6.4 EARLY SUCCESSIONAL HARDWOODS

by Peter and Erin Neave and David Bland

S. Strobl

Introduction

Early successional hardwood stands are comprised primarily of fast-growing but short-lived, shade-intolerant deciduous species such as poplars and white birch. In southwestern Ontario sassafras and tulip tree may be locally common. They are often the first trees to invade and dominate severely disturbed sites but typically last for only one generation or rotation. Unless the site is disturbed again (e.g., by intensive cutting, fire, disease outbreaks, or extensive wind damage), they will be replaced by more shade-tolerant species. Early successional hardwood stands are normally even-aged but they can also occur as pockets within larger stands, having established themselves in openings created by windthrown trees, small local fires, tree removal or death.

Species composition depends on site conditions and quality, existing seed sources, and occasionally, prior stand management. In southern Ontario, many young stands of early successional hardwoods, such as those that become established on abandoned agricultural land or marginal sites, are currently unmanaged. In other older stands, tree growth rates have slowed down and some trees are dying.

Dry-fresh white birch-poplar-conifer mixed forest ecosite (FOM5)

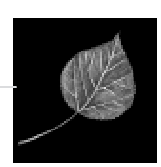
Species composition often depends on the presence of a seed source, and competition among species. For example, white birch can grow on almost any type of soil, but it does not compete as well with some associates (e.g., aspens) because it is slower growing. White spruce can become established with poplar, but generally remains in the subcanopy for some time because it is also slower growing. This is an early successional forest that originates following a disturbance.

This ecosite occurs on sand and loam soils, and the ELC describes two forest types. The dry-fresh white birch mixed forest type is quite common on abandoned agricultural land in eastern Ontario (Site Region 6E), but rare in Site Region 7E. The dry-fresh poplar mixed forest type is common throughout Site Region 6E but rare in Site Region 7E.

Common Species	white birch, trembling aspen, large-tooth aspen, balsam fir, white pine, and white spruce
Soil Moisture Regime	moderately dry (MR 0) to fresh (MR 1-3)

Fresh-moist poplar-white birch mixed forest ecosite (FOM8)

White birch tends to predominate on cooler, wetter sites while trembling aspen tends to predominate on drier, upland sites. Generally this is an early successional, even-aged forest that follows a disturbance.



This ecosite is found on a variety of different soils, primarily on lower slopes, bottomland, and in seepage areas. The ELC describes two forest types for this ecosite. Both the fresh-moist poplar and the fresh-moist white birch mixed forest types are fairly common in Site Region 6E but rare in Site Region 7E.

Dominant Trees	trembling aspen, large-tooth aspen, and white birch
Common Associates	balsam fir, hemlock, and black spruce
Soil Moisture Regime	moist (MR 4-6) to very fresh (MR 3)

Dry-fresh poplar-white birch deciduous forest ecosite (FOD3)

This ecosite represents an early successional stage, often associated with recently or frequently disturbed sites (e.g., heavy cutting, clearing of forest cover).These species are shade-intolerant and relatively short-lived. However, as other more shade-tolerant species invade and regenerate beneath them, the composition of these forests changes, ultimately becoming a later-successional forest comprised of more shade-tolerant species. There may be a high diversity of shrub and herbaceous plant species in the understory. Canopy closure ranges from about 60 to 85 %.

This ecosite is usually found on sands and coarse loams on upper to middle slope or tableland topographic positions. Soils are often quite shallow and droughty.

The ELC describes two forest types for this ecosite. The dry-fresh poplar deciduous forest type is common in Site Region 6E but uncommon in Site Region 7E. The dry-fresh white birch forest type is common in Site Region 6E and rare in Site Region 7E.

Dominant Trees	trembling aspen, large-tooth aspen, and/or white birch
Common Shrubs	maple leaf viburnum and poison ivy
Common Herbs and Ferns	Canada mayflower, Solomon’s seal, and bracken fern
Soil Moisture Regime	moderately dry (MR 0) to fresh (MR 1-3)
Soil Drainage	rapid (DR 2) to well-drained (DR 3)

Fresh-moist poplar-sassafras deciduous forest ecosite (FOD8)

Stands dominated by sassafras are restricted to southwestern Ontario. This ecosite also represents a young, early successional forest that has followed a major disturbance. Understory shrub and herbaceous plant species richness can be quite high. Canopy closure varies from about 70 to 85 %.

