet wide or patches up to 5 acres would also favor edge species. Cutting larger areas, progressive cutting, or two-stage, alternate-strip cutting in larger blocks would be more favorable for interior species.

Methods of increasing the acreage of spruce-fir include reserving from harvest stands likely to succeed to spruce-fir, or overstory removal in stands with a substantial spruce-fir understory. Decreasing the acreage of spruce-fir by conversion to aspen would most benefit edge wildlife species. This can best be accomplished in stands where enough aspen remains to provide a fully stocked sucker stand following clearcutting. Patches of 0.5 to 5 acres are recommended for most edge species, or even larger for moose.

Visual Quality

Except where it adds variety to the landscape, the type is not especially attractive. Where spruce-fir is extensive, small and medium-sized regeneration cuts may improve the overall visual appeal, especially if they open scenic vistas.

Selection cutting will maximize visual quality in stands that are not extensive. Aspen-spruce-fir management probably provides the greatest visual quality for the type.

The no-harvest option may maintain visual quality over limited areas, but salvage operations may be required periodically to remove windthrown, wind-broken, and insect-killed individuals. In spite of the abundant down and dead material, pristine vignettes displaying natural ecological processes have much appeal for some viewers—in this case, perhaps more philosophical than aesthetic.

Diseases

A number of diseases affect white spruce, but none is significant in its management. Balsam fir, however, is affected by several serious diseases.

Armillaria mellea causes a root and butt rot of balsam fir that is most severe where hardwood stumps remain from a previous forest.

Feather rot and balsam butt rot are the principal heart rot fungi responsible for nonutilization (cull) of balsam fir. Both of these fungi cause decay in the lower 12 feet of the first log.

Stereum sanguinolentum causes a heart rot of balsam fir. The fungus enters only through wounds, and therefore is most important in stands where uneven-aged management is practiced and in areas subject to ice storms.

Although *Armillaria mellea* will affect the visual quality of stands under the no-harvest option, none of the other diseases is important.

Insects

By far the most significant insect in the spruce-fir type is the spruce budworm; it is capable of causing widespread mortality. The balsam fir component is most severely damaged. Balsam fir generally will succeed itself in budworm-killed stands. However, the broken tops and snags persist for 10 to 15 years, and can provide fuel for fires and impede fire suppression efforts (Sando and Haines 1972). When fire follows spruce budworm outbreaks, succession tends to shift the composition toward other species. The spruce budworm is a natural component of the spruce-fir forest, and on a time scale of 50 to 100 years it assures ecological stability in the system (Baskerville 1975, Mattson and Addy 1975).

Mortality of balsam fir is increased when spruce is present in the stand, and is decreased when species mixtures not susceptible to budworm attack are present (Batzer 1969). Maintaining high stand density of fir also lessens the proportion of fir damaged. Injury to advance regeneration may be reduced by removing all mature host trees during clearcutting, since any residual mature spruce and balsam fir harbor the insects. When practical, partial cutting of balsam fir will reduce budworm damage in the residual stand (Batzer 1967).

BLACK SPRUCE
Type Description

The black spruce forest type occupies about 2.1 million acres of commercial forest land in the Lake States. Sixty-eight percent of this acreage is in Minnesota, and the remainder is in the northern parts of Michigan and Wisconsin. The black spruce type is a major resource for pulpwood in northern Minnesota. Christmas trees are harvested on a limited scale on sites too poor for growing pulpwood.

Black spruce grows in both pure and mixed stands; in some mixed stands it predominates, and in others it is important but not predominant, such as in the mixed swamp conifer, upland white spruce-balsam fir, and jack pine types.

