CHAPTER 40

NORTHERN HARDWOOD COVER TYPE

TYPE DESCRIPTION

Stand Composition

Any combination of sugar maple (*Acer saccharum*), beech (*Fagus grandifolia*), basswood (*Tilia americana*), white ash (*Fraxinus americana*), and yellow birch (*Betula alleghaniensis*) comprises more than 50% of the basal area in sawtimber and poletimber stands or more than 50% of the stems in sapling and seedling stands.

Sugar maple typically is the dominant species in northern hardwood stands in Wisconsin. In eastern Wisconsin, beech sometimes is dominant. Basswood is the most common associate of sugar maple, but only occasionally dominates. White ash and yellow birch are common minor associates, but only rarely dominate stands.

The northern hardwood and central hardwood upland forest cover types are differentiated as follows:

Northern hardwood type:

- Any combination of the five major species can dominate any stand, but typically sugar maple is the predominant overstory species.
- Important associates unlikely to occur in the central hardwood type are beech, yellow birch, hemlock, and fir.
- Occurs throughout Wisconsin, but is most common north of the tension zone.

Central hardwood type:

- Any combination of the five major northern hardwood species cannot be predominant.
- Tree species playing relatively greater compositional roles are oaks (especially white oaks), hickories, elms, ashes, red maple, black cherry, black walnut, butternut, hackberry, and box elder,
- In Wisconsin, it occurs within and south of the tension zone, commonly on sites submitted to long-term repeated disturbance.

Associated Species

Within the northern hardwood cover type, the predominant associates in Wisconsin currently are (1996 FIA): red maple (*Acer rubrum*), red oak (*Quercus rubra*), hemlock (*Tsuga canadensis*), white pine (*Pinus strobus*), and balsam fir (*Abies balsamea*). Many other tree species occurring in Wisconsin can be found as occasional associates in northern hardwood stands.

Soil Preference

The northern hardwood cover type develops and grows best on mesic sites with well drained to moderately well drained loamy soils; the very best soils are deep, well drained, silt loams. However, it occurs on a wide range of soil conditions, from well drained to somewhat poorly drained and from sands to clays. Dry, excessively drained sands and wet, poorly drained soils generally do not support the development of northern hardwood stands. Soil pH can range from 3.7 to 7.3, but a pH between 5.5 and 7.3 is most common.

Range of Habitat Types

The northern hardwood cover type currently is much more common in northern than in southern Wisconsin. About 89% of sugar maple net growing stock volume occurred (1996 FIA) within the northern habitat type groups. For the other northern hardwoods, 96% of yellow birch volume, 77% of basswood volume, 69% of beech volume, and 58% of white/green ash volume occurred within the northern habitat type groups.

1. Northern Wisconsin Habitat Types

In northern Wisconsin, the **occurrence** and **relative growth potential** of the northern hardwood cover type, and of the individual species comprising the type, vary by habitat type groups and habitat types.

The northern hardwood cover type currently is the predominant cover type occurring on mesic sites in northern Wisconsin. It is of common occurrence on the dry-mesic and the mesic to wet-mesic habitat type groups. It generally does not develop on the very dry to dry, dry to dry-mesic, and wet-mesic to wet groups.

Table 40.1. Northern hardwood tree species – estimated current relative occurrence by northern habitat type group.

Northern Habitat Type Groups	**Estimated Current Relative Occurrence for NH Species**				
	Sugar Maple	Beech[1]	Basswood	White/Green Ash	Yellow Birch
Very Dry to Dry	*	*	*	*	*
Dry to Dry-mesic	*	*	*	*	*
Dry-mesic	***	*	***	**	*
Mesic	****	**	***	**	**
Mesic to Wet-mesic	***	*	***	**	**
Wet-mesic to Wet	*	*	**	**	**

**** Major Dominant, *** Major Associate, ** Minor Associate, * Rarely Occurs (or does not occur)
1 – Beech occurs only in extreme eastern Wisconsin

Table 40.2. Northern hardwood cover type – estimated relative growth potential by northern habitat type group and habitat type.

Northern Habitat Type Groups	**Estimated Relative Growth Potential for NH Cover Type**				
	None to Very Poor	Poor	Fair	Good	Excellent
Very Dry to Dry	PQE PQG PQGCe PArV PArV-U PArVAo QAp				
Dry to Dry-mesic	PArVHa PArVAm PArVAa PArVAa-Vb PArVAa-Po PArVPo				
Dry-mesic		TFAa AVCl AVVb AVDe AVb-V	ACl AVb AAt ATFPo		
Mesic				AFVb ATM ATFD ATFSt	AAs ATD ATDH AHVb AFAd AFAl ACaCi AOCa AH
Mesic to Wet-mesic	PArVRh ArAbVC ArAbVCo ArVRp ArAbSn		ArAbCo TMC ASnMi AAtRp	ATAtOn ASaI ACaI AHI	
Wet-mesic to Wet	All Sites (no habitat types)				

2. Southern Wisconsin Habitat Types

In southern Wisconsin, the **occurrence** and **relative growth potential** of the northern hardwood cover type, and of the individual species comprising the type, vary by habitat type groups and habitat types.

The northern hardwood cover type currently is common (along with central hardwood and oak cover types) only on mesic sites in southern Wisconsin. It is a relatively uncommon cover type, but potentially can develop and become more common, within the dry-mesic, dry-mesic to mesic, dry-mesic to mesic (phase), mesic (phase), and mesic to wet-mesic habitat type groups. It generally does not develop on the dry and wet-mesic to wet groups.

Table 40.3. Northern hardwood tree species – estimated current relative occurrence by southern habitat type group.

Southern Habitat Type Groups	**Estimated Current Relative Occurrence for NH Species**				
	Sugar Maple	Beech[1]	Basswood	White/Green Ash	Yellow Birch
Dry	*	*	*	*	*
Dry-mesic	**	*	**	**	*
Dry-mesic to Mesic	***	*	***	***	*
Dry-mesic to Mesic (phase)	**	*	**	**	*
Mesic (phase)	**	*	**	**	*
Mesic	****	**	****	***	**
Mesic to Wet-mesic[2]	*	*	***	***	**
Wet-mesic to Wet[2]	*	*	**	***	*

**** Common Codominant, *** Major Associate, ** Minor Associate, * Rarely Occurs (or does not occur)
1 – Beech occurs only in extreme eastern Wisconsin
2 – All sites – Habitat types not defined

Table 40.4. Northern hardwood cover type – estimated relative growth potential by southern habitat type group and habitat type.

Southern Habitat Type Groups	**Estimated Relative Growth Potential for NH Cover Type**			
	None to Poor	Fair	Good	Excellent
Dry	PEu PVGy PVG PVCr PVHa			
Dry-mesic	ArDe-V ArDe	AQVb-Gr ArCi ArCi-Ph AArVb AArL		
Dry-mesic to Mesic			AFrDe AFrDeO ATiFrCi ATiFrVb ATiDe ATiDe-Ha ATiDe-As	
Dry-mesic to Mesic (phase)			AFrDe(Vb) ATiFrVb(Cr) ATiCr(O) ATiCr(As) ATiDe(Pr)	
Mesic (phase)			ATiFrCa(O)	ATiAs(De)
Mesic			ATiSa-De ATiSa	ATTr AFTD AFH ATiFrCa ATiCa-La ATiCa-Al ATiCa ATiH AFAs-O AFAs
Mesic to Wet-mesic	PVRh			

SILVICAL CHARACTERISTICS[1]

Sugar Maple

In Wisconsin, sugar maple is the forest tree species with the greatest net growing-stock volume; over 2 billion cubic feet on forest land estimated by the 1996 forest inventory and analysis (FIA). This represents about 15% of the total hardwood volume and 12% of the total wood volume growing in Wisconsin's forests (Schmidt 1998, Kotar *et al*. 1999).

Sugar maple is one of the most shade tolerant of the major forest species in the state. Trees respond to release from extreme and prolonged suppression. It is regionally significant as a late-successional (climax) dominant on dry-mesic to wet-mesic sites.

The site index at base age 50 years (SI_{50}) mostly ranges from 40-80, but on average to better sites (suitable for growing quality sawtimber) is typically 55-70. Where SI_{50} is less than 50, quality sawtimber development generally is not a stand management option (Erdmann 1986).

Sugar maple trees produce abundant and viable seed every 1-5 years; flower crops can be predictive of seed crops. Seeds are dispersed in the fall and early winter, lay dormant (undergoing stratification) on the forest floor during winter, and generally germinate in spring once the required temperatures are reached. The extremely low germination temperature (34^0F), high germinative capacity, and frequent good seed years facilitate abundant seedling crops. Early survival is enhanced by the vigorous development of a strong radicle (root) that has the strength and length to penetrate heavy leaf litter and reach mineral soil during the moist period in early spring (often under the snow). However, the young root system is rather shallow and fibrous, making seedlings sensitive to moisture stress and surface moisture conditions.

Seedlings are relatively slow growing. Some overstory shade (30-90% full sunlight) improves growth and survival of natural seedlings until 2-4 feet in height. Dense shade (<10% full sunlight) can result in poor growth and higher mortality. Full sunlight (>90%) also can result in poor growth and higher mortality due to moisture stress.

Sugar maple tree and stand growth rates can be expected to vary geographically and by site quality. Growth is somewhat slower than for most associated species, but relatively large sizes and old ages can be attained. Tree radial growth rates are strongly influenced by site quality, stand density, and tree age. In general, radial growth rates are greater on better sites, in less dense stands, and in younger stands. Dbh growth rates can range from 1-4 inches per decade; 1 inch is typical for mature unmanaged stands, 1-2 inches is average for mature managed stands, 2-3 inches is the maximum measured for sawtimber trees, and 3-4 inches is the maximum for poletimber trees (Crow *et. al.* 1981). In dbh, trees frequently reach 24 inches, older trees can reach 30-36 inches, while the maximum recorded is 84 inches. In general, throughout stand development, tree diameter growth continues at a decreasing rate with increasing age and size. Height growth also slows with increasing age, and becomes negligible at about 140-150 years. Trees average 12 inches/year height growth for their first 30-40 years of life. Sugar maple commonly attains 60-90 feet in height, older trees can reach 120 feet, while the maximum is 135 feet tall. Sugar maple trees can reach 300-400 years of age. In relict old growth forests the average age of canopy trees often ranges from 120-170 years, but trees 250-300 years old are common (Lorimer *et al* 2001, Singer and Lorimer 1997, Frelich and Lorimer 1991).

Stand basal area growth of 2.0-2.5 (ranges 1.5-3) ft^2/acre/year is typical for managed stands on average to better sites in the lake states. Similarly, typical values for net volume growth are 60-90 ft^3/acre/year, and 200-300 (ranges 100-400) bdft/acre/year (Crow *et. al.* 1981). Net growth equals mortality when basal area exceeds 125 sqft/acre in stands dominated by sugar maple (Crow in Hutchinson ed. 1992). Example total yields from average, well-stocked stands of northern hardwoods dominated by sugar maple on medium to good sites in the lake states are: 3,500 – 6,000 bdft/acre at 80 years, 7,000 – 11,000 bdft/acre at 120 years, 10,000 – 14,000 bdft/acre at 160 years, and 12,500 – 16,500 bdft/acre at 200 years.

[1] Mostly from Burns and Honkala 1990 (Crow 1990, Erdmann 1990, Godman et al. 1990, Schlesinger 1990, Tubbs and Houston 1990), and Harlow et al. 1979

Beech

In Wisconsin, beech is a minor species, representing less than 1% of the total net growing-stock volume on forest land (Schmidt 1998, Kotar et. al. 1999). Beech occurs only in the eastern quarter of the state, where it reaches its western range limit. Here, it occurs almost exclusively on mesic sites. Beech is moisture demanding, but intolerant of flooding.

Beech trees produce abundant viable seed every 2-8 years (the flowers are susceptible to damage by spring frosts). Seed are dispersed in the fall after the first heavy frosts, lie dormant (undergoing stratification) on the forest floor during winter, and generally germinate in spring to summer once the preferred temperatures are reached. Early survival is enhanced by the vigorous development of a strong radical (root) that has the strength and length to penetrate heavy leaf litter and reach mineral soil. However, seedlings are sensitive to moisture stress and surface moisture conditions.

Beech trees less than 4 inches dbh can produce vigorous and successful stump sprouts. Beech can also produce abundant root sprouts (suckers), and this can be an important mode of regeneration. Suckering is stimulated primarily by injury to the roots. Beech limbs can root when layered. Root grafting among beech trees is common.

Beech is very tolerant of shade (similar to sugar maple). Seedlings are slow growing, shallow rooted, and susceptible to desiccation. Best growth and survival are demonstrated under moderate shade (partial canopies and small, protected openings). In dense shade, seedlings can be abundant but growth is slow (e.g. 2 feet tall at 10 years and 5 feet at 20 years). In full sunlight, growth and survival are poor. Seedlings are seldom severely browsed by deer.

Beech is a slow growing, long-lived species. Site index at base age 50 years is lower than for any of its hardwood associates in the Lake States. Average diameter growth rates for pole and small sawtimber trees typically range from 0.8 inches/decade in unmanaged forests, to 1.7 inches/decade in managed forests, to 2.6 inches/decade in relatively open-grown conditions. Typically (within natural range), beech trees grow to 60-90 feet tall and 2 feet dbh. The maximum dimensions recorded within its range are 161 feet tall and 6 feet dbh. Trees can attain ages of 300-400 years.

Basswood

In Wisconsin, basswood is the forest tree species with the fifth greatest net growing stock volume; over 1 billion cubic feet on forest land estimated by the 1996 forest inventory and analysis (Schmidt 1998). Basswood is known to improve soil fertility; the leaves contain high levels of calcium, magnesium, nitrogen, and potassium.

Basswood trees produce abundant seed every 1-2 years. Seed are dispersed in the fall, and usually fall within 1-2 tree lengths of the parent tree. The seed lie dormant requiring both scarification (of the impermeable seed coat) and cold stratification (of the embryo) to break dormancy. Seed viability is poor; common problems are parthenocarpy (production of fruit without seed), insects, rodents, and rotting of seed. In a study in northern Wisconsin, only 2 percent of the identifiable seed found in the litter were sound (Godman and Mattson 1976). In some situations, viable seed can lie on the ground for over five years (if not damaged) without germinating while still maintaining viability.

Basswood is a prolific stump sprouter. Most trees less than 4 inches dbh and more than half of sawtimber trees will produce vigorous stump sprouts. Sprout regeneration can be managed for sawtimber, but early thinning of sprouts is needed to promote rapid growth and quality development. It is recommended to thin sprout clumps to 1-2 stems before they reach 10 years of age.

Basswood is tolerant of shade, but less so than sugar maple, beech, and hemlock. Shading influences seedling growth and survival. Partial shading aids seedling establishment and early survival, but heavy shade will limit growth and development. Once established, seedlings grow most vigorously in full sunlight. Basswood is able to maintain itself as an associate in late successional forests and in managed uneven-aged forests primarily through vigorous sprouting and rapid sprout growth. This sprouting ability also facilitates maintenance under even-aged management systems.

Basswood is a large, rapidly growing tree. Within its range, it typically grows to 70-130 feet tall. It often reaches a dbh of 24-48 inches. The maximum dimensions recorded within its range are 140 feet tall and 7 feet diameter. Basswood grows faster than most of the other northern hardwood species. On a given site, basswood often exceeds sugar maple, beech, and yellow birch in site index by 5-10 feet. Tree radial growth rates are strongly influenced by site quality, stand density, and tree age. In comparison to unmanaged stands, basswood radial growth rates have been nearly doubled by applying crop tree release and moderate single-tree selection cuts. "Relatively narrow bark ridges and V-shaped fissures, with new light-colored inner bark visible in the fissures, represent a high-vigor basswood. In contrast, low-vigor trees have scaly bark with wide bark ridges and shallow, short fissures, frequently producing a rather smooth surface" (T.R. Crow in Burns and Honkala 1990). Basswood trees can reach more than 200 years of age.

White Ash

In Wisconsin, white and green ash together represent about 3% of the total net growing-stock volume on forest land (Schmidt 1998, Kotar et. al. 1999). White ash typically grows as an associate in other forest cover types, and only rarely as a dominant.

White ash trees produce abundant and moderately viable seed every 3-5 years; flower crops can be predictive of seed crops. Seed are wind dispersed up to 460 feet in fall to early winter. The seed lay dormant (requiring moist, cool stratification) on the forest floor during winter. Germination usually occurs in spring to summer, but some seed may delay germination for 2-3 years.

White ash is shade tolerant when young, but intermediate when older. In dense shade, seedlings can survive for several years, but exhibit minimal growth. Seedlings can be abundant in the understory of northern hardwood stands, but generally do not grow into the overstory unless a canopy gap that provides increased light is created. Advanced regeneration can quickly capture newly formed canopy gaps. About 45% of full sunlight provides ideal conditions for early growth and development. Partial shade provides ideal conditions for seedling establishment, but once established increased sunlight provides for optimal development and vigorous growth.

White ash grows faster than most of the other northern hardwood species. On a given site, it often exceeds sugar maple, beech, and yellow birch in site index by 3-10 feet.

White ash is a rapidly growing tree that exhibits strong apical dominance. In height, it typically grows to 70-90 feet, but the maximum recorded within its range is 125 feet tall. In diameter, older trees can reach 24-36 inches dbh, while the maximum recorded is 84 inches.

Yellow Birch

In Wisconsin, yellow birch represents only about 1% of total net growing-stock volume on forest land (Schmidt 1998). It typically grows as an associate in other forest cover types, and only occasionally as a compositional dominant.

The successful germination of yellow birch seed and the establishment of abundant and vigorous seedlings depend on an adequate seed supply, favorable weather, a proper seedbed, adequate light, and control of competition. Yellow birch trees produce abundant seed every 2-3 years. Seed are wind dispersed in fall to winter. Most seed lands within 330 feet of the parent tree, but some seed can be blown across the snow up to 1300 feet or more. Seed viability is highly variable and germinative capacity generally is low. Seed problems include parthenocarpy (fruit without seed), hard frosts, insects, and disease. Pre-chilling and light can improve germination. Germination requires moisture and warm temperatures, and typically occurs around early June. Seedlings also require an adequate and consistent supply of moisture, and are susceptible to moisture stress. The optimal seedbed is disturbed and moist humus or mixed humus mineral soil with minimal competition. In undisturbed stands, favorable seedbeds include decaying wood (mossy logs, rotten stumps), windthrown hummocks, and even cracks in boulders. Yellow birch also can colonize sites with moist mineral soil following disturbance by catastrophic fire, logging, and blowdowns. On undisturbed forest floors, yellow birch radicals cannot pierce the hardwood leaf litter and the seedlings become susceptible to desiccation. Yellow birch benefits from soil disturbance and also requires openings in the canopy.

Yellow birch is intermediate in shade tolerance and is a gap phase species. Seedlings require overhead light for survival and vigorous growth. The optimal light level for seedling development and growth is approximately 50% full sunlight. After 5 years of age, yellow birch grows and develops best in full overhead sunlight. Yellow birch cannot compete with sugar maple under dense forest canopies.

Yellow birch is a slow growing, long-lived species. Average site index at age 50 years is 55-65. Growth rates tend to decline as trees age. Diameter growth of less then 1 inch/decade is common in unmanaged stands and in managed uneven-aged single-tree selection stands. Overhead light and crown expansion space facilitate growth and vigor. Release and thinning can significantly improve growth rates. Crop tree release can improve diameter growth up to 3 inches per decade in saplings, and diameter growth of 75% in poletimber, and 45% in sawtimber. Under intensive even-aged management, 18 inch trees can be grown in less than 90 years. Typically, yellow birch trees grow to 70-100 feet tall and 24-30 inches dbh. Maximums measured within its range are 114 feet tall and 60 inches dbh. In unmanaged forests, most growth (height and diameter) is completed by 120-150 years of age. Yellow birch trees commonly reach 300 years old, and can surpass 350 years.

Table 40.5. Summary of selected silvical characteristics.

	Sugar Maple	**Beech**	**Basswood**	**White Ash**	**Yellow Birch**
Flowers	March-May Polygamous	April-May Monoecious	June (May-July) Perfect	April-May Dioecious	Pistillate catkins May (Apr.-June) Monoecious
Fruit Ripens	Sept.-Oct. 1(2) seeded double samara	Sept.-Nov. 2(3) Nuts/Bur	Sept.-Oct. 1(2) seeded Nutlike drupe	Sept.-Nov. 1 seeded Samara	August-Sept. Strobile
No. of seeds/lb	7000 samaras/lb	1600 seed/lb	5000 seed/lb	10,000 seed/lb	450,000 seed/lb
Seed Dispersal	Fall to early winter. Wind dispersed up to 330 feet.	Fall. Near tree. Jays, rodents, and gravity can enhance dispersal.	Fall. Wind and gravity rarely disperse seed more than 1-2 tree lengths.	Fall to early winter. Wind dispersed up to 460 feet.	Fall to winter. Wind dispersed up to 300-1300 feet or more.
Good Seed Years	Every 1-5 years	Every 2-8 years	Every 1-2 years	Every 3-5 years	Every 2-3 years
Seed Bearing Age	20 years – minimum; 40-60 years – light crops; 70-100 years – moderate crops; >100 years – heavy crops.	Good crops by 40 years; abundant by 60 years.	Generally, 15-100 years.	20 years minimum. Good crops usually begin at about 30-40 years.	Generally, 30-40 years is minimum, and 70 years begins optimum.
Seed Viability	Prolific seeder. High viability. On forest floor doesn't remain viable beyond first year.	High viability.	Poor viability. Impermeable seed coat. Can remain viable on forest floor >5 years.	Moderate viability.	Prolific seeder. Viability highly variable; generally poor; usually best in good seed years.
Germination	Pronounced dormancy, requiring 1-3 months stratification. Spring; best at 34^0F; poor at >50^0F.	Pronounced dormancy, requiring stratification. Spring to early summer; best at 59^0F.	Pronounced dormancy, requiring 3-4 months stratification. Requires scarification. Spring to summer; best at 68^0F.	Pronounced dormancy, requiring 2-3 months stratification. Spring to summer; best at 84^0F.	Typically June; requires moisture and warm temperatures; best at 60-85^0F.

	Sugar Maple	**Beech**	**Basswood**	**White Ash**	**Yellow Birch**
Seedbed Requirements	Moist undisturbed leaf litter, humus, or mineral soil; often under snow.	Moist undisturbed leaf liter, humus, or mineral soil; poor on wet sites.	Moist with variable substrate	Moist leaf litter, humus, or mineral soil.	Disturbed and moist humus or mixed humus mineral soil with minimal competition. Also, moist mineral soil, decaying wood, and cracks in boulders.
Vegetative Reproduction	Seedlings sprout readily. Stump sprouts decrease with increasing tree size.	Seedlings and saplings produce vigorous stump sprouts. Prolific root sprouter. Also layers.	Wide range of diameter classes produce prolific and vigorous stump sprouts.	Seedlings and saplings produce vigorous stump sprouts.	Seedlings and saplings produce vigorous sprouts. Larger stems sprout poorly.
Seedling development	Best growth when light levels are 30-90% full sunlight. Dense shade or full sunlight can result in poorer growth and higher mortality. Sensitive to moisture stress.	Moderate shade facilitates best survival and growth. Dense shade slows growth. Full sunlight results in poor growth and survival. Sensitive to moisture stress.	Partial shade facilitates initial survival and establishment. Dense shade limits growth. Once established, (nearly) full sunlight facilitates vigorous growth.	Establishment and early growth best at about 50% full sunlight. Dense shade limits growth. Once established, (nearly) full sunlight facilitates vigorous growth.	Establishment, growth, and development best at about 50% full sunlight. Dense shade limits growth. Sensitive to moisture stress.
Shade Tolerance	Very tolerant. Good survival and response to release.	Very tolerant. Good survival and response to release.	Tolerant.	Tolerant when young, then becoming intermediate.	Intermediate.
Maximum Longevity	300-400 years	300-400 years	200-250 years	250-300 years	300-400 years

MANAGEMENT GOALS AND OBJECTIVES

Management objectives should be identified in accordance with landowner goals within an ecosystem management framework, which gives consideration to a variety of goals and objectives within the local and regional landscape. The silvicultural systems described herein are designed to promote the optimum quality and quantity of northern hardwood sawtimber. High quality sawlog and veneer production is the objective for most sites of average to better quality. These silvicultural systems may be modified to satisfy other management objectives, but vigor, growth and stem quality could potentially be reduced. The habitat type is the preferred indicator of site potential. Other indicators of site potential include site index and soil characteristics. Prior to development and implementation of silvicultural prescriptions, landowner goals need to be clearly defined and articulated, management units (stands) must be accurately assessed, and landowner stand management objectives should be detailed. In-depth and accurate stand assessment will facilitate discussion of management options and objectives in relation to realistic and sustainable management goals. Northern hardwood stand assessment should include quantifying variables such as present species composition, stand structure, stand quality (present and potential crop trees), stand age and site quality.

