Introduction

In this guide, a coniferous forest is comprised of at least 75 % conifer species. In southern Ontario, dominant species include white pine, eastern white cedar, eastern red cedar, eastern hemlock, and to a lesser extent, white spruce, balsam fir, and red pine. Coniferous forests are more common in northern areas of southern Ontario where the climate is colder and the growing season is shorter. They are often found on shallow or coarse-textured deep soils subject to limited moisture availability; cool areas such as north-facing slopes; very stony soils; in areas with heavy shade where tolerant conifer species can thrive; or in very wet areas.

Soil textures range from sand to clay; soil moisture regime ranges from dry (MR Ø, 0) to wet (MR 7-9); soils drainage classes range from very rapid (DR 1) to poor (DR 7).

In general, conifer species compete well with other species, including most tolerant hardwoods, on less productive sites (i.e., inadequate soil moisture, depth, nutrients) because the latter grow slower here than on more productive sites, allowing the conifers to compete and eventually predominate. Many conifer species are among the first trees to colonize a site after a disturbance. Establishment of white pine, red pine, and jack pine is promoted by fire. Eastern red cedar and white pine readily establish themselves in old fields.

Understory vegetation diversity is often low in conifer stands because high year round shade limits the number of species that can thrive. In addition, the density and basal area of these stands are often higher than in mixed or deciduous forests, thereby severely limiting the growth of other species. Also the accumulation of acidic litter leaches many cations from the surface mineral soil horizons. However, mosses and liverworts are common, as well as some shade-tolerant shrubs and herbaceous plants.

This guide provides silvicultural guidelines for three commonly-occuring conifer forest cover types found in southern Ontario: pines (both white and red pine), cedars (both eastern white and eastern red cedar) and hemlock. Other conifer species occur in southern Ontario, for example red and white spruce, but usually only as scattered individuals in natural forest stands.

Red spruce is found primarily in Site Region 5E (within Algonquin Park), but scattered occurrences have been reported in Site Region 6E (southeastern Ontario). Due to its rarity, management objectives should focus on conserving red spruce (**Appendix B**). Since this species requires a sheltered site for regeneration, group or single tree selection is recommended in stands where red spruce occurs. Mature red spruce should not be harvested until red spruce regeneration is well established.

Similarily, the less rare white spruce also occurs as relatively small, scattered populations at the southern edge of the species' Ontario range. In northern Ontario where white spruce is common, clearcutting is recommended for white spruce stands and uniform shelterwood for

mixed stands). In southern Ontario the management focus for stands that contain white spruce should be conservation, and use of uniform shelterwood is recommended. White spruce and other regeneration should be well established before the final harvest occurs. Silvicultural guidelines for white spruce are provided in "*A Silvicultural Guide for the Great Lakes-St. Lawrence Conifer Forest in Ontario*" (OMNR 1998*b*).

6.5 PINES

E. Boysen

by Peter and Erin Neave, and David Bland

Introduction

White pine is the most widespread and common pine in southern Ontario. It is found on a wide variety of sites and soil textures and thrives in full sunlight. In many parts of this region, it is most often occurs on drier, sandy soils but usually grows best on moist, sandy loams. In Site Region 6E it is a common tree of mixed forests and is frequently found growing in small pure stands or with hemlock, red oak and/or white oak. In Site Region 7E it is commonly associated with oaks. In can grow and persist in forests with a relatively open canopy.

In southern Ontario, natural red pine is not nearly as common as white pine. It is intolerant of shade and found on relatively infertile sites, often on sand plains, ridges, and rock outcrops. In this region, red pine occurs most often as scattered individual trees within a larger stand. White pine is a common associate. Occasionally it is found in small pure stands or with hemlock. In the past, (1920 to 1990), this species was planted extensively in plantations.

Natural jack pine is very uncommon in southern Ontario, occurring only in Site Region 6E on the Bruce Peninsula and in the Kaladar region. It is also intolerant of shade. It tends to grow on dry sandy soils and rocky outcrops. In this region, this pine most commonly forms pure stands, but can be found with white birch, white spruce, red maple, and poplars. This species is also dependent on fire for successful regeneration and perpetuation. It has been sporadically planted in plantations.

Pitch pine is a provincially rare species (S3) found only in Site Region 6E. In this area it usually occurs on rocky ridges, often where soils are too shallow and dry for most other species. More common associates include red oak, white oak, white pine, and red cedar. It is intolerant of shade. This species will likely prove difficult to manage and its perpetuation probably depends on repeated fires.

Dry-fresh pine coniferous forest ecosite (FOC1)

Canopy closure is usually greater than 75 %, except where occasional gaps occur from tree mortality or windthrow. As canopy closure increases, understory diversity (e.g., shrubs and herbaceous plants) usually decreases.

This ecosite is most commonly found on upper to mid-slope and tableland topographic positions on droughty, shallow soils over bedrock, rock, sands, and coarse loams. Shallow soils can be over limestone or granite; on some sites they may be almost completely replaced by slabs of limestone. Local site conditions are often extreme enough (i.e., dry, shallow soils) to limit the growth of other species.

This ecosite consists of two forest types. The dry jack pine coniferous forest type is dominated by jack pine with white pine, red pine, red maple and several oak species as more common

associates. The only natural stands of jack pine in southern Ontario occur in the Tweed-Kaladar area, on shallow soils over granitic bedrock, and on the northern half of the Bruce Peninsula on shallow soils over dolostone bedrock. Due to its limited natural distribution in southern Ontario, this guide does not provide silvicultural guidelines for this species which is rare in Site Region 6E and absent from Site Region 7E. Readers interested in forest management of this species, should refer to:

OMNR. 1997. Silvicultural guide to managing black spruce, jack pine, and aspen on boreal forest ecosites in Ontario. Version 1.1. Ont. Min. Nat. Resources, Queen's Printer for Ontario, Toronto. Three books. 822 p.

