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Silvics and Management Guidance Manual

Forest Resources Division
Wildlife Division

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Michigan Department of Natural Resources
Forest Resources
and
Wildlife Division

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Silvics and Management Guidance Manual

David D. Neumann, Editor

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Preface and Acknowledgements

The guidance in this manual has been developed to update previous Michigan Department of Natural Resources (DNR) guidance written circa 1980-2000. Updates include the addition of new Michigan- and State Forest-specific information on cover type characteristics and site productivity, and revised management recommendations for State forest lands based upon management experience and observed outcomes over the last 20 years. Updated Michigan-specific silviculture guidance is necessary because:

- Forest resources change over time, and past recommendations may no longer be appropriate for today's forests;
- Previous guidance lacked Michigan-specific site productivity differentiation;
- Management experience indicates that some previously recommended techniques are not reliable or are no longer advisable.

Management of Michigan forests has grown more complex over time, due in part to maturation of forests that originated after widespread harvesting and fires in the 1900's to 1940's, and also in response to changing demands on our forest resources for timber, wildlife habitat, biodiversity, recreation and aesthetic values. In response to these changes, the practice of silviculture is also changing.

- Silviculture is defined as "the art and science of controlling the establishment, growth, composition, health, and quality of forests and woodlands to meet the diverse needs and values of landowners and society on a sustainable basis"[1].

In this guidance, Michigan-specific information is present regarding:

- Site productivity, via Kotar habitat type classification;
- Cover type composition, age-class distribution and structural characteristics;
- Forest pests and diseases;
- Wildlife species and habitat values provided by cover types and associated tree species.

The guidance is structured as a manual, with one chapter dedicated to each of the major forest cover types. Each chapter begins with a discussion of the silvics of the major species comprising the cover type. Silvics is defined as "the study of the life history and general characteristics of forest trees and stands, with particular reference to environmental factors, as a basis for the practice of silviculture". In this guidance, the characteristics and ecological adaptations of the major, and in some cases, minor, species are compared, so that managers may gain insight on how the species may respond to different management techniques. The discussion of silvics is specific to Michigan, and may be applied to all ownerships.

Following the silvics discussion, management guidance is provided for use on DNR-administered State forest lands. The management guidance is intended to complement other guidance in effect for management of State forests, specifically:

- Within-Stand Retention Guidance;
- Woody Biomass Harvesting Guidance;
- Sustainable Soil & Water Quality Manual;
- The 2008 Michigan State Forest Management Plan;
- Other local and regional State Forest management plans.

Resulting discussion of some issues may occur with greater brevity, and discussion of some issues may be omitted in order to reduce redundancy with other guidance that is in effect. Managers of other lands are advised to refer to the above resources and/or seek comparable guidance.

For ease in navigation, a table of contents is provided for the manual. The table of contents is constructed with embedded bookmarks that can be used to quickly navigate to the desired sections.

[1] The Dictionary of Forestry, 1998, Society of American Foresters, John A. Helms, editor.

The manual may be viewed, saved or printed in its entirety, or as individual chapters.

For DNR State forest land management staff, this guidance should complement existing forest planning processes. Managers should consider the Silvicultural Guidance, as well as Regional and State Forest Management Plan cover type and local area recommendations when evaluating stands for potential treatments. Often the process of selecting stands for treatment occurs at the same time that short-term management objectives are developed through the inventory and annual compartment review process. When developing stand level management objectives, managers should:

- Take biological, economic, and social values or uses into account. These values include:
    - timber production
    - wildlife habitat
    - aesthetics
    - recreation
    - watershed protection
    - biodiversity conservation
- Set stand management objectives that are long-term, but adaptable. Objectives should consider site potential, current stand conditions, and long-term landscape strategies.
    - Evaluate proposed stand level objectives within the context of higher level landscape or regional plans, where they exist.
    - Be cognizant that multiple objectives can often be achieved simultaneously with minimal compromise. For example, snags can often be retained for wildlife habitat while simultaneously satisfying timber production objectives.
    - Use habitat type (Burger & Kotar 2003) as the preferred indicator of site potential and to inform decisions when setting objectives for stand species composition or regeneration.

Construction of this manual began in 2004 with assignment of the task to the DNR's Silviculture and Regeneration Team (S&R Team), a subgroup of the Vegetation Management Team. Each cover type was assigned to a lead author and a small group of co-authors from among the S&R Team members, and Dr. Michael Walters (Michigan State University, Forestry Department) for the northern hardwood chapter. Specific lead- and co-authors are identified in the preface for each cover type chapter. Members of the S&R Team and DNR Forest Resources Division's Forest Planning and Operations Section provided review and comment, and are named as reviewers in the acknowledgments for each chapter.

Introduction: Silvics and Management Guidance by Cover Type

This section presents silvics and management guidance for forest cover types that are common to the Northern Lower Peninsula (NLP) and the Upper Peninsula of Michigan. This guidance does not address management of Southern Lower Peninsula (SLP) forest cover types, in part because site conditions are significantly different between the upper two-thirds of Michigan and the southern region, and also because most site-specific DNR forest management experience is related to state forest lands. The DNR-administered lands in the SLP are limited to state game areas and state parks and recreation areas, which are managed primarily for the purposes of wildlife habitat and outdoor recreation.

Future revisions may include discussion of forest cover types particular to the SLP such as central hardwoods, black walnut, black locust, and oak-hickory.

1. Northern Hardwood

Preface and Acknowledgements

This document provides guidance for the management of northern hardwood stands in Michigan. General information on the ecological characteristics of the common tree species, wildlife and biodiversity values, and an overview of forest health concerns common to northern hardwood stands are presented in the Silvics section. Guidance for management of northern hardwood on DNR-administered State forest land is presented in the Management Guidance section. Both sections are intended to be used together.

The guidance was written over an eight-year period by a core team of DNR Forest Resources Division and Wildlife Division staff, and Dr. Michael Walters, a forest ecologist with Michigan State University, Department of Forestry. The DNR staff on the core writing team included Jim Ferris, Jim Bielecki, Sherri MacKinnon, Bob Heyd, Scott Throop, and David Neumann. Editors include: David Neumann, Debbie Begalle, David Price, and Georgia Peterson.

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Northern Hardwood Silvics Guidance

Introduction

In this guidance, northern hardwoods are described as sugar maple or beech dominated stands with species mixtures common to forests in the Northern Lower Peninsula (NLP) and Upper Peninsula (UP) of Michigan. Maple-beech dominated stands containing species typical of southern hardwood forests (e.g., sassafras and tulip poplar) that are more common in Southern Lower Michigan will be described in the yet-to-be-developed Central Hardwoods guidance. Northern hardwoods are also described as the chief component of the *mesic northern forest* community (Cohen 2000) or *northern mesic hardwood forests* (hemlock-hardwood forests) (Dickmann 2004).

The information provided in this document is posed in general terms, since stand dynamics are affected by a myriad of factors, in addition to species silvical characteristics. This guide is intended as one of several aids for

the practice of northern hardwood silviculture. The discussion that follows is organized under the following general headings:

- Range and Composition of the Northern Hardwood Cover Type;
- Common Stand Conditions;
- Site and Successional Characteristics;
- Reproductive Characteristics;
- Damage/Mortality Agents;
- Wildlife Habitat Attributes.

Range and Composition of the Northern Hardwood Cover Type:

Northern hardwoods occur on more than 50 million acres throughout the Northeast and North Central regions of United States (Smith et. al. 2003). In Michigan, northern hardwood stands occur on more than 6 million acres of forest land (FIA 2013 data). The geographic range of northern hardwoods has conventionally been defined by the natural limits of its dominant species: sugar maple, American beech, yellow and paper birch, and eastern hemlock. It is also the principal component of mesic northern forest communities. Figure 1.1 depicts the likely distribution of mesic northern forest communities in Michigan, circa 1800.

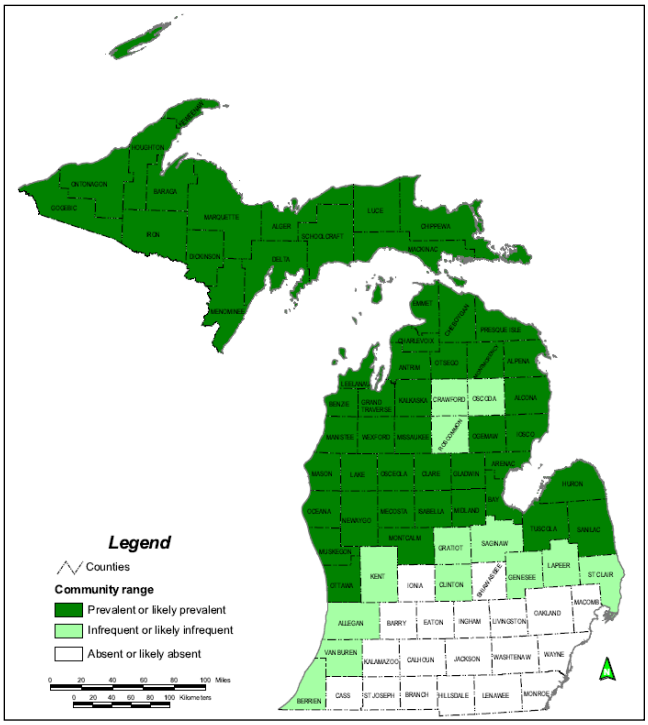

Figure 1.1. Likely Distribution of Mesic Northern Forest Communities in Michigan by County, circa 1800. (Albert et. al. 2008)

Northern hardwoods occur across a broad range of land forms and soil drainage classes, but most often occur on well to moderately well drained sites, with high soil moisture. Compared to other upland forest types, northern hardwoods usually occupy sites that are more nutrient rich and mesic.

Less mesic and less fertile sites typically support conifers and conifer-oak-red maple mixtures; whereas wet sites support lowland conifers and hardwoods. Within the range of nutrient poor/dry-mesic to nutrient rich/mesic sites, species composition and productivity vary dramatically. Common overstory species are listed by habitat type in Table 1.1.

Table 1.1. reveals several trends in overstory composition related to present site conditions:

- Sugar maple is dominant on all but the poorest sites, where red maple is often dominant instead.
- Common associates over a broad range of site conditions include eastern hemlock, yellow birch, and American beech, except in the Western Upper Peninsula (WUP).
- On poorer sites, common associates include red oak, quaking aspen, bigtooth aspen and paper birch.
- On richer sites, basswood and white ash are more common.
- Other associated tree species occurring in lesser numbers include black cherry, white pine, balsam fir, white spruce, hop-hornbeam, red pine, and elm.

Compared to survey records collected prior to the logging era, today's northern hardwood stands have less white pine, hemlock, yellow birch, and red pine, and more sugar maple, aspen, paper birch, and red oak.

Northern hardwood stands are usually described as late-successional or climax forests. Shade tolerant species predominate; however, representation by intermediate shade tolerant species (i.e., red oak, white ash, black cherry) can be maintained through creation of 70 to 100+ foot canopy gaps during harvesting or by medium-

scale natural disturbances (e.g., similar size canopy gaps created by ice storms, or windthrow of a few to several trees). Occasionally, stands of early seral species (aspen and birch, with some conifers) can become established where overstory trees and advanced regeneration of tolerant species are killed, and sufficient mineral soil is exposed. These conditions often result from wildfire. Alternatively, stands resulting from small- or medium-scale disturbances (e.g., wind or ice storms) can be comprised of the same shade tolerant species that dominate late succession, if advanced regeneration survives intact and/or there is vigorous sprouting from the top-killed northern hardwood overstory.

In the early part of the 20th Century, northern hardwood acreage declined after post-logging fires converted many acres to aspen. Since fire prevention and control measures have been implemented, northern hardwoods acreage has rebounded, showing significant increases between the 1933 and 1993 Forest Inventory and Analysis (FIA) surveys (Doepker, 2000). Logging history has strongly influenced current northern hardwood stand conditions in other ways. Selective removal of white pine, and in some areas hemlock, occurred in the mid- to late-1800's. Hemlock was used for the tanning industry. Extensive hardwood logging followed selective pine and hemlock removals, via commercial clearcuts in the first half of the 20th Century. The legacies of the logging era include:

A. Conversion of many stands from uneven-aged to even-aged structure. These stands are now 60 to 100 years old.
B. Lower representation of pine and hemlock species.
C. In high-graded stands, greater representation of poorly-formed older trees mixed with a younger even-aged cohort.

Since the 1950's, most stands have been managed using periodic thinnings and/or selection harvests with the intent of restoring uneven-aged stand structure.

Table 1.1 Typical Michigan Northern Hardwood Species Composition by Habitat Type, Overstory Composition, & Growth Potential & Site Index for Sugar Maple (Burger & Kotar 2003).

	Moisture Regime	Nutrient Regime	Region	Habitat Type	Typical overstory species composition[1]	Species more common historically than now[2]	Sugar Maple Growth Potential	Sugar Maple Site Index
Wet Sites / Dry Sites	mesic	rich-very rich	WUP	AOCa	sugar maple, basswood, white ash	white pine	very good	65-70
			NLP	AFOCa	sugar maple, basswood, white ash	hemlock	very good	65-70
		medium-rich	WUP	ATD, ATD-Hp	sugar maple, basswood, red maple	hemlock, yellow birch	very good	60-65
				ATD-Ca	sugar maple, basswood, white ash, yellow birch	hemlock, white pine	very good	60-65
			EUP	AFOAs	sugar maple, beech	hemlock	very good	60-65
			NLP	AFO	sugar maple, basswood, beech, white ash	hemlock, white pine	good	55-60
		medium	WUP	ATFAs	sugar maple, beech, hemlock, yellow birch	hemlock, yellow birch	very good	55-60
				ATM-O, ATM-Sm	sugar maple, red maple, basswood, yellow birch, paper birch, aspen	hemlock, yellow birch	good	60-65
				ATM	sugar maple, red maple, basswood, yellow birch, paper birch, aspen	hemlock, yellow birch	good	55-60
			EUP	AFPo	sugar maple, beech, red maple	hemlock, white pine	very good	55-60
		poor-medium	WUP	AARLy	sugar maple, red maple, yellow birch, red oak	hemlock	poor	55-60
			EUP	ATFD	red maple, sugar maple, beech, hemlock	white pine, hemlock, yellow birch	good	55-60
	dry-mesic	medium	WUP	AVVb, AVb	red maple, sugar maple red oak, aspen, birch	white pine, red pine	fair	60-70
		poor	WUP	AArAst	red maple, sugar maple, red oak, aspen	yellow birch, hemlock	poor	45-55

[1]Current dominant overstory species composition. Species are listed in decreasing order of abundance (left to right).
[2]Species more common at the time of European settlement than they are today.

Common Stand Conditions

Most northern hardwood stands are even-aged or uneven-aged second growth, although some stands retain old-growth conditions in specific reserve areas that have not had a history of intensive logging. Northern hardwood stand condition usually reflects the frequency and severity of past natural disturbances and management activities since then. Stand condition classes can be described as follows:

- Even-aged stands are "composed of a single age class, in which the range of tree ages is usually +/- 20% of rotation age" (Helms, 1998). In northern hardwood, this is usually 10 to 30 years.
- Uneven-aged stands typically have three or more distinct age classes represented within them (Helms, 1998).
- Old-growth northern hardwoods are uneven-aged, vertically complex systems, characterized by:
    - Numerous overstory trees older than 150 years;
    - Multiple canopy layers (including super canopies where white pine and white spruce are present);
    - Large canopy gaps;
    - Numerous tip-up mounds;
    - Approximately 100 trees/acre with a basal area greater than 110 ft2/acre;
    - Significant accumulation of coarse woody debris;
    - Greater than 6 snags/acre with diameters ranging between 28-83 inches;
    - High plant-species richness.

The highest quality old-growth stands are usually greater than 200 years of age and have never been altered or harvested by humans. Old-growth northern hardwood stands are characterized by small canopy gaps created when single trees or small groups of trees die or are damaged by wind. These gaps are then colonized by seedlings already established in the understory, creating the multiple age classes within the stand. Time between large disturbances on a given small area is usually quite long (i.e., > 100 years), but small gaps occur frequently within a stand and account for the canopy development of the majority of the overstory trees. Infrequent, large scale, catastrophic wind disturbances destroying significant portions of the stand have been estimated to occur on a 1,200 to 1,500 year cycle. These large scale disturbances have little effect on species composition, but contribute to both structural and spatial diversity (Cohen, 2000 & 2005).

Michigan's northern hardwood old-growth is largely confined to remnant stands with little history of logging including Porcupine Mountains State Park, Sylvania Recreation Area, and the Huron Mountain Club. Small remnant patches may occur elsewhere, including on State forest lands.

Site and Succession Characteristics

Northern hardwoods occur on a broad range of landforms and soil drainage classes; from till plains and moraines to outwash sands; and on well-drained or excessively well-drained to somewhat poorly-drained soils. They commonly occur on sandy loams and clay loams, but can also occur on loamy sands where soil moisture is adequate. Soil pH can range from 3.7 to 7.5 in northern hardwood stands, but a pH between 5.5 and 7.5 is most common. Tables 1.2 and 1.3 summarize site preference and successional characteristics for the major and minor species associated with northern hardwoods. Moisture and nutrient preferences, typical maximum lifespan, and successional status are described for each species.

Moisture and Nutrient Affinities: Information on relative site nutrient and moisture regimes can be inferred somewhat from differences in stand overstory species composition. However, habitat type can be a more accurate index of these characteristics than canopy composition (Berger and Kotar 2003). Relative to other forest communities, northern hardwoods are found on the most nutrient-rich and mesic to wet-mesic sites, typically on moraines, drumlins, and lacustrine deposits. These landforms tend to have high water-holding capacity without being waterlogged for extended periods of time, a characteristic that benefits northern hardwoods. However, within these sites, species composition can vary considerably, in part due to variation in moisture and nutrients.

On more poorly drained wet-mesic sites, the relative importance of hemlock, yellow birch and red maple is often higher. Ash is more important on the most mesic sites. Oak and pine are more common on less mesic sites. Hemlock can also be an important component on some of the higher quality hardwood sites in the NLP.

Lifespan and Successional Status: The average lifespan of northern hardwood tree species varies over 5-fold. Because many northern hardwood stands in Michigan are even-aged and 80 to 100 years old, many of the short-lived early successional species may be near the end of their life expectancy, and declining in canopy representation. Species such as white ash, basswood, paper birch, bigtooth aspen, and black cherry may be difficult to replace barring stand-clearing disturbance. Species such as red oak and white pine that are often characterized as mid- to late-successional are likely confined to early successional status on more mesic/nutrient rich northern hardwood sites, but can be maintained in the overstory into late successional stages due to their long lifespan. Late successional dominants such as sugar maple**,** hemlock, and yellow birch (a gap maintained species in late succession forests), have life spans exceeding 300 years.

Table 1.2 Site & Succession Characteristics: Major Species.

Species	Moisture Regime	Nutrient Regime	Lifespan (years)	Successional Status (e.g., early, mid-, late)
Sugar maple	mesic	medium to very rich	300-400	A late successional, climax species, but can be early successional following non-fire disturbances (wind, logging) where early successional species are lacking and sugar maple advanced regeneration or stump sprouts are abundant.
Basswood	mesic	medium to very rich	100-150	Early successional but maintained in old growth by vigorous stump sprouting of trees of all ages.
Yellow birch	wet to mesic	medium to very rich	300-350	Can be early successional and in more or less pure stands. Maintained as a tree-fall gap-regenerated species in old growth stands.
White ash	mesic	medium to very rich	100-150	Early successional species. Is not common in old growth forests.
American beech	mesic to dry	poor to very rich	250	Late successional climax species
Red maple	bimodal: --very dry to mesic –wet sites	poor to medium	80-150	Early successional on rich mesic sites Late successional on oak-pine sites
Hop hornbeam	mesic	medium to very rich	100-140	Early to late-successional. Shade tolerant and saplings can be abundant in the understory but relatively short-lived. Not an important gap species in late succession forests.

Table 1.3 Site & Succession Characteristics: Minor Species.

Species	Moisture Regime	Nutrient Regime	Lifespan (years)	Successional Status (e.g., early, mid-, late)
Balsam fir	dry to wet mesic	poor to rich	150	Late. Can strongly dominate understories on the more nutrient poor and wetter sites in the northern parts of its distribution.
Black cherry	very dry to mesic	poor to very rich	< 200	Early, but can be maintained in large gaps late in succession
Red oak	very dry to mesic	poor to medium-rich	200+	Early, but long–lived.
Bigtooth aspen	very dry to mesic	poor to very rich	100	Early.
Paper birch	very dry to mesic	poor to very rich	100-140	Early. Can be maintained as a gap species in old growth stands, but perhaps only in boreal conifer dominated forests.
White pine	very dry to mesic	poor to medium	300-500	Early on richer, more mesic sites, but very long lived. Late successional climax species on oak-pine and pine sites.
Eastern hemlock	very dry to wet-mesic	poor to rich	400	An important late successional climax species, but can be early successional and found in more or less pure even-aged stands. Many Great Lakes region stands are like this, likely of fire origins.

Reproductive Characteristics

Reproductive characteristics vary significantly among species (Tables 1.4 and 1.5) and are important in managing natural regeneration in northern hardwood stands. Adult tree characteristics related to seed production (age, size, crown) are generally not discussed because they are qualitatively similar among all species. Trees that produce the most seed are mature (but not over-mature and declining in vigor) and have large, well-exposed crowns. Most species, except small subcanopy trees (e.g., hop hornbeam and balsam fir), cannot be expected to produce appreciable seed until they are older than 50 years and greater than 10 inches DBH.

Characteristics related to artificial propagation of seedlings from seed (seed mass, viability of stored seed, stratification, dormancy, etc.) are not strongly relevant to the management of natural regeneration and are covered in detail elsewhere (Bonner and Karrfalt 2008; Burns and Honkala 1990).

Seed Production varies among years for nearly all trees and shrubs (Tables 1.4 and 1.5). No northern hardwood-associated species can be depended on to produce sufficient seed for natural reproduction and adequate stocking in any given year, due to periodic low seed production years. Among the more dependable species that produce seed in most years are red maple, red oak, basswood, yellow birch and paper birch. Seed production variability is a considerable challenge for forest managers relying on natural regeneration of desirable species.

There are some clues that can help managers predict when good seed crops will occur, such as flower production in sugar maple, first-year acorn density in red oaks (because red oak acorns mature in the second growing season), and years preceded by a severe drought. However, these clues only indicate a greater *likelihood* of a big seed year since other factors (late spring frosts and current year droughts) can abort large seed crops.

Seed Dispersal Distance refers to the distance from the tree that most seed falls due to gravity. This is important for species that rely upon animals as the primary dispersal agent (Tables 1.4 and 1.5).

Seed Viability under natural conditions varies tremendously across northern hardwood species, from one or two weeks for aspen to several years for black cherry (Tables 1.4 and 1.5). Extended seed viability (and delayed germination) can have a strong impact on the amount of seed that is available for germination on the forest floor. The effects of this existing seed bank can obscure the influence of recent seed production. For example, more ash seed often germinates the second spring after dispersal than the first year. Black cherry also provides a good example, where high seed bank densities can accumulate over time from long distance and low density seed dispersal by birds, and can result in relatively high densities of black cherry reproduction in areas with limited local availability of seed producing trees.

Seedbed and Light Requirements: Substrate conditions and light availability on the forest floor can have a strong effect on the early establishment of seedlings. Virtually all species benefit from exposed mineral soil mixed with humus. Small seeded species generally require a consistently moist, bare mineral soil mixed with moisture holding humus or rotting wood for establishment. In contrast, most larger-seeded species are less dependent upon such consistent seedbed conditions because they have greater reserves for early root growth into lower, sub-surface mineral soil layers. Substrate conditions in stands can vary broadly due to variation in past management practices, recent harvest practices, composition and site.

Given this potential variability, both stand substrate and potential post-harvest light availability should be assessed and considered during silvicultural planning. Substrate conditions *cannot* be assessed in isolation**,** because early seedling establishment also depends on light conditions on the forest floor, which are, in turn, affected by the openness of the overstory canopy. In general, species that have small seeds and/or that are less shade tolerant require partially-open canopies to provide enough light that is sufficient for growth, while also maintaining a moist seedbed.

Sprouting Ability varies strongly among species. The potential for stump and root sprouting from harvested trees needs to be considered in silvicultural planning for regenerating northern hardwood stands. Sprout**-**origin trees can dominate seed**-**origin trees in many northern hardwood stands.

In addition to variation among species, there is also large variation in sprouting ability within species. In general, trees that are young and vigorous have a greater ability to sprout than older trees, although some species (such as basswood) maintain the ability to sprout vigorously to large sizes and old ages.

Shade Tolerance refers to the ability to persist for long periods of time in the understory of a closed forest canopy. Shade tolerance is a major factor in the ability of a species to maintain populations of seedlings and saplings in forest understories, and the ability of these populations to respond with increased growth (i.e., release) in canopy openings. This capacity has been assessed most rigorously for seedling- and sapling-sized individuals. For some species**,** shade tolerance can change with size and/or age, both declining (e.g., black cherry) and increasing (e.g., basswood). Some shade intolerant species are able to maintain shorter-term populations of seedlings due to large energy reserves in seeds (e.g., oaks), but most seedlings die after 2 to 3 years.

Response to Release: Species differ in their response to release from suppression. Shade tolerant tree species generally respond best to release and do so in canopy openings that vary in size from large gaps to small clearings. Shade tolerance is important because sub-canopy trees of these species are more likely to maintain vigorous, large crowns for longer duration under low-light**,** suppressed understory conditions.

Trees of any species will respond better to release when young and relatively vigorous, and with large crowns and good form. Care must be taken in assessing older trees that will be released following partial harvests**,** because those with a long history of suppression may be of poor form and prone to decay.

Table 1.4 Reproductive Characteristics: Major Species.

Species	Large seed crops	Seed dispersal		Seed viability	Seedbed & light requirements	Sprouting ability	Shade tolerance	Response to release & established seedling/sapling growth
		Season	Distance					
Sugar maple	Every 2 to 5 years	Early Fall	2-4 tree lengths	One winter	Non-particular seedbed requirements. Open to shaded light conditions	Vigorously if < 10" DBH	Very tolerant	Strong release especially if suppressed < 20 years. Grows well in partial shade created by selection harvest systems and larger openings.
Basswood	Most years	Fall – Winter	2 tree lengths, some disperses greater distance by animals	Up to 7 winters. Germination often delayed (e.g. 2nd or 3rd spring)	Well decomposed humus is best. Partial shade. 25% light is ideal for initial establishment	Very vigorous even as large trees and up to 100 years old	Intermediate as seedling, tolerant, as sapling/tree	Unknown response to release. Once established, direct overhead light is required for growth (group selection or larger openings)
Yellow birch	Every 1 to 2 years	Fall-Winter	3-6 tree lengths; long distances over snow crust	>99% germinates first spring	Disturbed mineral soil with humus, and decayed wood substrates that are reliably moist. Open to partial shade. 40% canopy cover is ideal.	Stump sprouts have low vigor	Intermediate	Does not respond strongly to release. Once established, seedlings/saplings need overhead light. Does well in ¼ acre openings
White ash	Every 3 to 5 years Dioecious	Fall	3-4 tree lengths	At least 3 winters. 75% germinate the 2nd spring	Non-particular seedbed requirements except reliably moist soil. Open to partial shade.	Vigorously if < 10" DBH	Tolerant when young; becoming intermediate	Unknown response to release. Probably poor. Best growth in > 45% of full light. Larger openings
American beech	Every 2-3 years	After first hard frost	< One tree length, some may disperse greater distance by animals	One winter	Non-particular seedbed requirements. Shade to partial shade	Vigorously if < 4" DBH. Root suckers do not develop into good trees	Very tolerant	Strong, even if suppressed for long periods. Grows well in partial shade created by selection harvest systems.
Red maple	Every 1-2 years	June	3-4 tree lengths	Most germinate soon after dispersal; some the next year	Non-particular seedbed requirements. Partial shade to shade	Vigorously, although not as vigorously as oaks. Maximum at 12" DBH	Intermediate-Tolerant	Strong release if not suppressed a long time. Partial shade to fully light. May do best in ¼ acre openings
Hop hornbeam	Unknown-variable among years. Dioecious	Fall-Winter	Most within 2-3 tree lengths; long distances over snow crust	Unknown	Less-particular seedbed requirements. Open to shade	Vigorously	Tolerant	Strong release, aggressive. Grows well in partial shade created by selection harvest systems

Table 1.5 Reproductive Characteristics: Minor Species.

Species	Large seed crops	Seed dispersal		Seed viability	Seedbed & light requirements	Sprouting ability	Shade tolerance	Response to release & established seedling/sapling growth
		Season	Distance					
Balsam fir	Every 2-4 years	September - winter	3-4 tree lengths and longer distances over snow crust.	Probably most germinate the following spring.	Less-particular seedbed requirements. Shade to open	No	Very tolerant	Responds to release well, even if suppressed for a long time.
Black cherry	Every 3-4 years	Late summer - fall	<1 tree length, some much longer by animals	> 3 years and maybe much longer	Less-particular seedbed requirements. Open to partial shade	Vigorously; sprouts from larger/older trees are low quality.	Intermediate as young seedling becoming intolerant	Poor response. Low survival of suppressed trees. Direct overhead light required for growth. Group selection or larger opening.
Red oak	Every 3-5 years	Fall	< 1 tree length, some longer by animals	One winter	Less-particular seedbed requirements. Best if buried. Open to shade	Very vigorously; especially from smaller/younger stumps	Tolerant as a seedling (3 years or less); then becoming intermediate to intolerant	Strong if not suppressed for long periods of time. Shelterwood or larger opening required.
Bigtooth aspen	Every 4-5 years	June	Miles	1-2 weeks. Germinates quickly after landing on moist substrate	Dependably moist mineral soil. Open	Suckers vigorously up to 100 ft. from parent. Ability declines in old trees.	Very intolerant	Does not survive in suppressed state; requires full light. Large opening required.
Paper birch	About every 2 years	Fall-winter	3 to >6 tree lengths, long distances over snow crust	Probably the majority germinate in the first Spring	Disturbed mineral soil with humus, Open to partial shade.	Vigorously when young/small	Intolerant	Does not survive in suppressed state, requires full or nearly full light. Large openings required.
White pine	Every 3-5 years	Fall	2-3 tree lengths in stand. 600+ ft for open areas or from super-canopy trees.	Unknown	Less-particular seedbed requirements. Partial shade	No	Intermediate	Strong, but declines with size and length of suppression. Group selection, shelterwood sized openings required.
Eastern hemlock	Every 2-3 years	October-November	2-3 tree lengths in stand	1 year	Disturbed mineral soil with humus, & decayed wood substrates that are reliably moist. Shade to open.	No	Very tolerant	Strong release even if suppressed for long periods. Single tree- to group selection-sized openings required.

Damage/Mortality Agents

A certain amount of annual damage and individual tree mortality is considered normal in forest stands. At a nominal level, natural mortality and damage contribute to "healthy" ecosystem function, providing habitat and augmenting nutrient cycling in forests. However, when damage and mortality exceed certain levels, they may adversely affect economic, social, and ecological values for which the forest is being managed. This section identifies those agents that may lead to levels of damage or mortality that may be deemed excessive for some stands.

In addition to any current insect and disease damage in stands, managers should also consider the long-term potential for pre-disposing or inciting factors that might make northern hardwood stands susceptible to future insect or disease damage. This potential is also known as forest health risk.

Forest Health Risk is often expressed as the likelihood of mortality occurring in a forest ecosystem, and is a function of two types of risk:

- Susceptibility is the risk that insect and disease agents will be introduced and become established in the forest;
- Vulnerability is the risk that mortality will occur once an insect or disease is established.

Forests that are both very susceptible to a pest attack and highly vulnerable to its affects (typically trees that are weakened or stressed) are the most likely to experience significant mortality related to that pest. In some cases, the impact of a single insect or disease agent is sufficient to cause mortality. This is often the case with exotic insects and diseases because there are no natural enemies to keeping them in balance.