SILVICULTURAL SYSTEMS

Uneven-aged (sometimes called all-aged) silvicultural systems are commonly recommended for the management of northern hardwoods. Even-aged silvicultural systems may also be utilized to produce high quality products and to encourage mid-tolerant species that can increase tree species diversity and improve production on poor quality sites. Intermediate treatments are used to promote quality stem development and stand vigor. Recommended and generally accepted natural regeneration methods include:

- Single tree selection (uneven-aged)
- Group selection (uneven-aged)
- Shelterwood (even-aged)
- Overstory removal (even-aged)

Additionally, management recommendations include **generally accepted methods to convert from an even-aged condition to an uneven-aged system. Conversion** is one of the most commonly applied processes or management practices. The process of conversion requires specific stand manipulation techniques that are implemented over a fairly long-term period. Recommendations are also included identifying the process of managing degraded northern hardwood stands. A comparison of the characteristics of the even-aged and uneven-aged management systems is provided in Table 40.6.

Table 40.6 Comparison of relative characteristics between even-aged and uneven-aged (single-tree selection) silvicultural systems on good to excellent sites (adapted from USDA Forest Service 2005)

Even-aged	Uneven-aged (regulated)
Requires a rotation, with the elimination of the previous stand and establishment of a new stand	Continuous maintenance of a mature and structurally diverse forest
Provides opportunity for less shade tolerant species when combined with seedbed preparation	Favors shade tolerant species, especially sugar maple
Requires a different basal area stocking for every thinning depending on average tree diameter and species composition	Basal area stocking remains constant for every entry (thinning, harvesting, and regenerating at each entry)
Removes many small trees in each thinning	Removes fewer trees and larger trees at each entry
Early thinnings are all pulpwood and could be economically marginal	Timber products are mainly sawlogs with a small amount of pulpwood
A half to two-thirds of periodic growth can be sold while stocking is building	Nearly all the volume growth at each entry can be sold once the stand is regulated
Butt rot, resulting from winter sunscald of 1-3 inch diameter saplings on exposed sites, can reduce volume and grade in sugar maple and other species	Sunscald rarely occurs
Merchantable height will usually be less than two 16-foot logs in sugar maple	Merchantable height can be two to three 16-foot logs in sugar maple due to fork correction
Ideal for fiber production. Can produce high yields of high quality logs of mid-tolerant species	Produces the optimum balance of quantity and high quality logs in tolerant species such as sugar maple
Provides excellent habitat during the first 10-15 years of stand development for wildlife that prefer dense cover and browse	Provides increased structure favorable for some wildlife

MANAGEMENT RECOMMENDATIONS

Stem Quality

For most timber management objectives development of individual stem quality throughout the stand is paramount no matter which silvicultural system is utilized. Focus on quality should occur from establishment of seedlings and saplings through harvest and regeneration. Evaluation of risk, vigor and attention to future crop trees should be incorporated through the use of recognized marking guidelines appropriate for the chosen silvicultural system. Quality development in stands may be a long term process involving three or more entries, on a cycle of 10-20 years. Quality depends on stand history, species composition, stand density, site quality, tree age, and damage due to factors such as grazing, insects, disease, ice, wind, and poor harvesting.

Numerous research studies and field trials evaluating stem quality and growth as a result of management practices have been conducted in the Lakes States. Many replicated studies in northern hardwood management practices have been conducted on the USDA Forest Service, Argonne and Dukes Experimental Forests. One such study in place for over 50 years has tested alternative residual basal areas under uneven-aged management of 60, 75, and 90 sqft/acre in trees ≥5”DBH. Marking focused on harvesting in all overstocked size classes based on uneven-aged principles and the order of removal developed by Eyre and Zillgett (1953) and Arborgast (1957). To date, six harvests have been implemented and data recorded in the three trials. The 60 sqft/acre residual results have indicated a decrease in merchantable log heights over time. Repeated cuts to 90 sqft/acre have sustainably yielded the best quality logs but at a lesser diameter growth rate than the 75 sqft/acre trial. While there was no significant basal area growth rate difference between the 75 and 90 sqft/acre trials, the diameter growth rate was less for the 90 sqft/acre trial, reflecting the diameter growth on more individual trees (USDA Forest Service 2005). Both the 75 and 90 sqft/acre trials have provided a good balance of quality and quantity; this provides further support for the marking guidelines included herein which recommend a residual stocking of 84sqft/acre in trees ≥5”DBH.

Factors effecting stem quality include forks, epicormic branches, seams, cankers, rot, and logging damage, all of which contribute to lower log grades (Forest Health Protection Table 2). Logging damage should be avoided at any time of year. Logging damage can be most serious when active sap flow and tree growth is occurring, generally from April to July. Root damage is common when soils are not dry or frozen. Damage to root systems can reduce growth and lead to interior stem defects such as sap streak. Frequent entries into a stand for selection harvests or even-aged thinnings can increase the potential for damage due to logging operations.

Stem form problems, such as epicormic branching and forking, are directly related to stand density and crown development. Epicormic branch sprouts originate from dormant buds embedded in the bark of many hardwood species. Bud dormancy is controlled by growth regulators (auxins) which are produced by the terminal buds. Trees lacking a healthy, vigorous, and large crown, such as suppressed and intermediate trees in the understory or crowded overstory trees in unmanaged, even-aged stands, do not produce sufficient regulators to prevent epicormic sprouting. Some intermediate and co-dominant trees don’t epicormic sprout until after the stand is first thinned. (Godman, R.M. in Hutchinson ed. 1992)

Forking occurs in northern hardwood species that are opposite-branched, such as maples and ashes. Forking not only is a stem defect, but it increases the risk of crown or stem breakage. Forking is primarily caused by an insect called a bud miner which is present in stands from the seedling stage through maturity. Forks are less common in uneven-aged stands than in even-aged stands. Fork correction occurs continually in uneven-aged stands due to taller overstory trees shading out part of the fork. For this reason, uneven-aged stands can generally develop greater merchantable log height in stems. In even-aged stands fork correction occurs when shade from crowns of adjacent trees causes one side of the fork to loose vigor and the other will acquire dominance. Even-aged stand density should be maintained at or above recommended residual levels to correct forks. Thinning stands heavy to sugar maple prior to 40 years of age or below recommended stocking levels will cause forks to increase in size and increase the time required for correction.

Grading systems are established classifications based on the quality, use, or value of lumber, trees, or other forest products. These classifications vary regionally and over time. Log grade is a classification based on log quality, use, and value. Veneer grade is the highest grade of logs which are used for slicing or peeling thin sheets of wood from logs. Tree grade is a quantitative measure of stem quality and log potential using exterior characteristics of standing trees. The tree grade system developed by Hanks (1976) is often utilized as a standard measure for timber product stem quality though, numerous other grading systems exist.

Table 40-7 Hardwood Tree Grades For Factory Lumber (Hanks 1976)

Grade factor	Tree grade 1			Tree grade 2		Tree grade 3
Length of grading zone (ft)	Butt 16			Butt 16		Butt 16
Length of grading section (ft)	Best 12			Best 12		Best 12
DBH, minimum (in)	16			13		10
Diameter, minimum inside bark at top of grading section (in)	13	16	20	11	12	8
Clear cuttings (on best 3 faces)						
Length, minimum (ft)	7	5	3	3	3	2
Number on face (maximum)		2		2	3	Unlimited
Yield in face length (minimum)	5/6			4/6		3/6
Cull deduction, including crook and sweep but excluding shake, maximum within grading section (percent)	9			9		50

All timber management systems and thinning regimes in northern hardwood management focus on the recognition, development and selection of high quality, future crop trees. The process of crop tree selection and management is described for both timber and non-timber crop trees in Chapter 24, Marking Guidelines. The following characteristics are identified for selecting the ideal potential timber crop trees as adapted from The Lake States Manager's Guide for Northern Hardwoods (USDA Forest Service 2005, in prep.):

- Dominant or co-dominant
- Low Risk
- Good crown vigor
- At least one 16-foot butt log
- Potential for Grade 2 or better
- Desirable species (landowner objectives)
- Good form
- No low forks or high "V-shaped" forks (see FHP Table 2)

Single Tree Selection

Uneven-aged management using single tree selection is the preferred silvicultural system for the long-term production of shade tolerant species. Single tree selection is most applicable on mesic sites. Single tree selection produces greater board-foot volume production and yields longer, higher quality, clear boles than even-aged management, and provides a permanent cover of large trees (Erdmann 1986). Long term use of single tree selection may lead to a greater preponderance of shade tolerant species such as sugar maple and beech. Recruitment of regeneration within single tree selection occurs by creating openings or "canopy gaps" in the stand. Canopy gaps for regeneration (25-75' diameter) are created when large crowned trees or groups of trees are cut. Recognize and clean these gaps by cutting all poor quality stems greater than 1" DBH. Variation in canopy gap size (Table 40.8) can promote a greater diversity of mid-tolerant species (Strong 1998, Webster and Lorimer 2005). Uneven –aged stocking and stand structure recommendations for sustained yield of high quality products have been tested and verified through long term, replicated, research studies (Eyre and Zillgitt 1953, Arbogast 1957, Crow *et al.* 1981, Strong *et al.* 1995).

In each stand entry, using single tree selection, trees are harvested and regeneration is encouraged by establishing canopy gaps. The recommended residual stand structure (Arbogast 1957) is presented in Table 40-10. Once northern hardwood stands have reached an uneven-aged condition, with three or more distinct age-classes, the following recommended guideline should be adhered to when using single tree selection (adapted from Arbogast 1957 and USDA Forest Service 2005 in preparation):

- Follow basal area guidelines (Table 40.10). Recognize current and target structures. Recognize at least three sawtimber size classes.
- In overstocked size classes, cut the poorest trees to obtain the recommended density and to release timber crop trees. Follow the recommended order of removal (also see chapters 23 and 24):
  1. Risk – Cut high risk trees that are likely to die between cutting cycles.
  2. Release crop trees – Cut poorer quality competitors to provide crown growing space around 40-60 crop trees per acre to promote growth and quality development. Two-sided release in sawtimber sized trees and full release in pole and sapling sized trees.
  3. Vigor – Cut low vigor trees, based on crown size and condition, crown class, and potential stem decay.
  4. Stem form and quality – Cut poorly formed stems, based on usable log length and potential decay.
  5. Undesirable species (determined by landowner objectives)
  6. Improve spacing
- In understocked size classes, remove only high risk trees. To compensate for understocked size classes, additional basal area must be left in other size classes to meet the recommended 84 sqft/acre total.
- Repeat cutting on 10-15 year intervals (depending upon volume requirements for operability).

Group Selection

The group selection regeneration method in northern hardwood is appropriate for promoting a higher preponderance of species mid-tolerant of shade including yellow birch, ashes, oaks, basswood, red maple, white pine, and black cherry. This method tends to promote increased species diversity in northern hardwoods as compared to single tree selection. Group selection is useful over a wide range of site quality from dry-mesic to wet-mesic and nutrient medium to rich. Groups of trees are selectively or systematically removed to create medium sized gaps (Table 40.8) in the canopy of hardwood stands ranging up to approximately 0.5 acres in size (per Chapter 21, Natural Regeneration Methods, page 21-14). Factors affecting the size of the opening include stand management objective, structure, quality, vigor, and shade tolerance of desired regeneration species. The larger the group selection area the greater the potential representation of mid-tolerant and intolerant regeneration. Group patches often require site preparation and release of preferred species of regeneration from competition. The number of groups and rotation length are dependent upon the landowner objectives and the size of the area being managed. In application, group openings are cleaned of all non-crop tree stems down to one inch in diameter. Groups of trees cut to create openings are those of poorest stem form, vigor and quality or are at rotation age. Consider location of gaps relative to existing advanced regeneration or in relation to where there is need for developing regeneration within the stand. During group opening creation, thinning and crop tree release occurs throughout the remainder of the stand. On steep topography, group selection may occur without intermediate commercial thinning throughout the remainder of the stand, due to the limitations of harvesting equipment and to minimize damage to residual stems. Group selection can be difficult to manage, and is more expensive than single tree selection because site preparation and release typically are required.

Shelterwood

Even-aged management, using the shelterwood method, is preferred for the production of greater representation of less shade tolerant species such as yellow birch, ashes, oaks, basswood, red maple, white pine and black cherry (Erdmann 1986). Even-aged management is most applicable on mesic to dry-mesic, nutrient medium sites. Even-aged management may also be utilized in areas of steep topography where single tree selection harvesting is limited by equipment operability restrictions. While stands are maturing, intermediate even-aged thinning guidelines should be followed (see below). Stand rotation is based on landowner objectives, species present, site quality, and tree vigor and stand condition, and requires the presence of adequate established regeneration (see rotation length section). Regeneration is usually accomplished using a two-step shelterwood. Initial harvesting will provide for proper crown closure and tree spacing depending on the preferred regeneration species composition. Leave a high, uniform crown cover of 60-70% in the residual shelterwood overstory. Consider timing of the shelterwood cut and site preparation operations relative to the production of good seed crops. Site preparation is generally recommended when an increased amount of light-seeded species and oaks are the species preferred to be regenerated. Site preparation can be accomplished via mechanical or chemical methods, prescribed burning, or a combination of these techniques. The intent is to provide a moist, mixed seedbed of mineral soil and humus in addition to reducing competition. Complete the final removal of the shelterwood overstory and release established regeneration using the overstory removal methodology described below (typically 3-5 years following the seeding cut).

Overstory Removal

Overstory removal is an even-aged management system whereby all or a portion of the stand canopy is harvested, thereby placing established, advanced regeneration in a “free to grow” position. Sufficient established regeneration is required prior to overstory removal. Hardwood regeneration is considered established when regeneration reaches a height of 2-4 feet. Sufficient established regeneration of 2,000 to 5,000 stems per acre or more is optimum prior to considering overstory removal. No more than 20% crown closure of residual overstory is recommended for non-timber landowner goals without a reduction in growth of the regeneration. Overstory removal operations should be conducted during the winter or fall during non-growing season and preferably with frozen or dry soil conditions in order to minimize the damage to the regeneration. Overstory removal is conducted typically when the canopy is at or near rotation age or in degraded stands with adequate advanced regeneration.

Even-aged Thinning

When thinning stands, determine which trees to favor (future growth) and which trees to cut by following the recommended order of removal (also see chapters 23 and 24):

1. Risk – Cut high risk trees that are likely to die between cutting cycles.
2. Release crop trees – Cut poorer quality competitors to provide crown growing space around crop trees to promote growth and quality development.
3. Vigor – Cut low vigor trees, based on crown size and condition, crown class, and potential stem decay.
4. Stem form and quality – Cut poorly formed stems, based on usable log length and potential decay.
5. Undesirable species (determined by landowner objectives)
6. Improve spacing

Pole size stands (Avg. DBH 5-11”) (adapted from Erdmann 1986):

- Don’t thin stands dominated by sugar maple until at least 40 years of age to prevent setting low merchantable log heights
- Full crown release (approximately 7’) of 40-100 crop trees per acre. Leave an adjacent tree crown to shade and correct small forks (<2”) if needed.
- Thin through remaining stand following the order of removal.
- If first thinning and average DBH 5-9 inches then reduce stocking level to 80% crown cover and wait 20 years until crown closure and lower branch mortality on crop trees before the next thinning.
- If second or later thinning or if DBH >9”, then reduce stocking level to 90% crown cover and wait 10-15 years until crown closure and lower branch mortality on crop trees before the next thinning.

Sawlog size stands (Avg. DBH >11”) (adapted from Erdmann 1986):

- Partial crown release (1-3 sided) of 40-100 crop trees per acre (see Chapters 23 & 24)
- Thin through remaining stand, following order of removal, to stocking level at 90% crown cover
- Wait 10-15 years for next thinning

Release

Release treatments may be implemented in young stands of northern hardwoods to enhance growth on potential crop trees and to eliminate competition from undesirable species. Release from side competition should not be conducted where the majority of the stems are of opposite-branched species (maples and ashes) due to the increased potential for reduced clear bole lengths (Godman, R.M. in Hutchinson, ed. 1992). Increased bole lengths can be achieved with natural pruning due to increased stem density. Release of yellow birch can significantly improve growth and survival in young (10-20 year old) even-aged stands (Erdmann and Peterson in Hutchinson, ed. 1992). Crown release at age 10 should focus on 100 crop trees per acre providing for 5 feet between crowns (or 8 feet between boles) while leaving side competition for potential crop trees that are forked. If crown release occurs at age 20 the spacing between crowns should be increased to 7 feet on 75 to 100 potential crop trees per acre. Stump sprouts should be thinned early before potential crop trees reach 3 inches in diameter. Leave one to two sprouts per clump, as widely spaced as possible. Individual sprout characteristics to favor include: low sprouts originating less than six inches above ground, U-shaped stem attachment, well developed crown, large size, good form, and healthy (Godman, R. M. in Hutchinson, ed. 1992).

Conversion, Even-aged to Uneven-aged

Stands that are even-aged or two-aged may be converted to uneven-aged management by combining crop tree release, thinning, and canopy gap formation techniques. Crop tree release enhances growth and crown development on potential crop trees. Stem quality is controlled by upper crown development in individual trees and by shading from adjacent crowns of main canopy trees. Many even aged stands have closed canopy conditions, which prevent or limit the establishment and development of new regeneration. Installing canopy gaps will create proper growth conditions for regeneration and recruitment. The recommended procedure to convert even-aged stands to an uneven-aged structure is (adapted from Argonne Experimental Forest studies, USDA Forest Service 2005, and Erdmann 1986):

1. Crown release 40-60 crop trees per acre. Pole sized crop trees should receive a 4-sided, 7' crown release. Sawtimber sized crop trees should receive a 1-3 sided crown release (see chapters 23 & 24).
2. Create canopy gaps for regeneration on approximately 10% (range of 5-15%) of the area at each entry. Canopy gaps can range in size from 30 to 60 ft. in diameter. The percentage of area in regeneration gaps is based on the frequency and size of gaps. Recommended targets for gap numbers and size are 4, 35' gaps per acre (9% of stand area) or 6, 30' gaps per acre (10%). Occasionally, larger gaps can be included to encourage the representation of mid-tolerant species (e.g. 1, 35' gap and 1, 60' gap occupy 9% of an acre). See the following discussion on Canopy Gaps for Regeneration and Table 40.8. Gaps should be created by cutting groups of high risk or relatively poor quality stems. Within the gaps all poor quality stems >1" DBH should be cut to facilitate vigorous regeneration.
3. Apply even-aged thinning guidelines to the remainder of the stand; follow the order of removal.
4. Wait 15 to 20 years for the next entry. To facilitate the development of timber quality, the next cut should not be implemented until after crown closure and lower branch mortality occurs in crop trees.
   - If stand is predominantly pole to small sawtimber sized, then repeat the conversion process.
   - If stand is predominantly medium to large sawtimber sized, then apply target structure for uneven-aged single-tree selection guidelines. It is necessary to compensate for understocked size classes by maintaining stocking in other overstocked size classes to meet the total target goal of 84 sqft/acre.

It will probably require at least 3-4 cutting operations to develop a relatively well regulated and fully stocked (by size class) uneven-aged stand.

Canopy Gaps for Regeneration

For uneven-aged silvicultural systems and conversion methods, canopy gaps that facilitate regeneration should be established at each entry. Canopy gaps >25 feet diameter are created when single large-crowned trees or groups of trees are cut. Smaller gaps usually close quickly through crown expansion of dominant and codominant gap border trees and may reduce the recruitment of regeneration into the canopy (Goodburn 2004, Webster and Lorimer 2005). To facilitate the establishment of high quality, vigorous regeneration, these regeneration gaps should be cleaned of all poor quality stems >1 inch DBH. Regeneration gaps should be established on approximately 10% (range of 5 to 15%) of the stand area at each entry.

Table 40.8 Circular Canopy Gap Sizes for Regeneration in Northern Hardwoods (NH)

Diameter (feet)	Area (acres)	Considerations
25	0.011	Minimum gap size – favors the most shade tolerant species
30 - 40	0.016 – 0.029	**Recommended** standard gap for single-tree selection and conversion. Typical crown area of 18-26" dbh sugar maple trees (see Table 40.17).
50 - 60	0.045 – 0.065	**Recommended** gap for canopy recruitment of mid-tolerant species
66	0.079	Maximum gap size for single-tree selection in NH
75	0.101	Small group selection. Potential for increased shrub competition. Consider site preparation and release needs.
118	0.251	Group selection (consider site preparation and release)
167	0.503	Maximum size for group selection

Smaller regeneration gaps generally favor shade tolerant species (sugar maple, beech, hemlock). Larger gaps, site preparation, and preferential release can favor mid-tolerant species (e.g. yellow birch, white ash, oak). Site preparation may also be needed to reduce undesirable competing vegetation.

Some example gap distributions by number per acre and size are:

- 6, 30’ gaps per acre occupy 10% of the stand area
- 4, 35’ gaps per acre occupy 9% of the stand area
- 2, 35’ gaps and 1, 55’ gap per acre occupy 10% of the stand area
- 2, 30’ gaps and 1, 60’ gap per acre occupy 10% of the stand area

Distance between gaps is dependent upon existing stand matrix conditions and factors such as stand density, stem diameters, tree quality, and location of any existing gaps or advanced regeneration.

Managing “Degraded” Stands

Many stands throughout Wisconsin have been “degraded” or reduced in stand quality due to a multitude of factors including grazing, poor harvesting techniques, high-grading, fire, and other biotic and abiotic agents (disease, insects, wind, ice). Many of these stands have either an abundance of poor quality stems or some poor quality larger diameter stems overtopping a younger stand (poles, saplings or seedlings) containing potential crop trees.

Thorough stand assessment is required to determine the site quality, species composition, stand age, stand structure, number of potential crop trees, and management potential. If a minimum of 40 well-distributed, potential crop trees per acre exist the stand can be managed for northern hardwoods using even-aged or uneven-aged systems. Crop trees should not be damaged in the process of harvesting larger diameter, poor quality, or low value residual trees. If less than 40 potential crop trees per acre exist and natural regeneration is lacking, the stand could be allowed to reach seed bearing age and then follow the process to conduct a two-step shelterwood to regenerate a new stand. If adequate established regeneration is present, then follow the guidelines for Overstory Removal. Depending on present species composition and the landowner’s objectives, the stand could be considered for artificial regeneration following generally accepted practices (Chapters 21 & 22).

Managing NH Stands on Poor Quality Sites:

Relatively poor sites for northern hardwood management for the production of quality sawtimber typically include sites with site index less than 50-55. Typical habitat type groups are dry-mesic and wet-mesic, nutrient medium. Many of the recommendations and research on northern hardwood management are based on studies conducted on good to very good quality sites at the Argonne and Dukes Experimental Forests. Tables and charts developed on those sites may not apply as well on poorer quality sites.

On these sites, if continued northern hardwood management is the goal, consider even-aged management to encourage increased representation of mid-tolerant associates. These species generally offer greater potential growth and timber quality on these sites. Alternatively, group selection methods with larger patch sizes (up to 0.50 acres) may provide an uneven-aged system, which facilitates the inclusion of mid-tolerant species. Group selection on these sites would require site preparation and release to achieve adequate regeneration of mid-tolerant species. Single tree selection may be applied, but will result in the predominance of shade tolerant species, slower growth and reduced timber quality.

MANAGEMENT ALTERNATIVES

Stand structure stocking goals may be varied for changes in desired maximum tree diameter size class to better meet specific landowner goals. The recommended stand stocking developed by Arbogast (1957) has proven to be sustainable over time through numerous field replications to produce high quality and quantity of northern hardwood sawtimber. The maximum tree diameter size class in the Arbogast structure is 24-plus inches DBH. Stand structures for maximum tree diameter size classes of 18 to 30 inches DBH are alternatives to better meet some specific landowner goals. The 18” alternative may provide improved results on some measures of economic performance or as an alternative uneven-aged target structure for poorer quality sites. The 30” target structure may provide enhanced benefits for aesthetics, habitat for certain species of wildlife, and biodiversity. Structures for maximum tree diameter classes of 18”, 24”, and 30” are identified in Table 40-11. Further discussion is found in the section entitled Rotation Lengths and Cutting Cycle Intervals.

KEY TO RECOMMENDATIONS

Note: The following recommendations assume the management objective is to maximize quality and quantity of northern hardwood sawlogs and the site has the potential for fair to excellent northern hardwood growth as identified by habitat type(s) and/or site index. For degraded stands or stands on poor quality sites see previous discussion.