This ecosite is found on sand, coarse and fine loams, and occasionally on clay, on a variety of topographic positions.

The ELC describes two forest types for this ecosite. The fresh-moist poplar deciduous forest type is common in Site Region 6E but infrequently encountered in Site Region 7E. The fresh-moist sassafras deciduous forest type is restricted to southwestern Ontario, only being common in Essex, Kent, Elgin, and Lambton counties.

Dominant Trees	trembling aspen, large-tooth aspen, or sassafras
Soil Moisture Regime	moist (MR 4-6) to fresh (MR 2, 3)
Soil Drainage	well-drained (DR 3) to imperfect (DR 5), and sometimes poor (DR 6)

Other species combinations of early sucessional communities also occur, and may be difficult to classify to existing ELC ecosites, particularly in southwestern Ontario. For example, early successional forests that include green ash, white ash, hawthorns, white pine, white cedar and pin cherry, or stands dominated by any one of these species, except pin cherry. Stands dominated by black walnut or young, regenerating American elm also occur.

Changes since the presettlement era

Large-tooth and trembling aspen probably both flourished in large natural canopy openings created either by wind or fire. Since these species are both prolific seed producers, they probably became established in wind-created openings by natural seeding (Heeney *et al.* 1980). They probably dominated fire-created openings through root suckers, depending on the stock present in the stand. In both Ontario and the Lake states, most large stands of aspen originated from root suckers, following large fires (Heeney *et al.* 1980). This disturbance agent is likely responsible for the origin of many mature to overmature stands (i.e., greater than 150-years-old) in northern Ontario. Very hot fires are required to remove the duff and expose mineral soil so that aspen seed can germinate and establish, and these types of fires were uncommon (Heeney *et al.* 1980).

White birch probably persisted in blowdown areas and burned areas, where it has been found to exhibit rapid growth and excellent utilization of light (Carlton and Bazzaz 1998). Windthrow and burnt sites provide exposed mineral soil necessary for establishment (Safford *et al.* 1990).

In the absence of disturbance, the mature canopy of aspen and white birch stands likely provided suitable shade conditions for the establishment of other hardwoods, white pine, white spruce or white cedar, that probably replaced these short-lived pioneer species on many sites.

Since total forest cover in southern Ontario is now much lower, it is likely that this forest type occupies a smaller land area than it did in presettlement times. It is fairly common in much of eastern Ontario where the clearing of land for agriculture and its later abandonment have lef numerous old fields occupied by these early successional species.

Choosing an appropriate silvicultural system

The selection of the most appropriate silvicultural system is critical for the management of early successional forests and depends on several factors including:

- an understanding of the autecology of the desired species
- 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 trembling and large-tooth aspen (Davidson *et al.* 1988, Heeney *et al.* 1980, Laidly 1990)

Knowledge of the autecological characteristics of early successional species described below is an important prerequisite for the selection and implementation of the most appropriate silvicultural system(s) designed to encourage successful establishment and regeneration of early successional stands. **Table 6.4.1** summarizes important autecological characteristics for the most common tree species of this forest cover type. For other species not included in this table, see **Appendix B.**

Reproduction and early growth

- Most aspen regeneration originates from root sprouts, the majority of which are produced in the first season after stand disturbance. Soil temperature is an important factor controlling sucker formation and 23^{o} C appears to be the optimum temperature. Stand age does not appear to be a factor.
- Harvest of trembling aspen in the winter produces a higher density and stocking of suckers than in the summer, although generally enough suckers are produced to develop a well-stocked stand at either time of the year. To regenerate a fully stocked stand,120 mature parent stems per hectare are needed while 40 parent stems per hectare are required for minimum stocking. This is equivalent to as little as 5 m^2/ha of basal area in the original stand. Generally the regeneration of large-tooth aspen requires a greater parent stem density than for trembling aspen.
- Bare mineral soil that is constantly moist is an ideal seedbed for aspen. Seedlings are very susceptible to fungi, heat, drought, and competing vegetation. Light is a critical factor in the development of seedlings.

Reaction to competition

- Aspen is a very shade-intolerant species.
- High-density stands of suckers rapidly reach crown closure, and can begin to limit diameter growth within five years. Sucker growth rapidly outgrows competition, but seedlings need to be released from competition to survive. Dominance in sucker stands is expressed in seven to 10 years, at which time crop trees can be identified.

- Large-tooth aspen, trembling aspen, and white birch respond well to thinning. Thinning must often be done at an early age to maximize growth because these species are short-lived and grow rapidly.