Forest Decline. In the case of native insects and diseases, a condition known as forest decline is generally caused by multiple agents. Symptoms of forest decline are a loss of tree vigor which can result in tree mortality if stresses continue unabated. While decline is a natural process in the progression of forest ecosystems over time, it is a complex phenomenon developing from the interactions of several factors:

- Predisposing factors alter the trees' ability to respond to injury-inducing agents like insects and diseases.
- Inciting factors affect trees for a short duration, are physiological or biological in nature and generally produce dieback of small branches.
- Contributing factors are a collection of opportunistic environmental and biotic agents like root diseases and wood-boring insects that move weakened trees progressively toward death.

Most forest declines share some common elements, including:

- Climatic or site factors are predisposing or inciting factors;
- Roots and their mycorrhizae die prior to crown dieback;
- Declining trees usually have less stored carbohydrates than healthy trees. The energy produced by carbohydrates is necessary to start spring growth, manufacture chemicals for tree defenses against insects and diseases, and to regenerate defoliated leaves. Excessive depletion of these reserves limits a trees' ability to respond to tree stressing events.
- Armillaria root rot is commonly found in declining trees and forests.
- Age and/or drought are often factors in decline.

Few pests and diseases by themselves could be characterized as stand- or tree-killing pests or pathogens of northern hardwoods. With the exception of the exotic pests listed below, the agents listed in Tables 1.6 and 1.7 act principally as stand-weakening agents that can contribute to decline, but rarely kill the trees themselves. In most cases, tree species typical of northern hardwood forests can survive several years of defoliation or low levels of damage from fungal, wildlife, or environmental agents before succumbing. Nevertheless, damage from these agents, in combination with pre-disposing stress from drought, storm damage, or other human-induced stresses, can lead to more widespread mortality.

The most significant forest health threats in northern hardwood stands today are likely to be beech bark disease, emerald ash borer, hemlock wooly adelgid, oak wilt, and gypsy moth. Of these, the first three are

exotic pests that kill American beech, native ash species, and eastern hemlock**,** respectively. Oak wilt is a fungal disease that kills oaks when unchecked. For a full discussion of these pests, see the DNR forest health webpage. Climate change may become a significant threat to many forest types in the future.

Additional damaging agents for specific tree species are described in Appendix A of this chapter. Recommendations for management of these forest health issues are discussed in the section on Northern Hardwoods Management Guidance.

Damage and mortality agents are summarized in Tables 1.6 and 1.7 for major and minor northern hardwood tree species in the following categories:

Impact of Deer Browse Pressure refers to the relative effect of high deer densities on the density and vigor of tree seedlings and saplings. Deer densities throughout the state are both spatially and temporally variable, and the rankings are based on limited information. Furthermore, they may depend on both deer food preferences (i.e., the relative intensity of deer browse) and differences in species' responses to browse. For example, deer browse impacts for eastern hemlock are very high because deer preferentially browse it, and hemlock has a limited ability to re-grow following browse compared to other species. Methods for assessing local deer browse pressure are discussed in the Northern Hardwoods Management Guidance section.

Susceptibility to Decay & Stain Fungi. Normal levels of fungal infection in trees can be an important contributor to wildlife habitat. However, fungi can also cause large losses in wood volume and quality in northern hardwood stands from stain and decay. Species differ in their susceptibility to decay fungi, but decay fungi are generally more prevalent on poorer sites, in older trees, and in trees that have been suppressed for long periods of time. Stem and root damage resulting from logging, soil compaction and fine root damage, other human activity, or storms, can also make stands more susceptible to infection with stain and decay fungi.

Other Biotic Agents include the most important pests and pathogens of northern hardwoods in terms of potential mortality and/or loss of wood volume or quality.

Table 1.6 Damage/Mortality Agents: Major Species.

Species	Impact of Deer Browse Pressure	Susceptibility to Decay and Stain Fungi	Other Biotic Agents
Sugar maple	Moderate	< 100 years old--low (<7% cull). > 100 years-- high on poorer sites (27% cull at 150) and lower on richer sites. Also high for trees with history of suppression in all size classes	Forest tent caterpillar Cankers: *Eutypela paras.* *Nectria gallig.*
Basswood	High	< 120 years--low. One of least decay-prone species. 20% cull at 150 years old.	Few serious agents
Yellow birch	Very high	< 100 years old--low (<7% cull). 100 years--high (27% cull at 150). Larger, older trees are mostly cull.	Cankers: *Diaporthe alleg.* *Nectria gallig.* Forest tent caterpillar May be restricted by allelopathy with sugar maple
White ash	Moderate	Low. No data on cull.	Emerald ash borer. Ash decline including ash yellows
American beech	Low	High. 25% at 100 years, 35% at 150 years	Beech bark disease. Cankers: *Nectria gallig.* *Strumella spp.*
Red maple	Moderate-high	High. Cull 40% at 100 years, 50% at 150.	Few serious agents
Hop hornbeam	Low	Unknown	Few serious agents

Table 1.7 Damage/Mortality Agents: Minor Species.

Species	Impact of Deer Browse Pressure	Susceptibility to Decay and Stain Fungi	Other Biotic Agents
Balsam fir	Moderate	High, especially in older trees regardless of size.	Spruce budworm
Black cherry	Low to moderate	No data on culls.	Black knot Gum spot Fruit important for birds and other wildlife May be allelopathic to other tree species
Red oak	High	Low, cull 7% at age 100, 12% at age 140.	Oak wilt Cankers: *Strumella cor.* *Dothiorella q.* Defoliators: Gypsy moth Forest tent caterpillar
Bigtooth aspen	High	No data on culls	Few serious agents
Paper birch	Moderate/high	Medium, 12% at 100 years	Bronze birch borer
White pine	Low to moderate	Low. Cull < 15% at age 150	White pine blister rust Northern pine weevil
Eastern hemlock	Very high	Low. Cull 10% at age 150, though very high in very old trees	Hemlock wooly adelgid

Wildlife Habitat Attributes

Northern hardwoods are a climax forest community in Michigan, providing habitat for 114 wildlife species (MIWildHab, 2000). Some species of conservation concern that occur in northern hardwood forest communities include walking fern, hart's-tongue fern, goblin moonwort, fairy bells, red-shouldered hawk, black-throated blue warbler, smooth green snake, delicate vertigo, and northern goshawk. Refer to Michigan Natural Features Inventory (MNFI) Community abstracts and the Michigan Wildlife Action Plan for more complete lists of species of concern.

Several characteristics of northern hardwood forest affect the quality of habitat, including forest size and connectivity, structural and compositional diversity, and the presence of special microhabitats particular to northern hardwood stands. Also, northern hardwood stand structure resembling "old growth" has been associated with some flora and fauna. Large**,** contiguous blocks of northern hardwood forest provide important habitat for area**-**sensitive bird species, such as ovenbird, pileated woodpecker, wood thrush, American redstart, cerulean warbler, and mammals such as black bear and American marten. Maintaining habitat connectivity in this forest type is important for these species.

Uneven-aged northern hardwood communities are composed of multiple vertical strata, with wildlife species populating every vertical layer, from burrows of red-backed voles on the forest floor to canopy**-**nesting warblers. In particular:

- Dense underbrush provides cover from aerial predators for prey species such as grouse. Nocturnal animals, including bobcat and fox**,** bed down in the underbrush during the day.
- Fallen leaves and large woody debris provide refuge for moisture**-**seeking insects, amphibians, and reptiles.

Uneven-aged management promotes a forest of mixed-aged trees of many species and has the most positive impact on overall biodiversity within this forest type.

In addition to structural diversity, wildlife habitat quality in northern hardwoods is also dependent on compositional diversity within the stand. Tree species composition and the structural elements they provide are important:

- Conifer components of northern hardwood stands are important for blackburnian warblers and white-tailed deer.
- Nesting woodland raptors use mature, forked hardwoods to build heavy stick nests. Other raptors such as Cooper's hawks need mature conifers within hardwood stands for nesting.
- A steady supply of standing dead wood of varying size classes is necessary for cavity nesting birds such as the barred owl, pileated woodpecker, yellow-bellied sapsucker, black-capped chickadee and wood duck. These in turn help supplement woody debris on the forest floor.
- Coarse woody debris on the forest floor is important to a diverse array of species, including insects, herpetiles, small mammals, marten, fisher and black bear.
- Large diameter logs on the forest floor are especially important for wildlife, especially those that are hollow.

Mast-producing trees common in northern hardwoods are integral to wildlife:

- Beech, oak and hazelnut provide hard mast rich in fats and proteins for wood duck, black bear, white-tailed deer, turkey, and flying squirrel.
- Dry seeds, catkins and samaras of maple, elm, basswood, ash, hop-hornbeam and birch are valued by birds.
- Fleshy fruits from cherry, mountain-ash, serviceberry, hawthorn, elderberry, holly and wild raisin are rich in carbohydrates and vitamins and are especially important and relished foods for many bird and mammal species.

Many northern hardwood stands contain valuable micro-habitats. Rapids clubtail (state special concern) is a rare dragonfly that uses **quiet water pools and cool rapid streams** that flow through mesic northern forests. **Vernal pools** found in northern hardwoods are integral to some life stages of woodland frogs and salamanders. Also, **transition zones** between northern hardwoods and other cover types, and **areas of complex terrain** within northern hardwoods, often have high species diversity and structural complexity.

Higher stand densities and larger average tree diameters that are often found in northern hardwood stands with "old growth" characteristics may favor some species. Flora and fauna associated with these northern hardwood conditions include many species of lichen and moss, walking fern, green spleenwort, Blackburnian warbler, northern goshawk, brown creeper, scarlet tanager, Swainson's thrush, Acadian flycatcher, saw-whet owl, and black bear.

Tables 1.8 and 1.9 list the specific wildlife attributes of major and minor northern hardwood tree species. All tree species have *some* wildlife value; this summary is merely intended to illustrate some of the more commonly known uses to selected wildlife species.

Table 1.8 Wildlife Value: Major Species.

Species	Wildlife Value
Sugar Maple	• Seeds, buds, and twigs used by rodents • Persistent/durable snags often with large dimension cavities • Sturdy branching and forks are suitable for raptor stick nests
Basswood	• Heavy nectar producer • Seeds used by rodents • Moderately high cavity density • Live trees over 16-18 inches DBH are often hollow, providing home sites and refuge for multiple wildlife species
Yellow Birch	• Seeds used by some birds and rodents • Catkins, buds, and leaves used by grouse and hares • Bark characteristics are attractive to some insect-eating birds • Curling bark on mature trees are favored nest sites by some species of bats and birds such as the brown creeper • Large diameter trees are often hollow providing home sites and refuge for multiple wildlife species
White Ash	• Seeds buds twigs used by rodents and birds
American beech	• High cavity density • Beech nuts valuable mast for a broad range of animals, especially bear, white-tailed deer, wood duck, blue jay and turkey • Favored nesting tree of red shouldered hawk and other raptors due in part to its vase-shaped profile and high branching
Red maple	• Buds and seeds eaten by birds and small mammals • Preferred browse by white-tailed deer • Bark often peeled off in strips and eaten by moose and elk • Large diameter trees have exfoliating bark that provides nest sites for some species of birds and bats
Hop hornbeam	• Seeds used by some birds, including ruffed grouse and rodents • Catkins, buds, and leaves used by grouse and hares • Serves as a mid-canopy layer in the absence of other hardwood regeneration • Often a principle component of mid-story canopy which provides vertical habitat complexity.

Table 1.9 Wildlife Value: Minor Species.

Species	Wildlife Value
Balsam fir	• Cover and nesting sites for songbirds such as the yellow-rumped warbler and small raptors. • Balsam needles are a favorite food of spruce and sharp-tailed grouse
Black cherry	• Fruit eaten by broad range of wildlife--70 bird species, and mammals such as bears, foxes, eastern chipmunks, raccoons and squirrels • Primary food plant for more than 200 species of butterfly and moth caterpillars, including the hairstreaks and sphinx moths
Red oak	• Mast for many species (i.e., white-tailed deer, turkey, ruffed grouse, white-breasted nuthatch, brown thrasher, common grackle, and wood duck) • High cavity density • During gypsy moth outbreaks important for insectivorous birds (i.e., eastern wood pee-wee, American redstart, house wren, red-eyed vireo, & northern oriole)
Bigtooth & Trembling aspen	• Suckers and sprouts are highly preferred deer browse; bark and shoots are food for beaver • Male buds are particularly utilized by ruffed grouse • Important cavity tree; super canopy trees are important for primary nest excavators such as pileated woodpecker and secondary cavity users
Paper birch	• Seeds used by some birds • Catkins, buds, and leaves are eaten by black-capped chickadee, common redpolls, pine siskin, fox sparrow, all species of grouse, and hares • Bark and twigs preferred by snowshoe hare, cottontail rabbit, porcupine, white-tailed deer, and moose • A favored tree of yellow-bellied sapsucker, while ruby-throated hummingbird is a secondary feeder at sapsucker holes • Several species of birds use birch bark strips for exterior nest construction, including vireo and black-throated green warbler
White pine	• Thermal cover • Seeds eaten by many birds, (i.e. red-breasted nuthatch, pine grosbeak, pine warbler, red- & white-winged crossbills, pine siskin), and mammals including white-footed mouse, red-backed vole, chipmunk and red squirrel • Large trees are favored nesting sites for sharp-shinned hawk, Cooper's hawk, and owls; super-canopy trees are preferred nest sites for bald eagle • Dens and preferred escape trees for bear
Eastern hemlock	• Thermal cover • Nesting birds include golden-crowned kinglets, veeries, pine siskins, and black-throated blue-, black-throated green-, and Blackburnian warblers • Seeds eaten by black-capped chickadees, dark eyed juncos, crossbills, and pine siskins • Yellow-bellied sapsuckers often drill holes in the trunk where they periodically feed • Extremely slow rotting snags and nurse logs • Microhabitat for orchids such as showy orchid and rattlesnake plantain
White Spruce	• Seeds utilized by boreal chickadees, red-breasted nuthatch, red and white-winged crossbills, and red and gray squirrels • During budworm outbreaks, spruce-nesting birds become common (i.e., black-backed woodpeckers, ruby-crowned kinglets, yellow-rumped warblers, and Swainson's thrushes) • Spruce needles are a favored year-round food by spruce grouse and are utilized by snowshoe hare

Northern Hardwood Management Guidance

Introduction

This section contains recommendations for management of northern hardwoods on DNR-administered state forest lands. This information is intended as guidance only. Management decisions should also be informed by local experience and input from DNR's inventory and compartment review process.

Management Objectives

High quality sawtimber production is the primary timber objective for most northern hardwood stands, although pulpwood production is a secondary objective in most harvests, and may be the primary objective for stands on poorer quality sites and stands with poor stem quality or high percentages of internal defect. The choice of which silvicultural treatments and regeneration systems to use depends on management objectives, and stand characteristics including age, structure and species composition. The range of options for use in northern hardwoods is complex and thus warrants general discussion, including definitions and the potential results of these silvicultural techniques.

Silvicultural Systems andTreatments

Uneven-aged silvicultural systems are commonly recommended management of northern hardwoods, although even-aged systems may be appropriate in some circumstances, particularly:

- On nutrient poor habitat sites;
- Where natural processes and/or past management have resulted in poor quality or compositionally homogenous stands with a predominance of only a few (and potentially commercially undesirable) species; and
- Where there are regeneration problems associated with canopy closure, excessive competition from commercially undesirable species (i.e. American beech and hop-hornbeam), or deer browse.

Thinning is the most common intermediate stand treatment in even-aged northern hardwood stands, and it can be commercial, non-commercial (i.e., TSI), or some combination of the two. Common silvicultural treatments used in northern hardwoods are listed below, and described in the following section.

<u>Commonly Used Silvicultural Systems and Their Regeneration Standards:</u>

- Uneven-aged systems:
  - Single tree selection
  - Group selection
  - Uneven-aged regeneration standards
- Even-aged systems:
  - Clearcut (i.e., overstory removal)
  - Shelterwood
  - Even-aged regeneration standards
- Other silvicultural treatments
  - Thinning
  - Release thinning or cleanings (i.e., brushing)

Uneven-aged Silvicultural Systems

A. Single Tree Selection

General Characteristics:
Stands are entered for thinning every 10-20 years and individual trees dispersed throughout the stand are harvested from a range of diameter classes, such that a residual diameter distribution has an inverse-J shape. The diameter distribution recommended by Arbogast (1957) for a residual basal area of 84 ft^2/acre is in Appendix B, Table 1.12. The premise of this method is that marking to this diameter distribution will ensure the steady recruitment of trees from smaller to larger classes

between harvest entries, and produce a steady supply of timber over time. Residual basal areas between 75 ft^2 and 90 ft^2 are commonly recommended.

Advantages of single tree selection:

- Considered the best way to cultivate high quality sawtimber and veneer in northern hardwood stands;
- Provides a continuous supply of fiber, if correctly applied;
- Favors regeneration of shade tolerant hardwood species;
- Provides for a perpetual seed source;
- Canopy openings created by single tree removal mimic small-scale natural disturbances thought to be historically common in northern hardwoods from natural mortality, windthrow, and forest pests;
- Favors some wildlife species that require low levels of disturbance and maintenance of mature forest structure, such as some interior nesting songbirds, and red-shouldered hawk.

Disadvantages of single tree selection:

- Requires protection of the residual stand from damage and rutting during logging;
- Retention of higher residual basal area and small canopy gap size do not favor regeneration of intermediate and shade intolerant species;
- Requires more manpower and a higher degree of skill and training to properly implement;
- Produces a lower volume of wood per acre than the other silvicultural systems.

Results:
Single tree selection will nearly always favor shade tolerant, large seeded species. The light environment in the understory following single tree selection is likely unfavorable for regeneration of intermediate shade tolerance species (i.e., yellow birch, black cherry, white ash, red oak, and white pine), but favorable for shade tolerant species (i.e., sugar maple, American beech, hop-hornbeam, and hemlock). Hemlock regeneration is usually poor in single tree selection systems due to other factors, including lack of coarse wood and tip-up mounds as regeneration substrates, and browsing by deer. Single tree selection may work best on the most mesic sites, but information on its application on less mesic, less nutrient rich sites is scarce, as all the major long-term silviculture system experiments have been on mesic/nutrient rich sites (i.e. Argonne, Dukes Forest.) It could be an effective regeneration system for red maple on the poorer sites that northern hardwoods occupy, given the species silvics. Single tree selection also tends to produce higher quality timber than any other silvicultural system, due to the relatively high density and dispersed distribution of residual trees, combined with the removal of low quality stems at every entry. All else equal, greater residual basal area (e.g., 90 instead of 75 ft^2/acre), and longer entry intervals (e.g., 20 instead of 10 years) will promote higher quality, but at the expense of total volume.

In practice:
If using Arbogast's residual stocking structure (see Appendix B, Table 1.12):

1) Recognize current and target stocking structures. Recognize at least three sawtimber classes (as shown).
2) In overstocked size classes (as defined by the target structure), cut the poorest quality trees to obtain the recommended density and to release timber crop trees. Favor cutting of the following trees:*
    - Those at risk of dying before next harvest;
    - Poorer quality competitors of crop trees;
    - Low vigor based on crown size, crown form, condition;
    - Undesirable species.
3) In under-stocked size classes, remove only high risk trees.
4) Repeat cutting in 10-20 years.

*Note that in addition to these criteria aimed at improving the stand from a timber value perspective, there are a number of other tree characteristics that should be considered for retained trees, and these characteristics can be in opposition of the tree characteristics targeted for removal trees presented above. Consult the Within-Stand Retention Guidance (Michigan DNR 2012), for these criteria. Ideally, any marking scheme will be targeted toward striking a balance between stand improvement for timber value, and for wildlife and biodiversity.

Single tree selection and stand structure:
Use of selection-type thinning in even-aged northern hardwood stands over the last 30 years in Michigan may make it easier for managers to mistake them for uneven-aged stands. The majority of northern hardwood in Michigan is 100 years old or younger, and even-aged, having been entered for partial harvest twice or more. Harvest regimens in some stands have included timber stand improvement thinning starting in the 1970's and more recent partial cutting that largely emulates single tree selection. Where partial cutting has been practiced, residual stand structures are often similar to the inverse-J shaped diameter distribution of uneven-aged stands, and there is often abundant seedling- and sapling-sized regeneration of shade tolerant species in the understory. However, this is misleading given that the smaller pole-sized trees in these stands are usually as old as the largest trees, with most of the stems in the smaller classes being suppressed, and often with low vigor and little potential for response to release. It is important to distinguish between these even-aged stands, and truly uneven-aged stands where stems in smaller size classes are younger and have greater potential for favorable response in gap-light environments.

Even-aged stands where smaller size classes are dominated by low vigor or suppressed trees may be candidates for canopy removal or for conversion to an uneven-aged structure via group selection methods (see below).

In light of the historical application of uneven-aged stand marking and prevalence of managed even-aged northern hardwood stands, managers should critically evaluate age-class distribution, as well as diameter distribution for each stand when selecting an appropriate silvicultural system.

B. Group Selection

General Characteristics:
Group selection is identical to single tree selection in its goal of producing an uneven-aged structure via periodic partial harvests and resultant regeneration gaps. However, it differs from single tree selection in that groups of trees are taken instead of single trees. Group selection can result in a wider range of both harvest gap sizes and larger patches of undisturbed forest understory (because removal is clustered) than single tree selection. The potential result of these larger canopy openings is higher densities of less shade tolerant species including yellow birch, white ash, red oak, basswood, red maple, white pine, and black cherry. In some applications, areas between canopy gaps are also thinned during periodic stand entries via single tree selection or crop tree thinning.

Gap sizes vary from a few trees to ½ acre in size. Factors affecting the distribution of opening sizes include management objectives and the desired composition of regeneration. Given larger openings, group selection systems are more conducive to site preparation (e.g., scarification, pre-commercial thinning or removal of undesired advanced regeneration) or planting than single tree selection systems. These techniques could further increase the representation of less shade tolerant species, or hemlock (a small-seeded tolerant species).

Advantages of Group Selection:

- Is more likely to produce well-distributed natural reproduction than clearcutting, due to a well distributed residual seed source;
- Favors reproduction of intermediate shade tolerance species such as red oak and yellow birch;
- Can suppress shade intolerant species by controlling the level of available sunlight through gap size;
- Is more aesthetic than clearcut and shelterwood systems;
- Can produce an uneven-aged stand structure;
- May be logistically easier to harvest than single tree selection, and produces more wood per unit area harvested than single tree selection;
- Medium to large canopy gap sizes mimic medium scale natural disturbances (i.e., medium-scale windthrow events).

Disadvantages of Group Selection:

- Requires protection of residual trees and stand from logging damage and rutting;
- Results in greater disturbance of habitat for interior nesting songbirds, and may degrade habitat of some wildlife species, such as red-shouldered hawk;
- May require site preparation to regenerate some species, such as scarification in gap openings for hemlock and yellow birch reproduction;
- May require brushing or herbicide treatment to control the composition of regeneration on some sites.

Results:
Group selection has only more recently become an important regeneration system in the Great Lakes Region, so its legacies are incompletely understood. It is being used more frequently to promote the regeneration of intermediate shade tolerant species. Optimal gap sizes for individual specie's competitive abilities are largely unknown, but it is reasonable to assume that less shade tolerant species will do better in larger gaps. Opening sizes that encourage desired regeneration, but without a preponderance of competing non-tree vegetation (i.e. *Rubus spp.)* need to be evaluated. Because competing brush may be less of a problem on the lower quality sites, group selection systems may be particularly suited to less fertile, less mesic habitat types (Table 1.1).

More mesic, highly productive sites may not be good candidates for group selection because tolerant hardwood species tend to be ubiquitous and are strong competitors on these sites. Single tree selection may be more appropriate on these sites.

In Practice:
The criteria used for single tree selection can be also be used in group selection to identify "cut" trees and residual stand structure, except that they are applied for groups of trees. This will inevitably result in some deviation from single tree selection guidelines, such that the marking criteria should be considered a looser benchmark than when applied to single tree selection.

Future entries could include any combination of single tree and group selection practices, as long as they have a goal of creating three, or ideally more age classes. In some stands, single tree selection thinning could be conducted between group selection openings during the same entry. However, for most stands these may be scheduled as separate harvests during alternating entries. For example, the conversion of a mature even-aged forest to one with multiple age classes could begin with a group selection cut, followed by single tree selection in the uncut areas between the gaps, followed by another group selection entry, etc. Given these possibilities, group selection may be more complicated to manage than single tree selection, and it may be more costly given that site preparation and/or brushing could be required in larger gaps, especially on more nutrient rich habitat types.

Gap sizes for uneven-aged selection systems (Table 1.10) range from a minimum single tree gap size that can facilitate the recruitment of the most shade tolerant species (25 foot diameter) to gaps about ½ acre in size (167 foot diameter). Gaps do not have to be round, instead they should be marked to minimize the damage caused by the felling selected trees. Also, gap dimensions should be based in part on optimizing the grouping of trees with appropriate characteristics for removal, or conversely, for retention as part of the residual stand. However, to minimize the amount of forest edge created, gaps should be as close to circles as possible.

Table 1.10 Circular Canopy Gap Sizes for Regenerating Northern Hardwoods in Michigan. [adapted from WDNR Silviculture Handbook (2006)]

Diameter	Area (acres)	Considerations
25	0.011	Minimum gap size capable of facilitating recruitment of most shade tolerant species.
30-40	0.016-0.029	Typical crown area of 18 to 26 inch dbh sugar maple, **Recommended** standard gap size for single tree selection.
50-60	0.045-0.065	**Recommended minimum** gap size for canopy recruitment of intermediate shade tolerant species.
75	0.101	Maximum crown area of largest beech trees. Largest gap size for single tree selection. Common size for small group selection. Gaps 50 to 75 feet wide may be necessary to encourage red oak and black cherry. May need site preparation and/or control of undesirable regeneration.
167	0.503	Maximum for group selection. Minimum for even-aged systems.

C. Uneven-aged Regeneration Standards

To be meaningful, evaluation of the success of regeneration should consider the probability of seedlings successfully recruiting into the canopy. Seedlings, though abundant when small, cannot be considered as successfully established if there is a high probability that they will not survive to reach the canopy. In a stocking-level study in northern hardwoods, in the Upper Peninsula of Michigan, Tubbs (1968) reported over 2,000 large seedlings (36 inches tall and ½ inch DBH) and over 26,000 small seedlings (6 to 35 inches tall) per acre two years after treatments. In the same study, seedlings over 3 feet tall still numbered well over 6,000 stems per acre, 10 years after selection cutting to a residual basal area of 90 square feet. Tubbs (1977) later published recommended stocking guides for northern hardwoods at just over 200 trees per acre in the 2 to 4 inch classes. This stocking guide suggests that most of the seedlings are not expected to recruit into saplings. LeBouton et. al. (2006) reported nearly 200 stems per acre of sugar maple seedlings in the 5 to 8 foot height class in northern hardwood stands with “low” deer densities (0-3 deer/sq. mi.). In contrast, sugar maple seedlings in the same height classes were observed at 20 stems per acre in stands with higher deer densities (> 13 deer/sq. mi.). Based on these findings, the following provisional stocking guide is recommended:

1) Target stocking = 300 stems/acre in seedlings and saplings of acceptable species, > 6 feet tall, by 15 years following the last entry.
2) Minimum acceptable stocking = 150 stems per acre of seedlings and saplings of acceptable species, > 6 feet tall, by 15 years following last entry.

Criteria and target levels for acceptable regeneration at earlier ages are lacking at this time. However, to meet forest certification standards, minimum acceptable regeneration criteria were developed in 2009 for use on state forest lands. Under the new criteria in the Regeneration Survey Manual (IC 4145), managers are required to assess regeneration in these stands at the next regularly scheduled compartment inventory. For most state forest stands, this will occur within 4 to 6 years of harvest completion. A minimum acceptable regeneration density has been defined as the equivalent of 2,000 stems per acre, to be assessed in canopy gaps created during the last harvest.

Hardwood seedlings must be a minimum of 12 inches tall to be considered acceptable, and species composition can include any combination of the “desirable” species listed in the harvest prescription in the inventory database. These criteria apply to both even- and uneven-aged stands. Managers should consider the potential for preferential browsing on stump sprout origin maple and birch when evaluating the likelihood of success. Stands where the regeneration is predominantly comprised of stump sprouts with borderline stem densities and that appear to have high browse pressure or browse damage should be evaluated as “failing” to meet regeneration criteria.

Even-aged Silvicultural Systems

A. Clearcut (i.e., canopy or overstory removal)

General Characteristics:
Any near-complete canopy removal larger than 1 acre where the objective is to regenerate an even-aged stand is considered a clearcut. Unless they are exempted from post-harvest retention requirements (see Within-Stand Retention Guidance, Michigan DNR 2012), areas of canopy removal will still have 3-10% of their area in canopy trees retained for a broad range of values.

Clearcuts may be useful in the following situations:

- Canopy removal to release advanced regeneration. In these cases, advanced regeneration should be 2 to 4 feet high and 2,000 to 5,000 stems per acre.
- Canopy removal to promote a coppice-dominated forest, which will work for all deciduous species, but better for some (e.g., basswood and oak) than others (yellow birch), and for all species works better when stands are young (see Tables 2.1.5 and 2.1.6 regarding sprouting ability).
- Canopy removal to precede artificial regeneration by planting. This practice may be impractical and undesirable, except in rare circumstances (e.g., conversion to red pine) on northern hardwood sites.

Disadvantages of the use of clearcuts in northern hardwoods include:

- Long period between establishment of regeneration and the resumption of high quality sawtimber harvests (in some cases, 80 or more years).
- Greater competition from shade intolerant species (aspen and birch), where intermediate to shade tolerant species are desired.
- Usually several improvement thinnings and sometimes non-commercial TSI are required to steer composition and stem quality toward desired levels.
-

Results:
Canopy removal in northern hardwoods has not been used extensively on state forest lands in the last 30 years, given the current age distribution of northern hardwood stands and the more prevalent use of thinning and selection harvest methods. Perhaps the best way to try to understand the implications of clearcutting in northern hardwoods is to view the composition and structure of most current stands as a legacy of canopy removal harvests in the early 1900’s. It is important to consider that potentially higher impact logging in the early 1900’s and post-logging disturbances (fire in some areas, grazing and farming) have affected stands in ways that are very different from stands that may be clearcut today, given modern equipment and best management practices (BMPs).

However, the condition of current stands can provide clues as to how current stands would respond to complete canopy removal. Compared to selection cut stands, stands managed by clearcutting could be expected to have:

- Greater representation of intolerant and intermediate shade tolerant hardwoods;
- Greater proportion of coppice origin stems; and
- The development of thick pole-sized stands (in most cases).

In practice:
Managers are encouraged to experiment with clearcutting in a limited number of stands and to monitor the results. Clearcutting could be appropriate for:

- Sites on habitat types with lower fertility and moisture availability, where promotion of less shade tolerant hardwood species or conversion to planted pine is desired (see Table 1.1 for habitat types where pine may have been historically present);
- Conversion of stands that are badly degraded from past logging practices and other factors;
- Stands where it is desired to encourage greater representation of intolerant and intermediate shade tolerance species (e.g., bigtooth aspen, oaks, or ash). Good candidates for this are those stands that already have a large component of intolerant or intermediate shade tolerance species.

B. Shelterwood

General Characteristics:
The following discussion is largely drawn from the Ontario Ministry of Natural Resources silvicutural guides for tolerant hardwoods (OMNR 1998) and southern Ontario forests (OMNR 2000). Under the shelterwood system, canopy openings are larger than under group selection thinning; however, a significant residual overstory is retained to control light availability and provide seed for natural regeneration. The overstory is removed in two or more harvests, and this removal can be laid out in a dispersed pattern across the stand (uniform shelterwood) or in strip cuts that gradually progress across the stand (strip shelterwood). Of the two patterns, uniform shelterwood is more commonly used for northern hardwoods.