In the dry-fresh white pine-red pine coniferous forest type, white pine or red pine dominate the site, either separately or together. The distribution of red pine is limited in southern Ontario. It is scattered throughout eastern Ontario as a minor component of other stands. It is also found on beach-dune complexes at Pinery and Wasaga Beach Provincial Parks, and at Alliston Pinery (i.e., natural occurrences are rare in 6E and 7E). Coniferous forests of white pine are common in Site Region 6E, particularly in the northern parts of eastern Ontario, and are also found sporadically on sites such as the beaches at Wasaga. In Site Region 7E there are small remnant stands that were logged, but this species rarely occurs in pure stands.

Dominant Trees	white pine, red pine, or jack pine
Less Common Associates	oaks, white cedar, white birch, hemlock, balsam fir and red maple
Common Shrubs	low sweet blueberry, common juniper, wintergreen, buffalo berry, serviceberries, and sweet fern
Common Herbs and Ferns	bracken fern, gaywings, Canada mayflower, wild sarsaparilla and large-leaved aster
Soil Moisture Regime	dry (MR 1, 0) to fresh (MR 1, 2), occasionally moist (MR 4-6)
Soil Drainage	Very rapid (DR 1) to imperfect (DR 5)
Equivalent Ecosite in Central Ontario	ES14 (also ES11, 12, 13)

This chapter will focus primarily on white pine, with red pine as an associate. Silvicultural treatments for managing jack pine have already been thoroughly covered by silvicultural guides for northern Ontario. Due to the rarity of natural stands of this species in this region, management objectives will have a greater emphasis on protection and ecological restoration than on forest management.

Changes since the presettlement era

In the postglacial period of the last 12,000 years, white pine abundance and distribution have changed substantially. White pine probably survived the Ice Age on the continental shelf and then slowly colonized eastern North America as the ice retreated. It thrived best in areas where the frequency of forest fires was relatively high and precipitation was not much greater than transpiration (Jacobson and Dieffenbacher-Krall 1995). White pine appears to have declined over the past 4000 years as a cooling of the climate allowed boreal species to move southward

and fire frequency decreased (Jacobson and Dieffenbacher-Krall 1995). Fire encourages white pine regeneration by exposing mineral soil ideal for seedling establishment.

Since early settlement, the natural distribution of white pine has decreased due primarily to intense harvesting and its more specific regeneration requirements. High-grading harvests occurred frequently, removing mainly the biggest and best trees. In the early 1800s the Europeans cut red and white oak and pine mostly for the naval industry. Later that century the Americans imported high quality Canadian hardwoods, pine sawlogs, and lumber.

In southern Ontario planting programs subsidized by the OMNR have probably broadened the distribution of red pine and jack pine. Initially planting was done to stabilize marginal agricultural land, particularly the blowsands of St. Williams Forest Station, and the Simcoe County, York Regional, Durham Regional, Limerick and Larose and other former Agreement Forests. More recently, large areas of marginal farmland have been retired under Woodland Improvement Agreements (WIAs), thereby further increasing the range or occurrence of planted red and jack pine.

The use of fire by settlers to clear land following logging greatly increased the frequency of uncontrolled fires. Railways started many fires as well. Many of these fires were severe and repeated burning may have contributed to soil sterilization in some areas. In eastern Ontario, studies conducted at the turn of the century demonstrated that the diversity and density of trees were lowest in areas subject to more burns (Keddy 1993). The amount of white birch, red and white oak, and red and jack pine increased with repeated burning.

Choosing an appropriate silvicultural system

Selection of the most appropriate silvicultural option(s) depends on several factors including:

- an understanding of the autecology of the pine species of interest
- site potential or capability
- the current stand composition, structure, and condition
- wildlife habitat and other natural heritage values
- other considerations

These factors are briefly discussed below.

Autecology of eastern white pine

Some knowledge of the autecology of eastern white pine can help to improve the likelihood of successful silvicultural management of forest types with a dominant component of this species. Important biological information for white pine is listed below and additional information is provided in **Appendix B**.

Reproduction and early growth (Wendel and Smith 1990)

a) *Seeds and germination*

- Good seed years occur every three to five years.
- Seed is dispersed within a month of cone maturity and travels distances of 60+ m in closed stands and 210+ m in the open. Dispersal by squirrels was found to be responsible for most successful reproduction in New Hampshire.

b *Site factors*

- Seeds can germinate on both disturbed and undisturbed litter layers.
- Under full sunlight, moist mineral soil, *polytrichum* moss and short grass cover of low density are suitable seedbeds; dry mineral soil, pine litter, lichen and very thin or very thick grass covers are not suitable.
- Poor seedbed conditions can be overcome by scarification and/or shading.
- Overstory shading in a shelterwood cut has proven to be ideal, but shade from slash or competing hardwoods eventually proves detrimental.
- White pine growth rates are better on sandy or loamy sites than on soils with high clay content (Williams *et al*. 1990).

c) *Early growth*

- After establishment, light intensity is critical to the growth and survival of seedlings; at least 20 % of full sunlight is required for survival.
- Early height growth is quite slow for the first 10 years, but then may become quite rapid.

Reaction to competition (Wendel and Smith 1990)

- White pine is intermediate in shade tolerance and competition can be a major problem (Gillespie and Hocker 1986*a*). Trees can survive in as little as 20 % of full sunlight but it takes 45 % of full sunlight before maximum height growth is reached.
- Competition is much more serious during the seedling stage since height growth of white pine is relatively slower than that of its associates. If white pine can survive to the sapling stage its chances of survival are greatly enhanced.
- When competing with light-foliage species such as birch (i.e., species allowing sunlight through their canopy), white pine can usually predominate. When growing with aspen, oak, or maple, white pine usually fails to gain a canopy position and often dies out.
- Pure stands of white pine rarely stagnate. Variations in site conditions and tree phenotypes result in differentiation into different height and diameter classes and the most vigorous trees create their own canopy positions.
- White pine less than 30-years-old and with greater than one-third of their height in live crown generally respond well to release. Young stands will grow much better following thinning. Response to release declines proportionately with increasing age and decreasing live crown height.