A. Seedling and sapling stands, established and well stocked:

1. Management objective: encourage sugar maple	**Release** if overtopped, otherwise wait until 40 years of age (seed bearing age and merchantable size) and follow poletimber instructions
2. Management objective: encourage mid-tolerant species	**Release** (promote crop tree development)

B. Poletimber and sawtimber stands:

1. Even-aged or two-aged stand	**2**
1. Uneven-aged stand	**11**
2. Management objective best achieved by even-aged management (encourage mid-tolerants)	**3**
2. Management objective best achieved by uneven-aged management	**8**
3. Poletimber	**4**
3. Sawtimber	**5**
4. Not previously thinned	Follow **thinning** directions – thin to 80% crown cover Wait 20 years
4. Previously thinned	Follow **thinning** directions – thin to 90% crown cover Wait 10-15 years
5. Small sawtimber (11-15" DBH)	Follow **thinning** directions – thin to 90% crown cover Wait 10-15 years
5. Large sawtimber (>15" DBH)	**6**
6. Not at desired rotation age	Continue to follow **thinning** directions until rotation age is attained – thin to 90% crown cover, wait 10-15 years. Final thinning should occur 10-20 years before rotation
6. Desired rotation age attained	**7**

7. Adequate stocking of desired advanced regeneration established	Apply **overstory removal** regeneration method
7. Inadequate stocking of desired advanced regeneration established	Apply **shelterwood** regeneration method
8. Poletimber	**9**
8 Sawtimber	**10**
9. Not previously thinned	Follow **conversion** directions (thin to 80% crown cover and create gaps) Wait 20 years
9 Previously thinned	Follow **conversion** directions (thin to 90% crown cover and create gaps) Wait 15-20 years
10. Small sawtimber (11-15" DBH)	Follow **conversion** directions (thin to 90% crown cover and create gaps) Wait 15-20 years
10. Large sawtimber (>15" DBH)	Follow **conversion** directions (thin to 90% crown cover and create gaps) Wait 15-20 years
11. Management objective best achieved by even-aged management	Apply **shelterwood** regeneration method
11. Management objective best achieved by uneven-aged management	**12**
12. Management objective is uneven-aged to encourage significant representation of mid-tolerant species	Follow **single tree selection** regeneration method with larger gaps or group selection directions. Consider site preparation and release.
12. Management objective is uneven-aged to encourage predominance of tolerant species	Follow **single tree selection** regeneration method and recommended stocking guide(24" max. tree size) or alternative (18-30")

ROTATION LENGTHS AND CUTTING CYCLE INTERVALS

Even-aged Management

In even-aged silvicultural systems the rotation is defined as the period between regeneration establishment and final cutting. The length of rotation may be based on many criteria including culmination of mean annual increment, mean size, age, attainment of particular minimum physical or value growth rate, and biological condition. Ideally, the lower end of the rotation length range would be defined by the age at which maximization of mean annual increment (MAI) growth occurs. The upper end of the rotation length range would be defined by the average stand life expectancy. However, very little objective data exists identifying these endpoints in general and even less by site type.

Northern hardwoods are usually managed to produce sawtimber on sites (see Tables 40.2 and 40.4) where relative potential productivity is good to excellent (sugar maple SI>60). The recommended even-aged rotation to balance high quality development, high growth rates (vigor), and economic risk is 80-120 years. Rotations up to 150 years can be considered (on excellent sites), but volume growth rates may decline and economic risk will increase. On poorer sites (sugar maple SI<55), recommended rotation ages may be somewhat shorter (80-100 years, up to 120 years) however, expect reduced quality, reduced growth rates, and increased mortality. Individual trees and stands may maintain vigor longer or decline earlier than these rotation length guidelines indicate. In application, foresters will need to regularly review stands in the field and exercise professional judgment concerning quality, vigor, mortality, and merchantability. The numbers provided are based on general data, empirical evidence, and the best estimations of the authors and other contributors.

Uneven-aged Management

Uneven-aged management rotates individual trees rather than stands of trees. Individual tree rotations depend on stand stocking by size (proxy for age) class. Individual trees are removed from each overstocked size class to achieve the desired level of stocking. When selecting which trees to remove within each diameter class, the primary factors considered are tree risk, vigor, quality, and spacing. Trees with small crowns are thinned; resulting canopy openings will be filled by adjacent competitors. Trees with large crowns are rotated; resulting canopy gaps will be captured by suppressed trees or new regeneration.

The selection of the appropriate stocking guide and cutting interval depends on site quality, species, growth rates, operational considerations, and landowner goals. Where management goals attempt to achieve an optimal balance of sawtimber quality and quantity, the 24-plus inch maximum size class stocking guide is recommended (Table 40.10). The stocking guide based on an 18-plus inch maximum size class (Table 40.11) provides an alternative for poorer sites or for specific economic scenarios and goals (e.g. desired products, economic risk, product flow, market considerations). If stocking in the maximum diameter class is too low or other poorer quality trees are present, then the vigorous, low risk, high quality trees should be retained even if well beyond the maximum diameter.

In stands managed under uneven-aged management, the cutting cycle re-entry interval generally ranges from 8 to 20 years based on landowner objectives, site quality, and growth. Shorter cutting cycles can maintain higher tree growth rates but operability (costs and benefits) must be considered. Shorter, more frequent re-entries may increase the potential for degrading stand quality through stem damage and soil compaction. Conversely, shorter cutting cycles will allow for capture of more high risk and low vigor trees succumbing to mortality. Longer cutting cycles can maximize tree quality and reduce negative impacts, such as damage to residual trees, soil compaction, aesthetic impacts (e.g. reduced slash), and ecological impacts (e.g. habitat disruption).

Extended Rotations

Management goals for extended rotations attempt to balance economic, social, and ecological management goals. While timber production is still an important value, increased emphasis is placed on other values, such as aesthetics, wildlife habitat, and biodiversity. In northern hardwoods, extended rotations are most compatible with uneven-aged management. Appropriate stocking guides can utilize a 24-plus to 30-plus inch maximum tree size class (Table 40.11). Longer cutting cycles generally would be appropriate. Additional ecological management techniques will be applied, such as the retention of reserve trees, management of coarse woody debris (large snags and downed rotting logs), and the encouragement of coniferous associates (especially hemlock and white pine).

MANAGEMENT CONSIDERATIONS

Operational Considerations and Maintaining Soil Productivity

Managing northern hardwoods presents some unique operational considerations for implementation of silvicultural prescriptions and to maintain soil productivity and stand quality. The need for accurate stand assessments is essential in managing northern hardwoods. Site productivity, stand quality, stand structure, and stand composition all are important diagnostic measures. Silvicultural practices must be properly seasonally timed and implemented to prevent losses in soil productivity and reductions in stand quality. Care must be taken to prevent degradation to habitats of endangered, threatened, or species of special concern and cultural resources while implementing silvicultural prescriptions.

Assessing site productivity can be achieved through the evaluation of the Forest Habitat Type Classification System (FHTCS), soil site analysis, or through determination of site index. The FHTCS provides qualitative site productivity assessment and limited quantitative productivity data. The use of the FHTCS is limited to the period of active understory vegetation growth. Habitat types may be estimated during non-growing seasons using correlation with soil types and landforms, but these methods are less accurate than direct field determination. Broad-scale quantitative site productivity correlation with FHTCS is available through analysis of Wisconsin FIA data (Kotar *et.al.* 1999). For more detailed discussion on FHTCS see Chapter 12.

Accurate assessment of site index is another method of determining site productivity. Site index and stand age determinations are important factors in even-aged management of northern hardwoods. Northern hardwoods present challenges for accurate site index determination because of the difficulty in reading increment cores from diffuse porous species and in determining trees that were not previously suppressed. More precise determination of tree age, height, and site index may be accomplished through felling of representative trees (USDA Forest Service 2005). Additional discussion on site index considerations and proper measurement can be found in Chapter 11.

Stand composition and structure assessment can be attained by various inventory procedures. Individual tree species and diameters should be tallied when using either fixed-radius or the more common variable-radius inventory plots. An example variable-radius plot tally sheet to determine species composition and stand structure by size class is provided in Table 40.16. Other similar tally sheets and methods exist. The number of current and potential crop trees per acre should also be tallied.

Residual crown cover or crown closure is an important factor when implementing even-aged shelterwood seeding cuts. One method to assess residual crown cover is to utilize fixed area plots and tally crown areas of individual trees. Tree crown areas vary due to a variety of influences and past disturbances such as weather related events, fire, and root damage. Average tree crown areas by species and DBH for northern hardwoods are listed in Table 40.17. Included with Table 40.17 are instructions for a sample shelterwood marking exercise using fixed area plots to determine residual crown areas (USDA Forest Service 2005). Another tool to visually measure crown cover is a densiometer. Both spherical and flat densiometers use a grid-layout on a mirrored surface. Densiometers are used by counting the number of grid-cells occupied by reflected crowns. Densiometers are most effective when used during leaf on conditions.

Marking of individual stems often is required to appropriately implement either intermediate treatments or regeneration harvests in northern hardwood stands. Trees may be marked for removal or marked for retention depending upon the silvicultural system and prescription. Marking for removal is generally preferred in single tree selection, group selection, conversion, and thinning practices whereas marking to leave is generally applied in shelterwood harvests and when reserving trees. The marking should be on two sides of the boles of the trees to improve the visibility of the marks from all angles. This procedure will improve marking efficiency and enhance felling by either manpower or machinery thus reducing potential damage to residual stems. Improved felling technique can enhance residual stand quality. Clearly defined marking guidelines should be developed prior to implementation as outlined in Chapter 24.

Harvesting practices need to be properly implemented when timber products are to be removed from a stand of northern hardwoods. Poor skidding technique and seasonal timing can reduce residual stem quality, root health, and soil productivity. Damage to roots from skidding can lead to sapstreak in maple. Damage to the bole and branch breakage leads to reduction in log quality, grade, and potential decay. Harvesting when trees are actively growing can result in increased numbers and size of defects on residual stems as the bark is more easily damaged at this stage. Degrade of high value log products in some species such as sugar maple and basswood can occur due to staining of those products cut during the same time period.

Northern hardwoods frequently occur on finer textured soils on which vehicle travel can result in soil compaction. Soil compaction and rutting have been shown to decrease seedling and sapling growth in many forest types although specific effects depend on soil type and moisture content (NCASI 2004). The total area devoted to landings, roads, and trails should be minimized to limit the loss of productive area. Pre-planned skidding routes and landing areas should be used to limit the total area affected by vehicle travel and skid trails should be re-used in future entries wherever possible. Road layout guidance such as that found in the Wisconsin Forest Management Guidelines (WDNR 2003) should be used to minimize impact on hydrology and limit erosion and sedimentation. Harvesting when the soil is frozen or dry can reduce compaction. Increasing the interval for re-entry into stands may partially mitigate the effects and reduce the occurrence of compaction and rutting, although soil compaction is not readily ameliorated and effects can persist for several decades (NCASI 2004).

Vernal Pools

Where northern hardwoods grow on finer textured soils and/or somewhat poorly drained soils, inclusions may be found where seasonal ponding of water occurs. These ponds are called “vernal pools” (Rogers and Premo 1997). Vernal pools are characterized as small, seasonal, ephemeral, pools or ponds that lack predatory fish (Colburn 2004). Due to the lack of predators, these pools are important areas for amphibians and invertebrates to reproduce. The actual size used as definitional criteria of these “small” pools is debatable. Rogers and Premo described size range of vernal pools as “from a puddle to an acre or more.” Vernal pools contain species of aquatic flora and fauna not found throughout the terrestrial matrix of the remaining stand of northern hardwoods. The frequency and distribution of vernal pools are of importance to their function in maintaining or enhancing biodiversity. Some vernal pools should be buffered to protect amphibian foraging and breeding habitat. Harvesting should avoid felling trees into or skidding through these vernal pools and avoiding rutting in the nearby vicinity. These areas should be delineated in some manner prior to beginning harvesting. Vernal pools may not be apparent at certain times of the year due to their ephemeral nature and the lack of standing water or during periods of snow cover.

Wildlife Attributes

Northern hardwood comprises the highest acreage of the northern forest and management decisions affecting stand composition will also affect wildlife use. Maintaining and enhancing the assemblage of wildlife species in the northern forest depends on maintaining a healthy and diverse forest system. The five tree species that define the northern hardwood type provide a variety of benefits to wildlife. Associated tree and shrub species in northern hardwood stands also provide important wildlife benefits. There has been a trend toward greater dominance of sugar maple in the northern hardwood type. This simplification of the type can have negative consequences for wildlife dependent on a diversity of plant species.

Diversity of tree species and structure in the northern hardwood type contribute to the utility of the type for forest wildlife. Vertical structure, the arrangement and quantity of multiple layers in the forest, is of great importance. The forest floor, shrub layer, and sub-canopy along with associated tree species in the canopy contribute as much to wildlife use in the northern hardwood type as do the tree species definitive of the type. The potential for development of cavity trees and coarse woody debris in this type adds to the potential for wildlife use of the type. Harvesting systems appropriate to the northern hardwood type can be conducive to protection of sensitive natural features such as vernal pools, seeps, riparian areas, and microhabitat features such as rock faces.

Ground flora can be affected by silviculture. Studies of changes in ground flora following forest management activities in northern hardwoods are few. Some existing results show initial increases in diversity and coverage (see summaries in Roberts and Gilliam 2003) that are largely due to responses of common species (Crow *et al*. 2002). Some ground flora found in northern hardwood stands are light-sensitive and benefit from the shading provided by a closed canopy. Some of these plants are rare and management actions to protect them should be followed. Even-aged management techniques could be expected to have a greater impact on some sensitive forest interior herbs than uneven-aged techniques. Litter found on the forest floor that can be disturbed by harvesting activities can provide important wildlife benefits. However, some ground layer plants benefit from moderate disturbance and increased sunlight. Opening the canopy through harvesting techniques that provide a variety of different sized canopy gaps may help encourage a diversity of ground layer plants.

The shrub layer provides foraging and nesting opportunities. It also will increase the use of some mature stands by species more commonly found in early-successional habitats. This component of the vertical structure of a stand can be provided both by shrubs and by tree regeneration. Silvicultural techniques providing light penetration will help in the development of the shrub layer. Conifer species in the understory can be of particular importance to many wildlife species. This is best illustrated in increases in nesting by some neotropical migrant songbirds though many other wildlife species use conifers.

Diversity of tree species in the sub-canopy and canopy will increase wildlife use of a stand. Retention of yellow birch, ash, and associated mid-tolerant tree species in sugar maple stands is desirable. If oak is present, it will contribute greatly to wildlife use of the stand and should be maintained. Conifers, particularly hemlock and white pine, should be retained.

The management objective for optimum quality sawlogs lends itself to producing large trees and many Wisconsin wildlife species take advantage of these large trees. Uneven-aged management can create a diversity of conditions for a variety of niches. Because a wide variety of tree sizes are available in stands managed under uneven-aged regimes, cavities and den trees can accommodate the full range of cavity-using wildlife species

Amphibians are well represented in the northern hardwood type. Coarse woody debris and litter on the forest floor helps maintain amphibian populations. Vernal pools provide productive breeding areas due to the absence of fish. Those pools with thick moss that may harbor four-toed salamander need special management in and around the site. Pools with wood frogs and other salamanders can actually increase productivity if they are opened to sunlight, as long as the surrounding land contains coarse woody debris. These pools also contribute microhabitat diversity and they should be protected to prohibit harvest operations within the basin of these small wetlands. Retention of dead or dying trees is important to promote the recruitment of coarse woody debris in the future. Compaction of the litter and soil in the vicinity of vernal pools should be avoided.

According to Robbins (1990), 66 species of Wisconsin birds use northern hardwood forests for breeding habitat. An additional 11 species use this habitat when a conifer component is found in association with the northern hardwood species. Representatives of most guilds with the exception of grassland and wetland species can be found in some developmental stage of the northern hardwood type. The northern forest of Wisconsin is an important source breeding area for many species of songbirds declining in other portions of the species' ranges. Because the northern hardwood type is found throughout Wisconsin, some southern species are included in the list of breeding birds. Because these southern species reach the northern extent of their range in Wisconsin, conservation of their breeding habitat might be considered particularly important. Cavity-nesting birds are particularly well represented in the northern hardwood type.

Mammals using the northern hardwood cover type range from shrews and bats to black bears. Though higher populations of game animals can be found in other cover types, the northern hardwood type contributes habitat for deer and elk. Horizontal and vertical structural diversity can be great in the northern hardwood type. Uneven-aged management creates the possibility of developing significant amounts of coarse woody debris utilized by a variety of forest wildlife.

Because of the opportunity for long rotations and the development of large trees, use of northern hardwood stands by cavity-using wildlife is an important feature. Many large-bodied cavity-using wildlife and some colonial roosting species use cavities in trees 18" or greater in diameter. Examples include pileated woodpecker, turkey vulture, fisher, several bat species, and black bear.

Even-aged harvest systems in the northern hardwood type resulted in many of the stands we currently manage. Northern hardwood regeneration following a clearcut or shelterwood can provide many of the habitat requirements of early-successional dependent wildlife. Even-aged management may also help increase the representation of the less tolerant northern hardwood associated tree species in areas where dominance of sugar maple is a concern.

Habitat management for wildlife in the northern hardwood type should capitalize on the diversity possible in the type. The five major tree species definitive of the northern hardwood type as well as the variety of associates found in the type provide many options for wildlife. Tree species diversity should be encouraged within stands when possible. Habitat types and species assemblages dictate the extent to which this is possible but silvicultural techniques to promote diversity should be followed. Structural diversity can be encouraged through a variety of potential management and regeneration techniques.

A variety of canopy gap sizes to allow for the development of vertical structure within the stand should be included in cutting prescriptions if wildlife production is a goal. Retain as much diversity of tree species as possible within northern hardwoods. Trees such as yellow birch and hemlock are particularly important. Large trees, cavity trees, and snags all provide important wildlife habitat attributes and should be retained. Microhabitats within the northern hardwood type can contribute disproportionately to wildlife populations and diversity. These features should be identified and protected. Land managers working in the type should be particularly sensitive to wetland features, rock outcrops, and populations of sensitive plants.

Summary of Recommendations:

Encourage Habitat Diversity

- Tree species diversity especially mid-tolerants and conifers
- Current and future cavity trees
- Current and future snags
- Downed woody debris
- Large trees
- Vertical structure
- Horizontal structure (variety of stand/patch sizes)
- Variety of age-classes (a variety of gap sizes will contribute)

Protect special features

- Wetland features including vernal pools, seeps, and riparian areas
- Populations of rare plants or animals
- Topographical features such as cliff faces or rock outcrops

Endangered, Threatened and Special Concern (ETS) Species Considerations

Most typical northern hardwood management would not affect Endangered Resources (species listed in the Wisconsin Natural Heritage Inventory [NHI] Working List). However, in cases where ETS species are found in northern hardwoods they may be affected by excessive canopy removal. Many ETS species have habitat requirements that need moist environments protected from the direct sunlight of mid summer and the desiccating effects of wind. Seventy-two species on the NHI working list occur regularly in northern hardwood stands.

Several species, which are found in a variety of habitats, use northern hardwoods primarily for foraging. Several other species use northern hardwoods as breeding habitat, but also use many habitats. Several species are found only in northern hardwoods.

Wide-ranging species that utilize northern hardwoods for foraging:
Timber Wolf *Canis lupis,* Northern Myotis *Myotis septentrionalis,* Eastern Pipistrelle *Pipistrellus subflavus,* Woodland Vole *Microtus pinetorum,* Arctic Shrew *Sorex arcticus,* Pygmy Shrew *Sorex hoyi,* Water Shrew *Sorex palustris,* Bobcat *Lynx rufus,* Great Gray Owl *Strix nebulosa,* Cooper's Hawk *Accipiter cooperi,* and Rhinoceros beetle *Xyloryctes jamaicensis.* The remaining species use northern hardwoods as breeding sites and can be more directly influenced by stand management decisions.

Certain rare and uncommon plant species (not all are ETS listed species) are associated with mesic interior hardwood forests. Some of these plant species are poorly adapted to increased light and desiccation and their response to disturbance is unknown; they may grow and mature slowly, produce few propagules, disperse only short distances, or require a specialized pollinator (Meier *et al*. 1995). Several studies conducted elsewhere in the eastern United States indicate that some herbaceous species associated with late-successional hardwood stands may require 72 to more than 150 years to recover to predisturbance abundance and distribution after a major canopy-opening disturbance (Flaccus 1959, MacLean and Wein 1977, Duffy and Meier 1992). Matlack (1994) found that proximity to old forest was associated with the presence of shade-tolerant understory herbs in previously farmed successional oak-hickory forests, indicating that recolonization was likely important in maintaining their populations. Even-aged management techniques could be expected to have a greater impact on some sensitive forest interior herbs than uneven-aged techniques; other factors to consider include patch size, distance from potential colonists in older forest, presence of pollinators and dispersal agents, and time for population recovery before the stand is re-entered. Given the nearly complete lack of empirical information on the fate of rare and uncommon herbs in our area, research and monitoring is warranted.

The following is a list of some of the ETS species associated with northern hardwood stands, their general habitat preferences, and known locations in the state where they have been found:

Plants-

Allegheny vine *Adlumia fungosa* (special concern) – This plant has a narrow habitat niche growing on ledges imbedded in northern hardwood forests. Most records are from Door County although it could be found throughout the range of northern hardwoods. Keeping shade on the ledges would be the primary consideration. Single tree selection should accommodate the needs of this plant.

Assiniboine sedge *Carex assiniboinensis* (special concern)
Pale sedge *Carex pallescens* (special concern)
Long-spur violet *Viola rostrata* (special concern) – These grass-like sedges and the violet can be difficult to identify and may be more common than recorded. They can be found in shaded hardwoods across the range of northern hardwoods. Selection (single tree or group) harvesting in the winter is probably compatible with these species.

Blunt-lobed grape-fern *Botrychium oneidense* (special concern) – These plants of maple/basswood forest are found in moist depressions or along boggy edges. The fern seems to tolerate slight to moderate disturbance, although it still needs shade. Populations have increased in grazed woods or where ground fires have occurred. Selection harvesting including treatment of the shrub layer may enhance populations.

Braun's holly fern *Polystichium braunii* (state-threatened)
Green spleenwort *Asplenium viride* (state-endangered)
Maidenhair spleenwort *Aspenium trichomanes* (special concern)
Fragrant fern *Dryopteris fragrans* (special concern) - All four species grow on wet cliffs or rocky wet talus. All need shade and moisture to thrive. Due to the limited habitat available, most foresters will not encounter these species, however, for those that do, the management is straight forward. Keep shade on the plants and keep moisture on the roots. Special management should occur within 100 meters of the plant populations. Single trees could be removed from within the 100-meter area, but the site should be managed for shade on the rare plants rather than applying silviculture to the stand. The surrounding uplands should be managed to avoid soil drying – single tree selection and group selection would be the most compatible.

Broad beech fern *Phegopteris hexagonaptera* (special concern) – A more southerly plant, but can be occasionally found in northern hardwoods. This fern prefers sunny, more open spots in moist woods. The populations may be enhanced by selective harvest (single tree or group), if the landings and skid trails avoid most of the plants.

Broad-leaved twayblade *Listera convallaroides* (special concern) – Another plant that requires very cool soil. It is found almost exclusively on mosses or in springy areas in hardwood or hardwood/conifer areas in counties bordering Lake Superior. Single tree winter harvesting that leaves most of the canopy intact in the winter is probably compatible.

Christmas fern *Polystichium acrostichoides* (special concern)
Glade fern *Diplazium pycnocarpon* (special concern)
Mingan's moonwort *Botrychium minganense* (special concern)
Cooper's milkvetch *Astragalus neglectus* (state-endangered) – Not much is known about the habitat requirements for these species other than they grow in hardwood and hardwood-conifer forest. If the plant is found in a stand, the forester should contact the BER botanist to develop a management strategy.

Crinkled hairgrass *Deschampsia flexuosa* (special concern) – This grass is found mainly along the coast of the Great Lakes, but occasionally in northern hardwood stand on dry soils. Presumably the more dappled shade found in dry soil hardwoods would indicate a tolerance for selection harvest, but the site should be monitored.

Cucumber-root *Medeola virginiana* (special concern) – A plant found on medium nutrient soils on moraines and under beech, sugar maple and/or hemlock. This is another plant potentially affected by deer browse. Cucumber-root is affected in growth and reproductive capability by the light found in large gap edges and compaction, but increases in small gaps. The plant favors small gaps and the presence of tip-up mounds. Selection harvesting during frozen conditions with gaps limited to two tree lengths can accommodate cucumber-root.

Drooping sedge *Carex prasina* (state-threatened) – This sedge grows in wet wooded areas and along streams. Sites where the sedge is found remain wet due to springs or seeps. The plant is found primarily in the Baraboo Hills, Blue Hills, Door County and along the St. Croix River. Yellow birch and skunk cabbage are primary associates. Removal of single trees is probably acceptable, but more important is conducting forestry on the surrounding stands that does not affect the water table.