The shelterwood system can be used to:

- Convert poor quality mature stands with little potential for improvement through uneven-aged management to even-aged stands;
- Maintain even-aged stands;
- Promote greater regeneration of intolerant and intermediate shade tolerance species (i.e., yellow birch, oaks, ash, black cherry, basswood, and birches) in the future even-aged stand;
- Regenerate light-seeded species that require site preparation to expose mineral soil, and greater light availability than is common in uneven-aged systems (yellow birch, paper birch, hemlock).
- To remediate a lack of advanced regeneration that may be associated with canopy closure, excessive competition from commercially undesirable species (i.e., American beech and hop-hornbeam), or selective herbivory from deer.

Advantages of shelterwood include:

- Greater control of the species composition of regeneration by regulating light availability via residual overstory density to favor desired species, and help suppress some undesired shade intolerant species;
- Greater uniformity of regeneration due to a more uniformly distributed seed source;
- Protection of seedlings by the residual overstory from extremes of heat, and moisture conditions, and creation of germination conditions that are more optimal for some species compared to clearcuts;

- Mimics mid-scale disturbances that sometimes occur in northern hardwood forests, (i.e., larger windthrow events and understory fires);
- More aesthetic than clearcuts due to retention of a portion of the mature overstory until advanced regeneration is well established (i.e., it never looks like a clearcut);
- Rotation lengths can be shorter, as regeneration develops before the mature overstory is completely removed.

Disadvantages include:

- Greater technical skill is required to lay out and accomplish regeneration composition goals. Monitoring of regeneration and timing of follow-up harvests are critical. Shelterwood treatments are usually scheduled over a longer period of time (5 to 20 years) which requires good record keeping and timely follow-up;
- Residual overstory and advanced regeneration must be protected from damage during harvests—this may require harvests to be restricted to fall or winter;
- Logging costs are higher than for clearcutting, but probably less than for selective harvests.

Results:
On poorer habitat type sites (see Table 1.1), shelterwood could be the best option for regenerating intolerant and intermediate shade tolerant species. Some studies indicate that trees have better form, quality, and higher vigor when regenerated via shelterwood vs. clearcut. Less shade tolerant species, which often have better growth potential than shade tolerant hardwoods on these sites, respond better to the controlled light conditions produced by the amount of residual overstory. These controlled light conditions also permit some suppression of competing vegetation.

Form and quality of regeneration produced under shelterwood may also be better than that produced following clearcuts. Stem densities of desirable species are often higher under partial crown cover and maintenance of high stem density has been considered critical for producing good form and quality (Godman and Brooks 1971), as side shading and competition for sunlight induce seedlings and saplings to self-prune.

Use of the shelterwood harvest system may also be an effective strategy to remediate a lack of advanced regeneration that may be associated with canopy closure, excessive competition from commercially undesirable species (i.e., American beech and hop-hornbeam), or selective herbivory from deer (Sage et. al. 2003).

In practice:
Shelterwood harvests take longer to complete regeneration than the clearcut system. Shelterwood systems gradually remove the overstory of the mature stand via a series of partial harvests (preparatory cut, seeding cut, removal cut) that are typically scheduled over a period of 20% or more of the typical rotation length. In the traditional 10-year treatment cycle practiced on state forest lands, this could be spread out over two or more entries (20 years) before the stand is considered regenerated.

Shelterwood implementation typically involves two or three harvests to establish regeneration and then release it from overstory shade. These harvests are as follows:

1) **Preparatory Cut**—Typically involves removal of undesirable seed sources and thins the stand to encourage crown expansion on potential seed trees, basically to prepare them for greater seed production. This cut precedes a regeneration cut by at least 5 to10 years. This cut can be eliminated if the stand is already clean, and plenty of large-crowned, healthy trees of the desired species already exist.
2) **Regeneration or Seeding Cut**—The overstory is thinned to a level appropriate for creating optimal light availability for the target species, and under uniform shelterwood, to maintain

uniform seed tree spacing throughout the stand. Under strip shelterwood, the adjacent uncut stand area provides the seed source. Care must be taken to ensure that the residual overstory density is high enough to provide enough shade to discourage or suppress regeneration of undesired tree, shrub and herbaceous species. Criteria for this are discussed below under Implementing the Regeneration Cut.

3) **Removal Cut**—The remaining overstory is removed once sufficient advanced regeneration is present, except for trees left for within-stand retention purposes. Criteria for determining when to schedule the overstory removal are discussed below under Implementing the Removal Cut.

Implementing the Regeneration Cut

Successful regeneration depends heavily on achieving the optimal residual overstory density during the regeneration cut, retaining suitable seed trees, and seed bed/site preparation tailored to favor the target species. In areas where local deer population density exceeds 13 deer per square mile, the regeneration cut must be timed to correspond with windows of opportunity--when deer populations are lower, which occurs periodically and correlate with and follow severe winters (Sage et. al. 2003, Behrend and Patric 1969, and Behrend et. al. 1970). Another option can be to control local deer density through targeted hunting to achieve a population density of less than 13 deer per square mile. In marking the residual overstory, consider these generalities:

- Leave trees spaced somewhat uniformly, even if it means leaving some less desirable trees or poorly formed trees. However, the goal of uniformity needs to be balanced with retention goals, as a portion of trees left during the regeneration cut will ultimately be used for long-term retention.
- Choose seed trees of the target species as much as possible, subject to the constraints of uniform spacing and retention goals.
- Seed trees should have dominant or co-dominant canopy position, and have good form and vigor.

In general, leaving higher residual BA (80% crown closure) will favor sugar maple, beech and other shade tolerant hardwoods; and conversely, lower residual BA will favor less shade tolerant species. Leaving a residual BA with about 30-50% crown closure will favor intermediate shade tolerance species. Target levels of crown closure to favor various species are presented in Table 1.11.

Table 1.11 Recommended Crown Cover Targets for Regeneration Cuts by Species. (adapted from OMNR 2000)

Species	Recommended % Crown Cover for Regeneration Cut	Location of Study	Citation
Basswood	40-50%		
Black Cherry	30-40%	New England	Hornbeck and Leak 1992
Red Oak	60-70%		Dey and Parker 1996
White Pine	40-50%		OMNR 1998b
Yellow Birch	30-50%	New England	Leak et al. 1987
Yellow Birch	40-50%		OMNR 2000
Yellow Birch	50-60% (scarified sites)	Wisconsin/UP	Godman & Tubbs 1973
Yellow Birch	60-70% (burned sites)	Wisconsin/UP	Godman & Tubbs 1973

Seed tree selection should follow the general recommendations for identifying good quality crop trees—they should be healthy, dominant or co-dominant trees with good form, and be of the desired species. During marking for the regeneration cut, high risk trees should be removed, such as trees with cankers, weak forks, rot, cracks, etc.

Site preparation or seedbed preparation may be important for regeneration of some species. Some species like yellow birch, hemlock, and basswood may require exposed mineral soil conditions that require scarification. Most tolerant and intermediate shade tolerance species do not require

scarification—normal logging activity should be adequate as site preparation for those with heavy seeds (sugar maple, beech, white ash, red oak, and black cherry). In stands where American beech or hop-hornbeam exceed 500 stems per acre, herbicide application, cutting or both may be necessary to control the competing vegetation and to ensure adequate regeneration of desirable species (Tierson 1967, Sage 1987, and Sage et. al. 2003). Control of American beech may be particularly important following salvage harvests of mature stems that have produced an abundance of new root suckers prior to succumbing to BBD. Failure to control existing and undesirable species will likely yield poor results for forest regeneration.

Implementing the Seed Tree Removal Cut

The seed tree removal cut is usually scheduled once advanced regeneration has become well-established and beyond the reach of deer; sometimes 5 to 10 years after the regeneration cut is completed (Kelty and Nyland 1981), sometimes up to 20 years in other locations. Ontario Ministry of Natural Resources (OMNR) defines advanced regeneration as being at least 60 to 120 cm tall (24 to 48 inches) and ideally should be sapling sized to ensure recruitment, but does not specify density per acre. All remaining trees are usually removed, except for any that may be designated as within-stand retention.

C. Even-aged Regeneration Standards

To be meaningful, evaluation of the success of regeneration should consider the probability of seedlings successfully recruiting into the canopy. See the discussion on regeneration standards for uneven-aged stands.

Canopy removals (clearcuts) in northern hardwoods are typically scheduled only if sufficient advanced regeneration is present. In these cases, advanced regeneration should be 2 to 4 feet high and 2,000 to 5,000 stems per acre.

Under the shelterwood system, a seed-cut is initiated without sufficient regeneration present, but then the final overstory removal is delayed until sufficient advanced regeneration develops to meet the target listed above.

Minimum acceptable regeneration criteria for state forest lands were developed in 2009 to meet forest certification standards. Under the new criteria in the Regeneration Survey Manual (IC 4145), managers are required to assess regeneration in these stands at the next regularly scheduled compartment inventory. For most state forest stands, this will occur within 4 to 6 years of harvest completion. The minimum acceptable regeneration density has been defined as the equivalent of 2,000 stems per acre. Hardwood seedlings must be a minimum of 12 inches tall to be considered acceptable, and species composition can include any combination of the “desirable” species listed in the harvest prescription in the inventory database. These criteria apply to both even- and uneven-aged stands. Managers should consider the potential for preferential browsing on stump sprout origin maple and birch when evaluating the likelihood of success. Stands where the regeneration is predominantly composed of stump sprouts with borderline stem densities and that appear to have high browse pressure should be evaluated as “failing” to meet regeneration criteria.

D. Typical rotation ages for even-aged stands

In northern hardwood stands to be maintained in an even-aged condition, rotation lengths often range from 90 to 120 years, but vary depending on management goals for each stand (Tubbs 1977). Optimal rotation age for stands managed primarily for fiber production may occur at peak mean annual increment (MAI), at maximized net annual value growth, or at ages that maximize financial returns for specific discount rates (OMNR 1998a). Rotations for fiber may be as short as 50 years. In some cases, rotation may be determined when the dominant trees reach diameters that are deemed financially mature, depending on local growth rates and alternative rate of return (potentially

diameters of 14 to 27 inches DBH). Management for other objectives may suggest longer rotations—up to 200 years where aesthetics or wildlife habitat are a primary concern (Tubbs 1977).

Other Silvicultural Treatments

A. Thinning

Even-aged thinning should employ the same tree selection criteria used for uneven-aged selection harvesting, and strive to strike a balance between criteria for selecting trees to remove for improving fiber value, and for biodiversity and wildlife habitat maintenance or improvement. Specific suggestions for improving the fiber value of pole- and sawlog-sized stands follow (from Erdman 1986).

<u>Pole-sized stands (Average DBH 5-10”)</u>

- Do not thin stands dominated by sugar maple until at least 40 years of age, to prevent setting low merchantable log heights.
- Mark stands to achieve full crown release (approximately 7 feet around the crown) for 40 to 100 crop trees per acre, leaving an adjacent tree’s crown to shade and correct small forks (<2 inches diameter at the fork), if needed.
- Thin the remaining stand area following the order of removal. See Appendix C (Figure 2.2.1 and Table 13.2.1) for stocking guides for even-aged stands.
- If this is the stand’s first thinning and average DBH is 5-9 inches, then reduce the stocking level to 80% crown cover during this thinning. Wait 10-15 years until crown closure and lower branch mortality occur on crop trees before scheduling the next thinning.
- If this is the stand’s second or later thinning, or if average DBH > 9 inches, then reduce the stocking level to 90% crown cover. Wait 10-15 years until crown closure and lower branch mortality occur on crop trees before scheduling the next thinning.

<u>Sawlog-size stands (Average DBH > 10”)</u>

- Mark stands for partial crown release (release on 1-3 sides) on 40 to 100 crop trees per acre.
- Thin the remaining stand area following the order of removal, down to a stocking level of 90% crown cover.
- Wait 10-15 years before scheduling the next thinning.

B. Release Thinning or Cleanings (i.e., brushing)

Brushing or release thinnings are silvicultural interventions that aim to control species composition, or release desirable species from competition with overtopping less desirable species and/or poorly formed or suppressed stems of the same species. These treatments differ from site preparation in that release thinnings are often performed after a regeneration harvest has occurred, and are typically performed in stands that are sapling-sized or smaller. Two types of release thinning are commonly used—liberation thinnings and cleanings.

Liberation thinnings typically remove overtopping competition vegetation consisting of larger and often older, suppressed or poor vigor stems of the same species as the desirable younger regeneration. These older stems are often unmerchantable stems left after regeneration harvests that can effectively suppress younger regeneration. Liberation thinnings might be appropriate for some stands being managed by single tree or group selection thinning.

Cleanings (also sometimes called brushing) entail removal of undesirable stems or species of the same age as the desired regeneration. Cleaning seeks to maintain or improve dominance of the future stand by removing faster growing undesirable species or by removing poorly formed or surplus stems of desirable species. Cleanings might be useful in stands managed via group selection, shelterwood, or clearcut systems, where greater light availability may stimulate too much

regeneration of faster growing shade intolerant species. Also, under group selection and shelterwood systems, residual overstory densities that are favorable for establishment of some species (i.e., yellow birch, oak) may also benefit undesirable species such as hop-hornbeam and striped maple. In these cases, a cleaning may help suppress unwanted competition from these non-commercial species.

While release thinnings can offer the opportunity to improve or maintain dominance of desirable species among regeneration, the value of these treatments must be evaluated against the added cost and potential reduction in stem quality that may result from early stand entries. Heavier release treatments or very early treatments may result in poor fork correction, delayed self-pruning, and greater incidence of epicormic sprouting (Godman and Marquis 1969, Erdmann et. al. 1981, Lamson and Smith 1987).

The following are suggested for release thinnings in northern hardwoods:

- Use release thinnings only when stems of high value species are overtopped by less valuable species or stems of the same species;
- Delay release thinnings until canopy closure, usually at 10 to 20 years for most northern hardwood species;
- Release only dominant and co-dominant trees;
- Cut only stems whose crowns touch the crop tree;
- Delay release until age 25 in stands with a significant grapevine problem.

Management Considerations

This section is organized as a series of queries and responses. Note that there is some overlap between the sections due to their inter-relatedness.

1) *How can Kotar habitat type be used to inform management decisions?*
2) *Should I use an even-aged or uneven-aged silvicultural system?*
3) *For what species composition should I manage?*
4) *How does stand condition and structure influence management?*
5) *How do forest health considerations influence management?*
6) *How do I enhance wood quality?*
7) *How do I enhance wildlife habitat and biodiversity?*
8) *Is deer browse causing poor regeneration and how can I mitigate the problem*
9) *How do I manage for big trees?*
10) *How do climate change considerations influence management?*

1) ***How can Kotar habitat type be used to inform management decisions?***

In Michigan, northern hardwoods are found most often on the Kotar habitat types listed in Table 1.1. Habitat type is increasingly used in addition to site index, soils information, and other measures of site potential to inform stand management choices. Habitat type can indicate the relative growth potential for component species of northern hardwoods. Table 1.1 lists growth potential and an estimated site index range for sugar maple. Site index curves for the major northern hardwood species are in Appendix E.

In general, the more mesic and nutrient rich habitat types support best growth for all northern hardwoods species. On the higher quality sites, shade tolerant species have a competitive advantage over intermediate and shade intolerant species. On the poorer habitat types, intermediate shade tolerance species (i.e., red oak and yellow birch) often have a competitive advantage over shade tolerant species (sugar maple, beech, etc.).

Managers can use habitat type to help make stand management decisions on a site specific basis. Habitat type can be used to help identify options for management, including:

- Conversion to other forest types;

- Diversifying stand structure and composition using group selection or shelterwood techniques;
- Maintenance and enhancement of uneven-aged stand structure using traditional single tree selection;
- Options to restore species that are not present currently, but historically were important on the site.

To help identify which management options are appropriate, managers can use the following questions to evaluate each stand in light of habitat type information:

a. What is the quality and vigor of the current overstory, as a whole and by species (i.e. is it worth carrying trees in a selection system, and which species (if any) are doing well?
b. Is there sufficient density of good quality dominant and co-dominant trees of the right species and vigor to serve as seed trees in a shelterwood system?
c. What species are not currently present that the site could support as predicted by habitat type? For example, a poorer site currently dominated by low quality hardwoods could be converted to mixed pine-oak using a shelterwood harvest or clearcut combined with artificial regeneration, if a particular pine species seed source is not currently present on the site.
d. What are the current regeneration tendencies of the site?
e. Is there potential for conversion to aspen by clearcutting, based on its current presence in the overstory (10 ft^2/acre BA or more)? This could be a good option on some poor quality hardwood sites that contain some vigorous bigtooth aspen.

Habitat Type Characteristics by Region
General vegetation-site characteristics by habitat type are summarized in the section that follows. Click on the habitat type you are interested in or region to skip to the appropriate section.

Does habitat type suggest an appropriate silvicultural system to use?
Information from habitat type may suggest *in general* which silvicultural systems may work well for reproducing or cultivating the species that perform well on specific habitat types. However, these decisions should be made on stand or site specific basis.

In general, for northern hardwoods:
- Single tree selection and group selection systems appear appropriate on higher productivity habitat types where favoring shade tolerant species is an objective.
- Shelterwood and clearcut systems could be appropriate where there are regeneration problems, or on the lower productivity habitat types where favoring greater representation of intermediate shade tolerance or intolerant species is a goal.

However, any of these systems can work well on a given site to meet specific management objectives, or in light of specific current stand conditions. For example:
- Poor quality and vigor of the overstory on a high productivity habitat type may support use of clearcut or shelterwood techniques instead of single tree selection.
- Lack of suitable seed trees (poor vigor or wrong species) may suggest clearcutting on sites where habitat type might otherwise indicate the use of group selection or shelterwood systems.
- Poor quality northern hardwood stands could be converted to other cover types, as suggested by habitat type information (i.e., conversion of poor M-type to oak-pine by clearcutting and planting).

Conversion to other cover types may be appropriate based on presence of desirable regeneration in the understory, or presence of that species in the overstory (i.e., 10 ft^2/acre or more BA of aspen in the overstory)

Northern Lower Peninsula (NLP)	Eastern Upper Peninsula (EUP)	Western Upper Peninsula (WUP)
PArVVb AFO AFOCa	AFTD AFPo AFOAs	AVVb AVb TMC ATFAs AArAst AArLy ATM (ATM-O, ATM-Sm) ATD (ATD-Hp, ATD-Ca) AOCa

See Burger and Kotar (2003) for a detailed description of each habitat type.

Northern Lower Peninsula (NLP)

A. PArVVb (Pinus strobus-Acer rubrum/Vaccinium-Viburnum acerifolium):

PArVVb are the driest, most nutrient-poor sites that northern hardwoods can dominate in the NLP. These sites are found on outwash sands and coarse moraines, and often have cemented subsurface layers that create perched water tables (i.e., a fragipan). Stands can have a minor overstory component of some large stems of sugar maple and other mesic hardwoods (e.g., ash, black cherry, beech), but these species rarely dominate overstory. While seedlings and saplings of these species are common, they usually have low vigor on these sites.

More commonly, these stands are dominated by intermediate shade tolerant species--mixtures of red oak, red maple, and bigtooth aspen with smaller admixtures of white oak, white pine and red pine. These species all have good growth and form on these sites, usually better than the more mesic-associated shade tolerant species found here.

Because of the relative growth potential differences between tolerant and intermediate shade tolerant species on these sites, PArVVb may present better opportunities for managing several of the less shade tolerant hardwood species (e.g., oaks, bigtooth aspen) mixed with white pine, than for traditional sugar maple-beech dominated mixtures.

Red maple is the most aggressive competitor on these sites and may need special attention, if it is not desired as a dominant component of future stands.

B. AFO (Acer saccharum-Fagus grandifolia/Osmorhiza claytoni):

AFO habitat types are typically found on well-drained loamy sands with gravelly subsurface layers, are often associated with moraines, and are common in the northern and western areas of the NLP. Sugar maple is typically the dominant overstory species, but is also sometimes co-dominant with admixtures of basswood, American beech and white ash. Although usually a minor canopy component, red and white oak often have excellent form and growth here. Upland mesic conifers, such as hemlock and white pine, are not currently well represented, but were significant stand components before the logging era.

Managing the composition of regeneration may be a significant challenge on this habitat type, in part due to high site productivity. Canopy openings can have dense *Rubus spp.* cover, which can compete with tree regeneration. Stands with a history of partial harvest often have dense American beech and hop-hornbeam regeneration that may out-compete less common but desirable sugar

maple regeneration. Mechanical and/or herbicide treatments may be necessary to control excessive American beech and hop-hornbeam regeneration on these sites.

Traditional single tree selection systems will favor shade tolerant, large seeded species (maple, hop-hornbeam and beech).

Less tolerant species (e.g. red oak, white ash, white pine, and basswood) require openings larger than those typically used in single tree selections systems, combined with control of competing species (especially oak, hop-hornbeam, and occasionally American beech reproduction). Some species, particularly those with small seeds (e.g., eastern hemlock and yellow birch), may require establishment substrates that are currently poorly represented in managed forests, such as exposed mineral soil and coarse woody debris. Seed sources may be lacking for some species that were historically common on these sites (e.g., hemlock and white pine).

C. AFOCa (Acer saccharum-Fagus grandifolia/Osmorhiza claytoni-Caulophyllum thalictroides):

AFOCa has higher productivity than AFO due to finer textured soil sub-layers, and higher nutrient and water availability. AFOCa sites tend to be more restricted to moraines and drumlins than AFO. Like AFO, AFOCa stands are often dominated by sugar maple, but basswood, white ash, and beech are well represented and sometimes dominant. In the NLP, all hardwoods reach maximum growth potential and perhaps greatest quality on this habitat type. Black cherry far more consistently attains good form on AFOCa than on other upland habitat types where it occurs. Oak (if present) also has superior form on these sites.

Managing composition of regeneration and controlling competitors (like raspberry, hop-hornbeam, and elderberry) can pose significant challenges on these sites, and control with mechanical and/or herbicide treatments may be necessary.

Eastern Upper Peninsula (EUP)

A. ATFD (Acer saccharum-Tsuga Canadensis-Fagus grandifolia/Dyopteris spinulosa):

ATFD is the most nutrient poor habitat type that northern hardwoods typically ***dominate*** in the EUP.

Northern hardwoods species can be found as ***minor overstory components*** **on** the drier and more nutrient poor **PArVAa sites** in this area (e.g., beech, sugar maple, yellow birch, and hemlock), but they typically have poor vigor and form on these sites. Later successional forests on the PArVAa are dominated by red maple, white pine, and red pine, as they are better adapted to, and stronger competitors than sugar maple on these sites.

ATFD is usually found on deep sands that have fragipans starting at a depth of 2 feet. Sugar maple and red maple are the dominant species, however, beech, yellow birch, and hemlock can be important minor canopy components. White pine and hemlock were important components of these stands until the logging era. The growth potential for sugar maple on this habitat type may be lower than for some of its associates, including red maple and white pine, but it is possible to grow high quality stems of most species.

The most common regeneration components include beech, sugar maple, balsam fir, and red maple. Yellow birch, hemlock and white pine are generally absent, even if large trees are present. Cultivating preferred regeneration composition on these sites can pose a significant management challenge.

B. AFPo (Acer saccharum-Fagus grandifolia/Polygonatum pubescens):

AFPo is found on a variety of soils and landforms, and like ATFD sites usually have a fragipan at a depth of 2 to 3 feet. AFPO is considered to be more mesic and productive than ATFD. Composition is similar to ATFD, except sugar maple is more common and red maple less common. White pine and hemlock were both better represented in pre-logging era AFPO stands than now.

Management concerns and opportunities are very similar to ATFD sites, except that productivity is greater, and regeneration composition is somewhat different. Sugar maple strongly dominates regeneration, and red maple is of secondary importance on these sites.

C. AFOAs (Acer saccharum-Fagus grandifolia/Osmorhiza claytoni-Arisaema atrorubens):

AFOAs occurs on moraines and tills that have clay and/or gravel in subsurface layers. It is the most mesic and nutrient rich habitat type found in the EUP, and thus is highly productive for all species including northern hardwoods. Single tree selection will favor perpetuation of tolerant hardwood species including sugar maple, American beech and hop-hornbeam.

Less tolerant species such as red oak, white ash, white pine, and yellow birch require larger harvest openings and, in many cases, control of competing vegetation. Competitors to sugar maple regeneration often include raspberry, and advanced tree regeneration of American beech and hop-hornbeam, which may need to be controlled with mechanical and/or herbicide treatments on these sites.

Western Upper Peninsula (WUP)

A. AVVb (Acer saccharum/Vaccinium angustifolium-Viburnum acerifolium):

AVVb is scattered throughout the WUP and especially prevalent in Gogebic and Iron Counties. It occurs on well-drained moraines and pitted outwash. It is the most nutrient poor and least mesic habitat type that northern hardwoods commonly dominate in the WUP. Sugar maple has poor form and low productivity on these sites and should not be favored by management.

In contrast, red oak, white pine, red pine, red maple, aspen and paper birch all grow well on AVVb and should be favored for management, depending on goals and current stand conditions.

For example, white pine and/or red oak exist as advanced regeneration in some stands, and could be favored. Red oak has been shown to respond favorably to the shelterwood system on these sites, and in general, most of the species that grow best on AVVb would benefit from harvest methods that create larger canopy openings. Underplanting is also an option for augmenting oak and white pine on these sites.

B. AVb (Acer saccharum/Viburnum acerifolium):

AVb is a relatively rare habitat type, occurring near the Menominee River in western Menominee County and in southern Dickinson County. It is very similar to AVVb with respect to species growth potentials and silviculture. Specifically, sugar maple has poor form and productivity on these sites and should not be favored.

AVb sites may be well suited for regenerating white pine, red pine, red oak, paper birch and aspen, which have better form and productivity here than sugar maple. These species are often present, and competition from tolerant hardwoods (including sugar maple, American beech and hop-hornbeam) is less severe than on richer habitat types. Shelterwood or large group selection harvests are recommended to favor oak on these sites.

C. TMC (Tsuga Canadensis/Maianthemum canadense-Coptis groenlandica):

TMC is a common and widely distributed habitat type in the WUP. It occurs on most landforms within its range, typically in low lying areas, and near the edges of bodies of water. TMC has abundant soil moisture, often due to shallow water tables, but has only medium fertility. Growth of all species is poorer than on well-drained mesic sites. Sugar maple, red maple, hemlock and balsam fir are common overstory components and a wide array of species is well represented in regeneration layers. Productivity of sugar maple is relatively poor on TMC, whereas productivity of aspen, paper birch, red maple, hemlock and yellow birch is relatively good.

Due to the wet soils, managers should consider the risk windthrow, access restrictions and the potential for management to further elevate water tables following harvest.

D. ATFAs (Acer saccharum-Tsuga canadensis-Facus grandifolia/Arisaema atrorubens):

ATFAs is common in eastern Menominee and Delta Counties on soils with fragipans. Water availability is relatively high due to the fragipan, and nutrient availability is medium. Sugar maple now dominates these stands, however pre-logging era stands were likely mixed forests of hemlock, yellow birch, sugar maple, with white pine and American beech as strong associates. All upland native species have high growth potential on ATFA, and a wide variety of harvest methods can be used here. Where desirable, these sites may be particularly good for encouraging hemlock regeneration.

E. AARAst (Acer saccharum-Acer rubrum/Aster macrophyllus):

AARAst is scattered throughout the Keewenaw, Houghton and parts of Ontonagon Counties on a variety of soils. In this region, AArAst is the driest and most nutrient poor habitat type upon which northern hardwoods/sugar maple dominate. Like similar habitat types in other regions, the combination of a broad array of canopy species, relatively good growth of less shade tolerant species, and relatively low competition from tolerant species regeneration makes these sites ideal for favoring less tolerant species using a variety of harvest methods (e.g., group selection, shelterwood, seed tree, and clearcut harvests).

F. AArLy (Acer saccharum-Acer rubrum/Lycopodium annotinum):

AArLy is mostly found in Keweenaw and Houghton Counties on soils formed in deep coarse till or thin till over bedrock. Similar to AARAst, some of the less shade tolerant trees such as aspen, red oak, and red maple attain good growth here, whereas sugar maple has variable growth and form.

Compared to AARAst, regeneration of poorer site- and less tolerant-species (e.g., pine, oak) is less common, whereas tolerant sugar maple, balsam fir, and red maple are more common. Managing for less tolerant species will pose a somewhat greater challenge on AArLy than on AARAst due to greater competition from tolerant stems, but opportunities for this are still good. If managing for less tolerant species is the goal, then use of group selection harvest opening sizes larger than those for single tree selection are advised.

G. ATM (Acer saccharum-Tsuga canadensis/Maianthemum canadense):

ATM-O and **ATM-Sm** is found in Ontonagon, Houghton and Keewenaw Counties. It is a widespread, common habitat type found mostly on moraines, and has medium moisture and nutrient availabilities. ATM supports good growth of, and strong competition from, most tolerant species (e.g., sugar maple, basswood, hemlock). Hemlock was much more common and red and white pines were better represented on ATM sites in the pre-logging era. Nearly all species grow well on ATM, and both dominant trees and regeneration are among the most diverse of any habitat type in the WUP.

If maintaining stand diversity is the goal, it will be important to use larger harvest openings than are used for single tree selection. Managers will also have to evaluate the potential for competition from tolerant species, and the availability of seedling establishment substrates, if promoting less tolerant species or smaller seeded species is the management objective.

H. ATD (Acer saccharum-Tsuga canadensis/Dryopteris spinulosa):

ATD includes the **ATD-Hp** and **ATD-Ca** variants and is common and widespread in the WUP, where it is found mostly on coarse- to medium-textured moraines. ATD supports near optimal growth for northern hardwoods. Although there are some red oak, white pine, and aspen in the overstory, regeneration is strongly dominated by sugar maple and other shade tolerant hardwoods. Hemlock was a more important component in the pre-logging era, but now its seedlings are uncommon due to insufficient seed sources and regeneration substrates.

These sites are difficult to manage for anything other than shade tolerant northern hardwoods and hemlock because sugar maple is ubiquitous and a strong competitor for all but the most shade tolerant species. Less tolerant species such as oak, aspen and white pine grow well here, if they can become established.

I. AOCa (Acer saccharum/Osmorhiza claytoni-Caulophyllum thalictrodies):

AOCa is common and widespread in the WUP where it is associated with mostly ground moraines and drumlins. It is the most mesic and nutrient rich habitat type in this region and supports optimal growth for all northern hardwood species. Any harvest type will result in the perpetuation of shade tolerant hardwood species, as they dominate advanced regeneration and are very competitive here. Less shade tolerant species, such as red oak, white ash (which is a common overstory component), white pine, and yellow birch, require larger group selection harvest openings and (in many cases) control of competing vegetation.

2) ***Should I use an even-aged or uneven-aged silvicultural system?***

The choice of which silvicultural system to use depends on several factors, including:

- Productivity or growth potential of the site (see the previous section on habitat type);
- Current stand condition and structure (see the section that follows);
- Management goals and objectives for the stand;
- Economic factors—specifically, consideration of the timber production goals for the stand or area, and the costs and benefits that result from particular silvicultural systems;
- Social factors—aesthetic, recreational, and other values that can be affected by the system chosen;
- Wildlife and biodiversity goals and objectives (see the section entitled “How do I enhance wildlife habitat and biodiversity?”). In some areas, management to maintain or favor rare, threatened or endangered species may require the use of a particular silvicultural system (e.g., red-shouldered hawk and single tree selection).

At issue is a choice between two basic silvicultural systems:

Even-aged silvicultural systems*:* The entire stand is regenerated within a relatively short period of time, such that an even-aged stand results. Common even-aged systems include shelterwood, and clearcut.

Uneven-aged or all-aged silvicultural systems: Periodic partial harvesting results in the maintenance or creation of multiple age classes, such that the age-class distribution of the ideal stand fits an "inverse J-shape". Forest regeneration representing age cohorts results from periodic partial harvesting of mature and/or defective and undesirable trees as individual trees or in groups up to ½ acre in size. These systems are usually referred to as single tree selection and group selection, respectively.

These systems differ in the species diversity and composition that result, and the quality of sawtimber produced. Even-aged management results in greater species diversity and greater representation of less-shade tolerant species. By contrast, uneven-aged management often results in superior quality and value sawlogs, and regeneration dominated by shade tolerant species. Uneven-aged systems are also more aesthetically pleasing to most observers. A more detailed discussion on implementation of these systems is contained in the **Silvicultural Systems and Treatments** section. Crop tree selection and release are intrinsic to both systems. Refer to The Compleat Marker (Pierce et. al. 1994) for more information on crop tree identification and management.