The black spruce type is found mainly on organic soil in the Lake States, but it also occurs on mineral soil. Extensive areas of organic soil are found on gently sloping glacial lakebeds or smaller filled lakes associated with the Laurentian Shield, pitted outwash plains, and morainic areas. On both lakebed and filled-lake sites, the growth rate of black spruce is related to the surrounding ground water flow system. The best sites occur where the soil water is continuous with the regional ground water system and thus is enriched by nutrients flowing from mineral soil areas. The poorest sites occur where the soil water is "perched" above and thus is separated from this regional system. The fertility of these latter sites depends mainly on precipitation, which is relatively low in nutrients.

The growth rate of black spruce varies greatly; height of dominant trees at 50 years ranges from about 45 feet on the best sites to less than 15 feet on the poorest. Mature stands on good sites commonly yield 30 cords per acre for trees 3.6 inches d.b.h. and larger. In contrast, many stands on poor sites never produce merchantable pulpwood.

The black spruce type is common on mineral soil only in the Laurentian Shield area of northeastern Minnesota and in a few isolated areas of Upper Michigan. Here black spruce grows on gravelly and bouldery loam and on shallow soil over bedrock, where it usually is mixed with other species such as jack pine, aspen, and balsam fir, but occasionally forms a pure type. Growth is best where the slope is gentle and moisture is plentiful, either from a shallow water table or seepage. South of the Shield, black spruce is occasionally found on sandy soil with a high water table.

Black spruce stands on the best organic soil sites typically have a dense understory of tall shrubs such as speckled alder, willow, and red-osier dogwood. In contrast, stands on medium to poor sites are nonshrubby and have only some low shrubs such as Labrador-tea and leatherleaf. Sphagnum and feather mosses are common in nonshrubby black spruce stands. Pure black spruce stands on mineral soils are often characterized by poor development of shrub and herb components, but an extremely well-developed carpet of moss (Ohmann and Ream 1971).

Evaluation and Discussion (see table 8)

Timber

This discussion is limited to black spruce on *organic* soils. Black spruce is a fire type much like jack pine; much seed is stored in persistent cones, and becomes available for regeneration after fire. (The cones are not serotinous, however, and seedfall is dependable every year.) Thus, black spruce stands are initially even-aged but can eventually become uneven-aged as the stand matures and opens up, leaving openings for new regeneration. However, uneven-aged systems are neither optimal nor practical because they increase the risk of windthrow and infestation by dwarf mistletoe, and growth is less than in the full sunlight provided by even-aged systems.

Black spruce grows slowly, reaching merchantability in 60 to 150 years, depending on stand density. The highest rate of investment return and in many instances the only positive rate of return is obtained with short rotations on the better sites.

Table 8.—*Effects of some black spruce harvest options on forest resources—a desirability rating*[1] *(timber management objectives: pulpwood to a 3-inch top)*

Forest practice	Rotation length (years)	Size of harvest (acres)	Investment return	Water: Yield	Water: Quality[2]	Wildlife: Edge species	Wildlife: Interior species	Visual quality (landscape and on-site appeal)
Even-aged management with clear-cutting	60	1	U	0	[0]	+	U	+
		5	U	0	[0]	++	+	+
		20	++	0	[U]	+	+++	U
		50	+++	0	[U]	U	+++	U
	90	1	U	0	0	++	U	++
		5	U	0	0	+++	+	++
		20	+	0	[U]	+	++	+
		50	++	0	[U]	U	++	+
	150	1	U	0	[0]	++	U	+++
		5	U	0	[0]	+++	+	+++
		20	U	0	[0]	+	++	++
		50	+	0	[0]	U	++	+
No harvest			0	0	0	U	+	+++

[1]+++ = excellent; ++ = good; + = fair; 0 = no impact; U = unfavorable impact.
[2]Assumes winter logging on frozen organic soils.
[ ] = Local increases in streamwater phosphorus concentration on brushy sites. Not significant unless tree harvesting is on a massive scale.

Because the trees are small and the fiber makes a high-quality paper, pulpwood is the only practical management objective.