Factors limiting growth and development

- Over 300 insect species attack aspen; defoliators cause the most damage. The two most important defoliators are the forest tent caterpillar and the large aspen tortrix.
- Other damaging insects include leaf tiers, leaf rollers, leaf miners, and borers.
- At least four categories of fungal diseases attack aspen:
    - *Trunk and butt rots:* Trunk and butt rots are caused by a number of organisms including heart rot (*Phellinus tremulae*), *Fomes igiarius*, *Radulum casearium*, *Pholiota spectablilis* and *Armallaria mellea*. These rots cause serious volume losses and deterioration if stands are left beyond rotation age (Laidly 1990).
    - *Stain:* the mechanism of infection and staining is poorly understood since it appears to occur with or without microorganisms. Stain does heavily impact wood production in aspen (Laidly 1990).
    - *Cankers:* Hypoxylon canker is the most serious disease of the aspens (Laidly 1990).
    - *Leaf diseases:* Leaf and twig blight of aspen is common throughout Ontario on young regeneration, and ink spot periodically causes defoliation.
- Aspen is the preferred food of beaver. Although this mammal can seriously damage the timber value of a stand, it may also create valuable habitat for many other wildlife species.
- Porcupines can cause heavy damage by eating the bark.
- Fire damages or kills aspen because the species has thin bark. Fire damage provides entry points for disease organisms.

The autecology of both aspen species and the other pioneer species that occur in early successional hardwood sites is summarized in **Table 6.4.1** (from Safford *et al.* 1990, Griggs 1990, Beck 1990).

Table 6.4.1. Autecology of early successional hardwood species (Burns and Honkala 1990*a* and *b*).

Species	Large-tooth aspen	Trembling aspen	White birch	Sassafras	Tulip tree
Site	Moist, fertile, sands, loamy sands	Most site types; shallow, rocky to deep loam sands	Most site types; prefers well-drained, sandy loams	Most site types; prefers well-drained sandy loam soils	Well-drained, moist, loose-textured soils
Canopy openings to secure regeneration or growth	Clearings	Clearings	Fire or other clearings	Openings or clearings	Forest gaps
Seed periodicity	2-3 years	4-5 years	2 years	1-2 years	1 year
Seedbed type	Bare, moist mineral soil	Mineral soil, humus	Mineral soil, humus, decaying wood	Moist, rich loamy soil with layer of litter	Humus-mineral soil mix
Sprouting ability	Excellent	Excellent	Good	Good	Good
Likelihood of advanced regeneration	None	None	None	None	Moderate
Shade tolerance	Intolerant	Intolerant	Intolerant	Intolerant	Intolerant
Tending need	Self-thinning	Self-thinning	Self-thinning	Competition	Low at seedling-sapling stage; required at canopy closure
Self-pruning	Good	Good	Good	Good in well stocked stands	Good
Response to release	Good, if done early enough	Good, if done early enough	Good	Poor	Good
Rot/stain defect	High	High	High (red-heart, cambium miners)	Low	Moderate (log quality declines rapidly after cutting)
Bole/form defect	Hypoxylon canker	Hypoxylon canker	Stem cankers	Low	Moderate-high (grapevine a common cause of breakage, stem malformation)
Decline hazard	Moderate-high	Moderate-high	Moderate-high	Foliage diseases common	Low-moderate
Growth rate	Fast (declines with age)	Fast	Fast (declines with age)	Slow-moderate	Fast
Wildlife values	Wildlife cover, spring-summer food source for ruffed grouse, winter food source for beaver, moose; important but short-lived snag and cavity trees	Nesting cover, winter food source; important but short-lived snag and cavity trees	Cover, browse for deer, moose; catkins, buds food source for ruffed grouse; seeds food source for other birds	Browse	Browse

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

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

Early successional forests provide important wildlife habitat. **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.

Davidson *et al*.(1988) provides the following information about the use of early successional hardwood stands by wildlife.