Two factors that can influence the choice of silvicultural system for northern hardwoods are habitat type, and current stand structure/composition:

a) Among habitat types dominated by northern hardwoods, those that are less moist and less nutrient rich tend to support greater growth and quality for less shade tolerant species (e.g., oaks, bigtooth aspen) that are often mixed with pines. These less mesic/less fertile sites tend to be better candidates for even-aged silvicultural systems.

   Conversely, more fertile habitat types tend to be better candidates for uneven-aged methods due to the high competitive ability, optimal growth, and form of shade tolerant hardwoods on these sites. However, maintaining or increasing the less tolerant component on nutrient rich sites may be contingent upon creating larger group-selection regeneration gaps in combination with measures for controlling tolerant competitors.

b) Current stand structure and composition are also important factors to consider in a silvicultural system. In stands that currently have an uneven-aged structure and where the results appear satisfactory, continuing with uneven-aged management is usually the best choice. Satisfactory uneven-aged management results include development of adequate stocking of desirable species in all age classes. Unsatisfactory results could include poor stem or tree quality, stocking dominated by undesirable species, or failure to obtain desired regeneration composition.

Opportunities for Even-Aged Management in Uneven-Aged Stands

Even-aged management can be a useful tool for improving uneven-aged northern hardwood stands, in some situations:

- Where it is desirable to increase tree diversity and structure, modifying stands with a history of single tree selection by introducing some larger harvest gaps (>= ½ acre) could be appropriate.
- Stands with poor form and/or undesirable species composition could be candidates for even-aged management, even if there has been a history of uneven-aged management.
- Stands where chronic regeneration failure has occurred from deer browsing or other factors could also be well suited for even-aged management.

Predominance of Even-Aged Northern Hardwoods Stands on State Forests
Many northern hardwood stands in Michigan have developed following heavy logging and in some cases, were followed by fire, which has resulted in even-aged stands all across the state. On state forest lands, many of these stands are pole-sized or larger and most have been thinned (commercially or non-commercially) at least once. These stands should be evaluated based on the criteria described above for site potential and stand condition. Most stands are at a point of development where a choice should be made to perpetuate the even-aged structure that is a legacy of historic treatments, or to promote uneven-aged structure. Even-aged structure can be maintained by regenerating the stand using clearcut or shelterwood systems. Converting the stand to uneven-aged structure may take 80 or more years, where single-tree or group selection thinning is applied over time to develop the desired tree quality and stand structural characteristics.

Some stands are in a transition between even-aged and uneven-aged structure. Some of these previously even-aged sawlog-sized stands may be beyond benefit from additional crown thinning. In these stands, the crowns of mature residual trees are no longer able to respond to thinning to fill the growing space created by harvests. Before additional thinnings are prescribed, a choice should be made between using even-aged or uneven-aged systems to guide long-term development and regeneration of these stands.

3) ***For what species composition should I manage?*** Species composition goals are often informed by economic and biological goals, and constrained by site potential, current composition, and the economic costs and benefits of silvicultural treatments. Species composition can be altered by selective removal of individual species, and by silvicultural systems that favor one species over another. The potential species compositions listed below are:
   - Potential long-term goals for a stand;
   - Not limited by present species composition;
   - Not attempts to preclude species composition change via stand treatments.

   Conceptually, it is the site that is being managed in the long-run (and its productivity or limitations for individual species), rather than the current stand composition.

   A. Sugar maple dominant with basswood, ash, and/or yellow birch. These stands can be managed for either even-aged or uneven-aged objectives, depending on the site and stand conditions:
      a) To increase yellow birch and basswood, manage for even-aged conditions.
      b) To favor even greater dominance by (and better sawlog quality in) sugar maple, use uneven-aged management.
      c) Both pulpwood and sawtimber volume objectives can be achieved using uneven-aged or even-aged management.
      d) Even-aged management may be a more appropriate objective on sites where productivity or current tree form and log quality is poor. An alternative to even-aged management is to employ a combination of single tree selection and group selection methods, creating some larger canopy gaps than the single tree-sized gaps that are traditionally used in selection methods. Gaps larger than 74 feet in diameter (400 m^2 or about 0.1 acre) have been found to favor yellow birch (Webster and Lorimer 2005) and likely are required for other less tolerant hardwoods including ash, oaks and basswood saplings.

   B. Beech – sugar maple. These stands are best managed for uneven-aged conditions and are the most likely result of previous single tree selection uneven-aged management, especially on more mesic/nutrient rich habitat types. Beech bark disease is a threat to American beech in Michigan, with projected statewide losses of beech volume of about 800 million board feet. Management objectives for stands containing beech-sugar maple should focus on reducing the basal area of the beech component, and retaining a minor amount of healthy or potentially resistant morpho-type stems whenever possible. See the American beech management guidance (MDNR 2012) for more information.

C. **20% Aspen or paper birch– northern hardwoods**. These two associations have similar management options and potentially similar objectives. Stands that contain more than 20% aspen or paper birch could be good candidates for conversion to aspen or birch. Such stands can be managed for good quality pulpwood production with aspen and birch regeneration objectives using clearcutting, and heavy shelterwood or seed tree cuts respectively.

These sites can also be converted to high quality northern hardwoods where advanced regeneration of sugar maple is adequate. The process of moving these stands from predominantly aspen or birch to northern hardwoods may take several decades, and should only be undertaken on more nutrient rich Kotar habitat types, and when advanced sugar maple regeneration is well-established.

Maintaining birch and aspen as the dominant overstory species on the most fertile and mesic habitat types (e.g., AFOCa) may be difficult given aggressive competition from tolerant hardwood sprouts and advanced regeneration. However, maintaining a co-dominant or minor component of vigorously sprouting aspen in the overstory may be possible.

D. **Red oak – northern hardwood**. While red oak is a valuable component in these stands for timber production and mast for wildlife, none of the known silvicultural methods consistently maintains or increases oak in these stands (Tubbs 1977). The well-known oak researcher Paul Johnson has stated, “No scientifically based prescription for naturally regenerating red oak is available for any of the major forest types in which it occurs” (WI DNR, 2006).

Therefore, objectives for this type are usually limited to trying to maintain some of the oak component in the stand while managing for the more shade tolerant northern hardwood species. Clearcutting is not recommended.

By relying on stump spouts, managers have had some success in maintaining oak on even the richest habitat types. Oaks which are cut singly or in clumps, in the center of a 40-60 foot diameter canopy gap, provide the best possible conditions for vigorous growth of stump sprouts.

The best opportunities for maintaining or increasing the oak component in northern hardwood dominated stands are probably on the poorer habitat types. On these sites, competition from shade tolerant species is not as strong. However, favoring oak may still require control of red maple combined with even-aged silvicultural systems such as shelterwood.

Some opportunities may also exist for cultivating oak-northern hardwood stands in the understories of red pine plantations on mesic sites.

E. **Hemlock – northern hardwood.** Typical objectives for this type include maintaining the hemlock and/or yellow birch component, or increasing the dominance of sugar and red maple. If the goal is to promote sugar or red maple, then single-tree selection system should be used.

If the goal is to maintain or promote the hemlock or yellow birch components, then a shelterwood system should be used in combination with surface scarification on mesic to wet-mesic sites, or harvests should retain large diameter coarse woody debris. In the absence of scarification, the rotting wood of conifer logs has been noted by some authors as the only reliable substrate for the establishment of small seeded yellow birch and hemlock (Marx and Walters 2008). However, a history of harvesting (including removal of most of the conifer component) has left most sites low in conifer coarse woody debris, and in total coarse wood debris coverage (Hura and Crow 2004).

In some lake-effect influenced areas, staff have observed hemlock regeneration and recruitment in the absence of significant coarse woody debris.

Underplanting can also be used to restore or maintain the hemlock component in partially harvested northern hardwood stands. Where deer populations are less than 13 deer per square mile, hemlock and other mesic conifer seedlings can be planted in canopy gaps created during harvesting. In areas with higher deer population densities, hemlock and other mesic conifer seedlings are best planted only in less accessible areas, such as steep slopes.

However, in some areas of Michigan, excessive deer browsing precludes successful hemlock and yellow birch regeneration, regardless of the method employed.

4) ***How do stand condition and structure influence management?*** When considering management objectives, present stand condition and structure should be considered. Stand condition sometimes reflects site factors such as moisture availability or nutrient status, but it can also indicate poor past treatment or natural damage. Northern hardwood stands that are in poor condition or that have poor structure often have histories of natural disturbance (fire, wind damage, insect and disease problems), high-grading, or combinations of these factors. Sometimes the damage may impair stand productivity to the point that management for high value sawtimber and veneer is no longer justified.

In cases of poor stand condition, managers should consider whether to:

- Regenerate the stand to produce a new, vigorously growing cohort of the same species mixture, in cases where past management is the cause of the current poor structure or condition. A final harvest resulting in a new, even-aged stand (i.e., clearcut, shelterwood) could be considered to encourage regeneration of a stand with potential for higher quality fiber production, in addition to other goals.
- Use silvicultural systems that promote a different species mixture and that would have better productivity on the site.
- Manage the stand "as is" for biodiversity and wildlife habitat, when the cause of poor condition is poor site productivity for the existing species mixture. In these stands, practices that improve tree species diversity (conifers, mast producers, and intermediate shade tolerant species) and wildlife habitat attributes (den or nesting trees, coarse woody debris, and super canopy trees) could be favored.

Where stands are in good condition (exhibit well developed structure with a good range of age and size classes, well established advanced regeneration, and well developed herbaceous, shrub and mid-canopy layers) uneven-aged management objectives that build on these characteristics should be favored. A key question to answer when evaluating poor quality stands is:

"*Are the current stand conditions the result of past history or an expression of poor site quality?"*

Poor stand conditions due to management history can often be overcome through careful future treatment.

Poor site quality must be recognized before investing efforts to improve the stand. The forest manager is well advised to assess the stand's potential before management decisions are made.

5) ***How do forest health considerations influence management?***
Management guidance is listed below for the most significant damage and mortality causing pests and diseases affecting northern hardwood stands. A more complete listing of other biotic and abiotic damaging agents affecting northern hardwoods is included in Appendix A.

Predisposing Conditions:
Conditions that predispose northern hardwood stands to damage from insects and diseases include the following:

- Past Management: Northern hardwoods are particularly predisposed to declines in Michigan due to historical management practices, (e.g., clearcutting and highgrading harvests of old growth during the early 1900's, followed by slash fires or wildfire in some areas), storm damage, drought, and in some cases modern logging damage. Sapstreak is a disease that is likely induced by a combination of stressors and predisposing damage from injuries to the lower stem and roots resulting from logging.

- Extremely Low or High Stand Density: Over-stocked stands can have higher stress from competition for sunlight, and under-stocked stands can have stress from lack of protective shade. Thinning stands regularly to maintain recommended stocking can help minimize stress before primary pest infestations or infections occur.

- Poor Overstory Species Diversity: Damage can be exacerbated by poor overstory tree species diversity, poor stand structure, and poor average tree form. Stands dominated by only a few species tend to have higher risk of damage if a defoliator, disease, or virus is introduced that primarily attacks one of those species. Stands with higher diversity often experience lower damage in these events, in part because transmission between individual stems is more difficult in mixed species stands than in pure or nearly pure monocultures.

- Poor Stand Condition or Stem Form: Stands with poor stem form often experience greater damage during storms due to stem failure at fork unions or cankers. Whole stands may have poor stem form. These sites may be good candidates for management via even-aged systems, or by group selection to diversify species composition and regenerate better quality, more vigorous stock. Use habitat type as a guide when considering management options for these stands.

- Poor Site Productivity: Poor vigor stands on habitat types with a poor nutrient regime may be predisposed to forest health problems. Habitat type, site index and soils information may help managers identify stands where site productivity is a significant predisposing factor. Stands on lower productivity habitat types may be healthier if managed for mixtures dominated by less shade tolerant species, or if converted to other forest types that are better suited to the site's productivity, such as aspen, oak, or pine.

Inciting Factors:
The Emerald Ash Borer (EAB) and beech bark disease (BBD) can function as inciting factors in northern hardwood forests. They are causing considerable mortality, volume loss, and having a significant impact on stand composition, structure, function, and wildlife habitat. Other exotic pests that may become a factor in future stand management include the Hemlock Wooly Adelgid (HWA), and Asian Longhorned Beetle (ALB).

General recommendations for mitigating or avoiding specific forest health problems include:

- **Remove unhealthy, damaged, and high-risk trees** where they compete with crop trees during harvests. An example of a high-risk tree could be an American beech near the advancing front of beech bark disease. The high probability of individual beech dying before the next entry may make it a good candidate for removal. When choosing how many and which trees to remove, managers should weigh the risk of volume/value loss against other resource values, such as mast production, availability of cavity trees, and maintenance of the minimum recommended stocking.

Other types of high risk trees to prioritize for removal include:

- **Trees with cankers**--Maple borer, Eutypella and Nectria canker damage are more susceptible to breakage, in addition to being less valuable crop trees.
- **Trees with root damage from logging, frost cracks or sapsucker damage** should generally be candidates for removal.

- **Minimize harvesting damage**. Harvesting operations in hardwood stands should be set up and monitored carefully to minimize mechanical damage to roots and boles. Such damage provides entry points for pathogens like sapstreak disease and Armillaria root rot, and diminishes the tree's ability to absorb water and nutrients. Root injury is often associated with soil compaction.
- **Promote tree species diversity**. Higher tree species diversity greatly reduces overall stand susceptibility and vulnerability to biotic and abiotic stressors. Larger canopy gaps from group selection or shelterwood systems may be used to increase species diversity through the regeneration of less shade tolerant species like basswood, yellow birch, cherry, oak and red maple.
- **Consider site productivity when selecting which tree species to retain or favor during marking.** Use habitat type, site index, soils information, and other ecological classification systems when selecting species to promote. Matching the right tree species to the site greatly improves long-term vigor of the forest resource.
- **Report field observations of important and exotic invasive pests**. Beech bark disease, emerald ash borer and hemlock wooly adelgid are three exotic pests of concern in northern hardwoods. Report observations of these pests to the DNR FRD Forest Health Program.

Major Pests:

A. Emerald Ash Borer:

The Emerald Ash Borer (*Agrilus planipennis* Fairmaire) was discovered feeding on ash in southeastern Michigan in 2002. Ash trees native to North America appear to have little to no immunity to EAB. Since ash is a common component of northern hardwood forests, EAB is likely to have a significant impact on stand management. EAB now can be found in most parts of the LP and much of the UP. For a full discussion of EAB life history, management, and control strategies, see:

- Ash Management: Emerald Ash Borer IC4029 (Rev. 02/22/2012) (Michigan DNR 2012).

Guidance for salvage and pre-salvage of EAB and BBD affected stands on state forest lands can be found in:

- Ash & Beech Management Guidance: Emerald Ash Borer & Beech Bark Disease IC4029-8 (Rev. 09/28/2102).

Control Efforts—Quarantines

Regulatory efforts to eradicate populations in the LP are no longer feasible, although a quarantine remains in place in the UP to help control the spread of the pest. The MDARD website contains current quarantine language, maps, and updates: http://www.michigan.gov/mdard
Maps showing known EAB populations in North America are available on the internet at: http://www.emeraldashborer.info

General Management Recommendations:

In 2012, MDNR recommended staff salvage or presalvage stands with significant components of ash within the next 5 years in the LP and in parts of the UP. UP staff were advised to salvage infested stands, and presalvage un-infested stands in quarantined counties and within 10 miles of quarantined counties.

A slow-the-spread strategy was recommended for UP stands that were >10 miles from quarantined counties, specifically staff were advised to:

- Remove dominant and co-dominant ash first;
- Avoid reducing BA below 70 ft2/acre;

- If retaining some ash to meet minimum BA guidance, or for biodiversity retention, select vigorous pole-sized or smaller ash stems.

Guidance for management of stands on state forest lands with significant BA of both ash and American beech is summarized in IC4029-8, and briefly in the inset box below.

EAB Management Recommendation Summary:
Management options for EAB in northern hardwood stands differ depending on the commercial value of the ash and associated tree species, the relative abundance and distribution of ash in a stand, the vigor of the ash resource, and the amount of time before EAB reaches the stand. A summary follows:

In general:
- Salvage or presalvage ash, if ash + beech is > 10% of total stand basal area.
- **If all ash in the stand has poor vigor, then little or no ash should be retained.**

Specific recommendations include:

1. **Upland stands**:
   a) Do not reduce stand basal area below 75 ft^2/acre.
   b) Remove the largest ash first.
   c) Leave vigorous pole sized trees. Limit canopy gaps to 60 feet in diameter or less to discourage ash regeneration.
   d) Consider suppressing ash regeneration using chemical or mechanical treatments.

2. **Lowland stands**:
   Management may not be practical due to BMP concerns and/or low commercial value. In these situations:
   a) Allow EAB mortality to run its course.
   b) Consider short- or long-term management for non-timber objectives.
   c) Consider converting to different species mixture or another cover type after EAB kills most of the overstory ash.

3. **Stands in the UP > 10 miles from EAB quarantined counties:**
   These stands may have more than 10 years before EAB affects them. Consider:
   - Increasing tree species diversity and decreasing ash basal area using conventional silvicultural practices.
   - Give stands closer to known EAB populations higher priority for treatment.

4. **Tree species diversity and stand regeneration**.
   EAB mortality and harvests may lead to creation of understocked stands and conversion to undesirable species, or to non-forest cover. This is most likely to occur where beech and ash comprise a large part of stand basal area. In these stands, it may be necessary to:
   - Suppress ash regeneration through pre-commercial thinning and/or herbicide use.
   - Encourage regeneration of other tree species.
   - Underplant canopy openings to supplement stocking levels and species composition.

B. Sugar Maple Borer.

The sugar maple borer is a beetle whose larvae tunnel in the main stem of sugar maple. These tunnels cause lumber degrade from associated discoloration, decay and twisted grain. Serious defect and decay associated with borer damage is often the site of stem failure.

Management Recommendations:

a) Increase species diversity in sugar maple-dominated stands through selection thinning, group selection or other harvesting systems.
b) Remove over-mature, low vigor, and heavily infested sugar maples.
c) Maintain stand vigor through timely thinning.
d) Prohibit livestock grazing in northern hardwood stands.

See the USDA bulletin "How to Identify and Control Sugar Maple Borer" (Hoffard and Marshall 1978) for more information.

C. Bud Miners.

Two common species of bud miners, *Proteoteras moffatiana* and *Obrussa ochrefasciella,* overwinter in the terminal bud of sugar maple and kill it. This causes repeated forking, which reduces merchantable log length and adds to the risk of crown loss from splitting. Forking at the terminal bud occurs in trees of all ages, but is especially pronounced in overstory trees. Side crowding and overhead shading help correct lower forking. Early or heavy thinning sets the fork and causes shorter merchantable lengths. As fork members increase in size and weight, fork breakage also increases.

Management Recommendations:

a) Maintain minimum a basal area of 70 ft2/acre or more.
b) Select trees with weak bole forks for removal during harvests.

D. Fall Cankerworm, Bruce Spanworm, Linden Looper.

The larvae (loopers or inch worms) of these moths defoliate hardwoods in late- May to early-June. These epidemics occur periodically lasting 2 to 3 years. Outbreaks often involve hundreds to thousands of acres. This early season defoliation seldom causes tree mortality. These insects are seldom sprayed to protect timber values. Heavy defoliation over 2 to 3 years can reduce the sugar content of sap and reduce tree growth.

If stresses from defoliation are compounded by other events such as a drought, a decline may be triggered. They commonly affect mature to over-mature trees and/or species which are not well matched to the site.

Management Recommendations:

a) Monitor defoliation events.
b) If a decline progresses, a salvage or pre-salvage harvest may be needed to capture at risk wood volume and to renew stand growth and vigor.

Major Diseases:

A. Beech Bark Disease (BBD).

Beech Bark Disease is caused by a combination a scale insect, *Cryptococcus fagisuga,* and three species of the fungus *Nectria.* Decline, "beech snap" and mortality begin after Nectria fungi infect scale infested trees. "Beech snap" refers to the often observed snapping of the main stem of diseased trees with mostly healthy crowns. Beech bark disease develops in three stages:

- The advancing front is the area where beech are infested with beech scale, but not yet infected by Nectria. Advancing front stands can be infested with beech scale for a few years before Nectria infection begins. Estimates suggest that the advancing front spreads at an average rate of about 6 miles per year.
- The killing front is defined as the area where beech scale populations are high and Nectria infection is common. Tree mortality and beech snap are common. Salvage harvesting of scale infested trees prior to the onset of decline and mortality is often necessary due to high risk of beech snap.

- The aftermath forest is defined as the area that has experienced the first wave of beech mortality. In this area, most of the large, mature beech trees have died and remaining beech are mostly defective and declining. Some large beech trees remain. Some of these remaining trees are at least partially resistant to the scale, and therefore resistant to BBD.

All beech-containing stands in Michigan should now be considered vulnerable to BBD. For a full discussion on BBD management, see:

- American Beech Management: Beech Bark Disease IC 4029-7 (Rev. 02/28/2012).

Maps showing the current known extent of the BBD advancing and killing front are also located on the Michigan DNR Forest Health internet page: http://www.michigan.gov/dnr/0,4570,7-153-30301_30830---,00.html .

Management Recommendations:
Management guidance for BBD differs based on stand condition (uninfested or infested), the combined dominance of beech and ash (basal area), and proximity to existing BBD and EAB infestations. In 2014, beech scale had been found in most of the counties of the UP, and could be found in more than half of the counties in the NLP.

Guidance for salvage and pre-salvage of EAB and BBD affected stands on state forest lands can be found in:

- Ash & Beech Management Guidance: Emerald Ash Borer & Beech Bark Disease IC4029-8 (Rev. 09/28/2102).

General recommendations are as follows:

a) Un-infested Stands >40 Miles from the BBD Advancing Front

- Low dominance (beech is <10% of total stand BA): Consider maintaining beech as a minor component of the stand (do not harvest the beech.
- High dominance (beech is >10% of total stand BA): Consider reducing beech dominance in the stand by harvesting some of the large diameter beech and reducing beech BA overall in the stand.

b) Un-infested Stands <40 Miles from the BBD Advancing Front

Un-infested areas < 40 miles from the killing front will likely be impacted by BBD within a single cutting cycle (within 20 years). Managers will have less time to reduce beech basal area and increase stand species diversity; otherwise, management recommendations are similar to those for un-infested stands farther from the Advancing Front. More specific guidance is offered for these stands in IC 4029-7 and IC4029-8. If beech is a significant portion of the stand basal area, the effects of BBD will be severe:

- **Low Dominance (beech is <10% of total stand BA):**
  Do not harvest the minor beech component in these stands. When beech is 10% or less of the stand basal area, the impacts of tree loss on stand structure and volume will be offset by benefits of beech retention to wildlife and species diversity values. Some large snags and hollow beech trees can be left to provide nesting and den habitats and mast.
- **High Dominance (beech is >10% of total stand BA):**
  Favor regeneration of other tree species as described in 4) below. Consider reducing basal area below 70 $ft.^2$/acre BA in beech pockets.

c) Infested Stands:

Generally, increasing tree species diversity and shifting the beech component toward smaller, more resistant size classes through salvage or presalvage harvesting will help slow BBD development. Staff should strive to identify and retain potentially resistant beech in these stands, and restrict spread of the scale during transportation of timber during summer through fall. A summary follows:

In **Advancing Front areas:**

- Select trees for harvest that are heavily infested by scale.
- Identify, mark, protect, and report BBD resistant trees (See section on BBD Resistant Trees below).

In **Killing Front areas:**

- Salvage declining trees with thin crowns and yellowish foliage. These trees are often invaded by secondary decay fungi that can degrade wood within 2 to 3 years.
- Remove trees with sunken lesions or large patches of dead wood.
- Identify, mark, protect and report BBD resistant trees (See section on BBD Resistant Trees below).

Low Dominance (beech is <10% of total stand BA):

- Do not harvest the minor beech component in these stands. Impacts of beech loss on stand structure and volume are likely to be offset by benefits of beech retention to wildlife and species diversity values.
- Retain some large snags and hollow beech trees to provide nesting and den habitats and mast.

High Dominance (beech is >10% of total stand BA):

- Favor regeneration of other tree species.
- Consider reducing basal area below 70 ft.2/acre BA in beech pockets.

d) BBD Resistant Trees

About 1 to 3% of American beech are resistant to the beech scale. Such trees are not common, and tend to occur in groups. Identification and protection of resistant trees offers hope for a future healthy beech resource. Candidate trees are:

- > 9" inches DBH;
- Free of scales, or scales have remained scarce for > 1 year;
- Adjacent to trees heavily infested by beech scale.

Staff should mark resistant trees with white paint, placing an “R” on two sides of the tree. Protect the marked trees by leaving a buffer of other tree species to reduce risk of sunscald and possible windthrow. Staff should report locations of the marked trees to the DNR Forest Health Program for inclusion in resistance research.

Timber sale specifications should restrict the transport of beech firewood and logs out of infested stands to un-infested areas from July to November. First stage crawlers are mobile and might move from infested wood to live beech trees. This could establish beech scale infestations in new areas.

BBD Management Strategy for Un-infested Stands:

1) Reduce the basal area of overstory beech, but do not eliminate beech. Maintain a minimum of 70 $ft.^2$/acre BA to protect residual stems from sunscald.
   a. Discriminate against large, overmature trees with rough bark and decay. These trees will be the first lost and will offer the fewest advantages in terms of prolonged mast production.
   b. Consider impacts on wildlife food availability and habitat.
      - Leave scattered beech as snag and den trees to enhance wildlife habitat
      - Favor or underplant oak or other mast producing species to replace beech.
      - In areas with a history of red-shouldered hawk nests, favor growth of a few large diameter trees per acre of other species as potential nest sites.
2) Retain vigorous beech with smooth bark.
   - Vigorous trees often have smooth bark and are more often beech scale resistant.
   - Initially, scale populations build more slowly on smooth bark beech, even susceptible trees.
3) Minimize beech root damage during harvesting
   c. Root injury is the primary cause of beech root sprouts.
   d. Restrict logging to the fall or winter--spring root injury causes extensive root sprouting; whereas, fall injuries result in fewer sprouts.
   e. Beech sprouts from the stumps of young trees, but this ability diminishes after trees reach four inches DBH. Suckering is stimulated only slightly by tree removal.
4) Favor regeneration of other tree species via selection or planting in canopy gaps.
   f. Beech is shade tolerant and often is out-competed by other species in large canopy gaps.
   g. However, beech is avoided by browsing deer which may decrease recruitment of other species in areas with high deer numbers.
   h. Use 60 to 100 foot wide canopy gaps to encourage intolerant tree species regeneration when seed sources are present.
   i. Planting canopy openings may be necessary to attain the desired mix of tree species.
5) Survey stands to detect the arrival of beech scale. Knowing when scale enters a stand will establish a rough timetable for expected impacts and help define the dynamic borders of the killing front.

Citation: McCullough, D., R.L. Heyd & J.G. O'Brien. 2002. Biology and Management of Beech Bark Disease. Michigan State University Extension Bulletin E-2746.

B. Decay

Discoloration preceding decay is caused by bacteria and non-decay fungi. Decay is caused by a variety of fungi that produce "conks" on the host.

Management Recommendations:

Although no direct control of decay is known, losses can be reduced, as follows:

- Remove unwanted stems from clumps of stump sprouts before heartwood is formed. This will reduce decay that originates from the parent stump. Favor sprouts originating lower on the stump.
- In general, shorter rotation ages reduce decay losses--Since decay is known to increase with age, the key is to harvest before annual value losses exceed annual value growth.
- Maintain full stocking--This will regulate branch production and reduce weather related damage.
- Minimize basal wounding during logging operations. Stands with too much damage should be regenerated. Stain and decay will eliminate potential gains from a longer rotation age.

For more information on identification of decay, see Shigo & Larson (1969).

C. Sap Streak Disease of Sugar Maple.

Sapstreak is a vascular wilt caused by *Ceratocystis coerulenscen.* This fungus is soil-borne. Infection occurs through root and basal wounds caused by logging, sugar bush operations, and transportation related wounding. Sap streak causes tree decline and mortality. Symptoms include early fall color, progressive dieback and a characteristic wood discoloration.

Management Recommendations:

- Minimize basal and root wounds during logging.
- Use longer re-entry intervals in northern hardwoods.
- Remove infected trees during harvests.

For more information on how to control sap streak, see Kessler (1978).

D. Nectria Canker

Nectria is the most common canker disease of hardwood trees. It seriously reduces the quantity and quality of forest products, however it usually does not kill trees. It frequently attacks red and sugar maple, black walnut, yellow and paper birch, large tooth aspen and white oak. Most infections occur on trees 2 to 20 years old. Infections on yellow birch occur throughout its life. The oldest and most damaging cankers are found on the lower 10-foot sections of trees.

Management Recommendations:

- Yellow birch growing within 5 miles of the Upper Peninsula Great Lakes shoreline has a much higher incidence of cankering. It may not be economically desirable to grow yellow birch in these zones.
- Mature stands: If 20% or more of the stems are infected, regenerate to a less susceptible species mixture, such as red oak or any conifer. Use group selection or shelterwood techniques to favor regeneration of a greater percentage of intermediate shade tolerant or intolerant species.
- Immature stands:
  - **If > 20% of crop trees are infected,** then remove infected trees via commercial thinning or timber stand improvement.
  - **If 20 to 50% are infected**, then remove infected trees and shorten rotation.
  - **If < 50% of the trees are infected**, then regenerate to a less susceptible species mixture as described above using group selection or shelterwood systems.

For more information on how to control nectria canker, see Anderson & Mosher (1978).

E. Eutypella Canker.

Eutypella canker develops on most species of maple, but is most common on sugar maple. This species can kill trees less than 3 inches (7.5 cm) in diameter. On larger maples, perennial cankers limit production of quality wood and increase the risk of wind breakage. Typically, 2 to 20% of sugar maple stems in a stand are cankered, but infection rates can reach up to 60%. Infections occur through openings in the bark caused by branch stubs, logging wounds, sunscald or frost cracks.

Management Recommendations:

- Harvest cankered trees and remove cankers if feasible during stand treatments.
- Minimize basal stem wounds during logging.

For more information on Eutypella canker, see LaMadeleine et. al. (1980).

6) How do I enhance wood quality?

Northern hardwood stands can produce high quality, high value wood products such as veneer, higher grade sawlogs, special grain pattern sawtimber (i.e., birds eye maple and curly maple), as well as pulpwood and biomass. Careful management can improve individual stem and average sawlog quality and value over time, relative to current stand condition.

Management objectives for improving wood quality should be balanced with other values when planning management activities. Managing for wood quality should be only one of several management objectives. As in other aspects of forest management, multiple values can often be achieved simultaneously within a stand or a landscape. With minimal compromise, it should be possible to maintain or enhance wildlife habitat value while managing to improve timber quality. For example, cavity trees have high value for wildlife, but low value for wood products. It is often possible to enhance habitat for wildlife by retaining some standing dead stems or creating (by girdling trees) snags while thinning stands.

Enhancing wood quality at the stand scale can include two components: 1) promoting conditions that enhance wood quality for individual trees and; 2) increasing the proportion of high quality stems in a stand via careful selection of trees for retention as growing stock.

The goal of any effort to improve wood quality is to achieve a straight log, with a minimal number defects such as rot, knots, cracks, epicormic branches, crooks, or other flaws. For individual trees, the primary factors affecting these characteristics are tree vigor and stand density. Trees grown at high stand density in even-aged systems (large gaps or clearcuts) or trees in small gaps tend to develop straighter stems and smaller branches, self-prune earlier and produce smaller knots. However, the benefits of growing trees at high stand density conditions have to be balanced against the resulting reduction in tree vigor and slower growth compared to low density stands.