Clearcutting, followed when needed by prescribed burning to control brush and dwarf mistletoe and to prepare the seedbed, is the best way to regenerate black spruce. If clearcuts are small or in narrow strips, natural seeding from adjacent mature stands is sufficient. Direct seeding can be used in large clearcuts. Shelterwood or seed-tree methods have the same disadvantages as uneven-aged management and are not recommended. Thinning to control stand density is not considered economical and is not practiced. Release by aerial herbicide spraying is recommended where immature spruce is severely suppressed by shrubs or hardwoods.

Water

Black spruce stands occur mostly on organic soils with high water tables. In these situations harvesting does not affect annual water yields, although minor effects can be measured. Clearcut areas will have slightly higher water tables than mature forests during wet periods and slightly lower water tables during dry periods. At the extremes, water tables may be about 2½ inches higher and 5½ inches lower. The effect on annual streamflow is balanced out.

Clearcutting black spruce on the more productive organic sites will increase nutrient concentrations in streamflow until an effective shade-producing canopy reappears. Nutrient increases are most dramatic when air temperatures exceed 80°F. Increases in phosphorus concentrations may be desirable or undesirable when they reach lakes. Phosphorus is a limiting nutrient in most lakes, so some increase may stimulate desirable levels of algae and fish production. Excessive increases in phosphorus, however, may promote undesirable algae blooms and fish die-offs. On a practical basis it would take massive cutting of black spruce on organic soil to affect downstream lake productivity in a measurable way.

Wildlife

The simple structure of black spruce stands provides little habitat for edge wildlife species. The best habitat is found in the early regeneration stages, in lightly stocked stands, and where black spruce is mixed with intolerant species on mineral soils. Even in these instances, however, suitability for edge wildlife is comparatively low and transitory. Black spruce provides mediocre habitat for a few interior species.

Where black spruce makes up about 15 percent of the management area (the amount of conifer cover recommended by McCaffery (1970), edge wildlife will benefit most from even-aged management. Clearcutting in blocks of about 5 acres or secondarily in strips up to 220 feet wide is recommended. Cutting larger areas, progressive strip cutting, or two-stage, alternate-strip cutting in blocks would tend to favor interior species. Where conifer stands are in short supply and the more beneficial conifer types (jack pine and northern white-cedar) are unsuited to the site, black spruce can be increased by reserving from harvest stands likely to succeed to black spruce, and by removing the overstory in stands with a substantial black spruce understory. Decreasing the acreage of upland black spruce would be most beneficial to wildlife if stands with mixed intolerant species were clearcut in blocks.

As ruffed grouse do with aspen, spruce grouse use several age classes of black spruce. Thus, harvest should be spaced over time and the areas well distributed, with first priority given to partial harvesting of extensive even-aged stands.

Visual Quality

Extensive areas of black spruce may have little visual appeal, but smaller acreages where the type adds to the diversity of the landscape or occurs as a fringe around bogs have high visual quality. Where the type occurs around bogs, a tamarack component frequently grows at the fringe, providing a very pleasing contrast of colors in the fall.

Mature black spruce stands with 80 to 150 square feet of basal area and little or no undergrowth except for a well-developed moss layer have high visual appeal.

Where stands are not extensive, the no-harvest option will maximize visual quality, primarily between maturity to stand break-up. After about age 70 butt rot increases, and after age 100 windthrow due to the rot becomes common. Excessive windthrow tends to diminish visual quality.

Major infections of eastern dwarf mistletoe generally reduce visual quality under any management option. However, minor infections produce curiosities (witches' brooms) that can have positive visual effect. In extensive areas of black spruce, even major infections may have a positive visual impact by opening small vistas to break the monotony.

Diseases

The most important disease of black spruce over any rotation length is eastern dwarf mistletoe. Dwarf mistletoe is a plant that grows on black spruce branches, obtains water and nutrients from the spruce, and causes witches' brooms, stunted growth, and sometimes death of the tree. A leaflet on how to identify and control mistletoe is available from the North Central Station on request (Ostry and Nicholls 1976b).