Factors limiting growth and development (Wendel and Smith 1990)

Young white pines have thin bark and are sensitive to fire damage; damage to the bark often provides a point of entry for disease. Older trees have thicker bark and have moderate fire resistance. Frequent fires (i.e., less than every 10 years) may eliminate white pine reproduction.

A total of 277 insects and 110 disease organisms attack white pine but only 16 insects and seven diseases are of commercial importance. White pine weevil, white pine blister rust, and *Armillaria* root rot are the most important. These are described below.

- White pine weevil kills the terminal shoot, including up to the last two to three years of growth. Entire trees are rarely killed by the weevil and a lateral branch generally takes over as a new leader. The problem lies in the crook produced in the bole and the resulting loss of merchantable log length and quality (Rose and Lindquist 1984).
- White pine blister rust attacks all stages of growth throughout the range of white pine, often causing mortality. The rust kills the cells of the inner bark and recently formed woody tissue. Small trees die quickly after infection. Older trees become weak at the point of infection and the rust often girdles the trunk, slowing growth and sometimes causing breakage (Natural Resources Canada 1994).
- *Armillaria* root rot destroys seedlings and saplings for distances of up to 9 m from hardwood stumps. The fungus radiates out and girdles pines at the root collar causing resinosis. The rot kills the outer wood layers and cambium, causing decay in both sapwood and heartwood (Natural Resources Canada 1994).
- Other pests include wood borers and bark beetles that both attack damaged or dying wood and recently felled trees (Rose and Lindquist 1984). White-tailed deer and snowshoe hare browse young white pine and can hinder its ability to re-colonize a site (Heinen and Sharik 1990; Steingraber 1990).

Autecology of red pine

Some knowledge of the natural history of red pine can help to improve the likelihood of successful silvicultural management of forest types with a dominant red pine component. Important biological information for red pine is listed below and additional information is provided in **Appendix B**.

Reproduction and early growth (Rudolf 1990)

a) *Seeds and germination*

- Good seed crops are produced at intervals of three to seven years and cones usually open on hot autumn days.
- The effective range of seed dissemination averages 12 m from the parent tree.
- Seedlings only become established when there is adequate rainfall (e.g., more than 100 mm for May, June, and July in northern Minnesota); without sufficient rainfall the seeds may lie dormant for up to three years.

b) *Site factors*

- Red pine naturally becomes established after fire. Moderately intense fires prepare the seedbed, kill some competing trees, control brush for several years, reduce cone insect populations, and produce an open overstory canopy.
- After a fire, specific conditions are still needed for stand establishment. These include: a good seed crop, a relatively thin layer of ashes, weather conditions favorable for germination and establishment, and freedom from fire for several decades. It is believed that this combination of conditions only occurs once every 75-100 years in north-central Minnesota.

c) *Early growth*

- Approximately 35 % of full sunlight is required for successful seedling establishment and they can attain maximum height growth with as little as 45 % of full sunlight. Red pine seedlings usually grow slowly in the wild, especially if partially shaded.

Reaction to competition (Rudolf 1990)

- With the exception of jack pine, red pine is typically less shade-tolerant than its common associates. Red pine grows best in even-aged groups or stands.
- Most natural red pine stands are under stocked.
- Young stands with less than 6200 trees per hectare seem able to thin themselves. Denser stands will stagnate but respond well to thinning.
- Maximum volume growth can be attained through thinning with spacing approximating 20 % of the height of dominants. Height growth can be stunted when spacing falls below 15 % of the height of dominants.
- In the absence of fire, the natural succession sequence in the Lake States appears to be jack pine, followed by red and white pine that are eventually replaced by the tolerant hardwoods. On infertile sites, red pine can be a long persisting sub-climax species. In eastern Canada succession may move from red and white pine to spruce-fir or eastern hemlock.

Factors limiting growth and development (Rudolf 1990)

- Fire can be especially damaging, killing trees up to 21 m tall.
- Of the 100 insects known to feed on red pine, only a few cause mortality or serious injury. Several species of sawflies defoliate and kill seedlings and may also damage older trees. The redheaded pine sawfly is the most serious pest of red pine plantations in southern Ontario. Trees in young stands may sustain mortality or injury from Saratoga spittlebug, Zimmerman Pine moth, or the European pine shoot moth. The European pine shoot moth frequently deforms young red pine and white grubs can cut the roots and kill seedlings in dry years. Red pine scale can kill or severely injure trees of all ages.
- Scleroderris canker can kill young red pine but rarely kills trees over 2 m tall. The infection starts at the branch tips and moves towards the main stem. The fungus grows around the stem and may girdle the tree or form a canker (Natural Resources Canada 1994). Red pine is also susceptible to a number of needle cast diseases.

- Ice and sleet storms and strong winds can cause serious breakage and windfall in red pine stands. This was seen in the ice storm of 1998 in red pine plantations across Eastern Ontario.
- Spring flooding can kill red pine in only 20 days.
- When population cycles peak, both the snowshoe hare and eastern cottontail rabbit can kill or reduce height growth of seedlings. When browse is scarce, white-tailed deer may browse and/or destroy seedlings. Porcupines girdle saplings to small trees.
- Red pine will not thrive in soils with free carbonates within 50 cm of the soil surface. Once the trees reach maturity and produce their first seed crop they will begin to show signs of stress and dieback and many will die.