Foamflower *Tiarella cordifolia* (state-endangered) – Of the six known populations, four are on U.S. Forest Service land and two are on private land. This spring bloomer's habitat is stream banks, especially with cobble, and in ravines where cool air drainage and substrate water flow is present. Common tree associates are black ash, yellow birch, sugar maple and conifers. Primary threats are drying of the forest floor, soil compaction, garlic mustard invasion, and beaver. Suggested management on the national forest is to establish a 100-foot buffer around the population and use selection uneven-aged harvest in the surrounding uplands. The site should be monitored for garlic mustard and beaver activity.

Great toothwort *Cardamine maxima* (special concern) – The only known location is a rich deciduous forest in Ashland County. Searches for the plant should occur in from mid-May to mid-June. Single tree selection harvesting is probably compatible with this plant.

Green-leaved rattlesnake plantain *Goodyera oblongifolia* (special concern) – This evergreen rosette is mostly found in spruce-fir forest, but it does occur in hardwood/conifer stands. The plant requires very cool soil, thus it is limited to far northern Wisconsin. It is known to die after even-aged harvest. Another concern is collecting by orchid enthusiasts, which almost always dooms the plant. An appropriate strategy would be to use single tree selection harvesting during periods when snow is on the ground.

Handsome sedge *Carex formosa* (state-threatened) – This sedge grows in moist calcareous soil in deciduous woods. The plant is found only in the Northeast Region. It prefers light dappled shade and should be accommodated by light single tree selection harvesting.

Large-leaved sandwort *Moehringia macrophylla* (state-endangered) – Only two colonies of ten plants were known from the Penokee and Gogebic Ranges in 1999 down five populations from 1994. The plant lives on cliffs or mossy bluffs. Some botanists speculate that while the plant needs moisture and some shade, they may be influenced by too much shade. The known populations should have specific management plans developed for the sites.

Little goblin moonwort or Goblin fern *Botrychium mormo* (state-endangered) – This minute fern is associated with a thick (greater than 3 inches) organic horizon, also known as the O horizon or litter layer, and dense shade. Forest generally needs to be mid-aged to old, in order for this thick of an O horizon to develop. It is most commonly found in AH, AOCa, ATD, ATFD habitat types without hemlock and especially where pit and mound microtopography is found. The plant is sensitive to soil compaction and is eliminated when the litter layer is significantly reduced. The plant apparently can tolerate individual tree selection, but the effects of equipment need more research. Populations should be marked so vehicles would not travel over the plants. The affect of exotic earthworms in this species needs further research.

Male fern *Dryopteris filix-mas* (special concern) – Habitat for this fern in Wisconsin is the shade of sugar maple, ironwood or choke cherry in a rather open forest growing on 10 to 20% slopes on basalt. In other words, very limited habitat is available in Wisconsin. Management recommendations are unknown, but an adaptive management approach that incorporates light thinning around male fern populations may increase habitat availability.

Northern lungwort *Mertensia paniculata* (special concern) – The habitat is damp woods near the shore of Lake Superior. Little is known regarding species management however, moist soil appears to be most important. Consideration for maintaining water flow in surrounding stand management maybe critical.

Pinedrops *Pterospora andromedea* (state-endangered) – This parasitic plant on pine roots is occasionally found in rich humus under white pines. The plant can be found in predominately hardwood forest with a white pine component. Management recommendations are to maintain a high level of shade (single tree selection) and avoid soil compaction. These saprophytic plants depend on humus and roots to attain nutrients and may not flower every year.

Purple clematis *Clematis occidentalis* (special concern) – The plant is found on rocky, often calcareous slopes, in hardwood forest. The populations can fluctuate dramatically and are usually found on edges. Group selection next to existing populations may provide additional habitat.

Ram's-head lady-slipper *Cypripedium arietinum* (state-threatened) – This small orchid is most often found in conifer swamps, but it has also been recorded from mixed forests of maple, aspen, white birch, pines and balsam fir. The plant is mostly found in dappled shade with very little competition from understory vegetation. The key element is the presence of marl or lime-rich soils. In hardwoods, it seems to prefer a mid-succession forest that has experienced a ground fire or a balsam die-off. As with most orchids, this plant is sensitive to deer browse and soil compaction by equipment. Single tree selection or group selection harvest should be compatible if soil compaction is kept to a minimum.

Smith melic grass *Melica smithii* (state-endangered) – One known population in the Gogebic range, however conditions elsewhere on this range and the Penokee's are favorable for this species. The grass is found under sugar maples in rather dense shade. Light single tree, selection harvest would presumably be compatible with this grass.

Snow trillium *Trillium nivale* (state-threatened) - This showy flower grows in rich calcareous soils in the presence of beech/maple/basswood. Woodlot grazing is a major problem. Single tree selection is apparently compatible with this species although harvest should be prohibited from early March through late spring.

Spreading wood-fern *Dryopteris expansa* (special concern) – This fern reaches its southern distribution in Wisconsin and requires cool moist conditions for its persistence. Very limited single tree selection simulating individual tree gaps should retain this species in the stand.

White ground cherry *Leucophysalis grandiflora* (special concern) - The plant is found in sandier habitat types including northern hardwoods. It generally appears many years after a disturbance, especially ground fires, during early to mid-succession, but is seldom found in coppice or clearcut harvest areas. Management of known populations with regenerative fire may be an option for this species.

White mandarin *Streptosus amplexifolius* (special concern) – This plant of the lily family is found with sugar maple, hemlock, and mixed conifer/hardwoods in ravines and coves in hilly areas near Lake Superior. The plant is a favorite food of white-tailed deer and appears to have a reproduction bottleneck with small population sizes. The plant is capable of persisting with selection harvesting. The need for relatively large metapopulations indicates management units of 300 to 1000 acres are needed to accommodate this species.

Animals-
American marten *Martes americana* (state-endangered) – This species has been reintroduced to the state with populations centered in two locations – the Nicolet National Forest and the Great Divide Ranger District of the Chequamegon National Forest. This species optimal habitat is old conifer forest with numerous windfalls and an abundance of spruce and fir. Marten's will also use old northern hardwood forest if they have numerous hollow trees and a significant conifer component. Stand management should promote snag and conifer retention however, range wide management plans are needed to address the needs of the species more so than stand recommendations.

Appalachian pillar *Cionella morseana* (special concern)
Brilliant granule *Guppya sterkii* (special concern)
Boreal top *Zoogenetes harpa* (special concern) –
Black striate *Striaura ferrea* (special concern)
Dentate supercoil P*aravitrea multidentata* (special concern) - These five terrestrial snails appear to have very restricted habitats, cliffs, rocky talus and seeps. We do not know much about their life history nor their habitat requirements. In general, moisture is key. Where they are found, management should be light with consideration to maintain adequate soil, cliff or rocky talus moisture.

Bald Eagle *Haliaeetus leucocephalas* (special concern)
Northern Goshawk *Accipter gentilis* (special concern)
Osprey *Pandion haliaetus* (state-threatened)
Red-shouldered Hawk *Buteo lineatus* (state-threatened) – All of these raptors should have their active nest sites protected from disturbance during the nesting season. Moreover, to protect these species, they need management considerations that go well beyond silvicultural stand applications and nest site protection. Refer to forest raptor management guidance documents.

Common Goldeneye *Bucephala clangula* (special concern)
Common Merganser *Mergus merganser* (special concern)
Red-breasted Merganser *Mergus serrator* (special concern) – All three of these species are very common in winter, but a sparsely found breeding in Wisconsin. All three nest in cavities, especially those found adjacent to large lakes or rivers. One common merganser nest was documented at the bottom of a 25-foot deep tree cavity. Leave existing cavity trees and future cavity trees when planning a harvest.

Four-toed Salamander *Hemidactylium sculatum* (special concern) - This amphibian lays its eggs in April in dense mosses (>1.5 inches in depth, including sphagnum mosses) at either the edges of ephemeral and/or fishless wetlands or in dense mosses growing on large downed woody debris over the water. Upon hatching, the larvae drop into the water and develop until they metamorphose in July or August. Because dense moss is essential to this species, tree cutting should be limited in these wetlands and a 75-foot buffer. This species is also highly dependent on large-diameter (>10”) coarse downed woody debris on the forest floor. Forest management in areas surrounding the breeding wetland buffers should plan for the continuous accumulation of large downed woody debris to accommodate this rare forest-dependent species.

Great Blue Heron *Ardea herodias* Rookeries (special concern) - Avoid harvest in active rookeries. Winter harvest of trees in close proximity to the rookery could occur.

Northern ring-necked snake *Diadophis punctatus* (special concern) – This species is nocturnal living underground, under logs or rocks and is seldom seen. Special management prescriptions are lacking, but keeping the forest floor moist with numerous large woody debris and rocks should accommodate this species.

<u>**Rare Neotropical Migratory Birds –**</u> The followed three species have individual stand management silvicultural options that can be employed, however, a stand by stand approach may not help these species. All three species probably need to be managed at a large scale. The model for ruffed grouse management areas should be developed to address the needs of these species. Management blocks of 300 to 2,000 acres could be established around known dense populations. The purpose would be to manage the forest to accommodate the needs of the target species.

Acadian flycatcher *Empidonax virescens* (state-threatened) – This small flycatcher of southern interior forest is moving north in Wisconsin. The species prefers large tracts of mature hardwood forest with semi-open understory, with most territories near streams or in ravines. Management of the largest blocks of northern hardwood forest in southern Wisconsin using single tree selection should accommodate this species.

Black-throated Blue Warbler *Dendroica caerulescens* (special concern) - This understory warbler nests north of a line from Green Bay to Spooner. Its preferred habitat is dense under story saplings and shrubs primarily in deciduous forest. Populations are most often found in mature to old hardwood forests, and reach their highest densities in thickets formed after blowdowns. Stand management should release densely packed, but suppressed saplings by single tree or group selection.

Cerulean warbler *Dendroica cerulea* (state-threatened) – This southern warbler prefers mature to old-growth hardwoods of maple, basswood and especially red oak. Cerulean Warbler’s are found almost exclusively in the upper canopy. Most of the breeding records are south of a line from Marinette to Spooner, however, they have been recorded in every county of the state. This warbler can tolerate light timber harvest as long as 70% or more of the canopy remains. The most pressing need is for management considerations to cover blocks of potential habitat with a focus on the habitat requirements for this species.

West Virginia white *Pieris virginiensis* (special concern) – This butterfly is found in northern hardwood forests with adults in flight from mid-May to early June. The larvae feed on toothwort. Management recommendations are lacking, however, identification of patches of toothwort within stands and avoiding equipment compaction could help with enhancing the species populations.

Wood turtle *Clemmys insculpta* (state-threatened) – Prefers hardwood forest or wet meadows associated with moderate to fast-current streams with sandy or gravel substrates. South-facing sand riverbanks are used for nesting. Best Management Practices for Water Quality addresses most of the management issues. Timber sale design should also keep equipment, especially landings away from the sandy nesting sites. Maintain small sandy openings within 200 feet of the river.

Other rare species may occur in northern hardwood stands considered for harvest. Many of these species will be found in specialized habitats such as rock outcrops, cliffs, ephemeral ponds, and seeps. If an NHI occurrence or species verification is identified, contact the appropriate person according to the Department protocol. Information on species and habitat can be found at the Bureau of Endangered Resources web site: http://intranet.dnr.state.wi.us/int/land/er/nhi_portal/index.htm.

Landscape Considerations

The northern hardwood and hemlock-hardwood forest types were historically the 'matrix' communities (the most abundant and connected forest communities) of the northern Wisconsin landscape. Although northern hardwood forests are still abundant and widespread, they have undergone many changes during the past century. Considerations are related to the loss, simplification, and fragmentation of forested land, and other human-induced changes in ecosystem structure or function.

Historical Context

When the General Land Office Public Land Surveys (PLS) were conducted in Wisconsin (1832-1866), forests dominated by northern hardwoods and hemlock-hardwoods covered about 15.2 million acres (43.7% of the state) (Frelich 1995). Schulte *et al*. (2002) conducted a quantitative analysis of PLS data and found that these forest types were dominant on 42-46% of forested area in northern Wisconsin. These forests existed as quasi-equilibrium landscapes, with all age-classes and developmental stages represented, but older age-classes and advanced developmental stages were dominant. Frelich (1995) estimated that 89% of the northern hardwood forest was 120 years old or older. Old forests featured multi-layered canopies, large quantities of dead wood, trees with cavities and broken branches and trunks, and tip-up mounds on the forest floor.

Northern hardwood forests historically contained a large component of hemlock. Within its range in northern Wisconsin, hemlock made up about 21% of basal area (based on GLO data), and was the most common tree species in many areas. Yellow birch was typically the second-most dominant tree, with sugar maple ranking third. Basswood, ironwood, and white pine were other common associates of the historic forest. Hemlock still exists as a component of the northern hardwood forests, but is greatly reduced from levels found in the 1800s. FIA data show that it currently makes up about 3% of basal area in the northern forest (Schmidt 1998).

Wind disturbance was the primary factor in regenerating northern hardwood forests. Wind disturbance occurred mostly as small and medium-sized gaps that may have impacted 5.7 to 8.5 percent of the northern hardwood and hemlock-hardwood forests during a decade (Frelich and Lorimer 1991, Dahir and Lorimer 1996). Most canopy gaps were small (<0.1 acre), created by windthrow of one to a few large trees. Moderate intensity disturbances are defined as those that removed 30-50% of the forest canopy in a decade (Craig Lorimer, pers. comm.). These disturbances occurred at average return intervals of 325 to 410 years; heavier disturbances were associated with longer return intervals. Moderate intensity disturbances were likely responsible for creating much of the cohort structure observed in old growth forests (Frelich and Lorimer 1991, Bourdo 1983, Loucks 1983). Gap expansion processes, competition for soil moisture and nutrients (Loucks 1983), and drought events may have also contributed to development of cohorts. Catastrophic windthrows may have impacted about an additional 0.7 percent of the forest each decade on average (Canham and Loucks 1984). Wind disturbance is less of an impact in today's younger and less structurally diverse forests. Small canopy gaps are now being created in some locations through adaptive silvicultural techniques, but are still thought to be relatively scarce. A lack of small gaps can impact some species of concern, like the Canada warbler.

Fire is known to have occasionally followed windthrow in the historic northern hardwood forests. Fire would have been more likely to impact northern hardwood forests that bordered fire-prone conifer forests or grasslands. The interiors of northern hardwood and hemlock-hardwood forests were, and still are, quite fire-resistant due to their mesic nature. Roth (1898) noted that on loam and clay lands, "where the heavy hard woods and Hemlock predominate... the ground and litter is usually damp. Fires run only during exceptionally dry seasons." Fire is also a factor that historically limited northern hardwood forests from expanding onto more xeric sites, or in some cases, onto otherwise suitable sites that were frequently impacted by fires originating in adjacent areas.

There are a number of questions about effects of Cutover-era fires in northern hardwood forests. Land managers have noted that some lower-quality hardwood sites appear to be degraded, and have speculated that past fires played a role. There is little information on exact locations or intensity of fires in northern hardwoods; however, the overall impact can be partially deduced from historic writings. Roth (1898) describes conditions in northern counties at that time, noting that hemlock-hardwood forests suffered fire damage where pine "slashings" caught fire. White pine was a large component of many hemlock-hardwood forests. It was typically cut selectively with considerable damage to the remaining timber, much of which died and created fuel loads in addition to the pine slash, thus allowing fire to carry into the hardwood forest. Hardwoods adjacent to cutover pineries were also more likely to burn. Areas that were further away from pineries, with less of a white pine component, escaped heavy fire damage. By 1900, fires were less frequent because nearly all the pines had been cut, and fire suppression programs were developing (although not fully in place until the late 1920's).

Northern hardwoods were the last forest type to be heavily logged during the Cutover. Hemlock and hardwoods were harvested between about 1900 and 1930, usually by clearcutting or high-grading. These forests were initially accessed for hemlock bark, which was peeled in the woods during the spring and early summer and shipped to tanneries. The hemlock logs were generally used for lumber or pulp, although some were left to rot in the woods when demand was low, or were used as fill beneath railroads. After a stand was accessed for hemlock bark, removal of hardwoods soon followed, often during the following winter (Corrigan 1978). Selective logging began in the 1920s, and although much of this was high-grading, some longer term sustained-yield management also emerged.

FIA records show that northern hardwood forests have been increasing in extent during the past several decades. In 1968, the maple-basswood forest type group occurred on about 3.5 million acres; in 1983 it occupied about 4.1 million acres, and by 1996 had increased to about 5.3 million acres (Schmidt 1998). Although northern hardwood forests are occupying increasingly larger areas, they are still considerably reduced in extent from historic times, and their structure and diversity have been greatly changed.

Forest Simplification

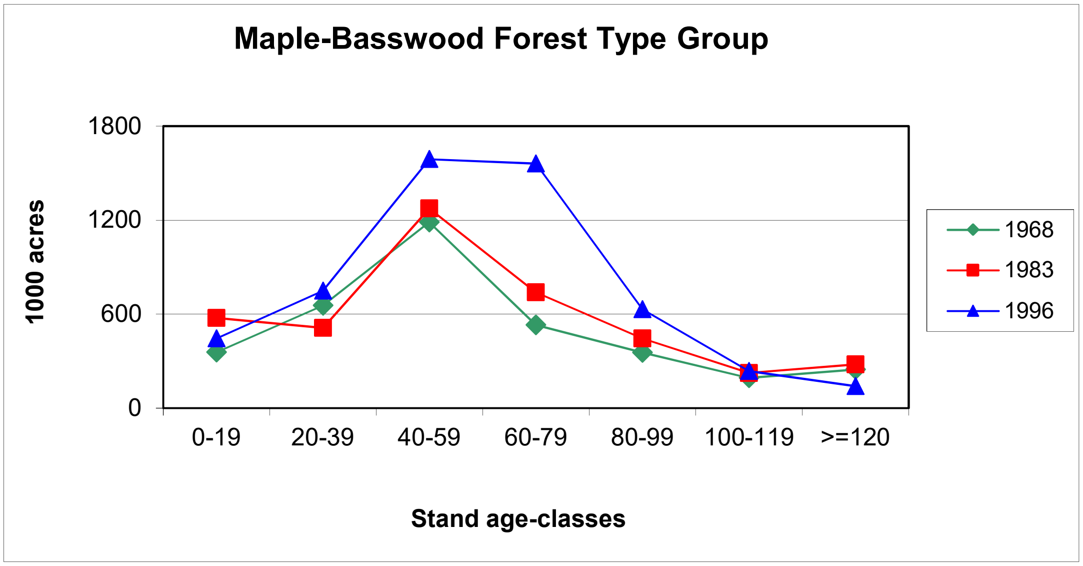
Forest simplification refers to a loss of species diversity and structural diversity, and an increased dominance of fewer species. The increase in sugar maple dominance that is occurring in northern hardwood forests is an example of simplification, as is the lack of features like large woody debris and tip-up mounds. Sugar maple is outcompeting conifers and other species that were common in the historic forests. Regeneration of hemlock and yellow birch are problematic in many cases, and basswood is also decreasing in abundance. Strict application of the single-tree selection method is probably a factor that increases sugar maple's dominance (Crow *et al*. 2002). White-tailed deer herbivory can give sugar maple a competitive advantage (Frelich and Lorimer 1985, Anderson and Loucks 1979), contribute to declines in some native plant species, and lead to homogenization of species composition among sites (Rooney *et al*. 2004). The northern hardwood forests have lost most of their Canada yew, a formerly widespread evergreen shrub that provided structural diversity. These changes occur at the stand level, but have cumulative effects at broader spatial scales.

At the landscape level, simplification and homogenization occur when forested patches become similar in size, shape, and composition. Land uses have led to homogenization and reduction of patch sizes, and creation of patch shapes that are less complex (Mladenoff *et al*. 1993). The cumulative effects of stand-level simplification make composition similar among patches. This is unlike the mosaic of forest patches found in remnant old growth hemlock-hardwood forests, where some are dominated by hemlock, some by sugar maple, and some a mixture of the two (Crow *et al*. 2002).

Lack of Older-Age Classes

Maintaining a desirable age-class distribution is a landscape-level consideration. A relatively stable age class structure, including all developmental stages, maximizes benefits to wildlife by providing a range of structural conditions. It also contributes to diversified economic interests by supplying different types of materials, including pulp, poles, sawlogs, and veneer. The average age of northern hardwood forests in Wisconsin increased between 1983 and 1996 because of increased acreage in the middle classes. However, acreage occupied by the oldest age classes decreased during this time period.

Figure 40.1 Forest age-class distribution for the maple-basswood forest type in Wisconsin, from FIA measurements taken in 1968, 1983, and 1996 (1000 acres).



Herbivory Effects

In the northern hardwood forest, browsing by white-tailed deer is partly the cause of:

- Reduced regeneration and growth of some tree species, and changes in species composition (possible economic impact in areas of high deer abundance).
- Local extirpation of some understory plant species, and changes in the relative abundance of others. Species most likely to be impacted are those that are less common.
- Reduction of habitat diversity and contribution to forest simplification.
- Indirect effects on other wildlife that depend on understory plants and shrubs (WDNR 1995).

Fragmentation and Edge Effects

Fragmentation effects have been described in the Aspen Chapter, and are also a landscape-level consideration in northern hardwood management. Even-aged management in northern hardwood forests has effects beyond the immediate area, bringing increased light and heat into the adjacent forest and attracting a different suite of species. Some of the species attracted to open and early successional forest patches compete with or prey upon species characteristic of interior northern hardwood forests.

Fragmentation is a term used to describe certain kinds of landscape structure. “Inherent fragmentation” describes landscapes that are naturally heterogenous due to characteristics of the physical environment, such as an area with numerous small lakes and wetlands dispersed throughout a pitted outwash plain. “Permanent fragmentation” refers to long-term conversion of forest to urban, residential, or agricultural uses. Roads can also create permanent fragmentation. “Habitat fragmentation” is defined as a disruption of habitat continuity, caused by human (e.g. tree cutting) or natural disturbance, creating a mosaic of successional stages within a forested tract. This kind of fragmentation is a shorter-term effect on species, and at a site level, impacts them during the time it takes for the forest to regrow. At a landscape scale, the aggregated amount and continuing nature of human disturbance may result in relatively high levels of habitat fragmentation.

In Wisconsin and elsewhere, the loss of forest habitat has a larger impact on species than shorter-term habitat fragmentation. Habitat loss is often correlated with measures of fragmentation (e.g. patch size, distance between patches, cumulative length of patch edges, etc.), making it difficult to quantify their separate effects. Habitat loss may result from second homes, utility or transportation corridors, and urban or industrial expansion. A drastic change in land cover, such as that which occurs after a clearcut harvest, represents a short-term loss of habitat for some species and a gain for others. Dispersal can be affected if species or their propagules cannot cross or get around the open land, find suitable habitat within it, or successfully compete with disturbance-adapted species.

Some species are "area-sensitive", requiring large patches of relatively homogenous habitat. The American marten and Northern Goshawk are examples of species that utilize larger areas of older northern hardwood forest.

Effects of Management on Neotropical Forest Migrants

During the past 20 years, there have been a number of studies that attempt to explain the decline of many neotropical migrant bird species (NTMB's) associated with forested landscapes. One segment of this research investigates the impact of edges and fragmentation generated by forest management.

Landscapes like those of southern Wisconsin were the focus of many NTMB studies conducted during the 1980's (building upon earlier studies going back to the 1950's). These areas have relatively high levels of permanent fragmentation due to agricultural and urban land uses. Most of this fragmentation creates "hard" edges, or abrupt changes between habitat types, such as when woodlands adjoin farm fields. Bird populations within these fragmented woodlots are heavily impacted by nest predation and by high levels of nest parasitism by brown-headed cowbirds. These populations are generally "sink" populations, maintained by recruitment of individuals from "source" populations. ("Source" areas have stable or growing populations that produce emigrants, while "sinks" are dependent upon immigrants to sustain their population size.)

Northern Wisconsin forests have different levels and types of fragmentation as compared with southern Wisconsin. The amount of edge in the northern forest is determined primarily by timber management and its associated infrastructure, and secondarily by permanent fragmentation associated with development.

Forests and associated wetlands of the northern lake states are important habitats - they support some of North America's highest densities and most diverse assemblages of breeding birds (Howe *et al*. 1996). This region is also thought to support source populations of many NTMB's.

Edge and fragmentation studies conducted since the 1990's have devoted more attention to predominantly forested landscapes. Most researchers tested whether hard edges would affect avian productivity as they did in agricultural settings. Predictably, edge effects in forested landscapes are more complex and local than those found in agricultural landscapes. Interspecific competition and predation rates are more significant than nest parasitism. This is partly because cowbird abundance is lower in northern Wisconsin (but can be locally important near agricultural areas). Predators of the northern forests include fishers, skunks, raccoons, foxes, Common Crows, Blue Jays, a variety of other birds, and assorted small mammals. They are the most important demographic factor limiting nest success.