1. Aspen is a fair browse source for deer in summer, and provides some summer shelter (Heinen and Sharik 1990). In some areas it is heavily browsed by deer in winter. In southeastern Ontario, aspen and white birch can provide key moose browse, particularly in summer.
2. Young poplar stands in southeastern Ontario often contain a variety of fruit producing shrubs including blueberries, cherries, raspberries and strawberries all of which can be utilized by black bears. Black bears also feed on swollen aspen buds in the early spring. Aspen foliage is a choice summer food for porcupines.
3. Beaver consume trembling and large-tooth aspen and balsam poplar bark, leaves and branches for food, and branches and twigs are used in dam and lodge construction.
4. Rodents, rabbits and snowshoe hares use poplar stands for food (especially in winter when they gnaw the bark), and the same stands are also used by many of their predators including lynx, fox, wolf, coyote, and weasel.
5. Aspen and white birch snags and decaying live trees are used by cavity-nesting ducks, woodpeckers, and mammals.
6. Staminate buds of aspen, along with catkins of birch, hazel and willow constitute 85 % of the December-March diet of ruffed grouse. Grouse need different age classes of aspen to meet specific needs: sucker stands for brood cover, sapling/polewood stands for adult wintering and nesting cover, and older male aspen to supply winter food and nesting cover (McCaffrey *et al.* 1997). The buds and catkins are a favored food for numerous other birds.
7. 116 species of birds are found in aspen-dominated stands, of which 16 breed in abundance.

Since early successional hardwoods are important to many wildlife species, they could be managed in southern Ontario:

- to diversify local or regional habitat, particularly in areas with little early successional forest or in areas with higher (> 30 %) forest cover
- to provide animal movement corridors by linking fragmented forest patches with larger forested areas. Many old fields are more rapidly reforested and/or restored with early successional species
- to provide buffers or gradual transitions around significant natural areas, especially those surrounded by incompatible land uses in densely settled or agricultural areas
- to increase the amount of forest interior by encouraging establishment of early successional species to fill in irregular edges
- to increase local populations of certain wildlife species that rely on this cover type for some habitat needs (e.g., ruffed grouse)

In southwestern Ontario, some early successional hardwood stands support Carolinian trees such as sassafras and tulip tree. Where these species are locally or regionally rare, they should be retained.

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 early successional hardwood stands.

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 early successional hardwoods

Early successional forests comprised of short-lived pioneer species such as trembling aspen, large-tooth aspen, and white birch tend to form even-aged stands. They can be managed by clearcutting, an even-aged silvicultural method designed to mimic sudden, large-scale natural disturbances that result in stand replacement by the same species. Clearcutting is preferred in mature stands of at least 0.5 ha in order to replace them with a new vigorous stand. It may also be used to rejuvenate selected stands that are degraded due to past mismanagement or insect or disease damage.

Although the practice of clearcutting is usually not recommended for use in southern Ontario, it has some merit for periodic application on large sites located in areas where forest fragmentation is not a problem. Well-planned clearcutting can help to create stands of different ages and species composition across the landscape, thereby improving the diversity of wildlife habitat and species in a region. Furthermore, on sites with unfavorable growing conditions for most species (e.g., low available moisture, poor soil drainage, shallow soil), it is often easier to maintain early successional species by using periodic clearcuts.

Two-aged stands can develop when shade-tolerant species such as spruce, fir, tolerant hardwoods, as well as, pine or cedar become established in the understory. Appropriate management can encourage this advanced regeneration and eventual succession to a different forest type that will have greater long-term timber value, provided that the surrounding forest cover, as well as land-owner objectives allow it.

Most early successional hardwood stands should probably be managed to encourage replacement by shade-tolerant species (i.e., to simulate natural succession in the absence of a major disturbance event). Provided that seed sources are found in adjacent woodlands, most of these stands in southern Ontario will require little or no intervention and in time, will develop an understory of shade-tolerant hardwoods, primarily dominated by sugar maple and American beech.

Locally or regionally rare, early successional hardwood species such as sassafras and tulip tree should be retained and regenerated. These two species are usually managed within tolerant hardwood stands by the group selection system.

The decision key presented in **Table 6.4.2** can help resource managers select appropriate silvicultural option(s) for early successional hardwood stands. Follow the numbered decision points in the table until a management option (in italics) is reached, that best describes the existing site and stand conditions. Then read the accompanying text description for further details on the management option.

Table 6.4.2: Decision key for early successional hardwood management in southern Ontario.