Site potential or capability

Landowners and managers must determine whether the prevailing site conditions and growth rates permit the production of timber products. If not, the stand is better left alone to provide other values such as wildlife habitat.

Current stand composition, structure, and condition

Silvicultural options vary for even-aged and uneven-aged stands. Managers must determine stand composition and structure, and current age-classes and condition of the stand, using a site/stand assessment. Past management and natural influences affect current stand condition and structure, as well as the quantity of advanced regeneration. Landowners and managers must also know what species are desired in the stand after harvest operations.

Wildlife habitat and other natural heritage values

Pine stands often support numerous wildlife habitats, as well as rare species and other important forest values. **Section 4.4** and **Table 4.4.1** briefly discuss many significant wildlife habitats that managers and landowners should be aware of when considering silvicultural management.

Large white and red pine are often the preferred nest trees for some birds of prey, including the endangered bald eagle (especially when the tree is located close to a productive waterbody). Eagles and ospreys frequently roost in large white pine. Also pine stands adjacent to suitable hunting areas (e.g., fields) are often winter roosting areas for several species of raptors. When tall enough to protrude above the main canopy, such supercanopy trees may attract songbirds and raptors, and provide refuge for mammals such as black bear and fisher.

In some parts of southern Ontario, natural conifer stands, especially older stands, have significant natural heritage value because they are an uncommon or even rare forest cover type. Therefore in these areas, management activities should not lead to an overall decrease in their area or representation within the larger region. The following provides further information on specific wildlife habitat provided by white, red and jack pine.

Box 6.5.1: Pine false webworm and European pine shoot beetle -- two introduced pine pests causing concern recently in southern Ontario.

Pine false webworm

The pine false webworm is an introduced insect that has been a serious pest for many decades in young plantations in Ontario. In 1992 it was observed defoliating mature and semi-mature red and white pine in Simcoe County and the Ganaraska Forest. However, the total area experiencing moderate-to-severe defoliation by this insect has declined for the second consecutive year to 1,457 ha in 1999 from 2,948 ha in 1998 and 8,755 ha in 1997 (Howse and Scarr 1999). Clearcutting and the experimental spraying of infected plantations have contributed to this decline.

This insect initially attacks older foliage, but once this is consumed, it begins feeding on current year foliage. Although trees can survive many years of defoliation, they do not add much new growth each year. In addition, older trees can tolerate less defoliation stress than younger trees. Up to 90 % tree mortality has been reported in a mature red pine plantation in Simcoe County.

Since it is a webspinning sawfly, applications of the bactericide *Bacillus thuringensis k.* are ineffective because it makes a web on the shoot, and then pulls in the needles on which it feeds. Currently, only chemical insecticides provide effective control. Recent experimental work has shown that the botanical insecticide Neem is effective when injected into the tree or sprayed from the ground or air. A registration package has been submitted to the Pest Management Regulatory Agency to have Neem registered for use against this and other sawflies. Managers of the Simcoe County and Ganaraska Forest have successfully controlled this pest by clearcutting the most heavily damaged sites in fall or winter, and leaving the slash on site. The adult insect emerges from the soil in the spring and lays eggs on the slash, but the larvae fail to reach maturity before the needles dry out (T. Scarr, OMNR, personal communication 2000).

European pine shoot beetle

This beetle was found in Ontario in 1992. Subsequent surveys have found it in several States, Ontario, and Quebec. Quarantine restricts the movement of pine products (e.g., logs with bark on them, Christmas trees, nursery stock) outside the affected area. In 2000, the quarantine applied to southwestern Ontario, west of and including Simcoe, Victoria, and Northumberland Counties.

The European pine shoot beetle attacks trees in two ways. Adults tunnel in the shoots of both healthy and stressed trees, causing the shoots to drop to the ground. The beetles also attack the trunks of stressed or dead trees, laying their eggs under the bark. The larvae then feed in the cambium, killing the tree.

In 1998, pine shoot beetles were reported consuming and killing Scotch, red, white, and jack pine in several locations in southwestern Ontario. Mortality was heaviest in Scotch pine (up to 90 %). Where native pines are killed, they are located close to heavily damaged Scotch pine. Other factors, such as drought and *Diplodia* tip blight, may also contribute to mortality. Research is underway to determine impacts, and whether Scotch pine must be present for the insect to reach damaging levels (T. Scarr, OMNR, personal communication 2000).

Insect populations can be kept low by removing slash and stressed, dead, or dying pines, and by cutting stumps close to the ground. Insecticides may have some effect, but have not been operationally tested.

White pine

Many mammals including beaver, snowshoe hare, cottontails, porcupine, red and gray squirrels, mice, and white-tailed deer eat seeds, bark, and/or foliage (Wendel and Smith 1990; Rudolf 1990). Many birds also feed on white pine seeds including the yellow-bellied sapsucker, black-capped chickadee, white-breasted nuthatch, pine warbler, pine grosbeak, and red crossbill (Wendel and Smith 1990). Wild turkey roost in large white pine (Kilpatrick *et al*. 1988). Mature white pine can provide winter cover for deer by intercepting falling snow thus reducing snow depth on the ground and by providing some thermal protection from harsh weather conditions. Both hemlock and eastern white cedar provide better winter cover.

Red pine

White-tailed deer, snowshoe hares, and cottontail rabbits browse seedlings and saplings. Porcupines eat bark and can girdle all sizes of trees. Red pine stands provide some cover and food and nesting sites for birds, as well as winter cover for deer and moose.

Jack pine

Jack pine stands provide food and shelter for white-tailed deer and snowshoe hare. Common understory shrubs associated with jack pine such as blueberry are also an important food source for many birds and mammals.

Other considerations

At least two other considerations, landowner objectives and available resources (e.g., financial, human, time), will also influence the choice of the silvicultural system for management of stands of pine.