Flaspohler *et al*. (2001a) studied edge effects generated by clearcuts (6 years or less) adjacent to large stands of older deciduous forests in Wisconsin. Hermit Thrush and Ovenbird, forest interior species that nest on the ground, had lower nest success within 300m of hard edges generated by clearcuts. Forest interior birds that nest in the canopy nested at lower densities within 50 meters of clearcuts, but at higher densities between 50 and 300 meters. American Robin and Rose-breasted Grosbeak, species known to be less sensitive to edge, had higher nest densities near recent clearcuts. Predation was the leading cause of nest failure for both ground and canopy nesting birds. A related study of Ovenbirds determined that while nest density was similar between edges and interior, predation and mean clutch size were both highest near edges. Therefore, net productivity was similar (Flaspohler *et al*. 2001b). We do not know whether this result applies to other species. More research is needed in this region to better understand local predator populations and how they affect nesting success of NTMB's.

Creation of edge and fragmentation in a landscape often benefits generalist bird species that are adapted to a variety of habitats. Many of these species (e.g. House Wren, Gray Catbird, American Crow, Blue Jay) are egg predators, and crows and jays also prey on nestlings, but their overall effects on local bird populations are not well known. Hamady (2000) found that Black-throated Blue Warblers, a forest gap-dependent species associated with shrub layers, declined in Upper Michigan landscapes with increasing habitat fragmentation because of competition with forest generalist species.

Current research also suggests that vegetation patterns in forest-dominated landscapes can affect the composition of avian communities within individual forest stands. In northeast Wisconsin, forested stands in landscapes with greater amounts of upland open land, as well as higher levels of fragmentation as indicated by measures of landscape pattern, had a lower abundance of edge-sensitive NTMB's (McRae 1995). Amounts of open land were correlated with landscape pattern measures, making it difficult to quantify these effects separately. Pearson and Niemi (2000) sampled mature aspen stands in Minnesota to determine whether both within-stand habitat characteristics and landscape patterns influenced breeding bird abundance in a forested landscape. Habitat specialists (Blackburnian Warbler and Magnolia Warbler) were found in aspen if there was a conifer component retained in the stand and also a large conifer component in the surrounding landscape (up to 1/3 mile radius). Forest generalists (Veery and Ovenbird) were less influenced by conifer components in landscapes. Retaining appropriate landscape-level conditions for certain habitat specialists should prove beneficial to their populations.

The overall effect of habitat fragmentation and edge on NTMB's in northern Wisconsin is not clear. Population estimates suggest that this region is a source population for many NTMB's and other bird species. Generation of excessive amounts of edge and habitat fragmentation within a landscape will be beneficial to some generalist NTMB's, but may prove detrimental to source populations of forest interior NTMB's, many of which are of higher conservation concern. Local research results are difficult to extrapolate, appearing to vary by ecosystem type. Additional local research is needed to determine how even-aged management of northern hardwoods affects patterns of interspecific competition and nest predation.

Effects of Different Silvicultural Techniques on Neotropical Forest Migrants

Information about effects of uneven-aged management on NTMB's is scarce. A study conducted in northern hardwoods in central Ontario suggested that lack of canopy closure in stands with repeated selection harvests could become a limiting factor for some species. Researchers found species-specific differences in breeding season abundance in stands recently harvested (1-5 years), versus stands harvested earlier (15-20 years) and stands in reserves (harvested more than 30 years ago) (Jobes *et al*. 2004). This landscape differed from that of Wisconsin in that rock outcrop occupied a significant part of the area.

A study on the Ottawa National Forest compared 40 acre plots in old growth, managed old growth, uneven-aged selection, and even-aged shelterwood treatments (Andres 1996). Plots were not replicated, but some species richness, composition, and abundance differences were reported among the four plots. The old-growth plot had the highest number of breeding bird territories, and the selection treatment had the second highest.

King and DeGraaf (2000) compared bird species distribution among clearcut, shelterwood, and unmanaged northern hardwood forests in New Hampshire. Again, species-specific differences in bird abundance were apparent. The authors recommended that a variety of management techniques should be used in a landscape to maintain bird species diversity.

Impacts of Equipment and Infrastructure

The cumulative effects of infrastructure development and soil compaction in forests have been studied in other parts of the country and found to be correlated with changes in hydrologic regimes, surface drainage patterns, and soil moisture. The negative ecological effects of soil compaction and rutting, and of forest roads, are well known at fine scales, but these issues have not been studied in an integrated fashion on larger landscapes in our area. Roads and utility corridors have been implicated in the spread of non-native invasive plants. They also act as barriers to the movement of some species, create fragmentation and edge, and can attract human disturbances.

Summary of Landscape Considerations

When deciding whether to actively manage a northern hardwood stand, and if so, which silvicultural practices to apply, consider the following factors:

- What are the characteristics of the broader-scaled ecological unit (LTA or Subsection) around the stand?
- Is the ecological unit already fragmented by either habitat or permanent fragmentation or by inherent fragmentation (a heterogenous landscape that contains a wide variety of habitat types, wetlands, and/or water bodies)?
- In even-aged management, are there opportunities to aggregate individual cuts to reduce the overall amount of edge?
- Are there NTMB's of concern in the surrounding LTA, which ones are they, and how is the proposed management likely to affect them?
- Is the area around the stand a large patch of older northern hardwood forest? Large forest patches with older age-class structure are scarce, and managing for interior NTMB's may be an important consideration.
- What kinds of silvicultural techniques have been commonly applied in the surrounding LTA or Subsection in recent years, and are there techniques that may be beneficial in creating underrepresented kinds of forest structure?
- How much of the landscape has been harvested recently? Are there sufficient amounts of closed-canopy, interior forest habitat available for interior forest NTMB's and other area-sensitive species?
- Consider emulating gap-phase windthrow in selection management of uneven-aged northern hardwoods.
- Are there issues with herbivory in the vicinity (e.g. lack of regeneration of hemlock, yellow birch, or Canada yew; excessive browsing of lilies and orchids)? If so, consider fencing or large block management to reduce deer impacts.
- What is the age class distribution of northern hardwoods in the broader-scaled ecological unit? Are there opportunities for providing a scarce successional stage?
- Are there opportunities for fencing to help restore understory and shrub components?
- Are there opportunities for increasing components of hemlock, yellow birch, or basswood?

Recommendations for the Management of Northern Hardwood Stands with Landscape Considerations

- Consider landscape composition and structure, including species composition; successional and developmental stage; age structure; stand/patch size; type, intensity, and pattern of fragmentation; habitat diversity; NTMB populations and habitat needs; and common/uncommon management techniques.
- Increase the representation of hemlock, yellow birch, basswood, and white pine.
- Increase structural diversity within stands (i.e. large trees, large cavity trees, large snags, large downed woody debris, and variable gap sizes).
- Manage larger stands where it is possible to coalesce adjacent northern hardwood or hemlock-hardwood stands.
- Increase the representation of large patches of older uneven-aged forest.
- Increase the representation of older trees and stands and later developmental stages (i.e. old forest and old-growth).
- Apply a variety of management techniques, including old-growth reserves, managed old forests, extended rotations, uneven-aged management, even-aged management, and the maintenance of reserve trees.
- Apply adaptive uneven-aged management that considers variability in application, including gap size and distribution, diameter distribution, cutting cycle, coarse woody debris management, and reserve tree management.
- Favor uneven-aged management (with even-aged patches), to increase and manage diversity within the northern hardwood forest type.
- Control deer and limit herbivory.
- Limit permanent fragmentation caused by development (e.g. roads and landings).

Table 40.10 Recommended residual stocking per acre (trees≥5" DBH) for fully regulated uneven-aged stands (Arbogast 1957)

DBH (inches)	No. of Trees	No. of Trees by size class	Basal Area (square feet)	Basal Area by size class
5	21	65	2.9	16
6	15		2.9	
7	12		3.2	
8	9		3.1	
9	8		3.5	
10	7	28	3.8	22
11	6		4.0	
12	5		3.9	
13	5		4.6	
14	5		5.3	
15	4	17	4.9	26
16	4		5.6	
17	3		4.7	
18	3		5.3	
19	3		5.9	
20	2	8	4.4	20
21	2		4.8	
22	2		5.3	
23	1		2.9	
24	1		3.1	
Total (per acre)	118	118	84	84

Table 40.11 Alternative residual stocking levels for single tree selection with different maximum tree size classes (prepared by T. Strong 2005)

DBH (inches)	Maximum Tree Size Class					
	18"		24"		30"	
	No. of Trees	Basal Area	No. of Trees	Basal Area	No. of Trees	Basal Area
2	118	2.6	118	2.6	118	2.6
3	53	2.6	53	2.6	53	2.6
4	31	2.7	31	2.7	31	2.6
Sub-Total	**202**	**8**	**202**	**8**	**202**	**8**
5	22	3.0	21	2.9	12	1.6
6	19	3.7	15	2.9	11	2.2
7	17	4.5	12	3.2	9	2.4
8	15	5.2	9	3.1	8	2.8
9	13	5.7	8	3.5	7	3.1
Sub-Total	**86**	**22**	**65**	**16**	**47**	**12**
10	11	6.0	7	3.8	6	3.3
11	10	6.6	6	4.0	5	3.3
12	9	7.0	5	3.9	5	3.9
13	8	7.3	5	4.6	4	3.7
14	7	7.4	5	5.3	4	4.3
Sub-Total	**45**	**34**	**28**	**22**	**24**	**19**
15	6	7.3	4	4.9	3	3.7
16	5	7.0	4	5.6	3	4.2
17	4	6.3	3	4.7	3	4.7
18	4	7.0	3	5.3	2	3.5
19			3	5.9	2	4.0
Sub-Total	**19**	**28**	**17**	**26**	**13**	**20**
20			2	4.4	2	4.4
21			2	4.8	1	2.4
22			2	5.3	1	2.6
23			1	2.9	1	2.9
24			1	3.1	1	3.1
Sub-Total			**8**	**20**	**6**	**15**
25					1	3.4
26					1	3.7
27					1	4.0
28					0.5	2.1
29					0.5	2.3
30					0.5	2.4
Sub-Total					**4.5**	**18**
Total ≥5"DBH	**150**	**84**	**118**	**84**	**94.5**	**84**

Figure 40.2. Recommended stocking levels for northern hardwoods in even-aged stands (USDA Forest Service 2005).

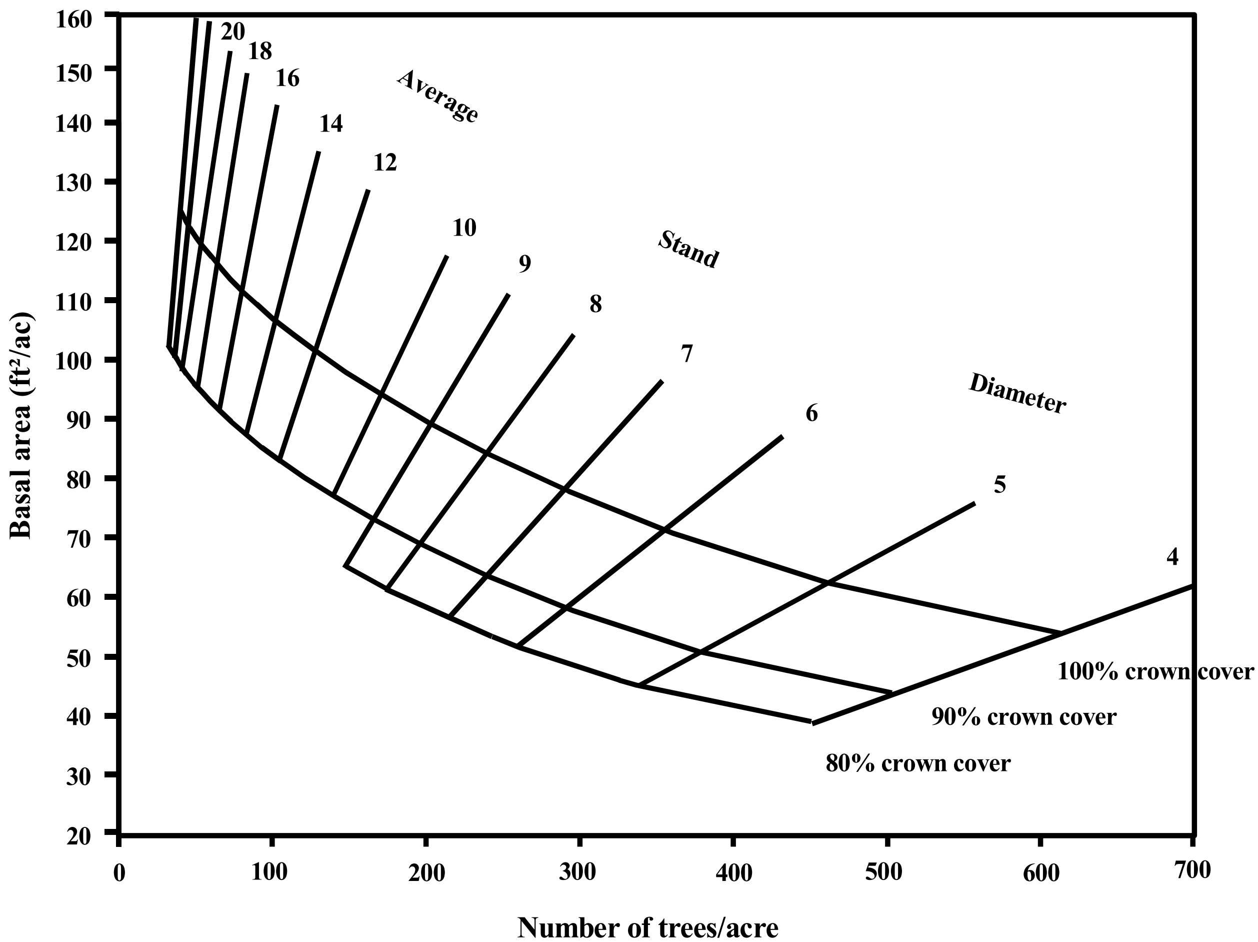


Table 40.12. Even-age stocking levels for northern hardwoods by mean stand diameter, basal area, and number of trees per acre for specified crown covers after thinning. (USDA Forest Service 2005)

Mean Stand Diameter (in)	Crown area/tree (ft^2)	Basal area/tree (ft^2)	Crown cover (percent of 43,560 ft^2/ac) 80 percent Trees/ac (No.)	80 percent BA/ac (ft^2)	90 percent Trees/ac (No.)	90 percent BA/ac (ft^2)
4	78	0.0873	447	39	503	44
5	104	0.1364	335	46	377	51
6	133	0.1963	262	51	295	58
7	164	0.2673	212	57	239	64
8	199	0.3491	175	61	197	69
9	238	0.4418	146	65	165	73
10	279	0.5454			141	77
11	325	0.6600			121	80
12	373	0.7854			105	83
13	422	0.9218			93	86
14	480	1.0690			82	87
15	536	1.2272			73	90
16	598	1.3963			66	92
17	662	1.5762			59	93
18	728	1.7671			54	95
19	803	1.9689			49	96
20	881	2.1817			44	97
21	952	2.4053			41	99
22	1035	2.6398			38	100
23	1120	2.8852			35	101
24	1207	3.1416			32	102

Table 40.13 Even-age stocking levels (residual basal area (ft²/ac) for northern hardwoods with various amounts of basswood by mean stand diameter (inches) for specified crown covers after thinning. (USDA Forest Service 2005)

	Percent of basswood							
	20		40		60		80	
	Crown cover (percent of 43,560 ft²/ac)							
Dbh	80	90	80	90	80	90	80	90
5	57	64	62	70	70	78	79	89
6	61	69	67	76	75	84	84	95
7	65	73	71	80	79	89	89	100
8	69	77	75	85	84	94	94	106
9	72	81	79	89	87	98	98	110
10		84		93		103		115
11		88		96		106		119
12		91		100		110		123
13		94		103		113		127
14		97		106		117		130
15		99		109		120		134
16		102		112		123		137
17		105		114		126		140
18		107		117		129		143
19		109		119		131		146
20		112		122		134		149
21		114		124		137		152
22		116		127		139		154
23		118		129		141		157
24		120		131		144		159

Table 40.14 Even-age stocking levels (residual basal area (ft^2/ac) for northern hardwoods with various amounts of red oak and /or red maple by mean stand diameter (inches) for specified crown covers after thinning. (USDA Forest Service 2005)

	Percent of red oak and/or red maple							
	20		40		60		80	
	Crown cover (percent of 43,560 ft^2/ac)							
Dbh	80	90	80	90	80	90	80	90
5	55	62	59	66	63	71	68	76
6	59	66	62	70	66	74	70	79
7	62	70	65	73	68	77	72	81
8	65	73	68	76	71	80	74	83
9	68	77	70	79	73	82	76	85
10		80		82		84		87
11		82		84		86		88
12		85		87		88		90
13		87		89		90		91
14		90		91		91		92
15		92		92		93		93
16		94		94		94		94
17		96		96		96		95
18		98		98		97		96
19		100		99		98		97
20		102		101		99		98
21		104		102		101		99
22		105		103		102		100
23		107		105		103		101
24		109		106		104		101

Table 40.15 Even-age stocking levels (residual basal area (ft²/ac) for northern hardwoods with various amounts of hemlock by mean stand diameter (inches) for specified crown covers after thinning. (USDA Forest Service 2005)

	Percent of hemlock							
	20		40		60		80	
	Crown cover (percent of 43,560 ft²/ac)							
Dbh	80	90	80	90	80	90	80	90
5	48	53	44	49	41	46	38	43
6	52	59	49	56	47	52	44	50
7	57	64	54	61	52	59	50	56
8	61	69	59	67	57	65	56	63
9	65	73	64	72	62	70	61	69
10		77		76		76		75
11		81		81		81		81
12		84		85		86		87
13		88		89		91		92
14		91		93		96		98
15		94		97		100		103
16		97		101		105		109
17		100		105		109		114
18		103		108		113		119
19		106		111		117		124
20		109		115		122		129
21		111		118		126		134
22		114		121		129		139
23		116		124		133		144
24		119		127		137		149

Table 40.16 Sample Northern Hardwood Tally Sheet

STAND STRUCTURE EXAM TALLY

Legal Description			PLOT TALLY AND TOTAL BASAL AREA PER PLOT										
Property	Comp	Stnd	1	2	3	4	5	6	7	8	9	10	Ave
Estimator	Date												

		SPECIES							VOLUME PER ACRE	CULLS	BASAL AREA TOTAL PrAC
DBH											
2-4									CORDS	CORDS	
5-10											
11-14	log sp	.5	1	1.5	2	2.5	3	3.5	4	BD FEET	
		3 7 10 13 16 20 23 26 29	6 12 18 24 36 42 48 54 60 66 72 78 94 100 106	9 17 26 35 43 52 61 70 78 96 104 113	10 21 32 42 52 63 73 84 95 105 115 126 137 147	13 26 39 52 65 78 91	15 30 45 60 75 90	16 32 48 64 80 96 112 128			
15-19		4 8 12 16 20 24 28 32 36 40 44	7 14 21 28 35 41 48 55 62 69 76 82 89 96 102 109 116 112	10 19 28 38 48 57 67 76 85 95 105 114 123 133	12 23 35 47 58 70 82 94 105 117 129 140 152 164 175 187 199	14 28 42 56 70 84 98 112	17 33 49 66 83 99 115 132	18 37 55 73 92 110 128 147 165 183 202	20 40 60 80 100 120 140 160 180 200 220		
20+		4 8 12 16 20	7 15 22 29 36 43 51	10 20 30 40 49 59	12 25 37 50 62 75 87	15 30 44 59	17 34 51 68	19 39 58 78 97	21 42 63 84 105		

VEGETATION TYPE	ACRES	SPEC	GTH	AGE	HT	TOTAL			
REMARKS:						AVE. PER ACRE			

4.3' RADIUS REPRO PLOT	1	2	3	4	5	6	7	8	9	10

Table 40.17. Tree crown area (ft²) by species and DBH (USDA Forest Service 2005)

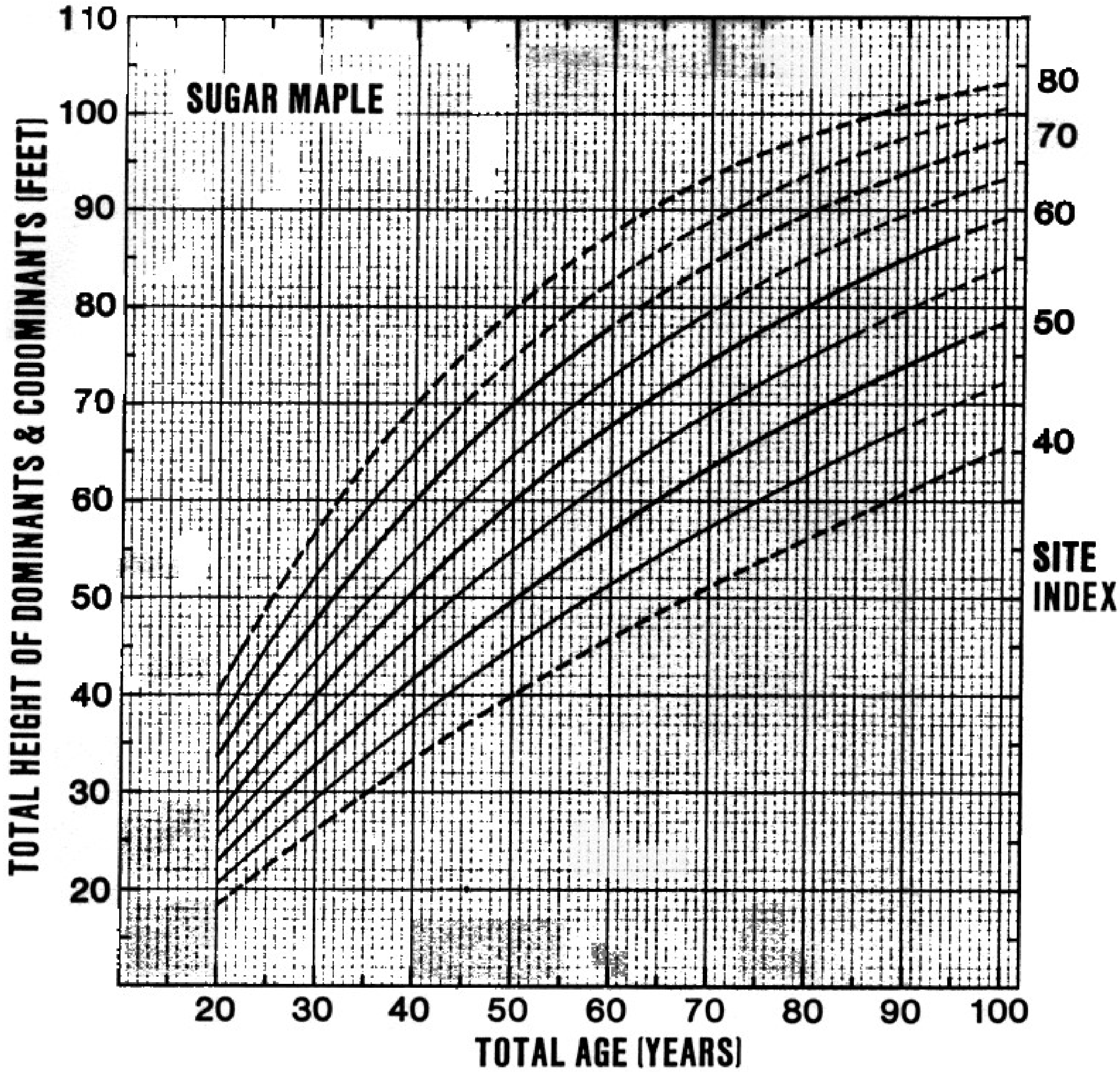
Dbh (in)	Hardwoods[1]	Red oak -red maple	Basswood	Hemlock
5	92	65	52	133
6	122	92	71	163
7	156	122	91	193
8	193	157	114	224
9	232	196	138	256
10	274	239	164	287
11	319	286	192	319
12	366	337	221	352
13	415	392	252	385
14	467	451	285	418
15	521	513	319	451
16	577	580	354	484
17	635	650	392	518
18	695	723	430	552
19	757	801	470	586
20	821	882	511	621
21	886	967	554	655
22	954	1055	598	690
23	1024	1147	643	725
24	1095	1243	690	760
25	1168	1342	738	795
26[2]	1242	1445	787	831
27[2]	1319	1551	837	866
28[2]	1397	1661	889	902
29[2]	1476	1775	941	938
30[2]	1558	1891	995	974

[1]Hardwoods includes sugar maple, yellow birch, white and black ash.
[2]Crown areas of these diameters are extrapolated.
[3]Data derived from even-aged, forest grown, dominant and co-dominant trees in northern WI and MI. Unpublished data from T. Strong and G. Erdmann, USFS, NCFRS, Rhinelander, WI.