Text	Decision Factor Description	Continue to Point No.
	Early successional species:	
1.	are dominant (i..e., comprise > 50 % of the canopy) …... ....…	2
1.	are not dominant (i.e., comprise 25-50 % of the canopy) ....…	5
	The stand age is:	
2.	<10 years …………………………………………………………………	*Wait until tree dominance is established – usually between ages 10 to 40*
	10-40 years …………………………………………………………………	*Thin to maximize growth & yield*
2.	40-80 years …………………………………………………………………	*Monitor for stand decay or decline*
2.	> 80 years ………………………………………………………………..	3
	The landowner's management objective is to:	
3.	maintain an early successional hardwood stand …………………... ….	*Clearcut*
3.	manage succession to a tolerant hardwood forest cover type……….	4
	Advanced regeneration of tolerant hardwood species:	
4.	exists under the mature early successional species canopy …..……….	*Promote/release regeneration*
4.	is not present under the mature early successional species canopy …...	*Underplant*
	The landowner's management objective is to:	
5.	retain some early successional hardwood species within stand ……...	*Group selection/Shelterwood*
5.	not retain any early successional hardwood species within stand……	*Single-tree selection*

1. Dominance of early successional species in the stand

To determine appropriate silvicultural options for stands containing early successional hardwoods, this silvicultural guide considers two stand types:

a) Stands with early successional species such as large-tooth aspen, trembling aspen, white birch, and sassafras that dominate (i.e., comprise more than 50 % of the canopy of the stand); and

b) Stands with early successional species such as tulip tree, sassafras, or other species that are minor components (i.e., comprise less than 25-50 % of the canopy of tolerant hardwood stands), and the objective is to increase or maintain their proportion.

Stands in which these species are predominant are best managed with even-aged silvicultural systems, while stands with only a minor component of these intolerant hardwood species can be managed with uneven-aged silvicultural systems.

2. Stand age and thinning to maximize growth and yield

Stand less than 10-years-old

Even-aged stands that are less than 10-years-old should be left alone so that dominance can develop. Once dominance has developed crop trees can be identified.

Stands 10- to 40-years-old

Even-aged stands from 10- to 40-years-old can either be thinned to maximize growth, or they could be left to thin naturally. Normally, thinning operations in early successional hardwood stands are only performed if the cost of thinning can be offset by increased revenue from eventual sales of higher value timber for which there is a local market (Davidson *et al.* 1988). First thinnings are preferably performed on young sapling and polewood stands.

Precommercial thinning in aspen stands accelerates diameter growth of remaining trees and might provide low value forest products (e.g., pulpwood) by removing suppressed or diseased trees. Early work in aspen stands in Ontario found that diameter growth was increased by thinning, height growth was not affected, and rotation lengths to merchantable products were decreased (Davidson *et al.* 1988). Historical data and computer simulation modelling in Minnesota determined that volume production following thinning could be increased by up to 40 % on good quality sites (Perala 1977). Although thinning response rates in southern Ontario will likely differ, they found that growth responses were greatest when thinnings were done at 10-, 20- and 30-years-of-age, reducing stand densities to 2470, 1235 and 617 stems/ha, respectively (Davidson *et al.* 1988). Also good results were achieved with just two thinning operations at age 10 and 30 years, to 1358 and 494 stems/ha, respectively (Davidson *et al.* 1988). Slightly less volume was produced with just two thinnings, and average stem diameter was 5 cm smaller, than when three thinnings were used (Davidson *et al.* 1988). Similar results were found in another study, where thinning was conducted seven years after clearcutting, reducing the stem count from 3750 to 695 stems/ha.

Aspen of 30- to 40 years-of-age also benefits from commercial thinnings. Thinned plots had a volume increase of 7.1 m^3 (17 cords) per hectare higher than uncut plots in stands where diseased and defective trees were removed and the remaining trees were left at a spacing of approximately 4 m by 4 m. After 15.5 growing seasons, veneer value (in 1969 dollars) on uncut plots was $912/ha, and on thinned plots it was $1402. Pulpwood value on uncut plots was $196.50/ha and on thinned plots it was $228/ha (Hubbard 1972). In other studies, thinning to a spacing of 2.5 m or 1600 trees/ha also resulted in a significant growth response (Davidson *et al.* 1988).

When thinning in aspen stands, damage to residual stems must be avoided because aspen are easily infected by disease that can enter through these wounds (Davidson *et al.* 1988).

Generally white birch should respond to thinning in the same manner as aspen mainly because it is also a short-lived, fast-growing species. Thinnings in white birch stands have been shown to increase diameter growth proportionately with the degree of release (Safford *et al.* 1990).

Tulip trees also respond well to release by thinning, and research has shown that young trees can strongly benefit from a four-sided crown release (Johnson *et al.* 1997).