Resources for additional guidance on recognizing tree defects, low vigor and marking stands for tree quality improvement include The Compleat Marker (Pierce et. al.1994) and the Ontario Tree Marking Guide (OMNR 2004).

Improving Individual Tree Quality:

Specific management activities that can enhance wood quality in individual trees via density management include:

(1) Limiting large openings, including clearcuts to sites and areas where regeneration typically occurs at high density;
(2) Maintaining high density in even-aged stands until adequate height has been achieved to maximize the length of high value logs (e.g., management for 3 high grade 16 ft. logs rather than 2.);
(3) Maintaining relatively high residual basal area during thinning (i.e., > 85 ft^2/acre instead of 75 ft^2/acre), and/or observing relatively long intervals between stand entries (e.g., re-entry every 20 years vs. every 10-15 years).

Improving Stand Quality:

To increase wood quality by increasing the proportion of high quality stems in a stand, thinnings should emphasize the removal of defective, low-vigor, low-quality, low-economic value and high-risk trees. Sugar maple sawlogs traditionally have a higher value than other species such as aspen, white birch, basswood, etc. Characteristics that can be used to assess tree vigor, stem quality, and risk are discussed below.

<u>Recognizing Low Vigor Trees:</u>

Vigor may be defined as the relative capacity of a tree to increase in size. Vigor is affected by the following characteristics which should be considered together when assessing overall tree vigor:

(1) **Crown position:** All else equal, trees in subordinate crown positions (i.e., intermediate or suppressed), have lower vigor, even if released by thinning, than trees in more dominant or co-dominant crown positions.
(2) **Crown size:** Generally, the larger the crown (length, width, volume), the more vigorous the tree is likely to be.
(3) **Crown quality:** Regardless of size and position, certain characteristics of a crown's form can indicate low vigor. These include dead branches, low leaf density and a flat-topped crown. A flat-topped crown is often apparent in intermediate and suppressed sapling- and pole-sized sugar maples that are old and have poor growth potential if released during thinning.
(4) **Bark character:** For most species, low vigor trees will have more platy, less firm and more deeply fissured bark than vigorous trees of the same size. This is especially apparent in smaller trees.

Recognizing Low Quality and High-Risk Stems:
Stem quality and risk can be assessed by looking for defects, and symptoms of defects. The main classes of defects are:

(1) **Knots:** For hardwood logs, knots are the most common defect, and all knots on hardwoods (regardless of size) count as defects.

(2) **Epicormic branches:** Epicorimic branches sprout from dormant buds on the bole and limbs, often in response to sudden increases in sunlight striking the bole following thinnings, or increases in stress due to management, weather, or pests and pathogens. They occur more often on lower vigor, and/or on poorer productivity sites. Epicormic sprouts are also more common on oak and sugar maple than on other northern hardwood species. They may also occur more often on subordinate canopy position trees and less often on dominant trees.

Suppressed or subordinate canopy position trees showing presence of young epicormic sprouts should be given higher priority for removal where wood quality improvement is a goal. Sprouts on these trees often dramatically increase following thinning in response to increased light on the bole.

Epicormic sprouts may not be as severe a defect or priority for removal when compared to other defects, such as V-shaped or acute forks. Epicormic sprouts are log quality defects, as they arise from the bole surface (rather than the center of the tree, as do normal branches) and because they usually occur above the first log, which is by far the most valuable.

(3) **Stress fractures:** Stress fractures include frost cracks, seams and splits. They are considered defects, if they extend to the interior of the tree.

(4) **Decay, crook and sweep:** These tree form defects decrease the merchantable volume of the bole. Although crook and sweep are readily apparent, and calculable with standard log grading procedures (Rast et. al. 1973), the presence of decay is estimated from visual symptoms on the surface of the tree. These include conks and other fungi, dark (as opposed to light) surface scars, butt swell, and seeps. Rot can also be expected at the base of clumps of trees originating from stump sprouts, and in the bases of high forks at "junction" wood.

(5) **V-shaped or acute forks:** Stems with acute forks are considered high risk for failure. Acute forks often have "included" or in-grown bark, a condition that arises as the branches that form the fork expand in diameter, encapsulating bark at the base of the fork. This forms a weak union, and often one-half of the fork breaks off in storms. Cracks and decay often occur in V-shaped forks as well. They are easy to spot by the presence of "tearing" and swelling or callous tissue at the base of the fork.

7) ***How do I enhance wildlife habitat and biodiversity?*** Northern hardwood forests are a climax community and provide habitat for many wildlife species. Important habitat features to consider during management in the northern hardwood forest are:

- Tree species diversity (including mast trees and conifer cover);
- Canopy structural diversity;
- Cavity trees;
- Coarse woody debris;
- Supercanopy trees;
- Rare or uncommon land features, such as vernal pools, seeps, intermittent streams, and glacial erratic boulders;
- Travel corridors.

Guidance for management of northern hardwood at the landscape scale has been included in the Regional State Forest Management Plans for each Management Area. Staff should consult their local biologist and review the guidance pertaining to wildlife habitat in the RSFMP MA summaries. The Within-Stand Retention Guidance (Michigan DNR 2012) provides recommendations for enhancing biodiversity and wildlife habitat at the stand level in the northern hardwood cover type.

8) Is deer browse causing poor regeneration and how can I mitigate the problem?

Although it seems it should be easy to identify a deer browse problem by the presence of partially browsed seedlings and saplings, or the lack of abundant seedlings and saplings, it is often not that simple. On one hand, high long-term deer browse pressure can eliminate seedlings and saplings, and not just damage them (Russell et. al. 2001). On the other hand, many factors independent of deer browse pressure impact seedling and sapling densities. Negative factors include inadequate soil moisture and nutrient availability (i.e., poorer habitat types), insufficient light from inadequate canopy gap sizes during regeneration harvests, and competing vegetation. Managers need to consider if any of these factors, in addition to deer browse, may be causal factors in regeneration failure. Not identifying and addressing <u>all</u> of the causal factors through management prescriptions will likely result in a continued failure of regeneration.

Characteristics of sites with a significant deer browse problem.

Despite the complicated nature of identifying a deer browse problem, there are several characteristics that alone (or ideally in combination) may help. These are:

- The site being identified as an area that has a high regional deer density in long-term DNR deer pellet count information.
- Estimates of relative deer density and county-level population (from the Michigan DNR internet website, typically under Hunting/White-tailed Deer/Relative Density of Deer, or Hunting/White-tailed Deer/Clickable Map of Proposed 2006-2010 Deer Population Goals).
- In areas with high regional deer density, stands that are within ½ mile of a lowland conifer stand are likely to have significant deer browse impact.
- The presence of many seedlings and saplings showing signs of being browsed several times. Repeatedly browsed seedlings will often be stocky, 1 to 4 feet in height, and have a club-like appearance.
- Observation of a low density of seedlings/saplings > 2 feet tall, in areas that otherwise should have abundant seedlings/saplings in this size class. This can be corroborated with evidence of seedlings and saplings taller than breast height in nearby stands that have been thinned about 10 to 12 years ago, or clearcut about 4 to 8 years ago.
- Greater relative densities of vegetation not preferred as deer browse. This includes: Pennsylvania sedge, bracken fern, and seedlings and saplings of black cherry, spruce, American beech, leatherwood, and hop-hornbeam.
- Low relative density of preferred browse species, including trillium, Canada mayflower, orchids, hemlock seedlings or saplings, Canada yew, yellow birch, oaks, and maples.
- Presence of browse lines on larger trees.

There is not a single threshold for deer density over which northern hardwood composition and dynamics are impacted, and under which it is not. Tolerable deer densities depend on the characteristics of interest for management. In larger harvest openings, even 40 deer per square mile may not negatively impact total forest regeneration density and height. However, much lower densities of deer (> 10 per square mile) can alter stand species composition by negatively impacting some of the most browse-sensitive species (e.g., hemlock and yew).

Strategies to mitigate deer browse problems:
In stands where regeneration of sensitive species is desired, managers should consider leaving sensitive species as residuals in the overstory to preserve seed sources for future times when deer may not be as abundant. In areas where local deer population density exceeds 13 deer per square mile, regeneration harvests may be timed to correspond with windows of opportunity, where there are periodic lower deer populations which naturally correlate with and follow severe winters (Sage et. al. 2003, Behrend and Patric 1969, and Behrend et. al. 1970). Local deer density control through targeted hunting can be another option to achieve a population density of less than 13 deer per square mile.

Larger canopy openings from group selection in uneven-aged management or use of even-aged management (clearcutting or shelterwood systems) should be considered to provide conditions where seedling and saplings are likely to outgrow the threat of browse more quickly (i.e., grow beyond 5 feet in height to escape deer browse).

9) How do I manage for big trees?

Management for large trees, whether in uneven-aged or even-aged stands, may be socially or ecologically desirable. In some areas, “big tree” management may be required to maintain or improve habitat for rare, threatened or endangered wildlife, such as the Red-shouldered Hawk. Note that management for large trees is not necessarily the same as managing for old growth. Old growth stands have several other features, in addition to the presence of some large trees.

Retaining large trees may be socially desirable in areas with high recreation use or along visual travel corridors. Some tree species are especially good at developing large dimensions and are long-lived, including white pine, red pine, white spruce, sugar maple, hemlock and red oak. Specific criteria for identifying trees to be retained or cultivated as large trees depend on stand goals, but can include timber and ecological considerations. Ecological considerations include compositional diversity, mast trees, wildlife use, and snags/dead wood which are covered in detail in the DNR Within-Stand Retention Guidance (2012).

In even-aged stands, large tree development can be accelerated by crown thinning to promote crown expansion, and thus increase growth rates of dominant and co-dominant stems. Suggestions for enhancing the large tree component differ somewhat between uneven-aged and even-aged stands:

(1) For even-aged stands, select five to eight trees per acre for maintenance or promotion to large tree status. These can be dominant/super canopy trees and co-dominant trees. If they are co-dominant trees, remove immediately adjacent crown competitors during thinning.

(2) For uneven-aged stands, follow the single-tree selection guidelines in the Silvicutural Systems and Treatments section with the following modifications:

a) Adjust the typical residual stand structure for a “Q” factor of 1.3, BA 85, and a maximum DBH of 22 inches in the following ways:
    - Set a residual stand density target of 100 ft2 BA, with 25 ft2 BA in trees exceeding 22 inches DBH.

b) Retain and restore all size classes by:
    - Having no set maximum DBH; but

- Retain no more than 25% of crown cover in stems 24 inches or greater DBH.

c) Retain at least 50 crop trees per acre (high quality sawlog potential) in the 6 inch or greater size classes.

d) Retain 5 to 8 trees/acre in the 24 inch or greater size classes:
    - About one-half of these should be supercanopy trees (full dominant crowns sticking above most of the stand), and in total should equal 5 to 25% of stand crown cover.

10) How do climate change considerations influence management?

Climate change is projected to negatively impact the northern hardwood forest type as of this writing, however management guidance had not been developed. It will be incorporated in future revisions of this guidance.

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Appendix A. Forest Health Issues for Northern Hardwood Species

This section describes specific damage and mortality agents affecting the major tree species found in northern hardwood stands:

sugar maple	American basswood
yellow birch	eastern hemlock
American beech	black cherry
white ash	red maple

Sugar Maple

Pests. At least two species of bud miners, *Proteoteras moffatiana* and *Obrussa ochrefasciella,* overwinter in the terminal bud of sugar maple and kill it. This causes repeated forking, which reduces merchantable log length and adds to the risk of crown loss from splitting. Forking at the terminal bud occurs in trees of all ages, but is especially pronounced in overstory trees. Side crowding and overhead shading help correct lower forking. Early or heavy thinning sets the fork and causes shorter merchantable lengths. As fork members increase in size and weight, fork breakage also increases.

Sugar maple is not highly susceptible to insect injury, except for bud losses. Serious outbreaks are not common. The most common insects to attack sugar maple are defoliators. Common defoliators include gypsy moth *(Lymantria dispar),* forest tent caterpillar *(Malacosoma disstria),* linden looper *(Erannis tiliaria),* fall cankerworm *(Alsophila pometaria),* spring cankerworm *(Paleacrita vernata),* green-striped mapleworm *(Anisota rubicunda),* Bruce span-worm *(Operophtera bruceata),* maple leaf-cutter *(Paraclemensia acerifoliella),* maple trumpet skeletonizer *(Epinotia aceriella),* and saddled prominent *(Heterocampa guttivitta)*.
Borers that attack sugar maple include the carpenterworm *(Prionoxystus robiniae),* sugar maple borer *(Glycobius speciosus),* maple callus borer *(Synanthedon acerni),* and occasionally horntails *(Xiphydria abdominalis* and X. *maculata).*

Diseases. Diseases of sugar maple generally deform, discolor, or decrease volume, but seldom kill the tree. The two most important diseases in managed second-growth are probably Eutypella *(Eutypella parasitica)* and Nectria *(Nectria galligena)* cankers. In a few instances, cankers may kill a tree, but generally only predispose it to breakage.

Some common fungi-causing heart rots in sugar maple are *Armillaria mellea,* primarily a root-rotting fungus; *Hydnum septentrionale,* which causes a soft, spongy, white heart rot; *Inonotus glomeratus,* which causes white to light brown spongy heart rot; and *Ustulina vulgaris,* which causes a butt rot.

Sapstreak, caused by *Ceratocystis coerulenscens,* enters through root injuries from logging and has been reported in several localities. This wilt is associated with sugar maple decline and mortality.

Environmental factors. Physical and climatic injuries often occur on sugar maple. Winter sunscald frequently occurs in even-aged sugar maple stands. The tree is damaged by late winter heating of the bole above the snowline on bright sunny days followed by rapid freezing that ruptures the cells. Most injury occurs when the stems are 1 to 3 inches DBH. Frost cracks or seams start at wounds or branch stubs. A sudden, sharp drop in winter temperature causes the outer layer of wood to contract more rapidly than the inner layer, which can result in a long vertical crack at weak points in the trunk. Frost cracking can occur repeatedly in the same place, causing a buildup of tissues and the formation of frost ribs or seams. These cracks are common sites for wood decay.

Wildlife factors. Sapsuckers frequently peck and cause degradation (log grade reduction) in some sugar maple trees, but rarely, if ever, kill the tree. On heavily pecked trees, in the spring, a fungus develops on the sap and causes the bark to turn black. Such trees probably should be retained in the stand to prevent other trees from being attacked.

Yellow Birch

Pests. The bronze birch borer *(Agrilus anxius)* is the most serious insect pest of yellow birch. It attacks both healthy and weakened birches, but apparently can normally complete its life cycle only in dead or dying wood in weakened trees. Mature and overmature trees left severely exposed after logging and in lightly stocked stands are more subject to attack than trees in well-stocked stands.

In outbreaks, the birch skeletonizer *(Bucculatrix canadensisella)* completely destroys foliage by August. Successive attacks reduce host vigor and may predispose birches to bronze birch borer attacks.

Although yellow birch is not a preferred host of the forest tent caterpillar *(Malacosoma disstria),* the gypsy moth *(Lymantria dispar),* the elm spanworm *(Ennomos subsignarius),* the hemlock looper *(Lambdina fiscellaria),* or the saddled prominent *(Heterocampa guttivitta),* caterpillars of these species defoliate birch in severe outbreaks. Two to three years of successive defoliation can kill birch trees.

Diseases. Mechanical wounds with more than 50 in² of exposed wood are important entrance courts for decay fungi. *Pholiota limonella, P. aurivella, Polyporus versicolor, Daldinia concentrica,* and *Hypoxylon spp.* are aggressive invaders of these larger wounds. *D. concentrica* and *Hypoxylon spp.* also invade branch stubs. Extensive decay is usually associated with larger mechanical injuries more than 20 years old and frost cracks more than 10 years old. Several microorganisms are frequently associated with increment-bore wounds in birch. Increment-bore wounds cause reddish-brown decay columns from 29 to 84 inches long within two years following boring.

Nectria galligena is the most common and damaging stem disease of yellow birch. It causes perennial target cankers, a twig blight, and subsequent crown dieback. The fungus can penetrate saplings, small branches, buds, and wounds, but usually enters the host through cracks originating at branch axils from heavy snow or ice loads. *Nectria* cankers cause localized defects that reduce stem quality and weaken the stem, increasing the chances for wind breakage.

Stereum murrayi causes elongated, sunken, bark-covered stem cankers and a yellow-brown stringy trunk rot of yellow birch. Cankers are common on branch stubs, and decay usually extends about one foot above and below cankers on pole-sized trees. Decay can be extensive in overmature yellow birch. *Phellinus laevigatus* also produces characteristic sunken, bark-covered cankers on mature and over-mature trees. Single cankers indicate extensive decay. It is more common on dead than living trees. *Inonotus obliquus* produces black, clinker-like, sterile conks that develop in trunk wounds and branch stubs. Sometimes conks of *L. obliquus* and *Phellinus igniarius* occur on dead branch stubs in the center of Nectria cankers. A sterile conk indicates from 50 to100% cull and decay extends from 5 to 7 feet above and below each conk. *Inonotus obliquus* is an aggressive decay fungus that can invade and kill tissues around these sterile conks.

Armillaria mellea, the shoestring root rot, is the most common and important root and butt decayer of yellow birch trees. The fungus causes a white root rot with black rhizomorphs on the roots.

Inonotus obliquus, *Pholiota spp*., *Phellinus igniarius,* and *P. laevigata* are the principal decay fungi of yellow birch trunks. The false tinder fungus *(P. igniarius)* causes a common white trunk rot of yellow birch. A single conk indicates extensive decay that extends 8 to 10 feet above and below the conk. *Pholiota aurivella is* an aggressive decayer of centers of larger birches and *Pholiota limonella* causes a yellow-brown stringy trunk rot.

Environmental factors. Thin-barked yellow birch is susceptible to fire injury. Seedlings and saplings are killed outright by even light surface fires. Winter sunscald can be a problem on the south and southwest sides of birch boles.

Post-logging decadence is a localized decline from which most trees recover. It consists of top dying and some mortality following heavy cutting in mature and over-mature stands. Yellow birch is more susceptible to root, stem, or crown injury and more severely affected than its common hardwood associates. Weakened trees are often attacked and eventually killed by the bronze birch borer (*Agrilus anxius*).

Periodic declines of yellow birch and paper birch trees, called birch dieback, have caused widespread mortality in Canada and the northeast United States. It affects yellow birches of all sizes, even in undisturbed virgin stands. The first visible symptoms of dieback are small, curled, cupped, yellowish, and thin leaves in the upper crown. Following this, tips of branches die, then dying progresses downward, involving entire branches and often more than half the crown within 2 or 3 years. Trees are usually killed within 3 to 5 years by the bronze birch borer and other associated secondary pests. Many researchers have attributed birch dieback to adverse climatic conditions, drought, and increased soil temperature, over an extended period, which caused rootlet mortality that weakened the trees and predisposed them to attacks by the borer. Others have considered over-maturity, past cutting practices, killing of associated trees by disease and the spruce budworm, and defoliating insect outbreaks as initially responsible for weakening the trees. More recently the "frozen soil" theory suggests that shallow-rooted birch trees in years without snow cover are apparently unable to replace moisture losses from their stems through both frozen rootlets and those broken from frost heaving. To date, no single explanation for birch dieback has been widely accepted. It is most likely the result of one or more stress factors.

Top-dying and reduced growth of yellow birch crowns has also been associated with heavy birch seed crops. This dieback occurs the year after bumper seed crops and is limited to the peripheral 2 to 3 feet of branch tips on mature trees and usually just the past season's growth on younger trees.

Discoloration and decay are the major causes of defect and loss in wood quality of yellow birch. They develop more rapidly in yellow birch than other diffuse-porous northern hardwood species.

Wildlife factors. Yellow birch is a favorite summer food source of the yellow-bellied sapsucker on its nesting grounds. Heavy sapsucker feeding can reduce growth, lower wood quality, or even kill birch.

American Beech

The thin bark of beech renders it highly vulnerable to injury by fire (large shallow roots are especially vulnerable), sunscald, logging, pruning, or disease. When large branches are broken they heal comparatively slowly and serve as entrance courts for a host of decay fungi.

Pests. Defoliation by insects can occasionally be a serious problem. The most damaging is the saddled prominent, *Heterocampa guttivitta,* although the forest tent caterpillar *(Malacosoma disstria),* gypsy moth *(Lymantria dispar),* fall cankerworm *(Alsophila pometaria),* and Bruce spanworm *(Operophtera bruceata)* occasionally cause heavy defoliation in local areas. Insect defoliation often renders trees susceptible to attack by the shoestring root fungus.

Diseases. Beech bark disease (BBD) is the most serious problem of this species. BBD is initiated when a scale insect, the beech scale, *Cryptococcus fagisuga,* attacks the bark and renders it susceptible to bark canker fungi of the genus *Nectria*. The scale allows the fungus to invade the trees. Nectria cankers form on the tree trunk and large branches, killing infected areas. Trees are eventually killed or break in wind or ice storms. “Beech snap” refers to the often observed breakage of the main stem of diseased trees, creating a highly hazardous environment. Beech bark disease develops sequentially in three stages, identified as the *advancing front*, the *killing front* and the *aftermath forest*.

The BBD advancing front refers to stands where trees are infested with beech scale, but not yet infected by Nectria. Estimates suggest that beech scale and the advancing front spread at roughly 12 to15 miles per year. Stands can be infested with beech scale for several years before Nectria infection begins killing trees and causing beech snap.

The BBD killing front refers to stands where beech scale populations are high and Nectria infection is abundant. Tree mortality and snap are heavy within the killing front. Salvage of heavily infested trees prior to the onset of decline and mortality is often necessary due to high risk of beech snap in infested trees with apparently healthy crowns.

The BBD aftermath forest refers to stands that have experienced the first wave of beech mortality. A large portion of the mature beech resource has been lost at this point. Residual beech trees in the aftermath forest are mostly defective and declining. Some large trees remain – many of the remaining large trees simply escaped scale infestation or Nectria infection, and some are at least partially resistant.

More than 70 decay fungi (a record for a hardwood species) have been reported for beech. The most important include *Daedalea unicolor, Ganoderma applanatum, Fomes fomentarius, Phellinus igniarius, Hericium erinaceus, H. coralloides, Steccherinum septentrionale, Inonotus glomeratus,* and *Ustilina vulgaris.* The shoestring fungus, *Armillaria sp.,* the most important root pathogen, attacks and girdles roots of weakened trees. Beech roots are also parasitized by the broomrapes, *Conopholis americana* and *Epifagus virginiana.* The latter, called beech drops, is specific to beech.

Environmental factors. In regions with low winter temperatures, long frost cracks often appear in the tree trunks. These cracks are sometimes superficial, but sometimes extend deep into the bole.

White ash

Pests. Emerald ash borer (*Agrilus planipennis*), or EAB, is an exotic beetle discovered feeding on ash (Fraxinus spp.) in southeastern Michigan in 2002. It is now found in many areas in the northern Lower Peninsula, Indiana, Ohio, and Ontario. EAB appears to be a permanent, serious limiting factor for Fraxinus species in both landscaped and forested environments in Michigan's Lower Peninsula. Infested trees exhibit top-down dieback, typical of other phloem borers such as two-lined chestnut borer or bronze birch borer. One-third to one-half of the branches may die in one year, while most of the crown can die within two years. Affected trees may have vertical splits in the bark 2 to 4 inches long. Dense sprouting of shoots can often be found arising from the trunk or roots. Although difficult to see, the adult beetles make a "D"-shaped exit hole in the bark, roughly 1/16 inches in diameter.

Other pests can damage this species. The ash borer *(Podosesia syringae)* may seriously damage young shade and shelterbelt trees. The ash and privet borer *(Tylonotus bimaculatus)* attacks and kills branches, especially on older trees. Both the red-headed ash borer *(Neoclytus acurninatus)* and the banded ash borer *(N. caprea)* colonize cut logs and dead or dying trees.

Diseases. Ash decline (also called ash dieback) is a serious forest health problem affecting white ash. The disease, ash yellows, caused by mycoplasma-like organisms (MLO), has been found associated with many of the dying trees. However, since not all dying trees are infected with MLO, ash decline is thought to result from multiple causes. Drought-weakened trees may be invaded by canker-causing, branch-girdling fungi such as *Fusicoccum spp*. and *Cytophorna pruinosa*. Competition induced stress of ash in overstocked hardwoods has predisposed trees to root invading fungi such as *Armillaria spp*. Subsequent root system failure results in tipping and windthrow, eventually losing much of the ash component. Air pollution, leaf-spotting fungi, and viruses are additional stresses that may be involved in the causes of ash decline.

Heartwood rots may be caused by *Perenniporia fraxinophilus, Phellinus* igniarius, *Pleurotus ostreatus, Tyromyces spraguei*, and *Laetiporus sulphureus.* These organisms usually enter through wounds or broken branches, mainly on older trees.

Environmental factors. Air pollution damages white ash. It is rated as sensitive to ozone and is severely injured by stack gases from soft coal consumption and from industrial processes, both of which emit sulfur dioxide.

American Basswood
The thin bark of this species is easily damaged by fire. Basswood is one of the hardwoods least susceptible to late spring frosts. Many different insects attack basswood, but few serious insect problems exist.

Pests. The introduced basswood thrips (*Thrips calcaratus)* is a recently recognized defoliator of American basswood in the Lake States. Over the past several years, basswood stands in northern forests have suffered moderate to severe defoliation. Damage often resembles early spring frost injury. Damage is characterized by bud drop in the early spring or a stunted, shredded appearance of expanding leaves. On fully expanded leaves, feeding damage appears as a silvering of the leaf cuticle. Repeated defoliation leads to thinned crowns and branch dieback, and eventual reduction in radial growth. Tree mortality has been rare.

Local infestations of other defoliators may occur. These include the linden looper *(Erannis tiliaria),* basswood leafminer *(Baliosus nervosus),* spring cankerworm *(Paleacrita vernata),* fall cankerworm *(Alsophila pometaria),* whitemarked tussock moth *(Orgyia leucostigma),* gypsy moth *(Lymantria dispar),* and forest tent caterpillar *(Malacosoma disstria).*

Diseases. The wood of basswood decays easily. Once exposed, the wood can be a host to many of the common hardwood decay organisms such as the yellow cap fungi (*Pholiota limonella)* and *Collybia velutipes*.

When basswood is harvested under 120 years of age, little defect is encountered. Beyond this age, the chances of losses due to decay are greatly increased.

Eastern Hemlock
Small eastern hemlock trees are highly susceptible to wildfire**,** but prescribed burns are beneficial for securing natural regeneration. The thick bark of older trees is resistant to light burns**,** but saplings are usually destroyed. Root injury often occurs from high intensity fires because of heavy litter accumulation.

Pests. The most important insect pests of hemlock are the hemlock borer, *Melanophila fulvoguttata*, and the hemlock looper (*Lambdina fiscellaria*). The hemlock borer attacks weakened trees. Symptoms usually consist of woodpecker-like holes in the bark, galleries filled with dark excrement, and yellowing shoot tips. The hemlock looper larva devours part of the needle after which the remainder turns brown. The looper can be extremely destructive to hemlock, balsam fir, white spruce and will defoliation a wide range of other associated tree species. Hemlocks may die after one year of severe defoliation.

The hemlock woolly adelgid (*Adelges tsugae*) has been in the United States since 1924. This exotic insect is a serious pest of eastern hemlock. It has not yet established in Michigan, but is moving this way. The hemlock woolly adelgid feeds during all seasons with the greatest damage occurring in the spring. It is dispersed by wind, birds and mammals. By sucking sap from the young twigs, the insect retards or prevents tree growth causing needles to discolor from deep green to grayish green, and to drop prematurely. The loss of new shoots and needles seriously impairs tree health. Defoliation and tree death can occur within several years. White cottony sacs on the base of the needles are good evidence of a hemlock woolly adelgid infestation. These sacs resemble the tips of cotton swabs. They are present throughout the year, but are most prominent in early spring.

Diseases. Seeds of eastern hemlock are sensitive to damage from several molds, particularly *Botrytis* spp., that reduce or delay germination. Some molds are borne internally while others colonize the seeds during germination. Generally, molds are less injurious than desiccation during the germination and seedling stages.

The most damaging agents to young seedlings, other than desiccation, are damping-off fungi and root rots *Pythium* spp. and *Rhizoctonia* spp. which flourish in wet, poorly drained soils and in well-drained soils, respectively, and are common on eastern hemlock. At least three root rots- *Cylindrocladium scoparium, Rhizina undulata* (common on burn areas), and *Fusarium moniliforme*- are common on eastern hemlock.

Several diseases affect the needles and twigs of eastern hemlock. The rust caused by *Melampsora farlowii* is one of the most damaging. It causes shoot blight and curls and attacks the cone**,** often resulting in cone abortion.

Living heartwood of eastern hemlock is attacked by *Tyromyces borealis,* particularly in the northeast, leaving white flecks in the wood. *Pholiota adiposa* is fairly common in the Lake States and causes a cavity along the pith axis. Other rots are the trunk rot caused by *Haematostereum sanguinolentum;* a brown, red ring rot caused by *Phellinus pini;* and a red heart rot caused by *P. robustus.*

Numerous fungi are associated with the root system. The most common are the shoestring fungus, *Armillaria mellea,* and the velvet top fungi, *Phaeolus schweinitzii, Tyromyces balsameus,* and *Heterobasidion annosum*.

Environmental factors. Drought is a serious damaging agent to eastern hemlock, especially during the seedling stage. Winter drying**,** caused by excessive transpiration on warm, windy days, causes severe needle injury.

In later stages of stand development, heavy cuttings predispose trees to windthrow because of their shallow rooting habit. Older trees are susceptible to radial stress cracks and ring shake, particularly in partially cut stands. Eastern hemlock is sensitive to salt spray or drift and sulfur fumes, and is one of the species most often struck by lightning.

Wildlife factors. Porcupines occasionally gnaw the bark on larger trees**,** causing serious wounds and top-kill. Sapsuckers have been associated with ring shake in some areas.

Black Cherry

Cherry trees of all sizes are highly susceptible to fire injury. Even large trees are killed by moderate to severe fire, but most resprout, unless the fire was unusually hot.

Pests. The most important defoliating insects attacking black cherry include the eastern tent caterpillar *(Malacosoma americanum)* and the cherry scallop shell moth *(Hydria prunivorata)*. Infestations of these insects are sporadically heavy, with some apparent growth loss and occasional mortality, if heavy defoliations occur several years in a row.

Attacks by numerous species of insects cause gum defects in black cherry, resulting in reduced timber quality. Gum spots in the wood are often associated with the Agromyzid cambium miner *(Phytobia pruni),* the peach bark beetle *(Phloeotribus liminaris),* and by the lesser peachtree borer *(Synathedon pictipes)*. A wide variety of insects can cause injury to terminal shoots of black cherry seedlings and saplings, resulting in stem deformity. *Archips* spp. and *Contarinia cerasiserotinae* are among the more important.

Diseases. The most common disease is cherry leaf spot caused by *Coccomyces lutescens*. Large numbers of black cherry seedlings are sometimes weakened or killed by this disease. Repeated attacks reduce the vigor of larger trees. Most other foliage diseases cause little damage.

Black knot (*Apiosporina morbosa*) is common disease of black cherry. It causes elongated rough black swellings several times the diameter of the normal stem. Small twigs may be killed within a year after infection. Large cankerous swellings, a foot or more in length, may occur on the trunks of larger trees. The tree has no lumber value where several such lesions are scattered along the bole.

Several basidiomycete fungi that cause root and butt rot of living black cherry trees include *Armillaria mellea, Coniophora cerebella, Polyporus berkeleyi,* and *Tyromyces spraguei.* Many other fungi cause decay of the main trunk; including *Fomes fomentarius, Fomitopsis pinicola, Poria prunicola. P. mutans,* and *Laetiporus sulphureus*.

Decay spreads fairly slowly in cherry, so long-term effects of wounding and breakage are less severe than many other associated hardwoods.

Red Maple

Red maple is generally considered very susceptible to defect. Especially on poor sites, red maple often has poor form and considerable internal defect.

Diseases. Many trunk rot fungi and stem diseases attack red maple. The most important of these, *Inonotus glomeratus,* infects branch stubs and wounds on the stem. *Phellinus igniarius* is another leading heart rot of red maple. Red maple may also be cankered by species of *Nectria, Eutypella, Hypoxylon, Schizoxylon, and Strumella*.