Instructions for a sample shelterwood marking exercise:

Lay out a 0.4 acre square plot (132 feet on a side) in the stand you are marking. To reach 60 percent crown cover in the practice plot you will need an accumulated crown area of 10,454 ft² (43,560 ft²/acre for 100 percent crown cover X 0.4 acre X 60 percent). Mark residual trees and tally the diameter, species, and crown area. Make sure the residual trees are well-spaced, low risk, and the desired species. Accumulate the crown area until reaching 10,454 ft². Visualize what the remaining crown cover would look like with all unmarked trees cut and proceed to mark through remaining stand.

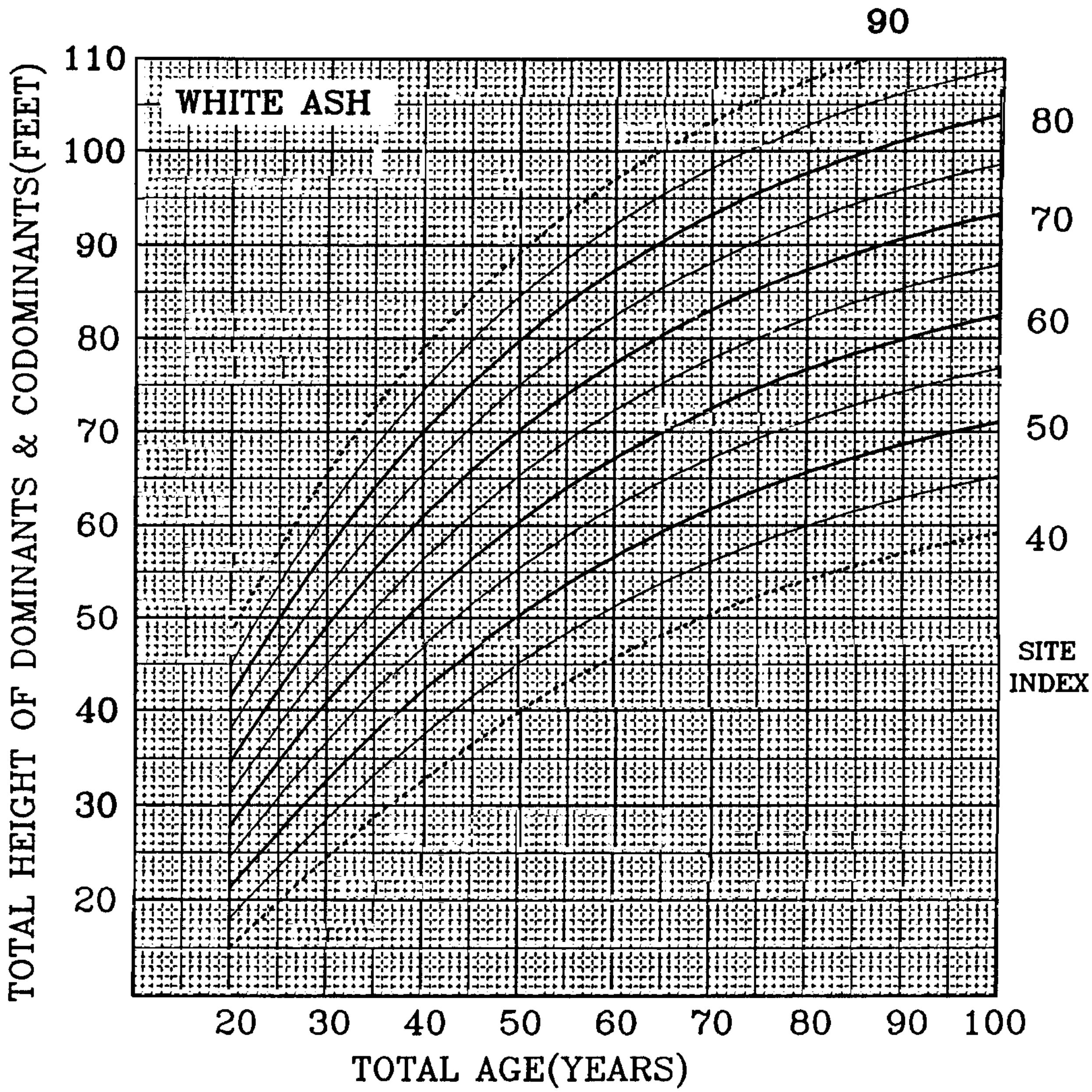
Figure 40.3 Site index curves for sugar maple in northern Wisconsin and upper Michigan (Carmean *et al*., 1989).



Sugar maple (Carmean 1978)
Northern Wisconsin and Upper Michigan
177 plots having 721 dominant and codominant trees
Stem analysis, nonlinear regression, polymorphic
Add 4 years to d.b.h. age to obtain total age (BH = 0.0)

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
H	6.1308	0.6904	-0.0195	10.1563	-0.5330	0.99	1.26	5.3
SI	0.1984	1.2089	-0.0110	-2.4917	-0.2542	0.98	1.90	6.7

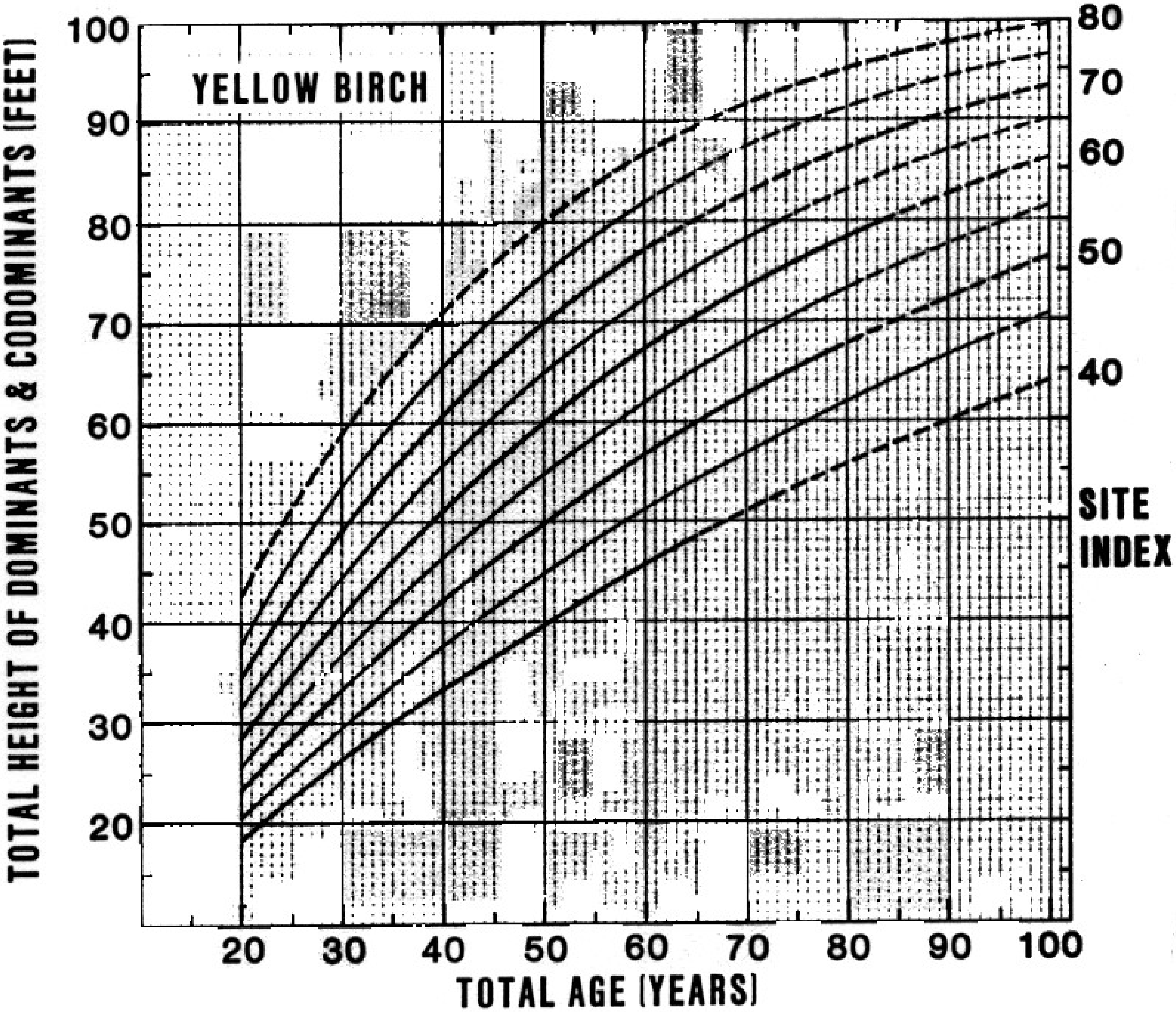
Figure 40.4 Site index for white ash in northern Wisconsin and upper Michigan (Carmean *et al*., 1989)



White ash (Carmean 1978)
Northern Wisconsin and Upper Michigan
73 plots having 275 dominant and codominant trees
Stem analysis, nonlinear regression, polymorphic
Add 4 years to d.b.h. age to obtain total age (BH = 0.0)

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
H	4.1492	0.7531	-0.0269	14.5384	-0.5811	0.99	1.37	5.1
SI	0.1728	1.2560	-0.0110	-3.3605	-0.3452	0.99	1.99	9.5

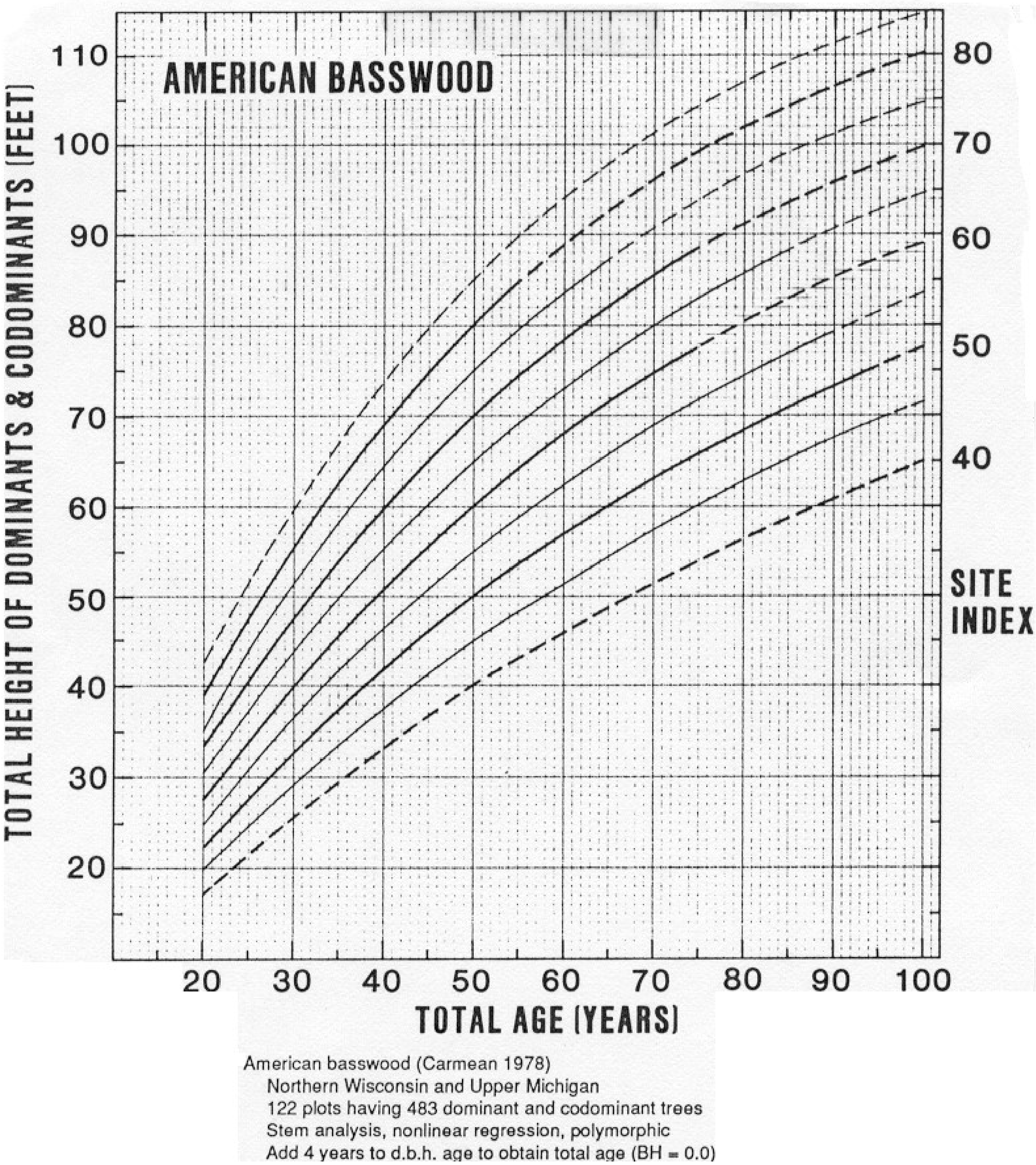
Figure 40.5 Site index curves for yellow birch in northern Wisconsin and upper Michigan (Carmean *et al*., 1989).



Yellow birch (Carmean 1978)
Northern Wisconsin and Upper Michigan
119 plots having 459 dominant and codominant trees
Stem analysis, nonlinear regression, polymorphic
Add 4 years to d.b.h. age to obtain total age (BH = 0.0)

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
H	6.0522	0.6768	-0.0217	15.4232	-0.6354	0.99	1.29	5.0
SI	0.1817	1.2430	-0.0110	-3.0184	-0.3180	0.98	2.05	7.7

Figure 40.6 Site index curves for basswood in northern Wisconsin and upper Michigan (Carmean *et al*., 1989).



	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
H	4.7633	0.7576	-0.0194	6.5110	-0.4156	0.99	0.70	2.7
SI	0.1921	1.2010	-0.0100	-2.3009	-0.2331	0.99	1.24	4.5

REFERENCES

Anderson, H.W. and J.A. Rice. 1993. A tree-marking guide for the tolerant hardwoods working group in Ontario. Ont. Min. Natl. Res., Science and Technology Series, Vol. 8.

Anderson, H.W., B.D. Batchelor, C.M. Corbett, A.S. Corlett, D.T. Deugo, C.F. Husk, and W.R. Wilson. 1990. A silvicultural guide for the tolerant hardwoods working group in Ontario. Ont. Min. Natl. Res., Science and Technology Series, Vol. 7.

Anderson, R.C. and O.L. Loucks. 1979. White-tailed deer (Odocoileus virginianus) influence on structure and composition of Tsuga canadensis forests. J. Appl. Ecol. 16:855-861.

Andres, S. 1996. Monitoring breeding birds in the Ottawa National Forest, 1994-95: Effects of management on neotropical bird populations. Michigan Birds and Natural History 3(3):141-146.

Arbogast, C., Jr. 1957. Marking guides for northern hardwoods under the selection system. USDA For. Serv. Lake States For. Exp. Stn. Pap. 56.

Barrett, J.W. (Ed.). 1980. Regional silviculture of the United States. Second edition. John Wiley & Sons.

Birds of North America, Vols. 1-18, 1990 – 2003, Birds of North America, Inc., Philadelphia, PA.

Borman, F.H. and G.E. Likens. 1979. Pattern and process in a forested ecosystem. Springer-Verlag, NY.

Borman, F.H. and G.E. Likens. 1979. Catastrophic disturbance and the steady state in northern hardwood forests. Amer. Scientist 67:660-669.

Bourdo, E.A., Jr. 1983. The forest the settlers saw, *In*: S.L. Flader, editor. The Great Lakes forest: An environmental and social history. Minn., MN, Univ. MN Press. pp. 3-16.

Braun, E.L. 1950. Deciduous forests of eastern North America. Blackstone Co., Philadelphia, PA. 596pp.

Burns, R.M. and B.H. Honkala (tech. coords.). 1990. Silvics of North America: 1. Conifers; 2. Hardwoods. Agric. Hndbk. 654. USDA For. Serv., Wash. D.C.

Canham, C. D., and O. L. Loucks. 1984. Catastrophic windthrow in the presettlement forests of Wisconsin. Ecol. 65(3):803-809.

Carmean, W.H. 1979. Site index comparisons among northern hardwoods in northern Wisconsin and Upper Michigan. USDA For. Serv. Res. Pap. NC-169.

Carmean, W.H., J.T. Hahn, and R.D. Jacobs. 1989. Site index curves forest tree species in the eastern United States. USDA For. Serv. Gen. Tech. Rep. NC-128.

Corrigan, G. 1978. Tanneries and the hemlock bark industry in Wisconsin. In: Hernandez, R.R., editor. Some historic events in Wisconsin's logging industry. Proceedings, Third Annual Meeting, Forest History Assoc. of Wisconsin, Inc. September 9, 1978, Univ. WI, Madison, pp. 23-30.

Colburn, E.A. 2004. Vernal pools: Natural history and conservation. McDonald & Woodward, Blacksburg, VA.

Crow, T.R. 1990. *Tilia americana* L. American basswood. In: Burns, R.M. and B.H. Honkala (tech. coords.). 1990. Silvics of North America: 1. Conifers; 2. Hardwoods. Agric. Hndbk. 654. USDA For. Serv., Wash. D.C.

Crow, T.R. and F.T. Metzger. 1987. Regeneration under selection cutting. In: Nyland, R.D., editor. Managing northern hardwoods, pp. 81-94. SUNY Coll. Environ. Sci. and For., Fac. For. Misc. Publ. No. 13 (ESF 87-002) (Soc. Am. For. Publ. No. 87-03).

Crow, T.R., D.S. Buckley, E.A. Nauertz, and J.C. Zasada. 2002. Effects of management on the composition and structure of northern hardwood forests in Upper Michigan. For. Sci. 48(1):129-145.

Crow, T.R., R.D. Jacobs, R.R. Oberg, and C.H. Tubbs. 1981. Stocking and structure for maximum growth in sugar maple selection stands. USDA For. Serv. Res. Pap. NC-199.

Dahir, S. E. 1995. Tree mortality and gap formation in old-growth hemlock-hardwood forests of the Great Lakes Region. M.S. Thesis. University of Wisconsin-Madison; 100 pp.

Dahir, S.E. and C.G. Lorimer. 1996. Variation in canopy gap formation among developmental stages of northern hardwood stands. Can. J. For. Res. 26: 1875-1892.

Davis, M.B., R.R. Calcote, S. Sugita, and H. Takahara. 1998. Patchy invasion and the origin of a hemlock-hardwoods forest mosaic. Ecol. 79(8):2641-2659.

Duffy, D.C. and A.J. Meier. 1992. Do Applachian herbaceous understories ever recover from clearcutting? Cons. Biol. 6(2):196-201.

Erdmann, G.G. 1986. Developing quality in second growth stands. In: Proceedings of the conference on the northern hardwood resource: management and potential, 18-20 Aug. 1986, Houghton, MI. Edited by G.D. Mroz and D.D. Reed. Mich. Tech. Univ., Houghton, pp. 206-222.

Erdmann, G.G. 1990. *Betula alleghaniensis* Britton. Yellow birch. In: Burns, R.M. and B.H. Honkala (tech. coords.). 1990. Silvics of North America: 1. Conifers; 2. Hardwoods. Agric. Hndbk. 654. USDA For. Serv., Wash. D.C.

Eyre, F.H. and W.M. Zillgitt. 1953. Partial cuttings in northern hardwoods of the Lake States: twenty-year experimental results. USDA Tech. Bull. No. 1076.

Flaccus, E. 1959. Revegetation of landslides in the White Mountains of New Hampshire. Ecol. 40:692-702.

Flaspohler, D.J, S.A. Temple, and R.N. Rosenfield. 2001a. Species-specific edge effects on nest success and breeding bird density in a forested landscape. Ecol. Appl. 11(1):32-46.

Flaspohler, D.J, S.A. Temple, and R.N. Rosenfield. 2001b.Effects of forest edges on ovenbird demography in a managed forest landscape. Cons. Biol. 15(1):173-183.

Flora of North America Association, 1993-2003, Flora of North America Vol 1 – 8, Oxford University Press, Inc. NY.

Frelich, L.E. 1995. Old forest in the Lake States today and before European settlement. Nat. Areas J. 15:157-167.

Frelich, L.E. 2002. Forest dynamics and disturbance regimes, studies from temperate evergreen-deciduous forest. Cambridge University Press, Cambridge, U.K.

Frelich, L.E. and C.G. Lorimer. 1985. Current and predicted long-term effects of deer browsing in hemlock forests in Michigan, U.S.A. Biol. Cons. 34:99-120.

Frelich, L.E. and C.G. Lorimer. 1991. Natural disturbance regimes in hemlock-hardwood forests of the Upper Great Lakes Region. Ecol. Mono. 61(2):159-162.

Godman, R.M. 1957. Silvical characteristics of sugar maple. USDA For. Serv. Lake States For. Exp. Stn. Pap. 50.

Godman, R.M. and D.J. Books. 1971. Influence of stand density on stem quality in pole-size northern hardwoods. USDA For. Serv. Res. Pap. NC-54.

Godman, R.M. and G.A. Mattson. 1976. Seed crops and regeneration problems of 19 species in northeastern Wisconsin. USDA For. Serv., NC For. Exp. Stn., Res. Pap. NC-123, St. Paul, MN. 5 pp.

Godman, R.M. and J.J. Mendel. 1978. Economic values for growth and grade changes of sugar maple in the Lake States. USDA For. Serv. Res. Pap. NC-155.

Godman, R.M., H.W. Yawney, and C.H. Tubbs. 1990. *Acer saccharum* Marsh. Sugar maple. In: Burns, R.M. and B.H. Honkala (tech. coords.). 1990. Silvics of North America: 1. Conifers; 2. Hardwoods. Agric. Hndbk. 654. USDA For. Serv., Wash. D.C.

Goodburn, J.M. 2004. Effects of opening size and competition levels on the growth and canopy recruitment of saplings in northern hardwood forests. PhD. Dissertation. Department of Forest Ecology and Management, University of Wisconsin, Madison, WI 98pp.

Goodburn, J.M., and C.G. Lorimer. 1998. Cavity trees and coarse woody debris in old-growth and managed northern hardwood forests in Wisconsin and Michigan. Can. J. For. Res. 28:427-438.

Hamady, M.A. 2000. An ecosystem approach to assessing the effects of forest heterogeneity and disturbance of birds of the northern hardwood forest in Michigan's Upper Peninsula. Ph.D. dissertation. Department of Fisheries and Wildlife, Michigan State University. East Lansing, MI. 261 pp.

Hanks, L.F. 1976. Hardwood tree grades for factory lumber. USDA For. Serv. Res. Pap. NE-333.

Harlow, W.M., E.S. Harrar, and F.M. White. 1979. Textbook of dendrology, covering the important forest trees of the United States and Canada. Sixth edition. McGraw-Hill.

Howe, R.W., G. Neimi, and J.R. Probst. 1996. Management of western Great Lakes forests for the conservation of neotropical migratory birds. Pages 144-167 In: F.R. Thompson III, ed. Management of Midwestern landscapes for the conservation of neotropical migratory birds. Proceedings of the symposium held Dec. 5, 1995, Detroit, MI. U.S.D.A. For. Serv., NC Res. Stn. Gen. Tech. Rept. NC-187. 208 pp.

Hura, C.E. and T.R. Crow. 2004. Woody debris as a component of ecological diversity in thinned and unthinned northern hardwood forests. Nat. Areas J. 24:57-64.

Hutchinson, J.G., editor. 1992. Northern hardwood notes. USDA For. Serv., NC For. Exp. Stn., St. Paul, MN.

Jacobs, R.D. 1968. Growth and yield. In: Sugar maple conference proceedings. pp. 96-104. 20-22 Aug. 1968. Mich. Tech. Univ., Houghton, MI.

Jobes, A.P, E. Nol, and D.R. Voigt. 2004. Effects of selection cutting on bird communities in contiguous eastern hardwood forests. J. Wildlife Mgmt. 68(1):51-60.

King, D.I., and R.M. DeGraaf. 2000. Bird species diversity and nesting success in mature, clearcut, and shelterwood forest in northern New Hampshire, USA. For. Ecol. and Mgmt. 129:227-235.

Kotar, J. and T.L. Burger. 1996. A guide to forest communities and habitat types of central and southern Wisconsin. Univ. Wisc., Madison.

Kotar, J., J.A. Kovach, and G. Brand. 1999. Analysis of the 1996 Wisconsin forest statistics by habitat type. USDA For. Serv., NC Res. Stn., Gen. Tech. Rep. NC-207. St. Paul, MN.