Root rots caused by *Armillaria mellea, Coniophora puteana, Polyporus schweinitzii, P. tomentosus,* and *Stereum abietinus* are major contributors to windthrow in black spruce, but wind alone, because of the shallow root system, can cause much uprooting. Although these rot fungi invade the butt log of black spruce, they do not cause significant cull.

Insects

Swamp black spruce is damaged little by insects even though the dense tree crowns may harbor a large variety of them.

NORTHERN WHITE-CEDAR

Type Description

The northern white-cedar type occupies 1.9 million acres of commercial forest land in the Lake States. The most extensive stands are in Michigan, which has 62 percent of the type's acreage. The remainder occurs in the northern parts of Minnesota and Wisconsin.

The white-cedar type is an important but greatly underutilized resource for both timber products and wildlife habitat. It produces large amounts of posts, poles, fencing, and lumber in certain localities of Upper Michigan, northern Minnesota, and northeastern Wisconsin. Present production of white-cedar pulpwood is minor, but the potential is substantial. The type also has great value for winter deeryards because northern white-cedar is highly preferred by white-tailed deer for shelter *and* browse. Although the extensive yards of Upper Michigan are particularly important, numerous smaller yards throughout the northern Lake States are vital during severe winters.

Northern white-cedar grows in both pure and mixed stands; in some mixed stands it predominates, and in others it is important but not predominant, such as in the mixed swamp conifer, black spruce, tamarack, and black ash-American elm-red maple types.

The northern white-cedar type is found primarily on organic soil in the Lake States, but it also occurs on mineral soil, mainly on seepage areas and limestone uplands. Growth is usually faster on mineral soil, and best on sites that are calcareous and moist but well-drained. Growth rate varies greatly; height of dominant white-cedar trees at 50 years ranges from at least 40 feet on the best sites to less than 15 feet on the poorest. Mature, fully stocked stands of pure white-cedar (at least 80 percent) on good sites commonly yield 50 cords per acre for trees 5 inches d.b.h. and larger. Much of this volume is in logs and poles, whereas many stands on poor sites produce only small posts.

Organic soil origin, degree of decomposition, and drainage in the upper horizons are good guides to site productivity, whereas soil depth is a poor guide by itself. The best soils are neutral or slightly alkaline and contain moderately to well-decomposed organic matter derived from woody plants or sedges. However, the upper 4 inches on these sites may be poorly decomposed sphagnum or other mosses. The best sites have moving soil water and are usually near streams or other drainageways. In contrast, the poorest sites have poorly decomposed acid soil derived from plants such as sphagnum moss throughout the whole root zone. These sites have little water movement (except during snowmelt) and are often far from drainageways.

Typically the tall shrub layer is well-developed, with species composition variable, depending on whether the stand is on organic or mineral soil. The low shrub layer is usually poorly developed, and the herb layer is also sparse. Mosses predominate over herbs in the latter, especially on organic soil.

Evaluation and Discussion (see table 9)

Timber

Because little management information is available for upland stands of northern white-cedar, the timber discussion is restricted to *swamp* stands.

This type is important for timber and winter deeryards, thus management decisions should attempt to accommodate both. Timber management objectives are to grow posts, poles, and sawtimber.

Even-aged management is recommended for regenerating northern white-cedar. Small clearcut patches or strips less than 200 feet wide are best for natural seeding from adjacent, uncut stands. Shelterwood cuts should be used to regenerate stands with no adjacent seed source.

Thinnings down to 150 square feet basal area per acre will remove undesirable hardwoods and tamarack (which have no shelter value for deeryards), as well as promote growth on crop trees. Rotation lengths vary from 80 to 145 years, depending on site and product objective.

Water

Comments for black spruce (page 25) apply equally well to northern white-cedar on organic soils. On mineral soils, dense stands of northern white-cedar have interception losses similar to those of dense spruce-fir stands.