Environmental factors. Mechanical injury is a common source of defect in hardwoods. Red maple is especially sensitive to wounding. Increment boring causes discoloration, and may lead to decay in red maple.

Appendix B: Stocking Guide for Uneven-aged Northern Hardwood Stands

Table 1.12 App B. Recommended Residual Stocking Per Acre for Fully Regulated Uneven-aged Stands. (Arbogast 1957)

DBH (inches)	No. of Trees	No. of Trees by Size Class	Basal Area (ft^2)	Basal Area
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

Appendix C: Stocking Guides for Even-aged Northern Hardwood Stands

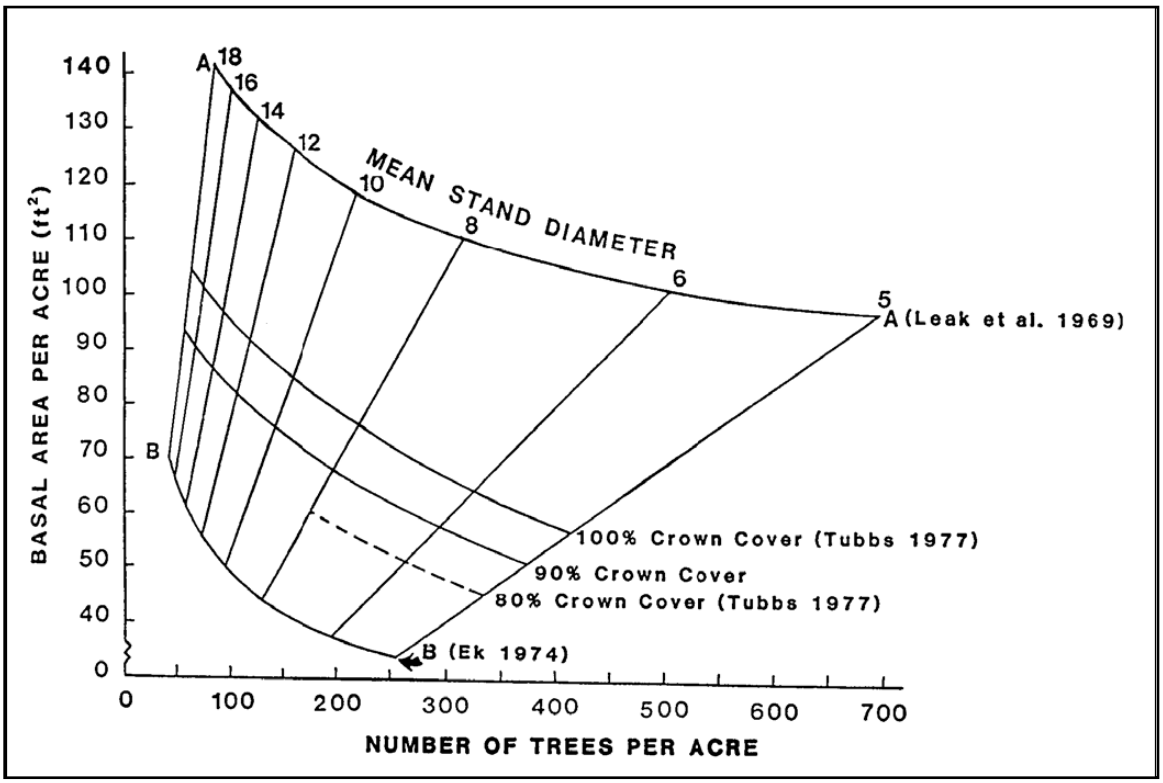

Figure 1.2 App C. Recommended Stocking Levels for N Hdwds in Even-aged Stands. For N Hdwd Stands Where Sugar Maple is Dominant Component [a] (Erdmann 1986)

Table 1.13 App C. Even-aged Stocking Levels for Northern Hardwoods by Mean Stand Diameter, Basal Area, & Number of Trees Per Acre for Specified Crown Covers After Thinning. (Erdmann 1986)

			Crown Cover %							
			80%		90%		100%		110%	
Mean Stand Diameter[a] (in.)	Crown Area Per Tree[b] (ft2)	Basal Area Per Tree (ft2)[c]	Trees/ Ac (no.)	BA/Ac (sq ft)	Trees/ Ac (no.)	BA/Ac (sq ft)	Trees/ Ac (no.)	BA/Ac (sq ft)	Trees/ Ac (no.)	BA/Ac (sq ft)
4	78	0.0873	447	39	503	43.9	558	48.8	614	53.6
5	104	0.1364	335	45.7	377	51.4	419	57.1	461	62.8
6	133	0.1963	262	51.4	295	57.9	327	64.3	360	70.7
7	164	0.2673	212	56.8	239	63.9	265	71	292	78.1
8	199	0.3491	175	61.1	197	68.8	219	76.4	241	84.1
9	238	0.4418	146	64.7	165	72.8	183	80.9	201	88.9
10	279	0.5454	125	68.2	141	76.6	156	85.2	172	93.7
11	325	0.66	107	70.8	121	79.6	134	88.5	147	97.3
12	373	0.7854	93	73.4	105	82.5	117	91.7	128	100.9
13	422	0.9218	83	76.2	93	85.6	103	95.2	114	104.7
14	480	1.069	73	77.6	82	87.3	91	97	100	106.7
15	536	1.2272	65	79.8	73	89.8	81	99.7	89	109.7
16	598	1.3963	58	81.4	66	91.5	73	101.7	80	11.9
17	662	1.5763	53	83	59	93.3	66	103.7	72	114.1
18	728	1.7671	48	84.6	54	95.2	60	105.7	66	116.3
19	803	1.9689	43	85.4	49	96.1	54	106.8	60	117.5
20	881	2.1817	40	86.3	44	97.1	49	107.9	54	118.7
21	952	2.4053	36	88.1	41	99.1	46	110.1	50	121.1
22	1,035	2.6398	34	88.9	38	100	42	111.1	46	122.2
23	1,120	2.8852	31	89.8	35	101	39	112.2	43	123.4
24	1,207	3.1416	29	90.7	32	102	36	113.4	40	124.7

[a] For tree of average basal area
[b] Godman and Tubbs, 1973
[c] BA/tree = D^2 x 0.00545415

Appendix D: Northern Hardwood Management Decision Key

Once stand management objectives have been determined, use the following key to help determine what management recommendations to follow. Start by deciding which size class best describes the stand in question. Starting with number one, read the two choices presented for each number. Proceed to the next number of the key indicated by the choice that most fits the situation. For even-aged stocking guides, or for first thinnings in pole stands, refer to the stocking level chart (Figure 1.2 App C) and associated stocking table (Table 1.13 App C) to determine residual stand stocking goals. Table 1.11 provides tree selection guidance to use for marking, and Table 1.13 App C provides residual stocking goals for all-aged management.

A. Seedling/Sapling Stands (0-5" DBH)

Key to Recommendations:		
1	Stand composed of tolerant species (> 50% of seedling plots stocked with tolerant species (sugar maple, red maple, beech).	2
1	Stand composed of moderately tolerant species (> 10% of seedling plots stocked with yellow birch, basswood, ash, red oak, black cherry, etc.).	3
2	Overtopped by poor or undesirable growing stock.	4
2	Not overtopped by poor or undesirable growing stock.	No treatment until commercial sale becomes feasible.
3	Overtopped by poor or undesirable growing stock.	4
3	Not overtopped by poor or undesirable growing stock.	5
4	Stocking adequate.	Remove overstory.
4	Stocking inadequate.	Open canopy to 50 to 60% crown cover. Remove overstory when regeneration stocking becomes adequate (2,000-4,000 stems/acre, 2-4 ft. high).
5	10 to 50 % of seedling plots stocked with moderately tolerant species.	Around 10 years of age, crown release about 100 crop trees per acre (21 ft. spacing) including basswood and red oak sprouts. Crown release 5 ft. between crowns or 8 ft. between boles on all sides, leaving competitors adjacent to forked crop trees. Thin sprout clumps to 1 or 2 stems.
5	More than 50% of seedling plots stocked with moderately tolerant species.	Around 20 years of age (2-4 inches DBH) crown release 75-100 crop trees per acre (21-24 ft. spacing) including basswood and red oak stump sprouts. Crown release 7 ft. between crowns on all sides, leaving competitors adjacent to forked crop trees. Thin sprout clumps to 1 or 2 stems.

B. Pole Timber & Sawtimber Stands (5-9" DBH and 10+" DBH, respectively)

Key to Recommendations:		
1	Long-term objective is **uneven-aged** management.	2
1	Long-term objective is **even-aged** management.	4
2	Regulated stands (i.e., fairly well balanced across all diameter classes).	Selectively remove trees in all merchantable size classes in order to maintain the residual structure defined in Table 4. Follow the order of removal listed in Table 3. In addition, create canopy gaps for regeneration. Cut poor quality stems, 2 inches DBH and greater, from the openings described below. Cutting cycles should occur every 10-15 years. Create a total of about 0.1 acre in crown openings, as appropriate to the silvicultural system used: Single Tree Selection: Create 5 openings, each 30 ft. in diameter. Group Selection: Create 1-2 openings, 50-75 ft in diameter.
2	Un-regulated stands (i.e., poorly balanced across diameter classes).	3
3	First thinning in even-aged stands.	Thin as needed to the stocking levels provided in Figure 1 and Table 2. Reduce stocking to recommended levels by the following procedure: Crown release about 50 crop trees per acre (30 ft. spacing) by creating about a 7 ft. opening around the crowns of crop trees, or by removing two competitors around sawtimber trees. Rule of thumb: for trees 8 or larger inch DBH, remove the two nearest crown competitors; for trees < 8 inch DBH, use 7-foot crown release. Cut high-risk, poor-quality and cull trees throughout the stand.

B. Pole Timber & Sawtimber Stands (5-9" DBH and 10+" DBH, respectively) (cont.)

Key to Recommendations:		
3	Previously thinned	Work toward structure of regulated stand by favoring growth into understocked DBH classes and removing trees from overstocked classes (see Table 4). Follow the order of removal as listed in Table 3. Create about 0.1 acre in crown openings per acre. This can be accomplished by creating 5 openings in the overstory each 30 ft. in diameter. Cut all stems 1 inch DBH and greater in the openings.
4	Immature stands	5
4	Mature stands, or stands that have met management goals & objectives for regeneration.	Regenerate via clearcut or shelterwood. See the general discussion in Section III on clearcut and shelterwood systems for a more detailed discussion.
5	First thinnings	Thin as needed to the stocking levels provided in Figure 1 and Table 2. Reduce stocking to recommended levels by the following procedure: Crown release 50-75 crop trees per acre (24-27 ft. spacing) or as many as 90 per acre (22-24 ft. spacing), if predominantly yellow birch. Use 7 ft. opening around crowns or remove 2 competitors around sawtimber crop trees. Mark high-risk and cull overstory trees. Mark sub-canopy trees beneath crop trees. Mark sub-canopy trees throughout the stand.
5	Subsequent thinnings	Subsequent thinnings must be delayed long enough to allow for crown closure, lower branch mortality, and the development of sufficient volume to support an operable cut. For stands previously thinned to 80% crown cover, plan subsequent thinning in about 20 years; those thinned to 90% crown cover, should be thinned again in about 15 years. When the above has been achieved, thin to 90% crown cover level as shown in Figures 1 and Table 2, using a general crown release of high quality crop trees first, followed by thinning from below. As stands mature, consider removal of undesirable seed sources.

Appendix E: Site Index Curves for Common Northern Hardwood Species (Carmean 1978).

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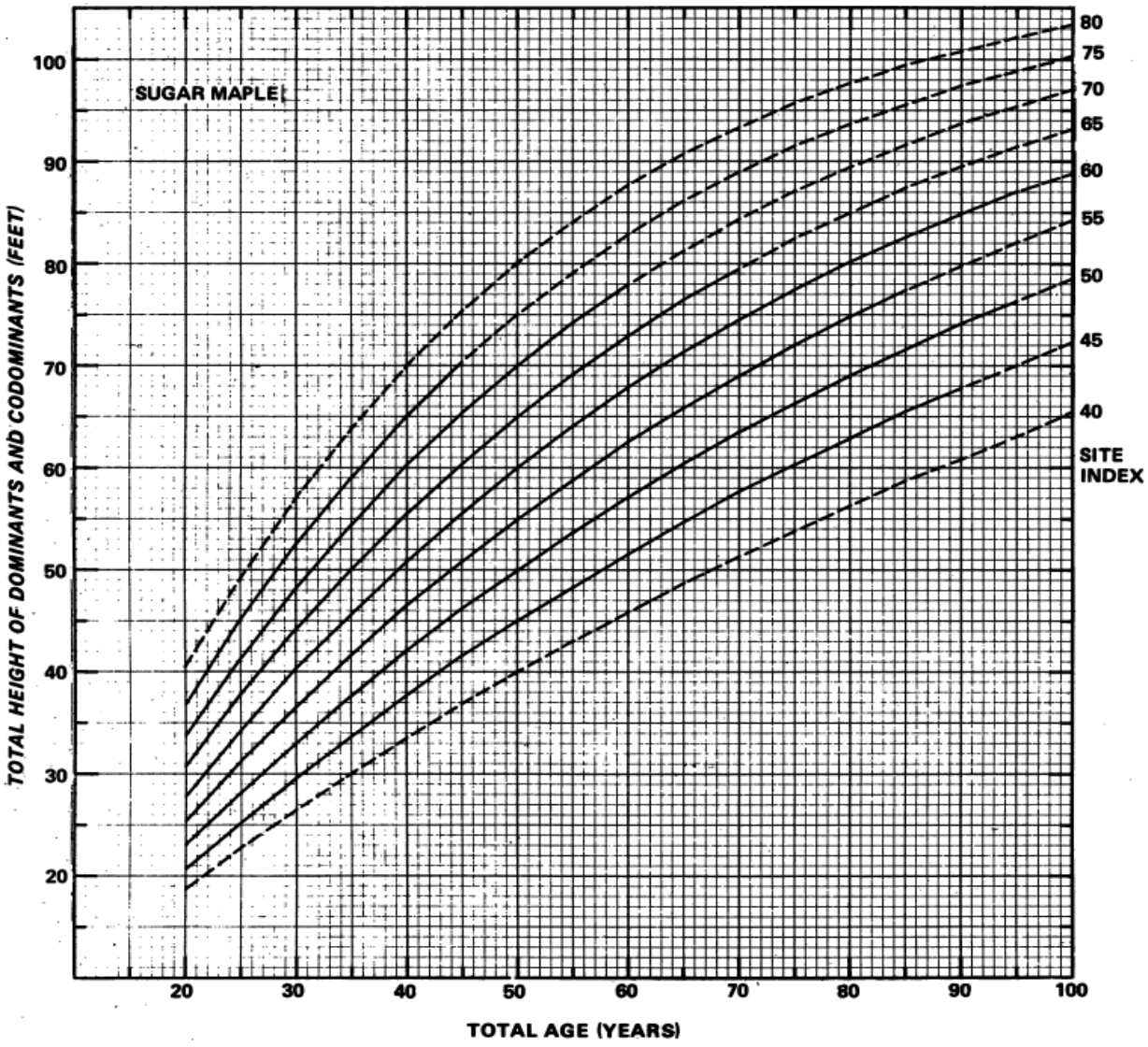

Figure 1.3 App E. Site Index Curves for Sugar Maple in Northern Wisconsin & Upper Michigan.

These curves are based on stem analyses of 721 dominant and codominant trees growing in 177 plots. Add 4 years to breast-height age to obtain total age. Dashed lines indicate extrapolations beyond actual observed data.

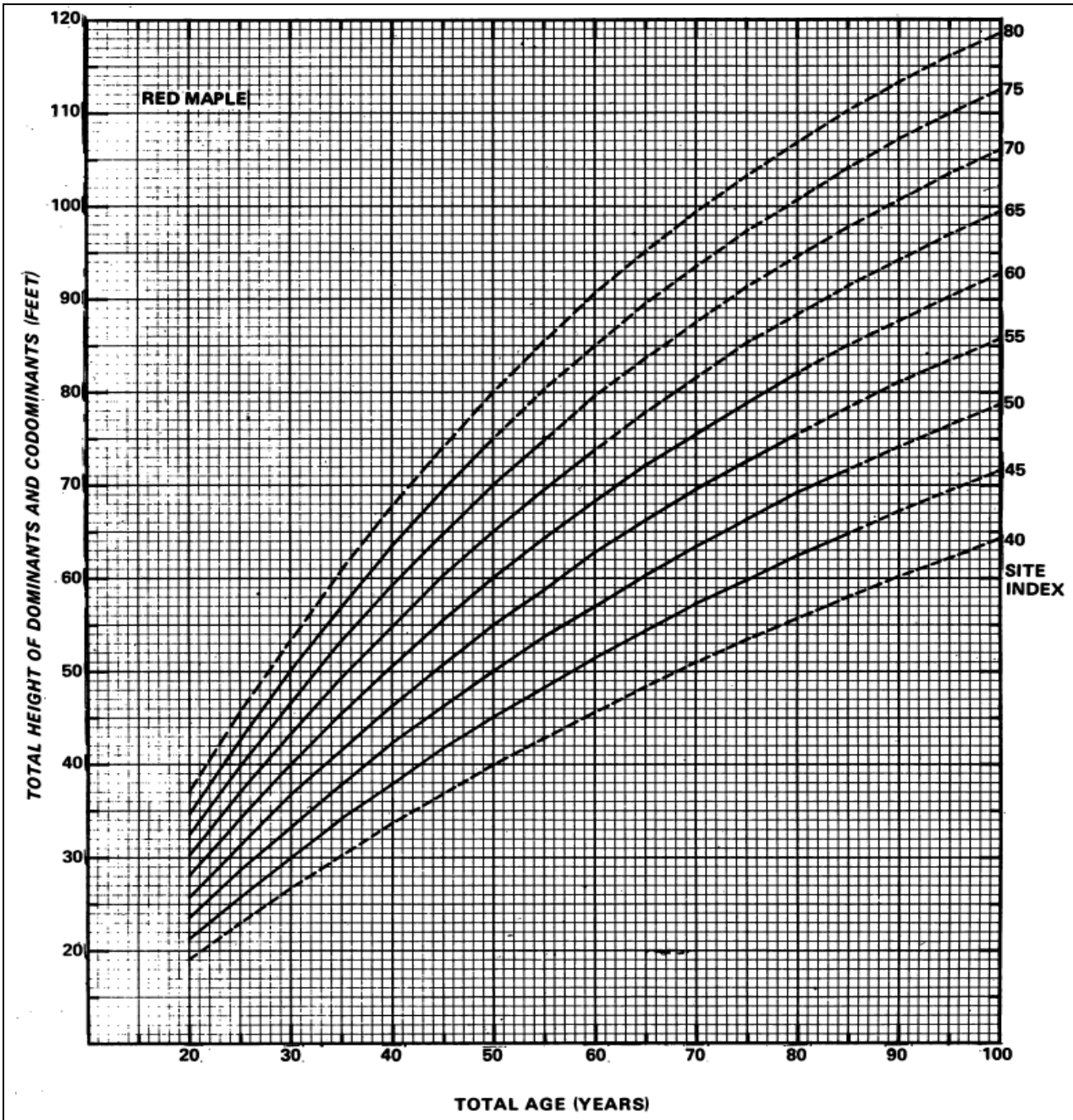

Figure 1.4 App E. Site Index for Red Maple in Northern Wisconsin & Upper Michigan.

These curves are based on stem analyses of 438 dominant and codominant trees growing in 114 plots. Add 4 years to breast-height age to obtain total age. Dashed lines indicate extrapolations beyond actual observed data.

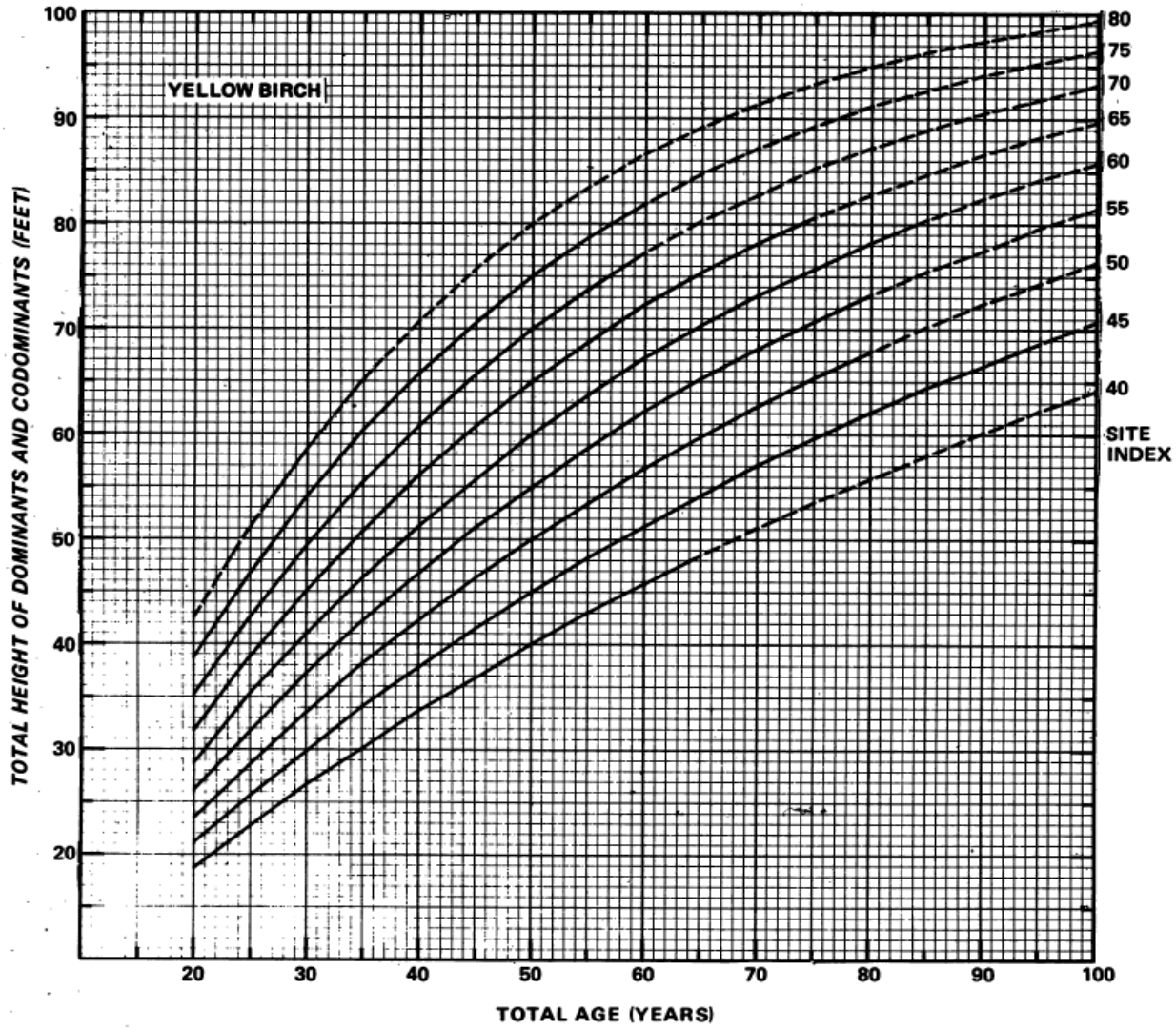

Figure 1.5 App E. Site Index Curves for Yellow Birch in Northern Wisconsin & Upper Michigan.

These curves are based on stem analyses of 459 dominant and codominant trees growing in 119 plots. Add 4 years to breast-height age to obtain total age. Dashed lines indicate extrapolations beyond actual observed data.

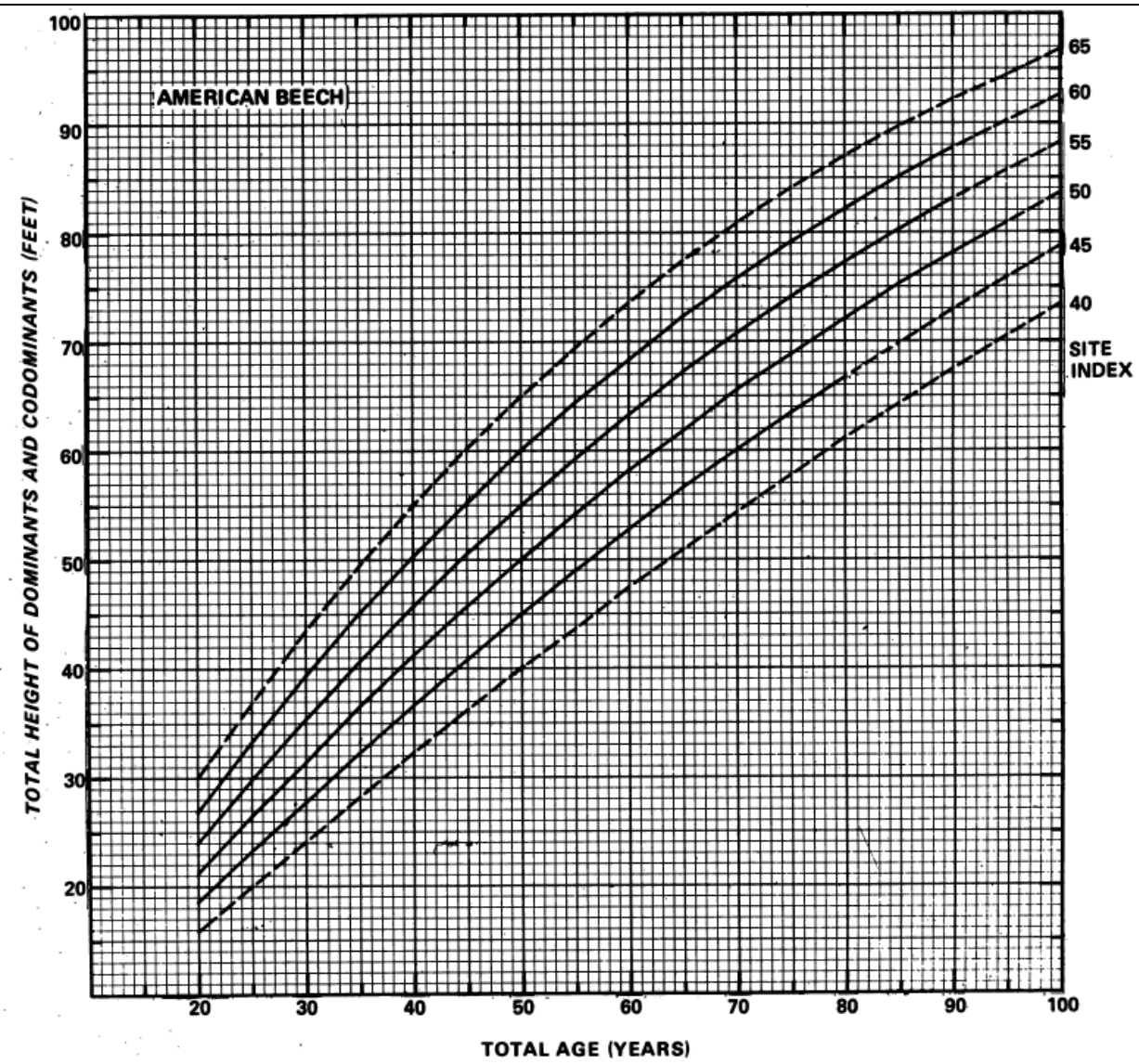

Figure 1.6 App E. Site Index Curves for American Beech in Northern Wisconsin & Upper Michigan.

These curves are based on stem analyses of 70 dominant and codominant trees growing in 19 plots. Add 4 years to breast-height age to obtain total age. Dashed lines indicate extrapolations beyond actual observed data.

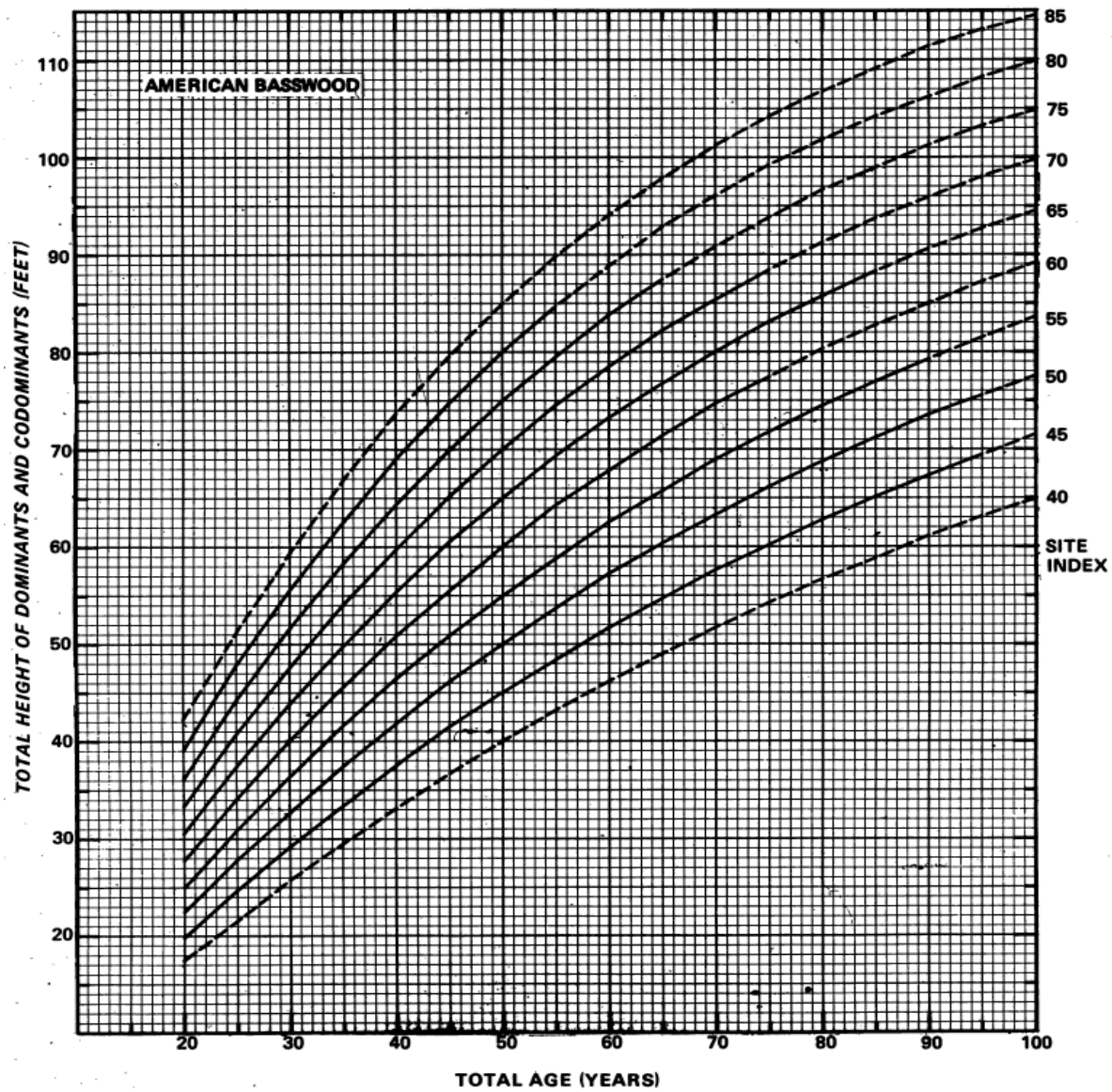

Figure 1.7 App E. Site Index for American Basswood in Northern Wisconsin & Upper Michigan.

These curves are based on stem analyses of 483 dominant and codominant trees growing in 122 plots. Add 4 years to breast-height age to obtain total age. Dashed lines indicate extrapolations beyond actual observed data.