Stand 40 to 80-years-old

Aspen and white birch are relatively short-lived species and consequently their rotation ages are short. Stands that are between 40- to 80-years-old should be monitored for stand decay or decline.

Accumulation of biomass/ha in aspen stands peaks at 30-40 years in southern Ontario (Davidson *et al.* 1988), and biomass production remains at this peak for a further 30 years (i.e., diameter increases but biomass/ha does not). After 70 years, biomass rapidly declines from rot, stain and mortality. For example, the cull rate in aspen stands changes from 10 % at age 30, to 17 % at age 100, and to 35.5 % at age 150 (Davidson *et al.* 1988). Forty years is the rotation age for pulpwood production, and 70-80 years is an appropriate rotation age for sawlogs or veneer aspen. If an aspen stand continues to develop high quality wood past this age however, it could continue to be managed until it started to decline.

White birch matures at about 60 years of age, and responds very little to release after this time (Safford *et al.* 1990). Seventy to 80 years would also appear to be a reasonable rotation age for white birch, although it could be longer if tree health and log quality remained high.

Stand > 80-years-old

Most stands of aspen and white birch are considered over-mature or declining by the time they are 80-years-old. At this stage, landowners should choose among silvicultural options that can either regenerate a stand comprised of similar species or encourage succession to a different stand type (e.g., tolerant hardwood or pine forest).

3. Choosing whether to maintain the early successional species in the stand

The choice of whether or not to maintain early successional species should be made keeping these factors in mind:

- If the stand contains uncommon deciduous tree species such as sassafras or tulip tree, the retention of these species will help to conserve local or regional species diversity.

- Aspen and birch have significant value for wildlife, especially in landscapes where there are few other such stands.
- Market prices for aspen products in southern Ontario are currently low but have improved recently due to new uses for poplar pulp (e.g., medium-density fiber board, oriented-strand board).
- White birch is more valuable than aspen, but less valuable than the tolerant hardwoods.

Regenerating early successional hardwood species to maintain them on sites where their mature canopies are declining will require clearcutting or some modification of this silvicultural system. Specific guidelines vary slightly, depending on the dominant canopy species to be regenerated. These are discussed below for stands dominated by either aspen, white birch or tulip tree. A modification of clearcutting, and other suggested actions to minimize the negative effects associated with clearcuts are also presented in this section.

If the management objectives for the stand are to promote natural succession to a later successional forest cover type such as a tolerant hardwood forest, clearcutting is not an appropriate option.

Aspen

In Ontario, regenerating aspen stands as early successional stands is accomplished by clearcutting. To reproduce a fully stocked aspen stand, 120 parent stems/ha are required, while 40 stems/ha will produce minimally stocked stands. The clearcut system is the only silvicultural system that creates conditions suitable for aspen regeneration (Davidson *et al.* 1988).

Clearcutting removes all trees in the stand, thereby promoting root suckering and providing full light for rapid growth. Any partial clearcut system (e.g., strip cutting) will reduce root suckering and growth, and limit future silvicultural options as re-entering the stand after sprouting will cause significant damage (Schier *et al.* 1985). Both merchantable and non-merchantable trees are generally removed, as residual stems are not conducive to optimum regeneration, growth or development (Davidson *et al.* 1988). Full-tree, or tree-length skidding are the best harvesting methods for promoting aspen regeneration as they destroy shrubs in the understory, and minimize slash accumulation. Harvesting in the winter season when trees are dormant produces a greater number of suckers of higher quality than harvesting in summer (Heeney *et al.* 1980), and a more even distribution of suckers (Bella 1986).

The selection, shelterwood, or partial clearcut systems reduce root suckering and growth and are not generally recommended to regenerate aspen because this species is shade-intolerant (OMNR 1997). The shelterwood system has been suggested for use in Wisconsin however, to regenerate trembling aspen and it appears to provide a potential advantage. Leaving 20-25 residual aspen trees per hectare should reduce the number of suckers produced through plant hormone regulation in the roots. With fewer suckers, more energy and production should be focused on potential crop trees (Ruark 1990). This system is not recommended in areas where mortality from pathogens or disease is anticipated to be high (Bates *et al.* 1989), as understocking may result. Furthermore, management plans should not count on retrieving the residual trees at a later date because re-entering the stand will cause significant damage to aspen suckers (Schier *et al.* 1985).