The maintenance of aesthetic appeal of the stand as a landowner objective may preclude the use of the shelterwood or clearcut silvicultural systems and suggest a selection system. The type of wildlife habitat desired by a landowner will also determine which silvicultural system is used.

Managing white and red pine stands

Both natural mixed stands of white and red pine and jack pine stands generally are even-aged, having become established after a catastrophic event such as fire. White pine, red pine, and mixed red and white pine stands are generally managed as even-aged stands as neither white nor red pine has adaptations to establish in small openings within a forest stand. The silvicultural systems best suited to managing even-aged stands include: the shelterwood system, the clearcut system, and group selection.

The decision key shown in **Table 6.5.1** was developed to help to select the most appropriate silvicultural options for a specific stand. Decisions are based on stand age and stocking. Follow the numbered decision points to reach a management option (in italics) that best describes the site and stand conditions. Then read the accompanying description for further details on the management option.

Table 6.5.1: Decision key for white and red pine management in southern Ontario.

Text Description	Decision Factor	Continue to Point No.
1.	Stand age is:	
	a. immature (less than rotation age) ……	2
	b. mature (rotation age): *Harvest and regenerate the stand* ……..……3	
2.	Stand composition is:	
	a. mixed white pine and/or red pine with hardwoods: *Use crop-tree management to thin pine for maximum growth*	
	b. primarily white pine or red pine: *Use crop-tree management OR density management diagrams to thin pine stems for maximum growth*	
3.	Stand species composition is:	
	a. primarily white pine and red pine and uniformly distributed .……	4
	b. white pine and red pine with a red oak and/or white oak component ……..	6
4.	Stand stocking is:	
	a. at least 12 m^2 /ha in pine: *Use the uniform shelterwood system*	
	b. less than 12 m^2 /ha in pine ……..……	5
5.	Landowner objective is to:	
	a. increase or maintain white or red pine component in the stand at the expense of undesired species: *Use patchcut with seed trees* to create small pockets of white pine regeneration	
	b. in a stand of otherwise desirable species, for example tolerant hardwoods: *Use group selectio*	
6.	*Use the same guidelines as for white pine and red pine (options 4 and 5) but consider oak stems as crop trees as well.*	

1. Stand age

Silvicultural work and preparatory treatments for regeneration of white and red pine generally begin at a stand age of 60 to 80 years. Rotation age is generally 80 to 100 years (OMNR 1998*b*). Timing of silvicultural operations can also depend on site quality and the presence of damaging agents. If a damaging agent is causing the stand to begin to decline before rotation age, silvicultural operations should be considered at an earlier time.

2a. Crop-tree management

Identifying crop trees early and managing them with thinning and pruning can substantially increase timber quality and return on investment. Immature stands can benefit from crop-tree management if they are overstocked or stagnating. Crop trees are chosen and released from competition, improving stand vigor and volume production over time. The priority for crop-tree release is the removal of those trees that interfere with the development of selected crop trees (Perkey *et al.* 1993). Both thinning and pruning activities comprise crop-tree management. Each activity is discussed below.

Thinning

Thinning will benefit the stand by:

- increasing the amount of merchantable wood
- removing undesirable species
- removing poor quality stems
- improving stem vigor and quality (Gillespie and Hocker 1986*b*).

Thinning (i.e. the number of stems or basal area per hectare to be removed):will release a set number of trees per hectare. Thinning can be selective (i.e., removing trees based on their individual merits) or systematic (generally used in plantations where rows or strips are removed). Use of either crop-tree management or area-wide thinning is recommended. Area-wide thinning is discussed under “2b. Density management diagrams”.

Crop-tree release is recommended in even-aged stands of pure pine or mixed pine-hardwoods. The species chosen as crop trees will strongly influence the species present at rotation age and in subsequent stands. Careful selection of species improves the likelihood of accomplishing landowner objectives for the stand.

The following characteristics should be considered when choosing white and red pine crop trees:

- Crop trees should occupy a codominant or dominant position in the stand.
- The number of crop trees with V-forks in the stem or crown (V-forks are forks whose connection can be traced back to the stem) should be minimized.
- Ideally each crop tree should provide two straight 5 m (16 ft.) logs.
- Crop trees should have well-developed crowns (i.e., one-third or more of the height in live crown).

- Only a minimal portion of the crop tree should have persistent dead branches.
- There should be no open wounds in the stem and no evidence of fungi, insect, or disease susceptibility in the stem or crown.
- The top should be intact with few or no broken branches.

Hardwood crop trees in the stand should:

- be mast producing trees for wildlife
- be commercially valuable where possible (i.e., red oak and sugar maple are preferred to birch or aspen)
- have a dominant or codominant position and limited defects (e.g., V-forks, wounds) (Perkey *et al*. 1993)
- not be prolific seeders (e.g., sugar maple that will compete with conifer seedlings), unless conversion of stand to predominately hardwoods is an objective.

Approximately 370 crop trees per hectare (or 150 crop trees per acre) should be selected and released on two or three sides at the polewood stage, if the stand is stagnating (OMNR 1986). Trees whose crowns are touching the crown of the crop tree should be removed on two or three sides of the crop tree. This will provide room for growth of the crown of the crop tree. The need for and timing of further release operations before rotation age is reached will depend on the timing of the first release, the success of the first release, and the objectives of the landowner. Ideally crop trees should be released every time their crowns are crowded by the crowns of other trees.

Pruning

Management of white and red pine for lumber requires the production of stems that are clear or free of loose knots (Smith and Seymore 1985). Pruning is necessary, especially in white pine stands, because the rot resistance of white pine results in poor natural pruning ability (OMNR 1998*b*). Red pine growing in pure stands also exhibits poor natural pruning ability (OMNR 1998*b*). Natural pruning and form of both white and red pine are generally good in mixed stands and pruning treatments usually are not necessary (Smith and Seymore 1985).