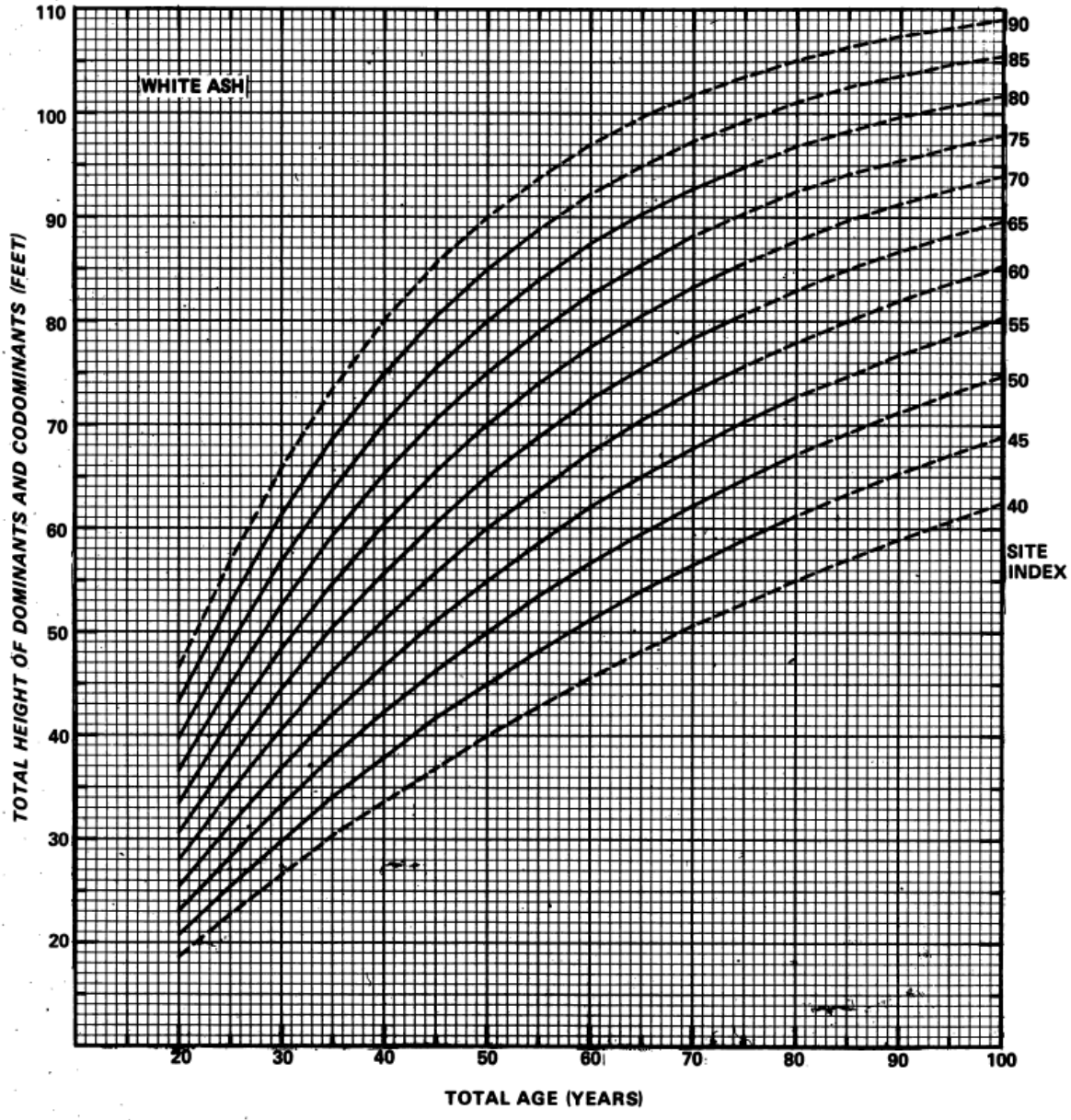

Figure 1.8 App E. Site Index Curves for White Ash in Northern Wisconsin & Upper Michigan.

These curves are based on stem analyses of 275 dominant and codominant trees growing in 73 plots. Add 4 years to breast-height age to obtain total age. Dashed lines indicate extrapolations beyond actual observed data.

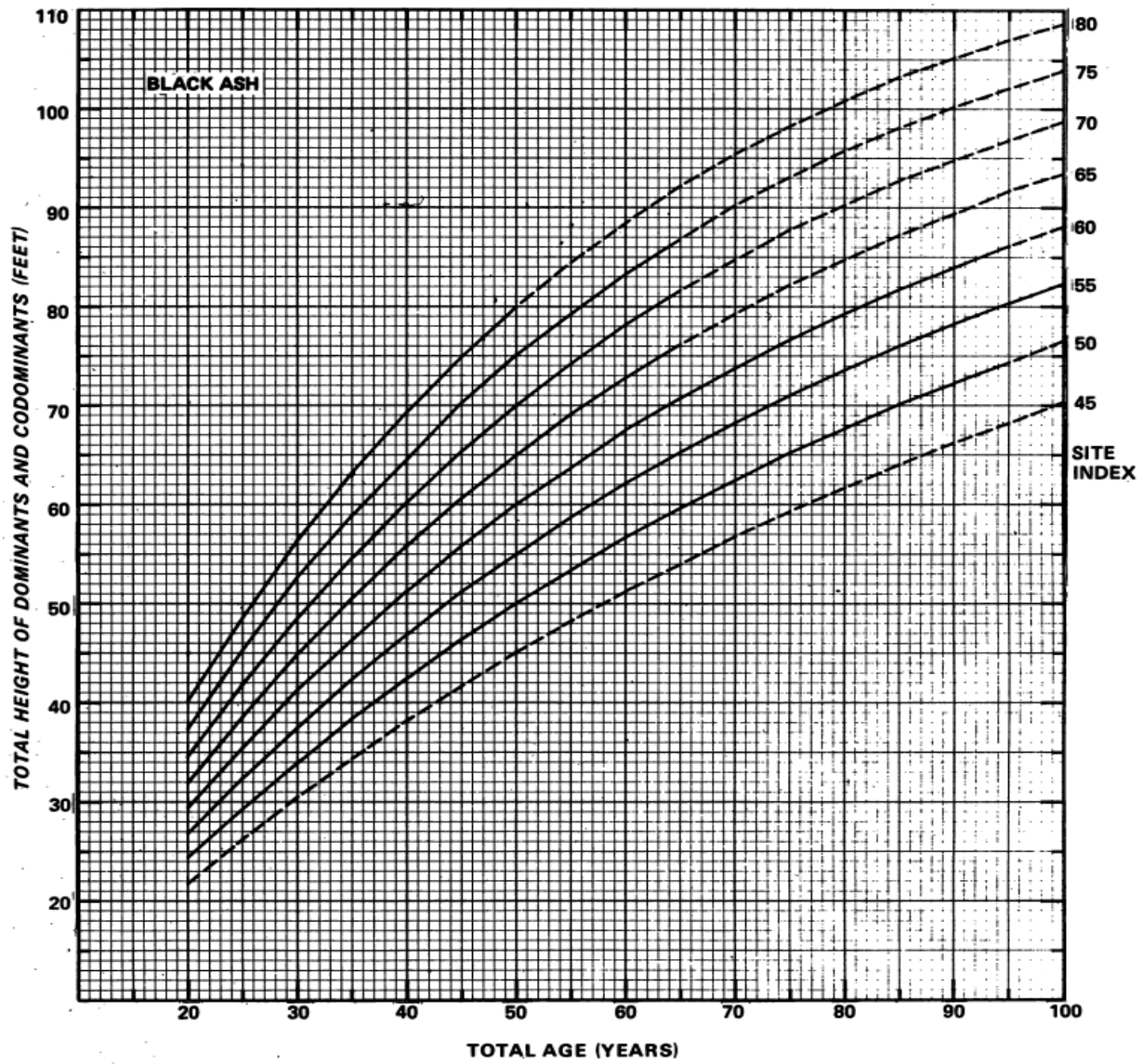

Figure 1.9 App E. Site Index Curves for Black Ash in Northern Wisconsin & Upper Michigan.

These curves are based on stem analyses of 143 dominant and codominant trees growing in 39 plots. Add 4 years to breast-height age to obtain total age. Dashed lines indicate extrapolations beyond actual observed data.

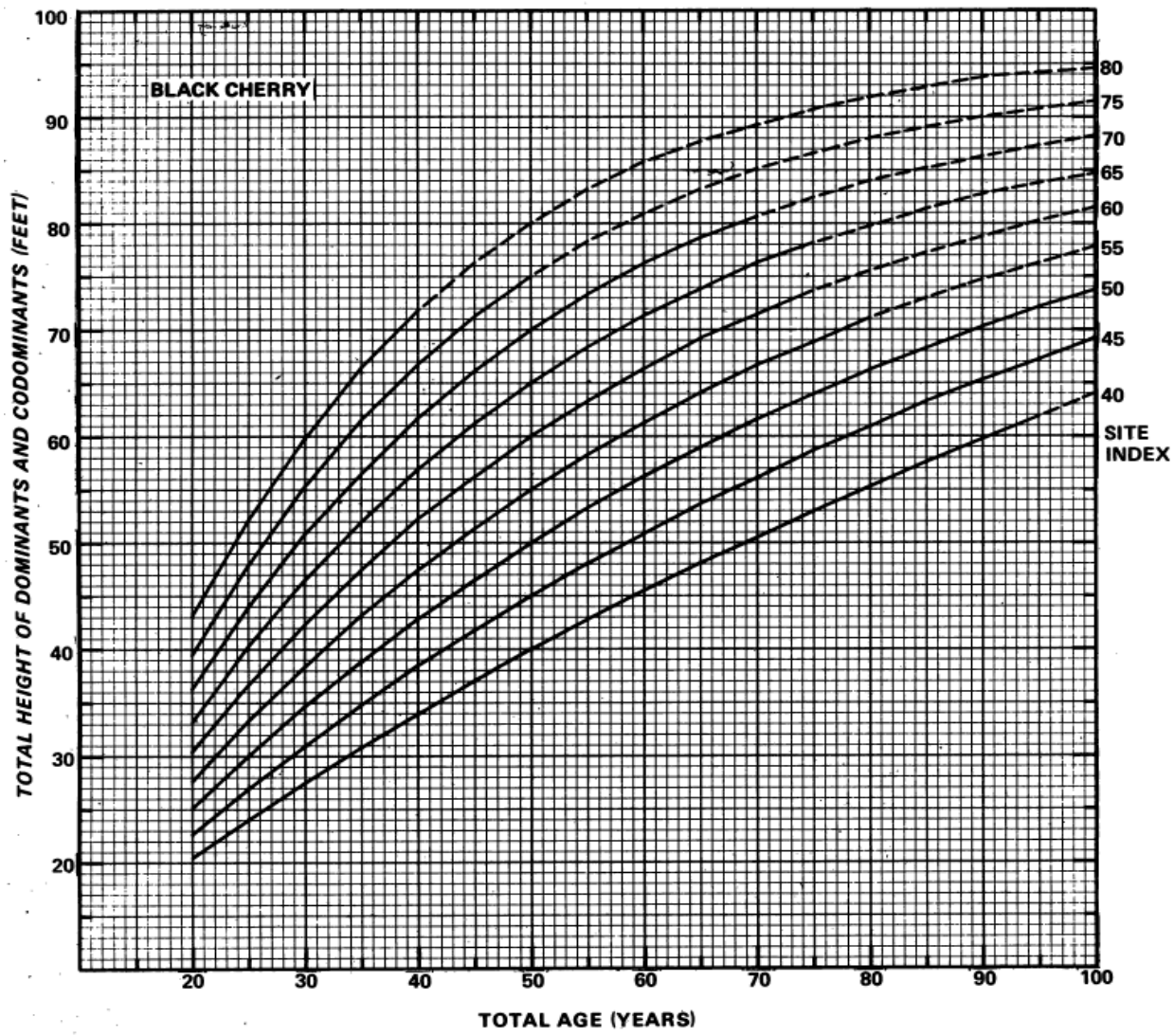

Figure 1.10 App E. Site Index for Black Cherry in Northern Wisconsin & Upper Michigan.

These curves are based on stem analyses of 126 dominant and codominant trees growing in 42 plots. Add 4 years to breast-height age to obtain total age. Dashed lines indicate extrapolations beyond actual observed data.

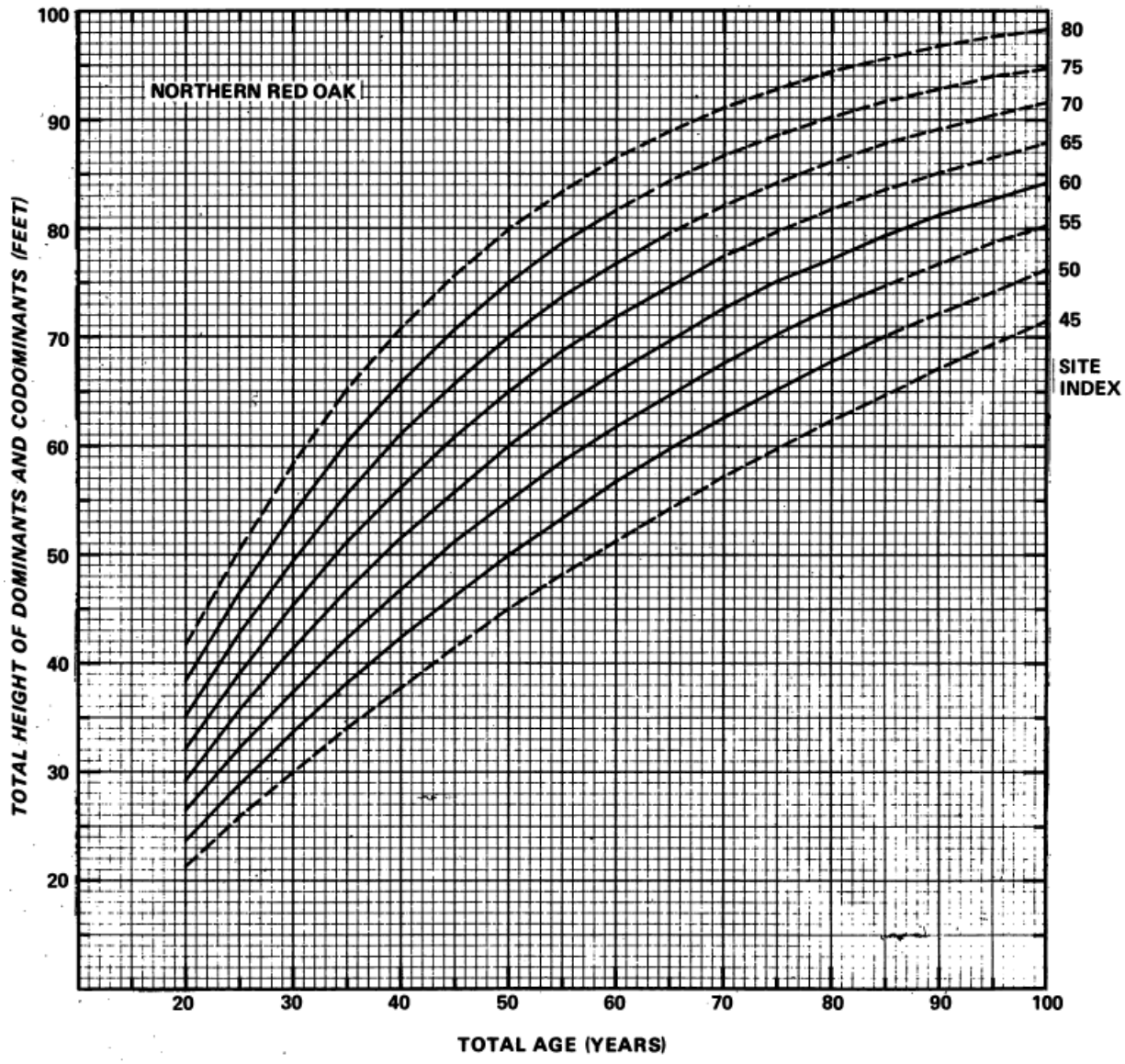

Figure 1.11 App E. Site Index Curves for Northern Red Oak in Northern Wisconsin & Upper Michigan.

These curves are based on stem analyses of 136 dominant and codominant trees growing in 37 plots. Add 4 years to breast-height age to obtain total age. Dashed lines indicate extrapolations beyond actual observed data.

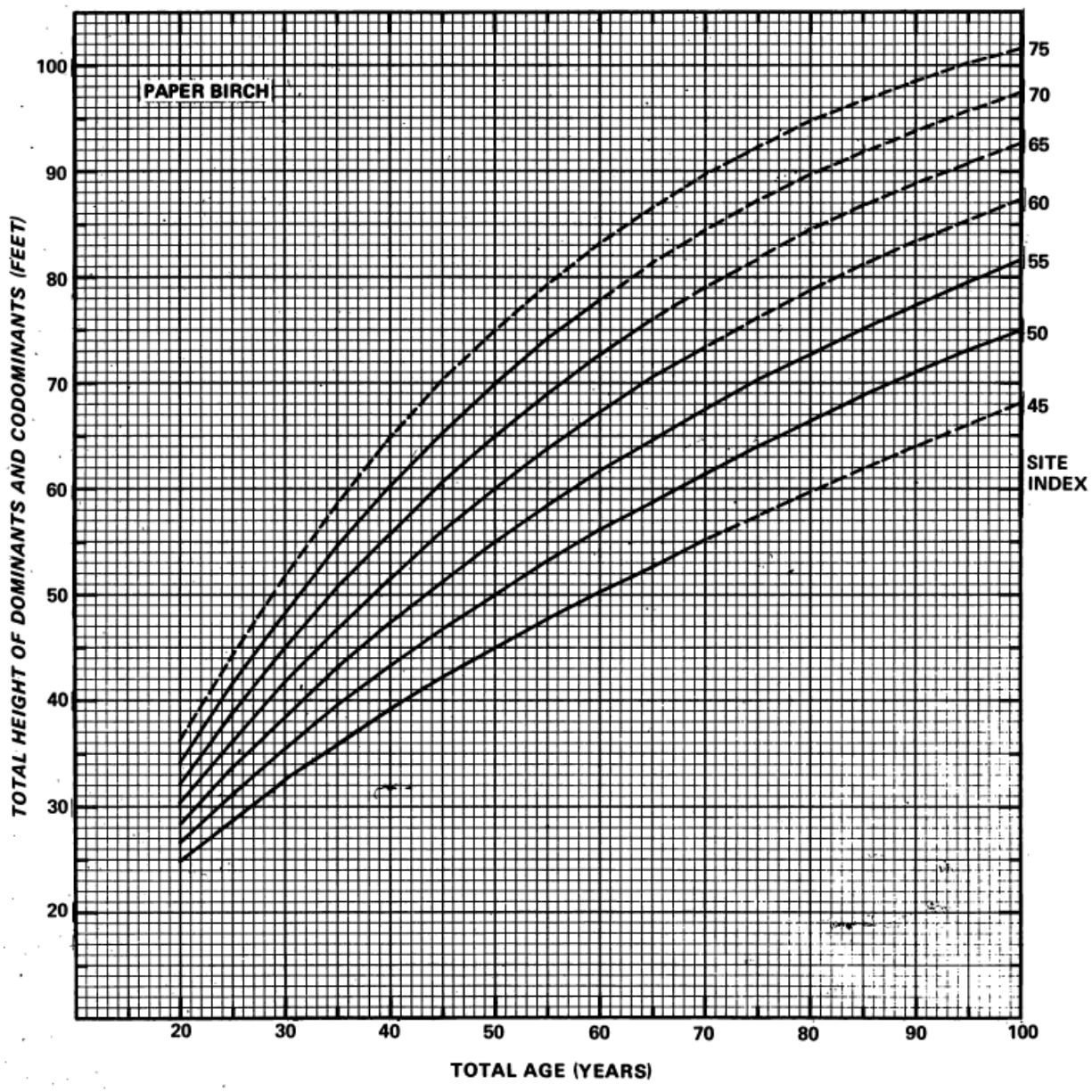

Figure 1.12 App E. Site Index for Paper Birch in Northern Wisconsin & Upper Michigan.

These curves are based on stem analyses of 93 dominant and codominant trees growing in 30 plots. Add 4 years to breast-height age to obtain total age. Dashed lines indicate extrapolations beyond actual observed data.

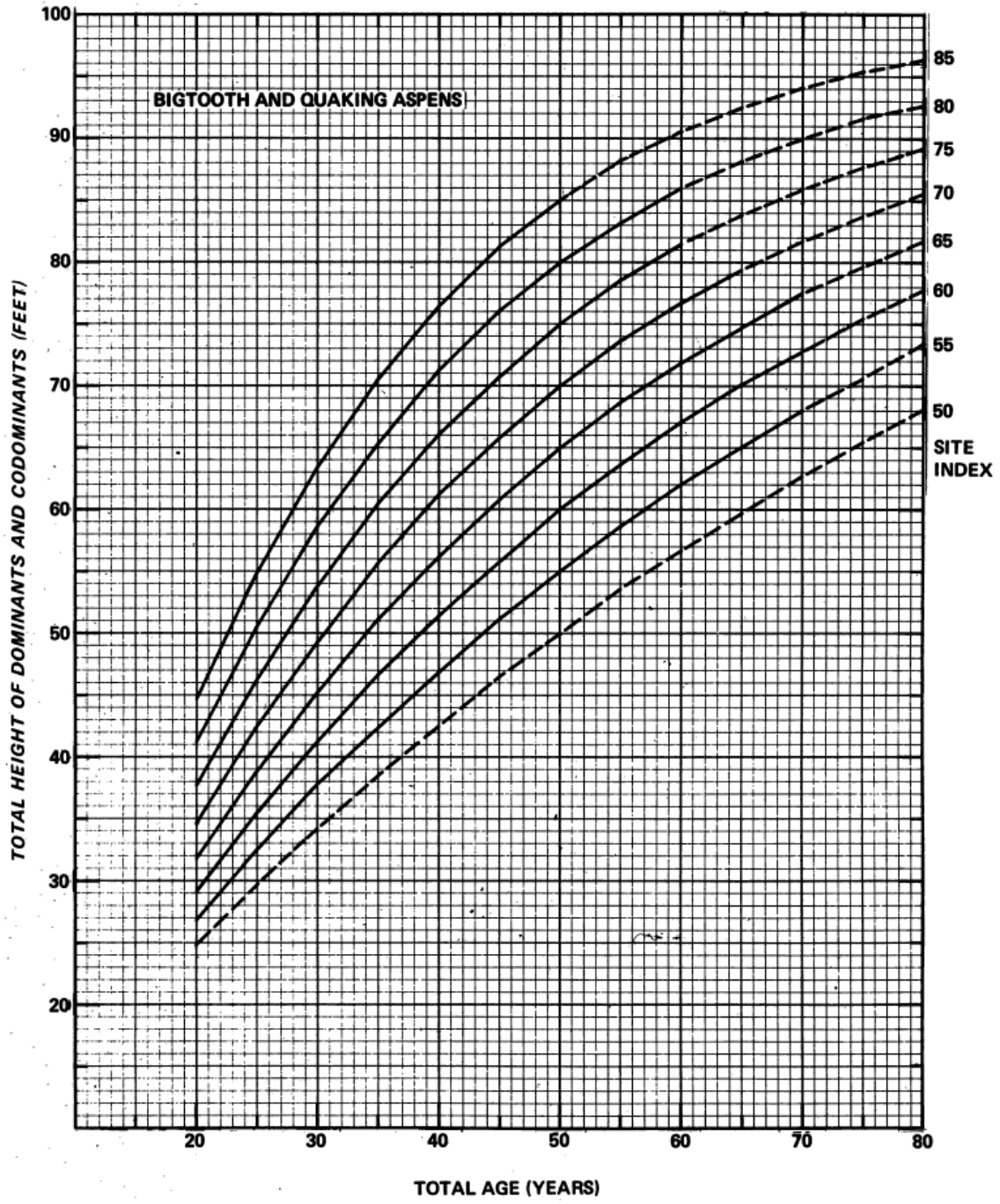

Figure 1.13 App E. Site Index Curves for Bigtooth & Quaking Aspen in Northern Wisconsin & Upper Michigan.

These curves are based on stem analyses of 42 dominant and codominant trees growing in 13 plots. Add 4 years to breast-height age to obtain total age. Dashed lines indicate extrapolations beyond actual observed data.

Appendix F: Common and Scientific Names for Species Cited

Common Name	Scientific Name
Trees	
American beech	Fagus grandifolia
balsam fir	Abies balsamea
basswood	Tilia americana
bigtooth aspen	Populus grandidentata
eastern hemlock	Tsuga canadensis
elm spp.	Ulmus spp.
hawthorn	Crataegus spp.
mountain ash	Sorbus americana
oak	Quercus spp.
paper birch	Betula papyrifera
red maple	Acer rubrum
red oak	Quercus rubra
red pine	Pinus resinosa
sassafras	Sassafras albidum
serviceberry	Amelanchier arborea
sugar maple	Acer saccharum
trembling aspen	Populus tremuloides
tulip poplar	Liriodendron tulipifera
white ash	Fraxinus americana
white pine	Pinus strobus
white spruce	Picea glauca
yellow birch	Betula alleghaniensis
Shrubs	
beaked hazelnut	Corylus cornuta
Canada yew	Taxus canadensis
elderberry	Sambucus spp.
hop-hornbeam	Ostrya virginiana
leatherwood	Dirca palustris
Michigan holly	Ilex verticillata
raspberry	Rubus spp.
wild raisin	Viburnum cassinoides
Forbs	
bracken fern	Pteridium aquilinum
Canada mayflower	Maianthemum canadense
fairy bells	Disporum spp.
goblin moonwort	Botrychium mormo
green spleenwort	Asplenium viride
hart's-tongue fern	Asplenium scolopendrium
Pennsylvania sedge	Carex pensylvanica Lam.
rattlesnake plantain	Goodyera pubescens
showy orchid	Galearis spectabilis (L.) Raf.
trillium	Trillium spp.
walking fern	Asplenium rhizophyllum
Animals	
Acadian flycatcher	Empidonax virescens
American marten	Martes americana
American redstart	Setophaga ruticilla

Common Name	Scientific Name
bald eagle	Haliaeetus leucocephalus
barred owl	Strix varia
beaver	Castor canadensis
black bear	Ursus americanus
black-backed woodpecker	Picoides arcticus
Blackburnian warblers	Setophaga fusca
black-capped chickadee	Poecile atricapillus
black-throated blue warbler	Setophaga caerulescens
black-throated green warbler	Setophaga virens
bobcat	Lynx rufus
boreal chickadees	Poecile hudsonicus
brown creeper	Certhia americana
brown thrasher	Toxostoma rufum
cerulean warbler	Setophaga cerulea
common grackle	Quiscalus quiscula
common raccoon	Procyon lotor
common redpolls	Carduelis flammea
Cooper's hawk	Accipiter cooperii
dark eyed juncos	Junco hyemalis
delicate vertigo	Vertigo bollesiana
eastern chipmunks	Tamias (Tamias) striatus
Eastern cottontail rabbit	Sylvilagus floridanus
Eastern gray squirrel	Sciurus carolinensis
Eastern wood pewee	Contopus virens
fisher	Martes pennanti
flying squirrel	Glaucomys spp.
fox sparrow	Passerella iliaca
golden-crowned kinglets	Regulus satrapa
hare	Lepus spp.
house wren	Troglodytes aedon
moose	Alces alces
northern goshawk	Accipiter gentilis
northern oriole	Icterus galbula
ovenbird	Seiurus aurocapilla
pileated woodpecker	Dryocopus pileatus
pileated woodpecker	Dryocopus pileatus
pine grosbeak	Pinicola enucleator
pine siskin	Carduelis pinus
pine warbler	Setophaga pinus
porcupine	Erethizon dorsatum
red- & white-winged crossbills	Loxia spp.
red fox	Vulpes vulpes
red squirrel	Tamiasciurus hudsonicus
red-backed vole	Myodes spp.
red-breasted nuthatch	Sitta canadensis

Common Name	Scientific Name
red-eyed vireo	Vireo olivaceus
red-shouldered hawk	Buteo lineatus
ruby-crowned kinglets	Regulus calendula
ruby-throated hummingbird	Archilochus colubris
ruffed grouse	Bonasa umbellus
saw-whet owl	Aegolius acadicus
scarlet tanager	Piranga olivacea
sharp-shinned hawk	Accipiter striatus
sharp-tailed grouse	Tympanuchus phasianellus
smooth green snake	Opheodrys vernalis
snowshoe hare	Lepus americanus
Swainson's thrush	Catharus ustulatus
turkey	Meleagris gallopavo
veery	Catharus fuscescens
white-breasted nuthatch	Sitta carolinensis
white-footed mouse	Peromyscus leucopus
whitetailed deer	Odocoileus virginianus
wood duck	Aix sponsa
wood thrush	Hylocichla mustelina
yellow-bellied sapsucker	Sphyrapicus varius
yellow-rumped warbler	Setophaga coronata
Insects	
asian longhorned beetle	Anoplophora glabripennis
beech bark scale	Cryptococcus fagisuga
bronze birch borer	Agrilus anxius
bronze poplar borer	Agrilus liragus
Bruce spanworm	Operophtera bruceata
bud miners	Proteoteras moffatiana
bud miners	Obrussa ochrefasciella
emerald ash borer	Agrilus planipennis Fairmaire
fall cankerworm	Alsophila pometaria
forest tent caterpillar	Malacasoma disstria
gypsy moth	Lymantria dispar
hemlock wooley adelgid	Adelges tsugae
linden looper	Erannis tiliaria
northern pine weevil	Pissodes approximatus Hopkins
Rapids clubtail	Gomphus quadricolor Walsh
sugar maple borer	Glycobius speciosus
Fungi	
Armillaria or shoestring fungus	Armillaria mellea
Black knot	Apiosporina morbosa
Diaporthe canker	Diaporthe alleg.

Common Name	Scientific Name
Dothiorella canker	Dothiorella q.
Eutepella canker	Eutypella parasitica
Nectria canker	Nectria galligena
oak wilt	Ceratocystis fagacearum
sapstreak disease	Ceratocystis coerulenscen
Strumella canker	Strumella spp.
White pine blister rust	Cronartium ribicola

2. Aspen

Preface and Acknowledgements

This document provides guidance for the management of aspen stands in Michigan. General information on the ecological characteristics of the common tree species, wildlife and biodiversity values, and an overview of forest health concerns common to aspen stands are presented in the Aspen Silvics section. Guidance for management of aspen on Michigan Department of Natural Resources (DNR) administered state forest land is presented in the Aspen Management Guidance section. Both sections are intended to be used together.

The guidance was written over an 8-year period, by a core team of DNR Forest Resources Division and Wildlife Division staff, including Jim Ferris, Don Kuhr, Mike Koss, Bob Heyd, and Scott Throop. The guidance was edited by David Neumann, Debbie Begalle, David Price, and Georgia Peterson.

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Aspen Silvics Guidance

Introduction

The name “aspen” or “popple” is a general term commonly used for two distinct species – trembling aspen (*Populus tremuloides*) and bigtooth aspen (*P. grandidentata*). Balsam poplar (*P. balsamifera*), often called “BAM” or “balm of gilead”, is a related aspen species that is generally restricted to lowland sites, where it can dominate stands. Guidance for balsam poplar **dominated** stands will be discussed in the lowland hardwood and lowland conifer guidance. Balsam poplar is referenced here as an associated species because it occurs as a minor component in some trembling and bigtooth aspen dominated stands.