Wildlife

The white-cedar community provides habitat for many edge and interior wildlife species. The dense tree canopy and tall shrub layer provide important winter food and cover for deer, and to a lesser extent for snowshoe hare. However, the importance of white-cedar stands to deer in winter depends on severity of weather and availability of other suitable conifer types. For snowshoe hare, other conifer types are probably more important.

Because white-cedar is tolerant and long-lived, the type is likely to retain its current prevalence. However, regeneration may be difficult to obtain where deer are abundant. In stands of less than 200 acres, the impact of dense deer populations can be lessened by two-stage clearcuts. The objective is to remove all winter cover for deer during the critical regeneration period, especially where the

Table 9.—*Effects of some northern white-cedar harvest options on forest resources—a desirability rating*[1] *(timber management objectives: posts, poles, and sawtimber)*

Forest practice	Rotation length (years)	Size of harvest (acres)	Investment return	Water		Wildlife		Visual quality (landscape and on-site appeal)
				Yield	Quality[2]	Edge species	Interior species	
Even-aged management with clearcutting or two-stage shelterwood; timber emphasis on posts, poles, and sawtimber; wildlife emphasis on deer browse and shelter	25	1	U	0	0	++	U	+
		5	U	0	0	+++	U	+
		20	U	0	[U]	+	U	U
		50	U	0	[U]	+	U	U
	50	1	U	0	0	++	U	+
		5	U	0	0	+++	U	+
		20	+	0[3]	[U]	+	U	+
		50	+	0[3]	[U]	+	U	U
	80	1	U	0	0	++	U	++
		5	U	0	0	+++	U	++
		20	++	0[4]	[U]	+	+	+
		50	+++	0[4]	[U]	+	+	+
	120	1	U	0	0	+	U	+++
		5	U	0	0	+	+	+++
		20	++	0[4]	[U]	U	++	++
		50	+++	0[4]	[U]	U	++	+
	145	1	U	0	0	U	U	+++
		5	U	0	0	U	++	+++
		20	+	0[4]	[U]	U	+++	++
		50	++	0[4]	[U]	U	+++	+
No harvest			0	0	0	U	+	+++

[1]+++ = excellent; ++ = good; + = fair; 0 = no impact; U = unfavorable impact.
[2]Assumes winter logging on frozen organic soils.
[3]++ on mineral soil areas with good drainage.
[4]+ on mineral soil areas with good drainage.
[ ] = Local increase in streamflow phosphorus concentrations on brushy sites. Not significant unless tree harvesting is on a massive scale.

area is small and the density of deer high. This forces deer out of the area so that a new stand can be established. In large stands, cutting units can generally be made big enough to obtain adequate regeneration in spite of the deer by applying two-stage strip cuts in blocks of 40 to 160 acres (Verme 1965). In the first stage, alternate strips 66 to 100 feet wide are cut in a large block to initiate regeneration. The remaining strips are removed as soon as sufficient regeneration is obtained, thereby creating an essentially even-aged stand large enough to withstand the impact of deer browsing. However, if the potential exists for a rise in the water table or an increase in speckled alder, large clearcuts should be avoided.

In regions where the impact of deer on regeneration is not a problem, the size of cut is less important. In these instances, Rutske (1969) recommends reducing the cut to as little as 10 acres. Scheduling the harvest of white-cedar stands during the winter further benefits deer by providing browse (Verme 1961).

Little is known about the requirements of other wildlife inhabiting white-cedar stands. However, the silvicultural treatments dictated by the presence of high deer populations should benefit interior species.

Visual Quality

Extensive areas of the type are not very appealing, but limited areas add diversity to the landscape and provide an attractive fringe around lakes, bogs, and swamps. Stands with high basal area, large trees, and little undergrowth have the highest visual quality.

On good sites the no-harvest option provides higher visual quality from maturity to stand break-up than the harvest options because of the longevity of the species.