In well-stocked stands of white and red pine, most lower branches are dead by the time pruning becomes necessary. It is normally easier to prune dead branches. Pruning of live branches should be carried out during winter months to minimize bark tearing and infection by disease or decay organisms. If live branches are pruned, avoid removing large live branches (greater than 3.7 cm or 1.5 in.), as these will be slower to pitch over and heart rot could be introduced (Smith and Seymore 1985; Perkey *et al.* 1993). Whether pruning live or dead branches, it is critical that pruning be done adjacent to the branch collar without injuring the branch collar or leaving a stub.

When pruning, do not reduce the live crown ratio by too much because this will stunt height growth (Smith and Seymore 1985). No more than one-quarter to one-third of the live foliage should be removed at any one time, less if pruning is done in several stages over a period of several years.

Managers may wish to leave crop-tree pruning until thinning operations have been conducted for the following reasons:

- there is less risk of physical damage to pruned crop trees (Smith and Seymour 1985)
- there is no risk of pruning trees that subsequently must be removed during thinning.
- to ensure selected trees have good vigor (Smith and Seymour 1985)
- to ensure branch stubs cover over quickly since thinning creates conditions favoring rapid growth (OMNR 1998*b*).

However, sometimes it may be advantageous to prune before thinning takes place, depending on available labor and markets for the small material from the thinnings. Also branches will be smaller when trees are pruned at an earlier age, although there will be a higher percentage of live branches.

Whether pruning before or after thinning, crop trees for pruning must be selected and marked by an experienced marker. Crop trees should be selected from dominant or codominant trees. When pruning before thinning, provision for initial row or strip thinning must be made by not selecting crop trees within rows or strips that will be removed in the initial thinning.

The first pruning is generally conducted after the trees have reached a height of the first log length for white pine and are in the polewood stage (10 to 15 cm in diameter). At this stage, if the first log length is straight, future white pine weevil attacks on the trees cannot affect that portion of the stem (Smith and Seymour 1985).

Approximately 370 trees per hectare (or 150 trees per acre) should be pruned (OMNR 1986).

Pruning can be done in two or more stages with a different length of tool or ladder for each zone of height. Pruning to a height of 5.5 m (17 ft.) will encourage the first 5 m (16 ft.) of log to be free of loose knots and decay (Smith and Seymour 1985).

2b. Density management diagrams

The preferred method to thin pine stands using area-wide thinnings is to use density management diagrams to manage growth.

The relationship between stand density and tree size can be used to enhance volume production in a stand. High density does not directly cause mortality, however density is related to competition that can lead to a decline in vigor and greater susceptibility to damaging agents such as insects and disease (Smith and Woods 1997). High densities and low vigor can cause stands to stagnate in growth. Thinning the stand will release some trees, increasing vigor and volume production.

In even-aged pure stands, the optimum level of stocking for an average tree size can be predicted using density management diagrams. **Appendix E** provides red and white pine density management diagrams and an explanation of their use.

In general, area-wide thinnings are conducted when using density management diagrams. Area-wide thinnings differ from crop-tree release thinnings. Instead of choosing crop trees and releasing them, inferior trees are chosen throughout the stand and removed releasing larger numbers of residual "crop" trees. To apply an area-wide thinning, first determine the number of trees to be removed using the density management diagrams. Convert this number to basal area using the following formula:

Initial basal area = initial sph*DBH*DBH*0.00007854

Basal area after thinning = residual sph*DBH*DBH*0.00007854

Where:

initial and residual sph = number of stems per hectare before and after thinning operations, and

DBH = average diameter at breast height. Note that this will be a larger value after thinning than before it.

The difference between initial basal area and basal area after thinning is the basal area to be removed. Mark the stand to reduce basal area by this amount. Trees that should be marked for removal include:

- those with intermediate crown positions
- undesirable species
- those with deformities including V-forks, large open wounds, diseases such as blister rust, crooked logs from weevil damage, and dead tops or dieback
- trees with below average diameter
- trees with narrow or shallow crowns.

Commercial thinning operations can be considered in mixed white/red pine and hardwood stands, although this might require delaying the treatment until a stand age of 30 to 40 years for white pine and 25 to 30 years for red pine (OMNR 1998*b*).

In thinnings after the age of 50, it is recommended that the site be disturbed to encourage the establishment of white pine in the understory (Perkey *et al*. 1993). The optimum seed bearing age for white pine begins at 50 years. If hardwood regeneration is undesired, control with herbicides or brush saws may also be initiated after this age to promote the development of white or red pine regeneration (Perkey *et al*. 1993).

3. Stand species composition

If the stand is primarily red and white pine, see points 4 and 5 in **Table 6.5.1.** However, if the pine stand contains red and/or white oak, both common associates of white and red pine, it may be worth managing the stand to promote regeneration of these valuable hardwood species, as well as the pine.

4. Stand stocking influences choice of silvicultural system for regeneration

Once the stand reaches rotation age, attention turns to final harvest and regeneration of the stand. The density and distribution of pine in the canopy will determine the choice of the most appropriate silvicultural system for regenerating the stand.

Where there is greater than 12 m^2/ha in white pine and/or red pine in the stand, a uniform shelterwood cut is the preferred method of regeneration. This basal area will give a uniform distribution of seed trees over the stand and allow for an adequate amount of seeding in from the residual white or red pine.

Where there is less than 12 m^2/ha, a clearcut with seed trees or group selection cut may be more appropriate because there will be fewer pine seed trees and greater competition from less desirable species.