Kotar, J., J.A. Kovach, and T.L. Burger. 2002. A guide to forest communities and habitat types of northern Wisconsin. Second edition. Univ. Wisc., Madison.

Leak, W.B., and S.M. Filip. 1975. Uneven-aged management of northern hardwoods in New England. USDA For. Serv. Res. Pap. NE-322.

Leak, W.B., D.S. Solomon, and S.M. Filip. 1969. A silvicultural guide for northern hardwoods in the Northeast. USDA For. Serv. Res. Pap. NE-143.

Leak, W.B., D.S. Solomon, and P.S. DeBald. 1987. Silvicultural guide for northern hardwood types in the Northeast (revised). USDA For. Serv. Res. Pap. NE-603.

Lorimer, C.G. 2001. Historical and ecological roles of disturbance in eastern North American forests: 9,000 years of change. Wildl. Soc. Bull. 29(2):425-439.

Lorimer, C.G. and L.E. Frelich. 1994. Natural disturbance regimes in old-growth northern hardwoods: Implications for restoration efforts. J. For. 92(1):33-38.

Lorimer, C.G., S.E. Dahir, and E.V. Nordheim. 2001. Tree mortality rates and longevity in mature and old-growth hemlock-hardwood forests. J.Ecol. 89:960-971.

Loucks, O.L. 1983. New light on the changing forest, *In:* SL Flader, editor, The Great Lakes forest: An environmental and social history. Minn., MN, Univ. MN Press, pp. 17-32.

MacLean, D.A. and R.W. Wein. 1977. Changes in understory vegetation with increasing stand age in New Brunswick forests: species composition, cover, biomass, and nutrients. Can. J. Bot. 55:2818-2831.

Matlack, G.R. 1994. Plant species migration in a mixed-history forest landscape in eastern North America. Ecol. 75(5):1491-1502.

Marquis, D.A. 1987. Assessing the adequacy of regeneration and understanding early development patterns. In: Nyland, R.D. (Ed.), Managing northern hardwoods, pp. 143-159. SUNY Coll. Environ. Sci. and For., Fac. For. Misc. Publ. No. 13 (ESF 87-002) (Soc. Am. For. Publ. No. 87-03).

McRae, B. 1995. Effects of landscape composition on edge-sensitive songbirds in a forest-dominated landscape. M.S. Thesis, Univ. Wisconsin-Madison.

Meier, A.J., S.P. Bratton, and D.C. Duffy. 1995. Possible ecological mechanisms for loss of vernal-herb diversity in logged eastern deciduous forests. Ecol. Appl. 5(4):935-946.

Mladenoff, D. J. 2000. A Tale of two forests: The history of the northern forest, and a tribute to Forest Stearns. Opening address of the workshop, "Northern Forest Restoration", September 27-29, 2000, Ashland, WI. Publ. by Sigurd Olson Environmental Institute, Northland College, Ashland, WI.

Mladenoff, D.J., M.A. White, J. Pastor, and T.R. Crow. 1993. Comparing spatial pattern in unaltered old-growth and disturbed forest landscapes. Ecol. Appl. 3(2):294-306.

National Council for Air and Stream Improvement, Inc. (NCASI). 2004. Effects of heavy equipment on physical properties of soils and on long-term productivity: A review of literature and current research. NCASI Tech. Bull. No. 887. Research Triangle Park, NC. 76 pp.

Niese, J.N., T.F. Strong, and G.G. Erdmann. 1995. Forty years of alternative management practices in second-growth, pole-size northern hardwoods. II. Economic evaluation. Can. J. For. Res. 25: 1180-1188.

Nyland, R.D. 1987. Selection system and its application to uneven-aged northern hardwoods. In: Nyland, R.D. (Ed.), Managing northern hardwoods. SUNY Coll. Environ. Sci. and For., Fac. For. Misc. Publ. No. 13 (ESF 87-002) (Soc. Am. For. Publ. No. 87-03).

Nyland, R.D. 1996. Silviculture: concepts and applications. McGraw-Hill.

Pearson, C.W. and G.J. Niemi. 2000. Effects of within-stand habitat and landscape patterns on avian distribution and abundance in northern Minnesota. In: Conrad, S.G., editor. Disturbance in boreal forest ecosystems: Human impacts and natural processes. Proceedings of the Annual Meeting, International Boreal Forest Research Association, Duluth, MN, Aug. 4-7,1997. USDA For. Serv., NC Res. Stn., GTR ND-209, pp. 81-95.

Roberts, M.R. and F.S. Gilliam. 2003. Response of the herbaceous layer to disturbance in eastern forests. In: Gilliam, F.S. and M.R. Roberts, eds. The herbaceous layer in forests of eastern North America. Oxford Univ. Press, NY, pp. 302-320.

Robbins, S. D. Jr. 1990. Wisconsin Birdlife. The University of Wisconsin Press, Madison, 702 pp.

Rogers, E. and D. Premo. 1997. Managing for biodiversity. White Water Associates, Inc., Amasa, MI., 34pp.

Rooney, T.P., S.M. Wiegmann, D.A. Rogers, and D.M. Waller. 2004. Biotic impoverishment and homogenization in unfragmented forest understory communities. Cons. Biol. 18(3):787-798.

Roth, F. 1898. Forestry conditions and interests of Wisconsin, with a discussion by B.E. Fernow. Bull. No. 16. US Dept. of Ag., Div. of For. Washington D.C., Government Printing Office. 76 pp.

Runkle, J.R. 1991. Gap dynamics of old-growth eastern forests: management and implications. Natl. Areas J. 11:19-25.

Schlesinger, R.C. 1990. *Fraxinus americana* L. White ash. In: Burns, R.M. and B.H. Honkala (tech. coords.). 1990. Silvics of North America: 1. Conifers; 2. Hardwoods. Agric. Hndbk. 654. USDA For. Serv., Wash. D.C.

Schmidt, T.L. 1998. Wisconsin forest statistics, 1996. USDA For. Serv., NC For. Exp. Stn., Resour. Bull. NC-183. St. Paul, MN. 150pp.

Schulte L.A., D.J. Mladenoff, and E.V. Nordheim. 2002. Quantitative classification of a historic northern Wisconsin (U.S.A.) landscape: Mapping forests at regional scales. Can. J. For. Res. 32:1616-1638.

Schulz, K.E., T. Marriage, E. Nauertz, S. Garske, J. Zasada, D. Buckley, and T. Crow. 2001. Response of understory herb species richness and cover to *Acer saccharum* regeneration thickets. Abstracts of the Ecol. Soc. of Amer. 86: 201.

Singer, M.T. and C.G. Lorimer. 1997. Crown release as a potential old-growth restoration approach in northern hardwoods. Can. J. For. Res. 27: 1222-1232.

Smith, H.C. and N.I. Lamson. 1982. Number of residual trees: a guide for selection cutting. USDA For. Serv. Gen. Tech. Rep. NE-80.

Sonderman, D.L., and E.D.Rast. 1987. Changes in hardwood growing-stock tree grades. USDA For. Serv. Res. Pap. NE-608.

Spencer, J.S., Jr., W.B. Smith, J.T. Hahn, and G.K. Raile. 1988. Wisconsin's fourth forest inventory, 1983. USDA For. Serv., NC For. Exp. Stn., Resour. Bull. NC-107. St. Paul, MN. 158 pp.

Stearns, F. 1949. Ninety years of change in a northern hardwood forest in Wisconsin. Ecol. 30:350-358.

Stearns, F. 1986. Ecological view of the second hardwood forest and implications for the future. In: Proceedings of the conference on the northern hardwood resource: management and potential, 18-20 Aug. 1986, Houghton, MI. Edited by G.D. Mroz and D.D. Reed. Mich. Tech. Univ., Houghton. pp. 51-66.

Strong, T.F. 1998. Variation in gap size study yields more mid-toelrants. IUFRO Conference.

Strong, T.F., G.G. Erdmann, and J.N. Niese. 1995. Forty years of alternative management practices in second-growth, pole-size northern hardwoods. I. Tree quality development. Can. J. For. Res. 25: 1173-1179.

Tyrrell, L.E. 1991. Patterns of coarse woody debris in old-growth hemlock-hardwood forests of northern Wisconsin and western Upper Michigan. Dissertation. Univ. of Wisconsin-Madison. 185 pp.

Tubbs, C.H. 1977. Manager's handbook for northern hardwoods in the north central states. USDA For. Serv. Gen. Tech. Rep. NC-39.

Tubbs, C.H. and D.R. Houston. 1990. *Fagus grandifolia* Ehrh. American beech. In: Burns, R.M. and B.H. Honkala (tech. coords.). 1990. Silvics of North America: 1. Conifers; 2. Hardwoods. Agric. Hndbk. 654. USDA For. Serv., Wash. D.C.

Tubbs, C. H., R. DeGraaf, M. Yamasaki, and W. Healy. 1987. Guide to wildlife tree management in New England northern hardwoods. USDA For. Serv., NE For. Exp. Stn., Gen. Tech. Rep. NE-118. 30 pp.

Vogt, R.C. 1981. Natural history of amphibians and reptiles of Wisconsin. Milw. Public Museum, WI.

Webster, C.R. and C.G. Lorimer. 2002. Single-tree versus group selection in hemlock-hardwood forests: are smaller openings less productive? Can. J. For. Res. 32:591-604.

Webster, C.R. and C.G. Lorimer. 2005. Minimum opening sizes for canopy recruitment of midtolerant tree species: A retrospective approach. Ecol. Appl. 15(4):1245-1262.

Wisconsin Department of Natural Resources. 1995. Deer population goals and harvest management. Environmental Assessment. Madison, WI. WDNR. 305 pp.

Wisconsin Department of Natural Resources. 2003. Wisconsin forest management guidelines. WDNR, Div. Of For., Madison. PUB-FR-226 2003. 306 pp.

USDA Forest Service. 2005, Unpublished/Under Development. Lake states manager's guide for northern hardwoods. T. Strong, editor. Rhinelander, WI.

U.S. Department of Agriculture, Forest Service. 1974. Seeds of Woody Plants in the United States. C.S. Schopmeyer, tech. coord. USDA Agric. Hndbk. 450. Washington, D.C.

U.S Department of Agriculture, Forest Service. Unpublished/Under Development. Woody Plant Seed Manual. F.T. Bonner, tech. coord., and R.G. Nisley, editor.

FOREST HEALTH PROTECTION (FHP) TABLE 1
FOREST TREE HEALTH MANAGEMENT GUIDELINES FOR NORTHERN HARDWOOD SPECIES
Species included in this table are sugar maple, basswood, white ash, yellow birch, and beech.

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
DEFOLIATING INSECTS			
Basswood leafroller – *Sparganothis pettitana* Heavy infestation of this insect, often together with other spring defoliators occasionally causes severe defoliation.	Basswood	• Maintain healthy forests through proper forest management	
Birch Leafminer – *Fenusa pusilla* Browning of leaves. Repeated heavy leafmining weakens trees to become susceptible to bronze birch borer.	Birch	• No direct control practical • Monitor heavily defoliated stands for birch dieback.	Birch (Betula) Disorder: Birch Leaf Miner. 1990. Urban Phytonarian Series A2117
Bruce Spanworm – *Operophtera bruceata* Occasional outbreaks of repeated heavy defoliation in early spring may cause twig/branch dieback and mortality	Sugar Maple, Beech	• Maintain healthy forests through proper forest management • Monitor defoliated stands for possible salvage	Pest alert: Bruce Spanworm. USDA FS NA-FB/P-26
Forest Tent Caterpillar – *Malacosoma disstria* Widespread heavy defoliation occurs periodically at intervals of 5-15 years. An outbreak usually lasts 2-5 years.	Northern Hardwood	• Maintain healthy forests through proper forest management • During an outbreak, insecticide applications can be an option to minimize the damage on highly valuable stands with high proportion of susceptible species.	Forest Tent Caterpillar in the Upper Midwest. 2001. USDA FS NA-PR-02-01
Gypsy Moth – *Lymantria dispar* Widespread heavy defoliation occurs periodically at intervals of 5-15 years.	Northern Hardwood except ash (gypsy moth does not feed on ash)	• Maintain healthy forests through proper forest management • During an outbreak, insecticide applications can be an option to minimize the damage on highly valuable stands with high proportion of susceptible species.	Gypsy Moth Silvicultural Guidelines for Wisconsin. C. Brooks and D. Hall. 1997. DNR PUB-FR-123
Introduced Basswood Thrip – *Thrips calcaratus* Occasional outbreaks of early spring defoliation may cause growth loss, branch dieback, and mortality	Basswood	• Maintain healthy forests through proper forest management • Conduct salvage or presalvage harvest of declining trees to minimize economic losses.	How to Identify Introduced Basswood Thrips. 1992. USDA FS NA-FR-01-92

FOREST TREE HEALTH MANAGEMENT GUIDELINES FOR NORTHERN HARDWOOD SPECIES

Species included in this table are sugar maple, basswood, white ash, yellow birch, and beech.

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
DEFOLIATING INSECTS			
Linden looper – *Erannis tiliaria* Although this spring defoliator is commonly found on a northern hardwood stand, outbreaks are infrequent.	Northern hardwood	• Maintain healthy forests through proper forest management	Sugarbush Management: A Guide to Maintaining Tree Health. 1990. D. Houston, et. al. USDA FS General Technical Report NE-129
Maple Leafrollers – *Sparganothis acerivoran; Acleris chalybeana* Occasional outbreaks of spring defoliation may cause twig dieback. A combination of this pest and multiple defoliators together with some pathogens and adverse weather factors may cause maple blight (see maple blight under decline).	Sugar Maple	• Maintain healthy forests through proper forest management	Studies of Maple Blight. 1964. Univ. Wis. Agr. Exp. St. Res. Bull. 250
Maple Webworm – *Tetralopha asperatella* Occasional outbreaks of summer defoliation may cause twig dieback. A combination of this pest and multiple defoliators together with some pathogens and adverse weather factors may cause maple blight (see maple blight under decline).	Sugar Maple	• Maintain healthy forests through proper forest management	Studies of Maple Blight. 1964. Univ. Wis. Agr. Exp. St. Res. Bull. 250
Saddled Prominent – *Heterocampa guttivitta* Occasional outbreaks of repeated heavy defoliation in mid-summer may cause twig/branch dieback. A combination of this pest and multiple defoliators together with some pathogens and adverse weather factors may cause maple blight (see maple blight under decline).	American Beech, Sugar Maple, Yellow Birch	• Maintain healthy forests through proper forest management • During an outbreak, insecticide applications can be an option to minimize the damage on highly valuable stands with high proportion of susceptible species.	Saddled Prominent. 1987. P. Rush and D. Allen. USDA FS Forest Insect & Disease Leaflet 167.

Late season defoliators American daggermoth – *Acronicta americana* Orange-humped mapleworm – *Symmerista leucitys* Green-striped mapleworm – *Dryocampa rubicunda* Maple trumpet skeletonizer – *Epinotia aceriella* Variable oakleaf caterpillar – *Heterocampa manteo* Defoliation by multiple defoliators occasionally causes severe defoliation. Late season defoliator complex may result in growth loss but mortality is rare.	Basswood, Beech, Maple	• Maintain healthy forests through proper forest management • No chemical control is necessary	Sugarbush Management: A Guide to Maintaining Tree Health. 1990. D. Houston, et. al. USDA FS General Technical Report NE-129

FOREST TREE HEALTH MANAGEMENT GUIDELINES FOR NORTHERN HARDWOOD SPECIES

Species included in this table are sugar maple, basswood, white ash, yellow birch, and beech.

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
FOLIAGE DISEASES			
Anthracnose – multiple Anthracnose causing fungi (see reference) Irregular dead blotches on foliage. Growth loss.	Northern Hardwood	• Direct control is impractical and usually unnecessary. • Silvicultural measures to encourage air circulation may reduce infection.	Anthracnose Diseases of Eastern Hardwoods. F. Berry. 1985. Forest Insect & Disease Leaflet 133
Tar Spot – *Rhytisma* spp. One to multiple black, shiny, tar-like spots on foliage. Growth loss.	Maple	• Direct control is impractical and usually unnecessary.	Sugarbush Management: A Guide to Maintaining Tree Health. 1990. D. Houston, et. al. USDA FS General Technical Report NE-129
SCALE INSECTS			
Lecanium Scale – *Parthenolecanium* spp. This insect sucks plant juice, causing twig and branch dieback, and growth loss.	Northern Hardwood	• Chemical control is impractical, and usually unnecessary.	Scale Insects of Trees and Shrubs. R. Wawrzynski and M. Ascerno. 1999. Univ. Minn. Ext. FO-01019.
CANKERS/CANKER ROT[1]			
Nectria Canker – *Nectria cinnabarina* Trunk deformity and growth loss (all ages). Although it rarely causes mortality, a tree may break off at the point of canker.	Northern Hardwood	• Silvicultural control measures are based on percent of infected trees in stand (see reference). • Most infections occur when trees are 12-20 years old. Conduct improvement cut after age 20.	How to Identify and Control Nectria Canker of Hardwoods. R. Anderson. 1978. USDA FS
Eutypella Canker – *Eutypella parasitica* Trunk deformity and growth loss (all ages). Although it rarely causes mortality, a tree may break off at the point of canker.	Sugar Maple	• Avoid wounding. • Spores can be produced and infections can occur from spring through fall. • Spore dispersal can be minimized by placing cankers face down on the forest floor.	How to Identify and Minimize Damage Caused by Eutypella Canker of Maple. K. Robbins. 1979. USDA FS. NA-FR-10 Eutypella canker of maple: Ascospore discharge and dissemination. Phytopathology 69:130-135

[1] Please see FHP Table 2. Northern hardwood trees – common defects, signs of defect and evaluation of potential impacts on risk, vigor and value

FOREST TREE HEALTH MANAGEMENT GUIDELINES FOR NORTHERN HARDWOOD SPECIES

Species included in this table are sugar maple, basswood, white ash, yellow birch, and beech.

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
CANKERS/CANKER ROT[1]			
Canker Rots *Inonotus obliquus* (birch) *Cerrena unicolor* (maple & oak) *Inonotus glomeratus* (maple*)* *Phellinus everhartii* (oak) *Inonotus hispidus* (oak) Wood decay. Entry through wounds. These fungi are not compartmentalized and continue to attack newly formed wood.	Sugar Maple, Beech, Birch	• Minimize wounding. • Remove canker-rot infected trees during thinning. • Trees infected with canker rots may also provide excellent den trees. Consider leaving an occasional canker-rotted tree as a cavity tree for wildlife.	A Photo Guide to the Patterns of Discoloration and Decay in Living Northern Hardwood Trees. A. Shigo and E. Larson. 1969. USDA FS Research Paper NE-127
WILT DISEASES			
Ash Yellows – Phytoplasma Tufted foliage. Crown thinning. Slow growth. Branch dieback. Mortality. White ash that become infected when young do not grow to merchantable size. Most merchantable sized diseased trees live for at least 5-10 years. More common in urban settings or in small woodlots that adjoin agricultural fields.	Ash	• No known way to prevent or cure this disease. • Harvest trees with more than 50% crown dieback within 5 years. • Remove other infected trees during harvests.	How to Identify and Manage Ash Yellows in Forest Stands and Home Landscapes. 1994. USDA FS. NA-FR-03-94.
Sap Streak Disease – *Ceratocystis coerulescens* Early fall color and progressive dieback. Tree mortality and wood discoloration. Fungus is soil-borne; infection occurs through root and basal wounds.	Sugar Maple	• Minimize basal and root wounds • Remove infected trees • Harvest for pulp or firewood	How to Control Sapstreak Disease of Sugar Maple. K. Kessler. 1978. USDA FS

[1] Please see FHP Table 2. Northern hardwood trees – common defects, signs of defect and evaluation of potential impacts on risk, vigor and value

FOREST TREE HEALTH MANAGEMENT GUIDELINES FOR NORTHERN HARDWOOD SPECIES
Species included in this table are sugar maple, basswood, white ash, yellow birch, and beech.

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
WOOD BORERS			
Sugar Maple Borer – *Glycobius speciosus* Value loss through wood decay and discoloration, initiated by larval feeding. Stem breakage at point of attack.	Sugar Maple	• Maintain healthy forests through proper forest management. • Maintain well-stocked stands. • Remove overmature, low-vigor trees. • Monitor sugar maple on stand edges and along roads, especially trees that are recently exposed to full sunlight. • See FHP Table 2 for specific recommendations related to impact.	How to Identify and Control the Sugar Maple Borer. W. Hoffard. 1978. USDA FS. NSEFES.
Bronze birch borer – *Agrilus anxius* Branch dieback. Mortality. Infestations are more successful and widespread during years of drought.	Birch (Yellow birch is less susceptible compared to white birch)	• Maintain healthy forests through proper forest management. Thinning should be done with care to minimize stand disturbance.	Bronze Birch Borer. S. Katovich et. al. Forest Insect & Disease Leaflet 111. USDA FS.
Emerald Ash Borer – *Agrilus planipennis*[2]	White, Green, and Black Ashes	• In stands where ash is a significant component, consider reducing representation through release, thinning, improvement cuts and sanitation operations and promoting species diversity. Retaining 5-10 high quality ash trees per acre could help maintain the ash seed source and species diversity.	
ROOT DISEASE			
Armillaria Root Disease (Shoestring root rot) – *Armillaria* spp. Stringy white rot. Dieback and mortality, especially during drought years or following 2 or more years of defoliation (all ages).	Northern Hardwood	• Maintain stand in healthy condition. • Harvest declining trees before mortality and decay take place.	Armillaria Root Disease. R. Williams, *et al*. 1986 USDA Forest Service, Forest Insect and Disease Leaflet 78

[2] As of 12/22/04, this insect had not been detected in WI. However, it is in Michigan and expected to arrive in WI within the next decade.

FOREST TREE HEALTH MANAGEMENT GUIDELINES FOR NORTHERN HARDWOOD SPECIES
Species included in this table are sugar maple, basswood, white ash, yellow birch, and beech.

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
ANIMAL DAMAGE			
Sapsuckers (*Sphyrapicus varius*) Value loss through wood decay and discoloration. Occasional tree mortality.	Northern Hardwood	• Leave attacked tree in place. It will concentrate most of the attacks on one tree.	How to Identify Sapsucker Injury to Trees. M. Ostry. 1976. USDA FS. NSEFES.
Voles/Mice (*Microtus* spp.) Mortality of reproduction through stem girdling in grassy plantations.	Northern Hardwood	• Control grass first five years	Animal Damage to Hardwood Regeneration and Its Prevention in Southern Ontario. F.W. Von Althen. 1983. Information Report 0-X-351.
Rabbits/Hares (*Sylvilagus* spp./*Lepus americanus*) Mortality of reproduction through stem girdling.	Northern Hardwood	• Control usually unnecessary	Animal Damage to Hardwood Regeneration and Its Prevention in Southern Ontario. F.W. Von Althen. 1983. Information Report 0-X-351
Squirrels (*Sciurus* spp., *Tamiasciurus hudsonicus*, *Glaucomys* spp.) Gnawing on bark of maple saplings occasionally causes tree mortality. Squirrels also tend to feed on the edges of fungal cankers.	Northern Hardwood	• Control usually unnecessary	Animal Damage to Hardwood Regeneration and Its Prevention in Southern Ontario. F.W. Von Althen. 1983. Information Report 0-X-351
White-tailed Deer (*Odocoileus virginianus*) Browsing can cause mortality, deformity, or reduced growth rates of seedlings. Preferential browsing can alter forest composition. Antler polishing can shred bark and can cause deformity or mortality of small trees.	Forests, including Northern Hardwood	• Population management by hunting • Fencing (exclusion) • Tree shelters, bud caps, and repellents	Controlling Deer Damage in Wisconsin. S. Craven *et al*. 2001. UW Extension G3083. Animal Damage Management Handbook. 1994. USDA FS PNW-GTR-332.
Livestock Potential impacts include: soil compaction, root and stem wounding, reduced tree vigor and sap production, mortality and deformity of seedlings, and altered forest composition. Damage can be severe when soil is saturated or grazing is heavy (large populations or extended time periods).	Forests, including Northern Hardwood	• Eliminate or limit livestock from forests.	Sugarbush Management: A Guide to Maintaining Tree Health. 1990. D. Houston *et al*. USDA FS GTR-NE-129. Wisconsin Forest Management Guidelines. 2003. WDNR PUB-FR-226.

FOREST TREE HEALTH MANAGEMENT GUIDELINES FOR NORTHERN HARDWOOD SPECIES
Species included in this table are sugar maple, basswood, white ash, yellow birch, and beech.