Diseases

Northern white-cedar is relatively disease-free, and none of its diseases should be a management problem under any of the options presented. Butt-rot fungi that cause a white, stringy rot (*Poria subacida*) or a brown, cubical rot (mainly *Polyporus balsameus* and *P. schweinitzii*) are common in mature trees on the drier lowland sites.

Insects

Although northern white-cedar is an occasional host to a number of leaf feeders and wood borers, the most significant damage results from galleries of carpenter ants (both red and black). Up to 20 percent of the stems in a stand may show loss in the lower 3 to 6 feet of the stem from the extensive nests of these insects (Graham 1918). Carpenter ants are also an important food of the pileated woodpecker. Mature stands are most affected by these insects.

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APPENDIX

Table 1.—Common and scientific names of species cited in text.

Common Name	Scientific Name
TREES	
American elm	*Ulmus americana*
Aspen (quaking)	*Populus tremuloides*
Balsam fir	*Abies balsamea*
Balsam poplar	*Populus balsamifera*
Bigtooth aspen	*Populus grandidentata*
Black ash	*Fraxinus nigra*
Black spruce	*Picea mariana*
Jack pine	*Pinus banksiana*
Northern pin oak	*Quercus ellipsoidalis*
Northern white-cedar	*Thuja occidentalis*
Red maple	*Acer rubrum*
Red oak	*Quercus rubra*
Red pine	*Pinus resinosa*
Tamarack	*Larix laricina*
White (paper) birch	*Betula papyrifera*
White pine	*Pinus strobus*
White spruce	*Picea glauca*
SHRUBS	
Alder	*Alnus* spp.
American hazel	*Corylus americana*
Beaked hazel	*Corylus cornuta*
Blueberry	*Vaccinium* spp.
Bush-honeysuckle	*Diervilla lonicera*

Cherry	*Prunus* spp.
Green alder	*Alnus crispa*
Labrador-tea	*Ledum groenlandicum*
Leather-leaf	*Chamaedaphne calyculata*
Mountain-maple	*Acer spicatum*
Red-osier dogwood	*Cornus stolonifera*
Speckled alder	*Alnus rugosa*
Sweet-fern	*Comptonia peregrina*
Willow	*Salix* spp.
Wintergreen	*Gaultheria procumbens*

LESSER PLANTS

Aster	*Aster macrophyllus*
Bracken fern	*Pteridium aquilinum*
False lily-of-the valley	*Maianthemum canadense*
Feather mosses	*Dicranum* spp., *Hylocomium splendens, Ptilium crista castrensis,* and *Pleurozium schreberi*
Sphagnum moss	*Sphagnum* spp.

DISEASE ORGANISMS

Armillaria pine root and butt rot	*Armillaria mellea*
Balsam butt rot	*Polyporus balsameus*
Brown cubical rot	*Polyporus schweinitzii*
Comandra blister rust	*Cronartium comandrae*
Davisomycella needle blight	*Davisomycella ampla*
Diplodia fungus	*Diplodia pinea*
Dwarf mistletoe	*Arceuthobium pusillum*
Eastern gall rust	*Cronartium quercum*
Feather rot (white stringy rot)	*Poria subacida*
Fomes heartrot	*Fomes pini*
Fomes root rot	*Fomes annosus*
Hypoxylon canker	*Hypoxylon mammatum*
Perennial canker	*Ceratocystis fimbriata*
Perennial canker	*Nectria galligena*
Phellinus (white) trunk rot	*Phellinus igniarius (=Fomes igniarius)*
Poria canker	*Poria obliqua*
Red pine needle case	*Lophodermium pinastri*
Red pine shoot blight	*Sirococcus stroblilinus*
Scleroderris canker	*Scleroderris lagerbergii*
Shepherd's crook shoot blight	*Venturia termula*
Stalactiform rust	*Peridermium stalactiforme*
Sweetfern rust	*Cronartium comptoniae*
White pine blister rust	*Cronartium ribiocola*