Uniform shelterwood

Uniform shelterwood can be used for pure stands of white pine, red pine, and mixed stands where an overstory exists. The desired species should be present in sufficient amounts (greater than 12 m^2/ha) so that a post-cut condition approximating the target crown closure level is achieved (OMNR 1998*b).* This system has some disadvantages when used to regenerate red pine because of the infrequent seed crops and strict environmental requirements for the establishment and growth of this species. Red pine establishment must be carefully checked following silvicultural work and artificial regeneration may be necessary in some cases (Rudolf 1990; OMNR 1998*b*).

A four-cut uniform shelterwood system should be used when the stand has the following conditions:

- greater than 50 % of the desired species of white pine, red pine, mixed white pine/red pine, or mixed pine with red or white oak (discussed in a following section)
- greater than 70 % stocking
- a greater proportion of white pine than red pine.

A two or three-cut uniform shelterwood system should be used when the stand has:

- only 30 to 50 % of the desired species or
- more red than white pine.

The four-cut and the two- or three-cut uniform shelterwood systems are the same with the exception of the removal cut. The uniform shelterwood system for pines is explained below. Differences in the four-cut and two- or three-cut systems are outlined in the description of the removal cut. The first cut is called a preparatory cut, the second is called a regeneration or seed cut, and the third and fourth cuts are referred to as removal cuts.

Preparatory cut

The preparatory cut is recommended for stands in the 61- to 80-year age class to enhance crown development. Young overstocked stands may have under-developed crowns that are too small for adequate seed production. This cut is appropriate where crown diameter is in the 4 to 5 m range. A preparatory cut may also be used to remove undesirable species from the stand in preparation for the regeneration of white and/or red pine.

Residuals trees (i.e., trees to be left on site) should be:

- codominant or dominant in canopy position
- uniformly distributed through the stand
- the desired species, especially white pine. While these species should be favored, the importance of other species for wildlife and conservation values and biodiversity objectives must be recognized.
- other desirable species that may exist in the stand (e.g., red and white oak) that can be favored in a preparatory cut in efforts to ensure a good seed source (OMNR 1998*b*).

Some site disturbance during this cut will encourage establishment of white and red pine seedlings in the understory (Perkey *et al*. 1993). This may be partially accomplished through summer logging, where this does not jeopardize other forest values.

The space created between crowns should provide for further crown development. A full crown spacing between residual trees, or spacing of one-third of the average tree height between residuals, should result in a 50 % level of crown closure.

Regeneration or seed cut

This cut is recommended for stands in the 81- to 100-year age class or approximately 20 years following a preparatory cut, to facilitate natural regeneration. Tree crowns should be 6 to 8 m in diameter to fulfil regeneration targets.

Residual trees should be:

- codominant or dominant in canopy position
- the desired species
- free of defects, with good form and symmetrical crowns

The stand should be thinned from below, concentrating on removing defective, low quality trees first while leaving high quality residuals for site protection, and seed and wood production. Crown closure should be reduced to 40 to 50 % to promote the growth of white pine seedlings while protecting them from destructive pests such as white pine weevil and white pine blister rust (**Box 6.5.2**). This crown closure may be achieved by one-half crown width spacing (i.e., if crown width is 4 m, one-half crown width spacing is 2 m) or spacing trees to 40 % of their height.

When dealing with stands that are predominantly red pine, canopy density should be reduced to 35 % crown closure or full crown spacing (OMNR 1998*b*).

Box 6.5.2: Control of white pine blister rust and white pine weevil.

Some research has indicated that the best way to reduce damage from white pine weevil and white pine blister rust is to manage young white pine under an existing overstory. The overstory reduces the formation of moisture on seedlings or saplings required for rust infections. Shade from an overstory is also detrimental to white pine weevils because it cools the local environment and slows terminal shoot growth. White pine weevils also prefer large diameter terminal branches and tend to avoid the smaller ones growing in shade (Katovich and Mielke 1993). It is important to balance the appropriate light requirements for maximum growth and development of white pine on a site, while still maintaining an overstory component to mitigate impacts from these commercially important pests.

Removal cut

This cut follows the successful establishment of natural regeneration on the site. The timing of this cut depends on factors such as:

- the period of establishment for regeneration of desired species (e.g., white pine, red pine)
- the success and vigor of established regeneration. Ideally there should be a white or red pine seedling every 1.8 m to provide a fully stocked stand.
- the need to control competing hardwood vegetation to release pine so that they can grow to the height standard
- the growth and increase in value of shelterwood trees
- the need to ameliorate impacts of white pine weevil and white pine blister rust (**Box 6.5.2**).

This cut may be carried out in two stages: a release cut, followed by a final removal cut in a four-cut uniform shelterwood system OR as a single removal cut in a two- or three-cut uniform shelterwood system.

Release cut (i.e., stage three of a four-cut uniform shelterwood)

In a release cut, 30 to 40 % canopy closure is maintained. This is approximately equal to one full crown spacing between residual trees. A release cut will provide extended canopy protection for white pine seedlings from white pine weevil and white pine blister rust. As with previous cuts, the best quality residuals should be favored for their future timber value (OMNR 1998*b*).

Final removal cut (i.e., stage four of a four-cut uniform shelterwood)

The final removal cut occurs when regeneration height is 5 to 6 m. Some of the large residual trees could be retained even following this cut as seed trees, cavity trees, or supercanopy trees. These trees have wildlife value and by retaining them this silvicultural system will better mimic disturbances such as intense fires, the natural disturbance regime for pine, that might have left the largest, thick-barked stems. Ideally, supercanopy and cavity trees should still be

healthy and vigorous and have the ability to persist for many years. Many of them also provide habitat for numerous species of birds that eat the white pine weevil (OMNR 1998*b*). These trees could be identified in an earlier stage for retention.

Single removal cut (i.e., final stage of a two- or three-cut uniform shelterwood)

The single removal cut is recommended if there is little risk of white pine weevil damage and if a minimum of 1000 seedlings/ha will remain uniformly distributed over the site after the final removal cut is made. This cut can be made once regeneration has reached a height of 1.5 m for white pine and 1.0 meter for red pine. Some of the large residual trees should be retained for their wildlife values.