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
ANIMAL DAMAGE			
European Earthworms (*Lumbricus, Dendrobaena, Octolasion, and Aporreclodea* species) Declines in native understory plant species and tree seedlings follow the invasion of non-native earthworms. They rapidly decompose the leaf litter that makes up the duff layer, leaving a bare soil surface inhospitable to tree seedlings and other plants that germinate in the duff or require it for protection. Partial recovery occurs after the invading front has passed and the earthworms become naturalized.	Forests and open lands, including Northern Hardwoods.	• Prevent new earthworm introductions. Don't transplant plants and trees into areas where earthworms are not present. Dispose of extra fishing bait in the trash. • Experts recommend limiting deer populations in areas with new invasions to avoid stacking stresses on flora.	http://www.stolaf.edu/depts/biology/mnps/papers/hale2001202.html http://www.extension.umn.edu/yardandgarden/YGLNews/YGLN-Mar0103.html
ABIOTIC and MECHANICAL DAMAGE			
Storm damage Limb and trunk breakage. Decay and discoloration through wounds.	Northern Hardwood	• See FHP Table 2 for specific recommendations related to impact.	Caring for ice-damaged woodlots and plantations. 1999. Ontario Extension Notes
Cold injury Cold injury occurs when the winter temperature falls to approximately -35° F or colder. Species' sensitivity varies. Injury is typically manifested by patches of dead (brown and black) cambium. In spring, affected trees will have reduced bud break and may have epicormic sprouts.	Northern Hardwood	• Monitor for dieback in upper and outer crown. If more than 50% of the crown dies, expect decline to continue to mortality.	
Late Spring Frost Damage This phenomenon is unpredictable and occurs when temperatures dip below freezing during bud expansion, break and when foliage is just emerging. Foliage turns black and wilts. Twig dieback can occur. New lateral buds can break within 4 weeks after damage.	Northern Hardwood	• In frost pockets, expect injury to new expanding growth during years with late spring frost. • Monitor for dieback in upper and outer crown. If more than 50% of crown dies, expect decline to continue to mortality.	

FOREST TREE HEALTH MANAGEMENT GUIDELINES FOR NORTHERN HARDWOOD SPECIES

Species included in this table are sugar maple, basswood, white ash, yellow birch, and beech.

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
ABIOTIC and MECHANICAL DAMAGE			
Drought Symptoms of drought include premature defoliation, thin crowns, subnormal leaf size and in severe cases, wilting foliage. If drought persists for more than one year, dieback of the upper and outer crown may occur.	Northern Hardwood	• Monitor for dieback in upper and outer crown. If more than 50% of crown dies, expect decline to continue to mortality. • Hardwoods take longer to recover from drought than conifers. Improvement in crown may not be noticeable for a year after normal precipitation returns.	
Logging damage Wounds. Limb and trunk breakage. Decay and discoloration through wounds.	Northern Hardwood	• Careful felling and skidding, directional felling techniques, careful harvest plan layout. • Limit harvest activities to times when soil is frozen or dry enough as to minimize soil compaction. • See FHP Table 2 for specific recommendations related to impact.	
DECLINE			
Maple blight Maple blight was first reported in Florence County in 1957. Affected trees suffer branch dieback, foliage chlorosis and wilt, epicormic sprouting and tree mortality. It is caused by a combination of stand conditions, weather, insects and diseases. Maple blight causes up to 30% mortality of pole and sawlog sized trees and up to 50% mortality of saplings.	Sugar Maple	• Maintain healthy forests through proper forest management. • In known problem areas where defoliation has caused tree mortality, reduce maple in overstory to less than 35% of the trees. • Monitor stands for possible salvage.	Studies of Maple Blight. 1964. Univ. Wis. Agr. Exp. St. Res. Bull. 250

FOREST TREE HEALTH MANAGEMENT GUIDELINES FOR NORTHERN HARDWOOD SPECIES

Species included in this table are sugar maple, basswood, white ash, yellow birch, and beech.

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
INVASIVE PLANT SPECIES			
Black-bindweed, False buckwheat *Polygonum convolvulus* Black-bindweed can outcompete and displace other flora.	Forests, including Northern Hardwoods.	• Little is known about control in forests. Herbicide or hand-pulling may be used where control is needed.	http://ianrpubs.unl.edu/horticulture/nf585.htm
Field Bindweed *Convulvulus arvensis* A Wisconsin state-listed "noxious weed" that can outcompete and displace other flora.	Forests, including Northern Hardwoods.	• Little is known about control in forests. Herbicide or hand-pulling on a regular basis (perhaps only once per year), may be used where control is needed.	http://tncweeds.ucdavis.edu/esadocs/documnts/convarv.html
Garlic Mustard *Alliaria petiolata* A major invasive plant that outcompetes herbaceous flora and tree seedlings. There is some evidence of allelopathy to beneficial mycorrhizae. Small seeds spread easily on equipment and clothing.	Forests, including Northern Hardwood. One of the few invasive understory plants to thrive in full shade.	• Use preventative measures; clean equipment and clothing before entering the forest. • Monitor to ensure early detection. • Small infestations can be eradicated by hand pulling, or by repeatedly cutting the flower stalk close to the soil surface before flowering begins. • Spray with glyphosate in spring or fall to kill basal rosette; avoid non-target species.	http://www.dnr.state.wi.us/org/land/er/invasive/factsheets/garlic.htm
Japanese Knotweed *Polygonum cuspidatum* Outcompetes and displaces other flora. Early emergence, height, and density allow it to shade out other vegetation and limit tree regeneration. Not yet widespread in Wisconsin. Difficult to eradicate once established.	Northern Hardwood forests, riparian forests, open lands with mesic or wet-mesic conditions.	• Repeated cutting (3x per growing season) provides control but may not eradicate a stand. • The herbicide glyphosate can be effective, especially applied in fall. • Continued monitoring and follow-up are needed after treatment.	http://tncweeds.ucdavis.edu/esadocs/documnts/polycus.html
Japanese Barberry *Berberis thunbergii* Has potential to limit forest regeneration as it becomes more abundant. With a concerted effort, potential remains to suppress this species. It can outcompete and displace other flora. Its thorns make it difficult to work or recreate in an infested area.	Forests and semi-open areas, including Northern Hardwoods. Tolerates full shade.	• Mechanical removal in early spring is recommended for small infestations. Wear thick gloves. • Glyphosate or triclopyr herbicides can be effective. Avoid impacts to non-target vegetation.	http://www.dnr.state.wi.us/org/land/er/invasive/factsheets/barberry.htm http://tncweeds.ucdavis.edu/moredocs/berthu02.pdf

FOREST TREE HEALTH MANAGEMENT GUIDELINES FOR NORTHERN HARDWOOD SPECIES
Species included in this table are sugar maple, basswood, white ash, yellow birch, and beech.

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
INVASIVE PLANT SPECIES			
Common Buckthorn and Smooth (Glossy) Buckthorn (*Rhamnus cathartica* and *R. frangula*) Tall shrubs form dense thickets that outcompete and displace other flora. There is some evidence that they are also allelopathic. Seeds are spread by birds, and in mud on equipment.	Forests, including Northern Hardwood, and open lands. Smooth buckthorn is more restricted to wet and wet-mesic areas.	• Monitor to ensure early detection. • Clean equipment before entering the forest. • Small plants can be eradicated by hand pulling. • Large shrubs can be mechanically removed, cut and stump-treated, or controlled with a basal bark application. Foliar sprays should be restricted to fall months when buckthorn is still actively growing but other species are dormant, to avoid impacts to non-target vegetation. Trichlopyr may be more selective than glyphosate. In areas with high water tables, use herbicides labeled for use over water. • Continued monitoring and follow-up are needed after treatment.	http://www.dnr.state.wi.us/org/land/er/invasive/factsheets/buckthorns.htm
Bush Honeysuckles (*Lonicera* species) Forms dense shrub thickets that outcompete and displace other flora. Seeds are spread by birds, and in mud on equipment.	Forests, including Northern Hardwood, and open lands.	• Monitor to ensure early detection. • Clean equipment before entering the forest. • Small plants can be eradicated by hand pulling. • Large shrubs can be mechanically removed, or cut and stem-treated. • Foliar spray using glyphosate in spring, prior to emergence of native plants. In areas with high water tables, use herbicides labeled for use over water.	http://www.dnr.state.wi.us/org/land/er/invasive/factsheets/honeysuckles.htm

FOREST TREE HEALTH MANAGEMENT GUIDELINES FOR NORTHERN HARDWOOD SPECIES
Species included in this table are sugar maple, basswood, white ash, yellow birch, and beech.

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
INVASIVE PLANT SPECIES			
Norway Maple *Acer platanoides* A tree species that can outcompete and displace other flora, including sugar maple seedlings. The sap is not suitable for maple syrup. Identification is difficult, as morphology is ambiguous with sugar maple. Flattened seed cavity is distinctive. Norway maples may or may not have milky sap.	Northern Hardwood and other upland forests. Tolerates shade. Prolific stump sprout reproduction and viable seeds.	• Pull seedlings. • Cut stump and treat with glyphosate or basal bark spray stem with triclopyr.	http://www.dnr.state.mn.us/invasives/terrestrialplants/woody/norwaymaple.html
Amur Maple *Acer ginnala* A tall shrub or small tree that can outcompete and displace other flora. Foliage turns bright red in fall.	Northern Hardwood and other upland forests. Tolerates shade. Prolific stump sprout reproduction and viable seeds.	• Mechanical removal of small infestations • Cut stump and treat with glyphosate or basal bark spray stem with triclopyr.	http://www.dnr.state.mn.us/invasives/terrestrialplants/woody/amurmaple.html
Pennsylvania Sedge *Carex pennsylvanica* This native sedge can impact northern hardwood regeneration by forming impenetrable mats on the forest floor. Physical impedance is the mechanism by which damage occurs. Past management may have contributed to development of existing sedge mats; increases in size and density after opening the forest canopy have been observed.	Mesic forests, including Northern Hardwoods.	• There is limited information on control. Fire, herbicide, scarification, or tilling (particularly on roadbeds or landings) may be effective in some situations.	http://web4.msue.msu.edu/mnfi/abstracts/ecology/pine_barrens.pdf http://www.ecologyandsociety.org/vol7/iss2/art10/main.html http://www.fs.fed.us/database/feis/plants/graminoid/carpen/index.html

*** General References**
Diseases of Trees and Shrubs. 2nd edition. W. Sinclair et. al. 1989. Cornell University
Insects that Feed on Trees and Shrubs. W. Johnson and H. Lyon. 2nd edition. 1991. Cornell Univeristy
Insects of Eastern Hardwood Trees. A. Rose and O. Lindquist. 1997. Natural Resources Canada
Field Guide to Tree Diseases of Ontario. C. Davis and T. Meyer. 1997. Natural Resources Canada
http://www.na.fs.fed.us/spfo

Forest Health Protection (FHP) Table 2. Northern Hardwood trees: common defects, signs of defect, and evaluation of potential impacts on risk, vigor and value

DEFECT	High Probability of Mortality or Failure (high risk)	High Probability[1] of Degrade due to Defect
Canker Localized area of dead bark and cambium; wood behind canker may or may not be decayed. Commonly caused by fungi. Fungal cankers are a source of spores that may infect healthy trees.	• Canker affects >50% of the stem's circumference or >40% of the stem's cross section. • Horizontal crack on a canker face. • >20% of combined circumference of the stem and root collar are affected by butternut canker. • White pine blister rust canker on main stem but located below crown where stem failure would leave a minimal crown.	• Decay associated with large canker (affects >50% of stem's circumference). Fruit body visible in the canker's face. Extent of decay and discoloration will vary depending on organisms involved. • Basswood infected with Nectria canker, if multiple infections on the main stem are common.
Wounds Any injury to tree that exposes the cambium or wood beneath cambium.		• Maple, white and yellow birch: 1 or more wounds ≥50 in^2 or ≥30% of tree's circumference. • >1 sugar maple borer wound (discoloration associated with borer typically limited to 24" above and 12" below). • >2 large (>5") branches broken close to the stem. • Codominant ripped from stem.
Decay Wood that is missing or structurally compromised. Canker rot fungi are not compartmentalized and will cause significant decay.	• Decay in main stem results in <1" of sound wood for every 6" in diameter; must have 2"of sound wood for every 6" dbh if there is also a cavity present. • Decay or cavity affects >40% of the stem's cross-section. • Tree infected with a canker-rot fungus (see next column).	• Tree infected with a canker-rot fungus including but not limited to: *Inonotus obliquus (birch),* Cerrena unicolor (maple & oak), Innonotus glomeratus (maple), Phellinus everhartii (oak) *Inonotus hispidus (oak).*
Cracks (open, can see into the tree at least an inch) A split through the bark, extending into the wood. Wood fibers are not fused. Cracked stems or branches cause the affected area to act as 2 or more separate beams, weakening mechanical support. Open cracks are more likely to be associated with decay and discoloration.	• Crack goes completely through a stem or is open for >4-6' (length). • Two open cracks occur on the same stem segment. • The stem has an open crack in contact with another defect such as decay, a canker, or weak union.	• >1 face with open crack or seam or any spiral crack.

[1] There is a high probability that the defect will cause a significant reduction in value over a 15-year period; rate of decay/stain development varies by species. Defect may be limited to localized area.

DEFECT	High Probability of Mortality or Failure (high risk)	High Probability[1] of Degrade due to Defect
Weak Union Union with ingrown bark between stems; wood fibers are not fused. Weak unions are characterized by an acute angle between stems.	• Stump sprouts joined above ground in V-shaped union and associated with a crack, showing failure has already begun.	• Large (>8" diameter stems) tight union that is either cracked or decayed or associated with another defect. Could result in failure; stain and decay will vary.
Structural Compromise Unusual form typically initiated by storm damage.	• Leaning tree with recent root lifting. • Leaning tree with a horizontal crack, long vertical crack, or buckling wood on the underside of the tree. • New leader formed in response to a dead or broken top. Risk increases as top gets larger and stem decays at break point.	
Root Defects Loss of structural support due to root rot, wounding, severing or any other factors that cause root mortality.	• More than 33% of roots severed, decayed or otherwise compromised. • Stump sprouts with a tight union where root structure is not sufficient to support stems.	• >3 root wounds within 4' of the main stem; each wound encompasses >30% of root diameter.
Crown Density/Dieback/Leaf Condition Crown symptoms are often showing a response to poor root health, stress such as defoliation or drought or infestation by cambium-mining beetles. Large dead branches/tops/codominants keep wound "open"; decay will advance more rapidly with an open wound. Failure of dead wood is unpredictable. Could cause damage upon failure.	• 50% of the crown dead, unless loss of crown is due to stem breakage. • 75% of leaves subnormal in size or abnormal in color. (excluding iron chlorosis.) • Signs of cambium miners such as the two-lined chestnut borer or bronze birch borer.	• Multiple large (>5" diameter) dead branches, dead top or codominant (>10" diameter).

[1] There is a high probability that the defect will cause a significant reduction in value over a 15-year period; rate of decay/stain development varies by species. Defect may be limited to localized area.

Summary of Principles Related to Discoloration and Decay Development
Jane Cummings Carlson

1. Wounding; the death of large branches, sprouts or codominants; and any activity that exposes the cambium to air and moisture initiate discoloration in trees with naturally white wood throughout.
2. After wounding, discoloration may be caused by bacteria, oxidation of phenolic compounds and degradation of the cells by fungi.
3. Discoloration and decay typically do not move throughout a tree as it ages but are compartmentalized and limited to tissue present at the time of wounding. Known exceptions to this include trees that are infected with canker-rot fungi.
4. Discoloration tends to form in vertical columns, tapered at the ends.
5. The further the wound or breakage is from the main stem, the lower the chance discoloration and decay will occur to the main stem.
6. Discoloration resulting from a broken top or split stem will progress downward and be limited to the diameter of the tree at the time of wounding. Rate of spread is variable; approximately 4 inches per year has been noted in sugar maple if wound is significant (> 40% of circumference).
7. Wounds initiated in the spring will form callus more quickly than wounds initiated in the fall but if the wounds are the same size, the discoloration resulting from both wounds will likely be similar after 3 years.
8. The presence of prior defects appears to influence the rate of formation (hasten) of additional discoloration from newer wounds.
9. Trees with lower starch content (i.e. defoliated) tend to be more negatively impacted by wounds, as there is a reduced rate of callus formation. Vigorous trees may slow or halt the discoloration/decay process more readily than trees of poor vigor.
10. Decay and discoloration are more likely and more extensive in wounds that remain open; decay and discoloration moves more slowly after wounds are closed.
11. Volume of discoloration and decay increases with increasing wound width; wound area is a good indicator of value loss.
12. Wounds are initiation points for cracks.
13. Factors such as site, genetic controls, wound type, frequency of wounding, host species and microorganisms present all potentially influence wound closure and in turn the rate and severity of discoloration and decay development.

Summary of Guidelines Related to Stain and Decay Development

Species	Issue	Rule of Thumb
Maple, No. Hdwds.	Oxyporus populinus Ganoderma applanatum Canker rots	Decay 2-4' above and below Decay 4-6' above and below Decay 5-7' above and below
Sugar Maple	Rate of vertical development of discoloration.	Wound 20% of circumference: 1"/yr. 30% of circumference: 2"/yr. 40% of circumference: 4"/yr. These numbers are for upward movement from a basal wound, downward movement may be slower.
Sugar Maple	Decay/discoloration severity	Age, severity and proximity to other wounds all influence volume of discoloration and decay.
Sugar Maple	Sugar Maple Borer Wounds	Discoloration more likely when both a horizontal and vertical trail is present. Discoloration/decay columns typically limited to 24" above and 12" below the scar.
Sugar Maple	Discoloration common in larger/older trees.	Large Dead branches appear to result in physiologically induced discoloration in the main stem. This is also influenced by the presence of certain microorganisms.
Yellow Birch	Rate of development of column of decay	5 years: column length equal to wound length 15 years: column length 2 X wound length 20 years: column length 3-5 X wound length

Slower decay → **Faster decay**

Hickory Sugar Maple Ash Red Maple White birch Yellow Birch
White, Red Oak Black Oak Basswood Beech, Aspen
Cherry

Less discoloration (with same wound size/severity) → **More discoloration**

Hickory Ash Basswood White birch Sugar Maple Red Maple
Oak Yellow Birch
Cherry

References for FHP Table 2 and Summaries of Principles and Guidelines (by Jane Cummings Carlson):

Basham, J.T. 1964. Cull Studies: The defects and associated Basidiomycete fungi in the heartwood of living trees in the forests of Ontario. Can. Dept. For. Pub. No. 1072.

Basham, J.T. 1991. Stem decay in living trees in Ontario's forests: A users compendium and guide. Great Lakes Forestry Centre, Info. Rep. O-X-408.

Basham, J.T. and H.W. Anderson. 1977. Defect development in second-growth sugar maple in Ontario. I. Microfloral infection relationships associated with dead branches.

Baxter, D.V. and G.A. Hesterberg. 1958. Fungi associated with decay in sugar maple following logging. USDA For. Serv. Lake States For. Exp. Stn. Tech. Note No. 528.

Benzie, J.W., G.A. Hesterberg, and J. Ohman. 1963. Pathological effects of logging damage four years after selective cutting in old-growth northern hardwoods. J. For. 61(10): 786-792.

Bruhn, J. 1990. Damage to the residual stand resulting from mechanized thinning of northern hardwoods. In: Hardwood thinning opportunities in the Lake States, USDA For. Serv. Gen. Tech. Rep. NC-113.

Campbell, W.A. 1937 Decay hazard resulting from ice damage to northern hardwoods. J. For. 35: 1156-1158.

Campbell, W. and R. Davidson. 1940. Top rot in glaze-damaged black cherry and sugar maple on the Allegheny plateau. J. For. 38: 963-965.

Chapeskie, D. and C. Coons. 1999. Effects of ice storm damage and other stressors on sugar bush health and sap productivity: Literature review.

Erickson, M. *et al*. 1992. Silvicultural influence on heartwood discoloration in sugar maple. N. J. Appl. For. 9(1): 27-29.

Greifenhager, S. and A. Hopkin. 2000. After the ice storm: Decay, stain and wood-boring beetles. Eastern Ontario Model Forest Report.

Hesterberg, G.A. 1957. Deterioration of sugar maple following logging damage. USDA For. Serv. Lake States For. Exp. Stn., Stn. Paper 51, St. Paul, MN. 58p.

Hesterberg, G.A., J. Wright, and D. Frederick. 1976. Decay risk for sugar maple borer scars. J. For. 443-445.

Kelley, R.S. 1996. Photographic guide to selected defects associated with sugar maple logging wounds. State of VT Dept. of Forests, Parks and Recreation.

Kubler, H. 1983. Mechanism of frost crack formation in trees-a review and synthesis. For. Sci. 29(3): 559-568.

LaVallee, A.and M. Lortie. 1968. Relationships between external features and trunk rot in living yellow birch. For. Cron. 44: 5-10.

Miller *et al*. 1978. Timber quality of northern hardwood regrowth in the Lake States. For. Sci. 24(2): 247-259.

Neely, D. 1970. Healing of wounds on trees. J. Amer. Soc. Hort. Sci. 95 (5): 536-540.

Ohman, J. 1968. Decay and discoloration of sugar maple. For. Pest Leaflet 110. USDA For. Serv., 7p.

Ohman, J. 1970. Value loss from skidding wounds. J. For. pp 226 - 230.

Ostrofsky, W. 2003. Recovery of ice storm damaged trees. Univ. Maine Coop. Ext. Pub. 9013.

Sharon, E. 1972. Some histological features of *Acer saccharum* wood formed after wounding. Can. J. For. Res. 3:83.

Shevenell, B. and W. Shortle. 1986. An ion profile of wounded red maple. Phytopathology 76 (2):132-135.

Shigo, A. 1966. Decay and discoloration following logging wounds on northern hardwoods. USDA For. Serv., NE For. Exp. Stn. Res. Pap. NE-47.

Shigo, A. 1975. Biological transformation of wood by microorganisms. In: Proceedings of the Sessions on wood products pathology, Minneapolis, MN.

Shigo, A. 1976. Microorganisms isolated from wounds inflicted on red maple, paper birch, American beech, and red oak in winter, summer and autumn. Phytopathology 66: 559-563.

Shigo, A. 1984. How to assess the defect status of a stand. N. J. Appl. For. 3: 41-49.

Shigo, A., W.C. Shortle, and P.W. Garrett. 1977. Genetic control suggested in compartmentalization of discolored wood associated with tree wounds. For. Sci. 23: 179-182.

Shortle, W. 1998. Tree biology and ice storm. Univ. New Hamp. Coop. Ext. website, www.ceinfo.unh.edu/treebio

Shortle, W.C., J. Menge, and E. Cowling. 1977. Interaction of bacteria, decay fungi and live sapwood in discoloration and decay of trees. Eur. J. For. Path. 8: 293-300.

Silverborg, S.B. 1959. Rate of decay in northern hardwoods following artificial Inoculation with some common heartrot fungi. For. Sci. (5) No. 3: 223-228.

Simmons, G.A. and F.B. Knight. 1973. Deformity of sugar maple caused by bud-feeding insects. Can. Ent. 105: 1559-1566.

Smith, K. and W. Shortle. 1998. A first look at tree decay: An introduction to how injury and decay affect trees. USDA For. Serv. NE State & Private For. NA-PR-02-98.

Solomon, D.S. and A. Shigo. 1976. Discoloration and decay associated with pruning wounds on yellow birch.

Toole, E.R. 1967. Rates of wood decay behind open and closed wounds. Plant Disease Rep. 51 (1): 600-601.

Wargo, P. 1977. Wound closure in sugar maple: adverse effect of defoliation. J. For. Res. 7: 410-414.

Wargo, P. 1998. Integrating the role of stressors through carbohydrate dynamics. In: Sugar maple ecology and health: Proceedings of an international symposium, pp 107-112.

WISCONSIN DEPARTMENT OF NATURAL RESOURCES
NOTICE OF FINAL GUIDANCE & CERTIFICATION

Pursuant to ch. 227, Wis. Stats., the Wisconsin Department of Natural Resources has finalized and hereby certifies the following guidance document.

DOCUMENT ID

FA-20-0001

DOCUMENT TITLE

Silviculture Handbook

PROGRAM/BUREAU

Forest Economics and Ecology, Applied Forestry Bureau

STATUTORY AUTHORITY OR LEGAL CITATION

S. 823.075, Wis. Stats. & NR 1.25, Wis. Admin. Code

DATE SENT TO LEGISLATIVE REFERENCE BUREAU (FOR PUBLIC COMMENTS)

2/10/2020

DATE FINALIZED

4/6/2020

DNR CERTIFICATION

I have reviewed this guidance document or proposed guidance document and I certify that it complies with sections 227.10 and 227.11 of the Wisconsin Statutes. I further certify that the guidance document or proposed guidance document contains no standard, requirement, or threshold that is not explicitly required or explicitly permitted by a statute or a rule that has been lawfully promulgated. I further certify that the guidance document or proposed guidance document contains no standard, requirement, or threshold that is more restrictive than a standard, requirement, or threshold contained in the Wisconsin Statutes.

March 27, 2020

Signature | Date