White birch

White birch readily seeds into clearcut areas, often dominating the site and outgrowing aspen seedlings (Smith and Ashton 1993). It regenerates on sites through a combination of suckering and seeding. Regeneration is best on bare mineral soils, such as those found after fire or following litter disturbance by logging (Safford *et al.* 1990). White birch disperse seeds in the fall (Safford *et al.* 1990), and clearcutting operations could begin in December following a good seed year. Site scarification is important as seed germinates best on mineral soil. For example, in Alaska, scarified sites were 100 % stocked with white birch; non-scarified sites were only 30 % stocked (Safford *et al.* 1990). Scarification can be accomplished through logging (best done in snow-free periods), disking, or controlled burns (Safford *et al.* 1990).

Tulip tree

Clearcuts have been used to regenerate tulip trees in the Appalachians (Smith and Miller 1987), but this system would probably not succeed in southern Ontario since this species usually occurs as scattered, uncommon individuals within a stand (i.e., too few tulip tree seed sources). Patch clearcuts might be an option in larger stands providing that there is a substantial seed source. This type of regeneration is covered under group selection (**Section 6.1**).

Minimizing the negative impacts of clearcutting

Patch cutting can help to reduce some of the negative aspects of the clearcutting system (**Box 6.4.1**). For example, a 30 ha stand of aspen could be cut in patches. Five, 15-year rotations amounts to 75 years or approximately the rotation age of aspen. One 5-ha patch could be clearcut every 15 years, creating a variety of age classes and wildlife habitats in the landscape. The sixth 5-ha patch could be left to decline as old growth aspen, eventually being replaced by more tolerant tree species. Variations of this scenario could apply to a variety of different stand conditions, or other early successional hardwood species, provided the stand is relatively large (i.e., applicable in very few southern Ontario stands). Small clearcut patches also provide excellent habitat for ruffed grouse (McCaffrey *et al.* 1997) provided that such stands are adjacent to more mature stands that provide other grouse habitat needs. A network of different-aged patches also benefits moose, deer, black bear, marten, fisher, lynx, and fox (Davidson *et al.* 1988).

4. Managing succession to a tolerant hardwood, pine, or cedar forest cover type

If advanced regeneration of desirable tolerant hardwoods, pine, or cedar exists in the understory of a mature early successional hardwood stand, these understory species could be managed to later become the dominant species on the site. The understory trees may range in size from seedlings to polewoods with an intermediate crown position. The key to successful release of this understory is to wait until it reaches a size where it can shade out any aspen regeneration and aspen suckers can no longer overtop it.

Box 6.4.1. Considerations for minimizing negative impacts when using the clearcut system.

- Anticipate possible environmental impacts (e.g., increased streamflow, soil erosion); uncut buffers should be left around significant features including streams and seepageways.
- Determine presence of any significant wildlife habitats (e.g., habitat for rare species, seasonal concentration area, especially for songbirds during migration, ruffed grouse, woodcock).
- Avoid scheduling clearcutting operations during critical times of year for wildlife (i.e., March-August breeding season).
- Adjust the size, shape, and orientation of clearcut patches, depending on site and objectives (e.g., wildlife habitat creation).
- Use site quality and objectives to locate patches (e.g., create openings in areas likely to provide most benefit to wildlife, provide greatest chance of successful regeneration or improve site conditions for target species, minimize site damage due to erosion).
- Do not locate clearcuts on poor sites (e.g., ridges, frost pockets, poorly drained areas) as these sites will be difficult to regenerate.
- Anticipate other potential problems following harvest (e.g., severe browsing by deer, competition by shrubs and/or other undesirable vegetation, increase in invasive exotic vegetation).
- Retain some trees (e.g., at least 6/ha) to provide wildlife habitat (e.g., snags for perches, large trees for dens and/or nest cavities).
- If applicable to silvicultural objectives, protect established (advanced) regeneration of desired species.

First-year height growth of aspen suckers can be quite high, ranging from 0.3-1 m. Height growth usually slows after this point, as the stem produces lateral branches (Davidson *et al.* 1988). The desirable species in the understory should probably be at least 3 to 4 m tall before they are released; otherwise they might be rapidly overtopped, resulting in a mixed stand or pure aspen stand. A minimum stocking of advanced regeneration is also required before canopy removal treatments begin. Ideally there should be a healthy, vigorous understory tree approximately every 3 m.

If the early successional canopy is too thick for the understory to grow and reach the desired height of 3 to 4 m, the canopy may have to be thinned to promote understory growth. Thinning should be light however, so as not to promote the regeneration of early successional species. Canopy basal areas should not be reduced below 24 m^2/ha**.** Diseased and poor quality stems could be removed from the canopy in these stands thereby promoting growth of the best stems, understory seedlings, and saplings, prior to canopy removal.