When stands are dominated by red pine, a single removal cut is recommended because red pine requires a quick release from overstory shading. If the release is delayed, the red pine regeneration cannot successfully compete with more shade-tolerant species such as white pine, white spruce, red maple, and balsam fir.

5a. Patch cut with seed trees

Patches are clearcut to maintain or enhance the conifer component (e.g., white or red pine) in stands with a significant proportion of hardwood species. Also this option can be used to restore white and red pine to their appropriate ecosites or to maintain these species at current low levels of abundance in stands with less than 12 m^2/ ha of pine (OMNR 1998*b*). Due to the small average size of forest stands in southern Ontario, a maximum size of 2 ha or less is recommended for this option.

One to 2 ha patches are clearcut, retaining 10 to 35 seed trees per hectare of the desired pine species well distributed across the site. The selected trees should have the following characteristics:

- high quality
- codominant or dominant crown position
- a windfirm position
- a wide crown
- the capacity to produce viable seed.

For stands dominated by red pine, it is recommended that seed trees be one tree length apart where possible.

Site preparation may be required for white or red pine seedlings to establish themselves. Disturbing the site mechanically, chemically, or through prescribed burning may increase its suitability for white and red pine colonization. This "scarification" has been shown to increase seedling survival and health for both white and red pine in a number of studies (Burgess *et al*. 1995; Weber *et al*. 1995; Herr *et al.* 1994).

Once white or red pine seedlings have become established, the seed trees may be removed. Some seed trees should be left as supercanopy and cavity trees to add structural diversity to the stand and provide habitat for nesting, denning, and foraging wildlife (Rogers and Lindquist 1992).

Understory vegetation management is critical; otherwise, intolerant hardwoods will gain a competitive advantage and eventually become predominant (OMNR 1998*b*). Competition from hardwood seedlings will probably need to be controlled with herbicides or manual methods such as brush saws (**Section 8.1**). Opportunistic species such as birch and aspen will grow much faster than white and red pine and eventually shade out the pine seedlings.

5b. Group selection

This silvicultural system is used when the landowner wishes to create small pockets of regeneration of pine in a stand where only a small portion of pine currently exists (e.g., less than 12 m^2/ha). However, managing young white pine in openings can be risky because small openings tend to collect cool air, providing adequate moisture formation for the development of white pine blister rust. Use of the group selection system will subsequently convert an even-aged stand to an uneven-aged stand.

To regenerate white and red pine using the group selection system, use the following guidelines:

- Size of canopy openings to be created should equal one to two times the height of the stand. White pine and especially red pine are not shade-tolerant and need more light than the typical one tree height openings created when managing mid-tolerant hardwoods.
- Openings should be placed downwind and within 60 m from a good white pine seed source or 12 m from a good red pine seed source (Wendel and Smith 1990; Rudolf 1990).
- In stands with an oak component, red and gray squirrels will cache white pine seeds and effectively disperse seeds (Wendel and Smith 1990).
- Openings should be created following good seed years. Good white pine seed crops are produced every three to five years after the age of 50 years; good red pine seed crops are produced every three to seven years after age 50 (Wendel and Smith 1990; Rudolf 1990).
- The site should be scarified (i.e., scuffed up) to expose mineral soil.
- No more than 20 % of the stand should be in openings at any one time.
- The next set of group openings is made in 20 years.

6. Managing white and red pine stands with a component of red and/or white oak

Red oak and white oak are common associates of pine in southern Ontario. Stands of white pine and red pine mixed with red and white oak can be managed in a similar manner to stands managed solely for white or red pine. Before managing mixed pine-oak stands it may be helpful to review the autecology of the oak species (**Section 6.2**).

The three silvicultural systems (i.e., uniform shelterwood, patch cut with seed trees, and group selection) should be applied as previously described for managing a stand for white and red pine, but the following factors should be kept in mind to increase the success of oak regeneration:

1. Suitable red oak or white oak crop trees can be identified and released prior to rotation age. At rotation age the appropriate silvicultural system should be chosen and implemented to regenerate pine with an oak component. The optimal management strategies for regenerating pine are quite

different than those for oak since maximum growth occurs at relatively high basal areas for pine (Hibbs and Bentley 1987). Oaks must be established and have adequate growing space to compete successfully with pines.

2. Both red oak and white oak regenerate through sprouting and seeding and although they initially have a slower growth rate than pine, they eventually catch up (Lloyd and Waldrop 1992). Red oak and white oak seedlings invest much more energy into rooting systems than pine and although they are slow to start, they are able to persist in the understory and respond well to release (Tworkoski *et al.* 1986). Every effort should be made to establish oak seedlings at the time of preparatory cuts so that they are well established by the time of the regeneration cut.

3. Both red oak and white oak will sprout from cut stumps. Oaks stems cut during the preparatory cut should sprout, depending on diameter/age, and be large enough to compete with germinating pine seedlings that become established after the regeneration cut. Oak sprouts grow much faster than seedlings and can readily compete with pine seedlings. The seedlings that establish themselves after the regeneration cut will likely not become part of the next stand (McGee and Loftis 1993).

4. White oak has a tendency to develop epicormic branches. Therefore, when selecting white oak crop trees and trees to be left as seed trees, avoid selecting those with existing epicormic branches and dormant buds that can become epicormic branches (Perkey *et al*. 1993).

Refer to **Section 6.2** for more details on oak regeneration.

The presence of acorns and the associated digging and gathering by wildlife contribute favorably to seedbed preparation for white pine (Alexander *et al.* 1985). The mix of oak and white pine also has its risks for white pine development. Damage to white pine from gypsy moth has been shown to increase with increasing proportions of oak in a stand (Brown *et al.* 1988).