INSECTS

Aspen stem borers	*Saperda* spp., *Oberea* spp., *Agrilus* spp.
Birch skeletonizer	*Bucculatrix canadensisella*
Birch leaf miner	*Fenusa pusilla*
Black carpenter ant	*Camponotus pennsylvanicus*
Bronze birch borer	*Agrilus anxius*
European pine shoot moth	*Rhyacionia buoliana*
Forest tent caterpillar	*Malacosoma disstria*
Introduced pine sawfly	*Diprion similis*
Jack pine budworm	*Choristoneura pinus*
Jack pine sawflies	*Neodiprion pratti banksianae, N. swainei*
Large aspen tortrix	*Choristoneura conflictana*
Poplar borer	*Saperda calcarata*
Redheaded pine sawfly	*Neodiprion lecontei*
Red carpenter ant	*Camponotus ferrugineus*
Saratoga spittlebug	*Aphrophora saratogensis*
Spruce budworm	*Choristoneura fumiferana*
White grubs	*Phyllophaga* spp.
White pine weevil	*Pissodes strobi*

Table 2.—Some representative edge and interior wildlife species found in the aspen, birch, and associated conifer forest types of the Lake States.

MAMMALS

Edge species	
Beaver	*Castor canadensis*
Black bear	*Ursus americanus*
Bobcat	*Felis rufus*
Deer mouse	*Peromyscus maniculatus*
Eastern chipmunk	*Tamias striatus*
Fisher	*Martes pennanti*
Least chipmunk	*Eutamias minimus*
Masked shrew	*Sorex cinereus*
Moose	*Alces alces*
Short-tailed shrew	*Blarina brevicauda*
Snowshoe hare	*Lepus americanus*
Southern red-backed vole	*Clethrionomys gapperi*
White-tailed deer	*Odocoileus virginianus*
Interior species	
Marten	*Martes americana*
Red squirrel	*Tamiasciurus hudsonicus*
Northern flying squirrel	*Glaucomys sabrinus*

BIRDS

Edge species

Common name	Scientific name
American robin	*Turdus migratorius*
American woodcock	*Philohela minor*
Black-capped chickadee	*Parus atricapillus*
Boreal chickadee	*Parus hudsonicus*
Broad-winged hawk	*Buteo platypterus*
Chestnut-sided warbler	*Dendroica pensylvanica*
Chipping sparrow	*Spizella passerina*
Common flicker	*Colaptes auratus*
Common redpoll	*Acanthis flammea*
Kirtland's warbler	*Dendroica kirtlandii*
Least flycatcher	*Empidonax minimus*
Ovenbird	*Seiurus aurocapillus*
Pine siskin	*Carduelis pinus*
Purple finch	*Carpodacus purpureus*
Red-breasted nuthatch	*Sitta canadensis*
Red-eyed vireo	*Vireo olivaceus*
Ruffed grouse	*Bonasa umbellus*
Song sparrow	*Melospiza melodia*
Yellow-bellied sapsucker	*Sphyrapicus varius*

Interior species

Common name	Scientific name
Bald eagle	*Haliaeetus leucocephalus*
Bay-breasted warbler	*Dendroica castanea*
Blackburnian warbler	*Dendroica fusca*
Black-throated green warbler	*Dendroica virens*
Canada warbler	*Wilsonia canadensis*
Cape may warbler	*Dendroica tigrina*
Gray jay	*Perisoreus canadensis*
Magnolia warbler	*Dendroica magnolia*
Nashville warbler	*Vermivora ruficapilla*
Osprey	*Pandion haliaetus*
Pileated woodpecker	*Dryocopus pileatus*
Ruby-crowned kinglet	*Regulus calendula*
Saw-whet owl	*Aegolius acadicus*
Spruce grouse	*Canachites canadensis*
Tennessee warbler	*Vermivora peregrina*
Veery	*Catharus fuscescens*
White-throated sparrow	*Zonotrichia albicollis*
Yellow-rumped warbler	*Dendroica coronata*

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