Once the understory is established satisfactorily, the canopy of early successional species should be removed if there is a market for the material. Otherwise the trees can be left to die naturally. If the landowner wishes to accelerate succession to more tolerant species, the stems could be girdled or treated with herbicide. Girdling or killing with herbicide is preferable as it should result in less damage to the understory, and killing with herbicide will eliminate root suckers. **Section 8.1** provides more information on vegetation management guidelines, including girdling and/or herbicide treatment options for polewood size stems.

On sites with little or no understory of desirable species, and/or isolated stands where suitable seed sources for desirable species are not found in the vicinity, underplanting is an option. For example, white pine has been successfully established under hybrid poplar plantations in eastern Ontario.

Planting spacing of white pine should be close, either 1.5 by 1.5m or 1.8 by 1.8m. These spacings are used by the Ontario Ministry of Natural Resources under shelterwood cuts, and are also recommended by the United States Department of Agriculture to help control white pine weevil and blister rust (Katovich and Mielke 1993). Once the planted trees are well-established and 3-4 m in height, the canopy is removed. Or a partial cutting of poplar (e.g., take one, leave one) might be conducted to release the pine but still maintain adequate canopy closure to minimize damage to pine by weevils.

Intermediate to shade-tolerant species that are suited to the soil texture and moisture conditions of the site could be underplanted under early successional canopies. An appropriate species list for underplanting could be determined by inventorying tree species in nearby forested stands that are located on similar site types. Landowners are encouraged to plant a variety of suitable species.

5. Managing stands with a small early successional component

Many stands in southern Ontario have a small component of early successional species mixed in with tolerant hardwoods, pines, or cedar. This section presents options for maintaining pockets of early successional Carolinian species such as tulip tree or sassafras in tolerant hardwood stands. Both tulip tree and sassafras are shade-intolerant species that are found growing with maples, oaks, and other more shade-tolerant species in southwestern Ontario. Retaining these uncommon species in a stand enhances species diversity.

Neither tulip tree nor sassafras can reproduce successfully under the lower light levels of the understory created by the single-tree selection system commonly used to manage tolerant hardwoods. However, these species can regenerate successfully in the larger canopy openings created by the group selection system (Weigel and Parker 1997). Refer to the tolerant hardwood section for more detailed information on group selection.

To regenerate tulip tree using the group selection system, use the following guidelines (Beck 1990):

- The opening diameter should equal the height of the stand (i.e., approximately 30 m). This is a compromise since diameter and height growth are slowed if openings are smaller than 1.24 ha, but the small size of most forest stands in southern Ontario does not realistically allow the creation of openings this large.
- Openings should be placed downwind and within 60 m from good tulip tree seed sources.
- Openings should be created following good seed years. In the US, good seed crops are produced annually; they may be less frequent in southern Ontario.

- The site should be scarified (i.e., scuffed up) to expose mineral soil and well decomposed organic matter, the preferred seedbed for tulip tree seed germination.
- Cutting and skidding should be conducted in the fall to expose mineral soil and to allow germination of seeds that must overwinter in the soil seed bank to be viable.
- Any tulip trees that are cut while creating openings should successfully reproduce through stump sprouts. Cutting in the winter dormant season will encourage regeneration by sprouting.

To regenerate sassafras using the group selection system use the following guidelines (from Griggs 1990):

- The opening diameter should be equal to stand height (i.e., approximately 30 m).
- Openings should be located downwind from and near suitable mature sassafras seed trees. It is not known how far sassafras seeds will travel from the parent tree, but they are broadly disseminated by birds, small mammals, and water. Limited predictable distribution of seeds from parent trees, however, may limit success with the group selection system.
- Any sassafras left intact in group selection openings should readily produce root sprouts that can help to regenerate the site. Cut sassafras will readily produce stump sprouts, and cutting in the winter dormant season will encourage regeneration by sprouting.
- A moist loamy soil with a protective layer of leaves and litter is the preferred seedbed, so site scarification is not necessary.

Stands should be thinned as described in the tolerant hardwoods section, and tulip trees and sassafras would be preferred crop trees.

If the management objectives do not include retaining some of the early successional hardwood component, then the stands should be managed using the silvicultural options appropriate for the dominant species or forest cover type and stand structure.