This discussion of aspen silvics is intended as one of several aids for the practice of aspen silviculture. The discussion that follows is organized under the following general headings:

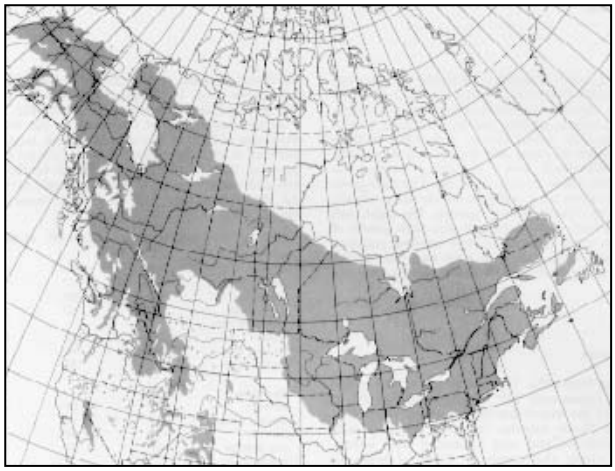
- Range and Composition of the Aspen Cover Type
- Historical Influences
- Common Stand Conditions
- Site and Successional Characteristics
- Reproductive Characteristics
- Damage/Mortality Agents
- Wildlife Habitat Attributes

Range and Composition of the Aspen Cover Type

Aspen are distributed across North America from the Canadian Maritime Provinces to Alaska (Figure 2.1). Aspen stands comprise about 2.6 million acres or 13% of total Michigan forest land (FIA, 2009). About 1/3 of Michigan aspen (860,000 acres) occurs on state forest lands administered by the Department of Natural Resources (DNR) (Unpublished DNR inventory data, 2011).

Trembling aspen is found throughout the state and reportedly hybridizes with bigtooth aspen. Bigtooth aspen is common throughout the Lower Peninsula (LP), but most abundant in the northern Lower Peninsula (NLP). It is found occasionally in the Upper Peninsula (UP) (Barnes & Wagner 1981). Balsam poplar is found more frequently in the NLP and UP, but is rare in the southern Lower Peninsula (SLP).

Native range of trembling aspen



Native range of bigtooth aspen

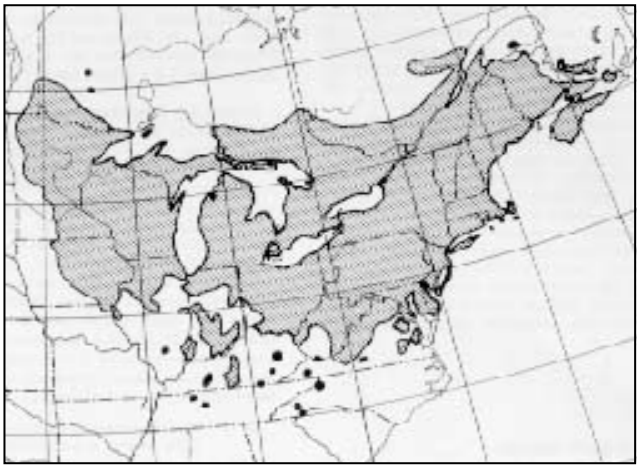


Figure 2.1 Native Range of Trembling & Bigtooth Aspen in N. America (Burns & Honkala 1990)

Aspen is a short-lived, shade-intolerant, early successional or “pioneer” species that quickly reproduces and dominates sites following severe disturbances such as wildfire or logging. Often it dominates sites and forms nearly pure stands, but it is also often an associate or minor species in other cover types. Aspen stands are a component of several natural communities: primarily mesic northern forest, dry-mesic northern forest, and dry northern forest.

Because it is shade-intolerant and relatively short-lived, aspen-dominated stands gradually convert to shade-tolerant species over a 50 to 100 year period, in the absence of severe disturbance. Common overstory associates vary by moisture regime and also by region (Tables 2.1 & 2.2) and include red maple, balsam fir, white pine, and white spruce. Associated herbaceous plants include bracken fern, raspberry, large-leaved aster, yellow beadlilly, and wild strawberry. There is often a well developed shrub layer including beaked hazel and dogwood.

Historical Influences

Aspen acreage increased dramatically across the Lake States after the wildfires at the end of the pine and hardwood logging eras of the late 1800’s through the 1940’s. As post-fire aspen forests matured, perception of aspen changed from little more than a weed species in the 1950’s and 1960’s to that of a preferred fiber source by the 1970’s. Harvests increased as paper and board manufacturing industries began to utilize aspen. Increased harvest activity in turn led to the regeneration of many acres of young aspen across the region.

Common Stand Conditions

All stages of development are represented in Michigan, from sucker and sapling size to sawtimber size. Seedling/sapling- and pole-sized stands are most common, especially on state forest lands. On state forest land, seedling/sapling-size stands are most abundant by acreage (45%), followed by pole–size stands (29%) (Figure 2.2). A similar pattern exists for other ownerships with seedling/sapling stands (32%), pole-size stands (57%), and sawlog size stands (11%) (FIA 2009).

The majority (~80%) of state forest aspen is less than 40 years old and is skewed to younger stands (<40 years), with a small proportion of total acreage in the older age classes (60+ years) (Figure 2.2.3). By contrast, federal and private lands appear to have a greater proportion of their aspen acreage in older age classes, with stands <40 years of age comprising 40% of federal and 48% of private aspen acreage (Figure 2.4).

Regional differences are also apparent on state forest lands. In the western Upper Peninsula (WUP), the 10 to 39 year age classes are over represented, the 0 to 9 age class approaches, and all other age classes are below, a hypothetical even distribution level for the region (Figure 2.5). In the eastern Upper Peninsula (EUP), the 10 to 29 year age classes are over represented, while the 1 to 9 and 30 to 39 age classes approach the regional reference level. In the NLP, there is a surplus of acres across the 10 to 49 year age classes, and all other classes are under represented.

Most aspen stands are even-aged. Two-aged and multi-aged aspen stands occur as a result of partial harvests where high quality stems were cut, leaving the rest. This practice is locally common where markets exist for high quality aspen for bolts or pulpwood. Two-aged and multi-aged aspen stands also occur as a result of succession to more tolerant species. On state forest lands, multi-aged stands represent about 1% of total aspen acreage (11,000 acres).

Table 2.1 Typical Wet- to Mesic Sites Described by Nutrient Regime, Habitat Type, Associated Late Successional Overstory Species, & Aspen Growth Potential. (Burger & Kotar 2003)

	Moisture Regime	Nutrient Regime	Region	Habitat Type	Late Successional Overstory Species[1]	Aspen Growth Potential	Aspen Site Index[4]
Wet Sites	Wet	un-classified	ALL	un-classified	lowland hardwood and conifer species	fair to poor	variable
Wet Sites	wet-mesic to mesic	medium	WUP	**TMC**	sugar maple, red maple, balsam fir, hemlock	good-fair[2]	45-60[5]
Wet Sites	wet-mesic to mesic	poor	NLP	**PArVCo**	red maple, white pine, aspen, red oak	very good	55-75
Dry Sites	mesic	rich-very rich	WUP	*AOCa*	sugar maple, basswood, white ash	very good[3]	75-85
Dry Sites	mesic	rich-very rich	NLP	*AFOCa*	sugar maple, basswood, white ash	very good	75-85
Dry Sites	mesic	medium-rich	WUP	*ATD*, **ATD-Hp**[3]	sugar maple, basswood, red maple	very good	70-80
Dry Sites	mesic	medium-rich	WUP	*ATD-Ca*	sugar maple, basswood, white ash, yellow birch	very good	70-80
Dry Sites	mesic	medium-rich	EUP	*AFOAs*	sugar maple, beech	very good	70-80
Dry Sites	mesic	medium-rich	NLP	*AFO*	sugar maple, basswood, beech, white ash	very good	70-80
Dry Sites	mesic	medium	WUP	**ATM,** *ATM-O, ATM-Sm*	sugar maple, red maple, basswood, yellow birch, paper birch, aspen	very good	65-80
Dry Sites	mesic	medium	WUP	*ATFAs*	sugar maple, beech, hemlock, yellow birch	very good	65-80
Dry Sites	mesic	medium	EUP	(AFPo)[4]	sugar maple, beech, red maple	very good	70-80
Dry Sites	mesic	poor-medium	WUP	*AARLy*	sugar maple, red maple, yellow birch, red oak	good	65-80
Dry Sites	mesic	poor-medium	EUP	*ATFD*	red maple, sugar maple, beech, hemlock	very good	70-80

Bold = aspen is commonly found as a significant component, or can dominate stands.
Italics = primarily a component in stands dominated by more tolerant species.
(Parenthesis) = Infrequent or minor associate and/or isolated occurrence in a community.

[1]Typical late successional dominant overstory species composition. Species are listed in decreasing order of abundance (left to right).
[2]On TMC, growth potential is good to fair due to drainage problems; these sites often have greater representation of balsam poplar also.
[3]Aspen grows very well on AOCa, but often a northern hardwood management objective is preferred on these sites due to competition from hardwood species, timber value of other hardwoods, and scarcity of high productivity hardwood sites.
[4]Estimated site index base 50 years, adapted from Coffman et. al. 1980, unless otherwise noted.
[5]Estimate derived from use of Perala's (1977) crosswalk for quaking aspen to red pine, basswood, and paper birch, and values for these species in Coffman et. al. (1980).

Table 2.2 Typical Dry- Mesic to Dry Sites Described by Nutrient Regime, Habitat Type, Associated Late Successional Overstory Species, and Aspen Growth Potential. (Burger & Kotar 2003)

	Moisture Regime	Nutrient Regime	Region	Habitat Type	Late Successional Overstory Species[1]	Aspen Growth Potential	Aspen Site Index[2]
Wet Sites	dry-mesic	medium	WUP	**AVVb, AVb**	red maple, sugar maple red oak, aspen, birch	very good	70-80
		poor	WUP	**AArAst**	red maple, sugar maple, red oak, aspen	good	65-80
	dry-mesic to dry	medium-poor	WUP	**PArVAa[w]**	white pine, red pine, aspen, red oak, red maple	good	65-80
			NLP	**PArVVb**	red oak, red maple, bigtooth aspen	very good	65-75
		poor	WUP	*PArVAa*	red pine, red maple, white pine	good	65-80
			EUP	*PArVAa*	red pine, red maple, white pine	very good	65-80
	Dry	poor	WUP	**PArV[w]**	pine (jack, red, white) and aspen	fair	55-75
				PArV-Co	pine (jack, red, white), red maple, and paper birch	fair	60-70
Dry Sites	dry to very dry	poor	NLP	**PArVHa**	red oak singly or mixed with white oak, black oak, bigtooth aspen, red maple, white pine	fair-good	50-65
		poor-very poor	WUP	(PArV)	red & white pine	fair	50-65
				(PQE)	jack pine	poor	50-65
			EUP	**PArV, PArV-Ao**	red and white pine with red maple on PArV, plus jack pine on PARV-Ao	fair-good	50-65
	very dry	poor-very poor	EUP	(PVE)	jack and red pine stands	poor	40-60[3]
		very poor	WUP	(PVDc), (PVCx)	jack and red pine stands	poor	40-60[3]
			NLP	(PVCd)	jack pine	poor	≤40[3]

Bold = aspen is commonly found as a significant overstory component, or can dominate stands.
Italics = primarily a component in stands dominated by more tolerant species.
(Parenthesis) = Infrequent or minor associate and/or isolated occurrence in a community.

[1]Typical late successional dominant overstory species composition. Species are listed in decreasing order of abundance (left to right).
[2]Estimated site index base 50 years, adapted from Coffman et. al. 1980, unless otherwise noted.
[3]Estimate derived from use of Perala's (1977) crosswalk for quaking aspen to red pine, basswood, and paper birch, and values for these species in Coffman et. al. (1980).

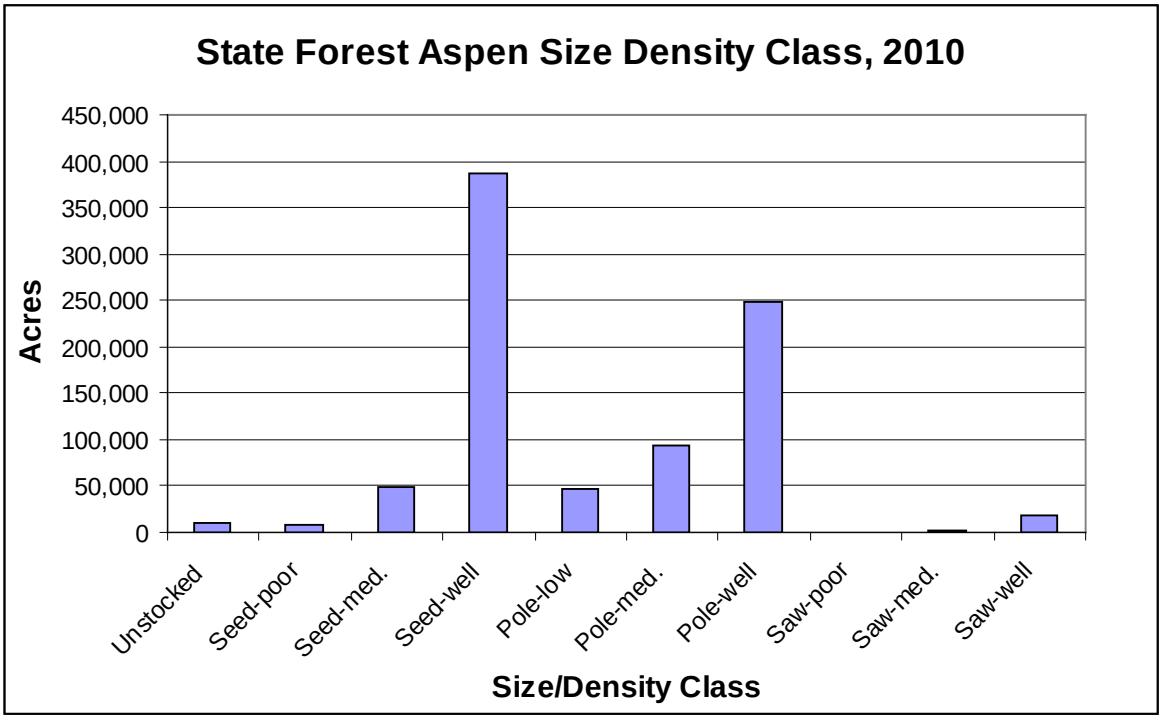


Figure 2.2 State Forest Aspen Acreage by Size-Density Class (Unpublished DNR Inventory Data 10-2010)

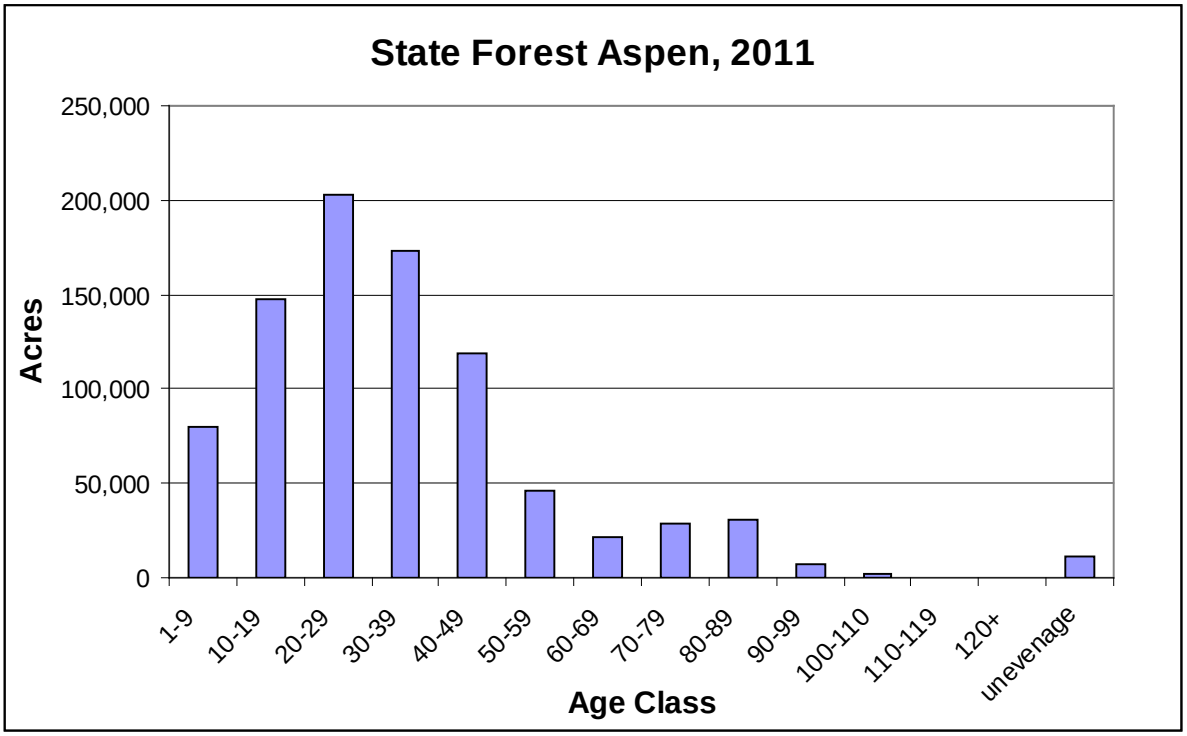


Figure 2.3 State Forest Aspen Acres by Age Class (Unpublished DNR Inventory Data 01/28/2011)

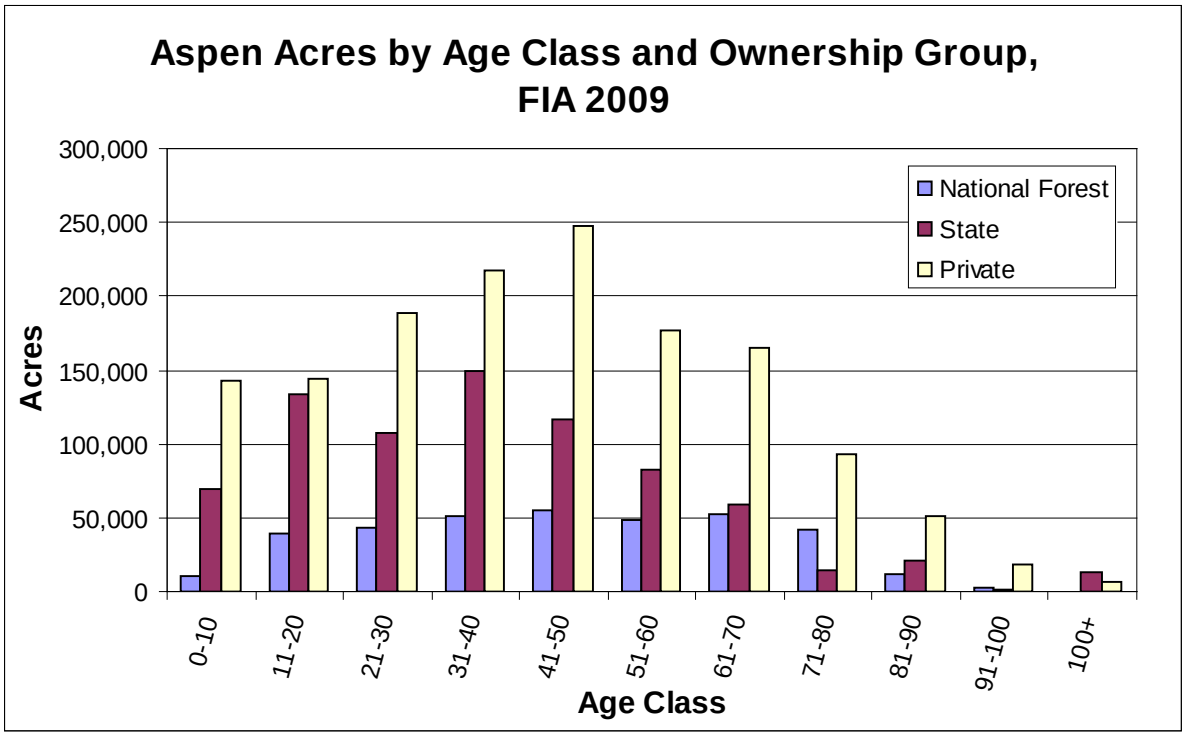


Figure 2.4 Michigan Aspen Acreage by Age Class & Ownership Group (2009 FIA Data)

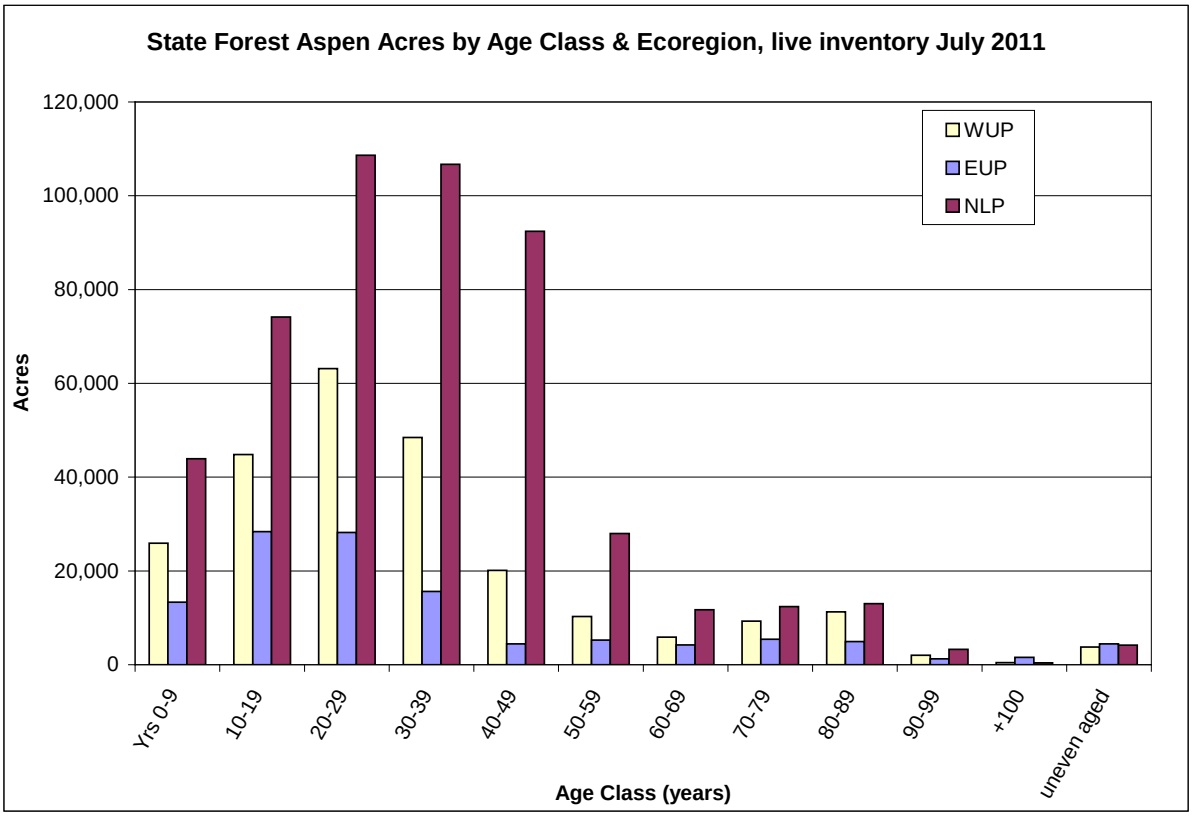


Figure 2.5 State Forest Aspen Acres by Age Class & Ecoregion (Unpublished DNR Inventory Data 07/2011)

Aspen is typically found in three age-related physiological conditions common in any of the species associations or landscape positions where it occurs. These conditions are immature, mature, and over-mature:

A. Immature Stand Condition (1 to 30 years).
   - Well stocked immature stands are characterized by a dense thicket of suckers or saplings arising from roots after a complete overstory removal, typically by clearcutting.
   - Stem densities may range from >35,000 per acre in young stands to <1,000 per acre at age 30.
   - Net growth rates are very high in immature stands, even though mortality is high, as the dense sucker stands self-thin.
   - The number and density of other tree and shrub species found in fully stocked immature stands is relatively low as compared to more mature stands.
   - Immature stands tend to have a more or less homogenous canopy, with little vertical structure development.

B. Mature Stand Condition (31 to 70 years).
   - Mature stands are characterized with many fewer stems per acre – less than 200 at age 70 and site index of 80 (Perala 1977).
   - Growth slows as trees mature, with net growth eventually becoming zero (Pothier et. al. 2004).
   - Trees in these stands are larger in both height and diameter, and mature stands tend to have a greater diversity and abundance of associated tree and shrub species.
   - These factors contribute to a more diverse vertical structure in mature stands as compared to immature stands.

C. Over-mature (greater than 70 years).
   - Over-mature stands are characterized by large aspen trees in the main canopy, usually with a well developed subcanopy comprised of more shade-tolerant species.
   - Depending on the site and seed sources, the subcanopy may contain red maple, sugar maple, American beech, white spruce, balsam fir, white pine or hemlock.
   - Beaked hazelnut, blueberry, American fly honeysuckle, and bush honeysuckle are common understory shrubs (Burger and Kotar 2003).
   - Aspen mortality increases over time in over-mature stands, creating snags and adding large woody debris to the forest floor.

Site and Successional Characteristics

Aspen stands occur on a wide range of landforms, soil types, moisture and nutrient conditions (Tables 2.1, 2.2, and 2.3). Both species can be found across the full range of site conditions, with:

- Trembling aspen occurring predominantly on dry-mesic to wet sites;
- Bigtooth aspen occurring predominantly on very dry to dry-mesic sites;
- Bigtooth aspen also occurring as a minor component in northern hardwood stands on very rich sites, where it achieves large diameters and high wood quality;
- Both species usually occurring as minor canopy components or infrequently as pure patches on both nutrient-poor/dry sites, and nutrient rich/mesic sites; and
- Aspen more frequently occurring as a major or dominant canopy component on dry-mesic to dry sites.

Aspen tolerates a wide range of moisture and nutrient conditions, but is most often found on dry and nutrient poor sites. Growth potential is fair to good for all sites, except the following:

- Dry, excessively drained sands;
- Poorly drained wet sites; and
- Heavy clay soils.

Stands generally reach their best growth and development on upland dry-mesic and mesic sites, with soils that are usually well drained, loamy, and high in organic matter and nutrients. On mesic, nutrient-rich sites, aspen has high to very high growth potential, and individual stems may reach greater ages on such sites. However, it usually occurs as a minor component due to competition from shade tolerant species. Trembling aspen also occurs on lowland sites with poor drainage (occasionally in pure stands), but more commonly as in association with white birch, balsam poplar, balsam fir and other species. On these sites, its growth potential is often fair to poor.

As an early successional community, aspen quickly dominates sites. As stems age and die, they are often replaced by more shade tolerant species, such as red or sugar maple, oaks, and conifers. Without severe disturbance such as clearcutting or storm damage, stands convert to more shade tolerant species. Aspen species have short life spans, typically ranging from 50 to 100 years in the Lake States, depending on site conditions (Table 2.3).

Reproductive Characteristics

Reproductive characteristics of the major species common in aspen stands are summarized in Table 2.4. Most aspen regeneration occurs vegetatively, from sprouts on clonal root systems. Aspen sprouts prolifically following severe disturbance such as timber harvest, extensive storm damage, or wildfire that removes most or all of the mature aspen stems. Sprout densities typically range from 10,000 to 25,000 stems per acre within the first few years following clearcutting in the Great Lakes region.

Sprouting is influenced by soil temperature, and may also be suppressed by hormones produced by mature stems in clonal root systems. Season of harvest also influences sprout density, with winter harvesting generally producing higher sprout densities than summer logging. Soil compaction and rutting can also reduce sprout densities.

Aspen clones can vary in size from 1/10 to 1/5 acre, up to 4 acres (Perala 1977). Variation in stem characteristics (height, growth rate) is more significant between clones than among stems within a clone. Clones can be encouraged to expand by clear cutting or removing all competing vegetation within one tree length of the clone’s edge.

Table 2.3 Site & Succession Characteristics of Aspen Association Species. (WDNR Silvicultural Handbook)

Species	Moisture Affinity	Nutrient Affinity	Lifespan	Successional Status (e.g., early, mid-, late)
Bigtooth aspen	Wet to dry; grows best on dry mesic to mesic sites	Medium to very rich	40-70 years	Early successional
Trembling aspen	Wet to dry; grows best on dry mesic to mesic sites	Medium to very rich	55-60 years	Early successional
Balsam poplar	Mesic to wet mesic, but will occur on drier sites	Medium to very rich	up to 100 years	Early successional
Paper birch	Dry to wet, but grows best on mesic	Medium to very rich	100-150 years	Early successional
White spruce	Dry to Mesic	Poor to very rich	100+	Early to mid-successional; increases in importance as aspen stands age. Shade tolerant, but sensitive to competition as a seedling. Will survive 40-50 years of suppression and still respond to release.
Red maple	Bimodal: very dry to mesic; also wet sites	Poor to medium	80-150 years	Early successional on rich mesic sites. Late successional on oak-pine sites.
Balsam fir	Mesic	Medium to very rich	50 to 200 years[2]	Early to mid-successional. Shade tolerant as a seedling/sapling, but needs full light for best growth.

Reproduction from seed is infrequent compared to that from root sprouts and can rarely be counted on for most managed stands. Reproduction from seed often requires extensive soil preparation, severe natural disturbances, or intense fire. Bare mineral soil forms the best seedbed. Good seed crops are produced on a frequency of every 2 to 5 years. Bigtooth aspen produces good crops more frequently than trembling aspen, although some seed is produced almost every year, starting as early as ages 2 to 5. Best seed crops are produced from 50 to 70 year old trees. Aspen seeds ripen from May to June, and are wind-dispersed over long distances (miles) over a 3 to 5 week period. Seeds germinate within 1 to 2 days of dispersal on moist seed beds. Seedlings are very sensitive to drought, heat and competing vegetation during this period, and consequently few survive.

Both root sprouts and seed-origin stems are very sensitive to light for early growth. Early aspen growth is rapid up to 20 years of age, and then declines with increasing age.

Table 2.4 Reproductive Characteristics of Aspen Association Species. (Silvics of North America)

Species	Large Seed Crops	Seed Dispersal		Seed Viability	Seedbed & Light Requirements	Sprouting Ability	Shade Tolerance	Response to Release & Established Seedling/Sapling Growth
		Season	Distance					
Bigtooth aspen	2-3 years, starting at 10 years	April to May	Miles	Short (2-3 weeks)	Moist bare mineral soil is essential, open conditions. Seedlings are uncommon, due to sensitivity to drought, heat, competition etc.	Suckers vigorously up to 100 feet from parent. Ability declines in old trees.	Very intolerant	Responds well to release, if done early enough. Does not survive in a suppressed state, requires full or nearly full light. Large openings required.
Trembling aspen	4-5 years, starting at 10-20 years, peak at 50-70 years	May-June	Miles	Short (2-4 weeks)	Bare mineral soil required and open conditions. Few seedlings survive.	Excellent, from roots.	Intolerant	Responds well to release, if done early enough. Does not survive in a suppressed state, requires full or nearly full light. Large openings required.
Balsam poplar	Almost every year, starting at 8 to 10 years	May-June	By wind, several hundred feet; also disperses via rivers.	Short (4-5 weeks)	Disturbed mineral soil	Excellent from roots, but also from stump sprouts (but will not survive in mature stands), & from buried branches in flood plains.	Intolerant	Responds well to release, if done early enough. Does not survive in a suppressed state, requires full or nearly full light. Large openings required.
Paper birch	2 years	Fall or winter	3 to 6 tree lengths, long distances over snow crust.	Most germinate in the first Spring.	Disturbed mineral soil with humus. Open to partial shade.	Vigorously, from stumps, when young/small.	Intolerant	Does not survive in a suppressed state, requires full or nearly full light. Large openings required.
White spruce	2-6 years, starting at 30 years., peak 60+	Fall	Most within 330 feet, but some up to 1,000 feet.		Best on moist mineral soils, but on undisturbed sites best on rotting logs.	NA	Intolerant	
Red maple	Every 1-2 years	June	3-4 tree lengths	Most germinate soon after dispersal; some the next year.	Non-particular seedbed requirements. Partial shade to shade.	Stump sprouts vigorously, although not as vigorously as oaks. Maximum at 12" DBH.	Intermediate-Tolerant	Strong release, if not suppressed a long time. Partial shade to fully light. May do best in ¼ acre openings.
Balsam fir	2-4 years, starting at 15 yrs., peak at 30+ years	September – winter	3-4 tree lengths and longer distances over snow crust.	Most probably germinate in the first Spring.	Less particular seedbed requirements. Shade to open	No	Very Tolerant	Responds to release well, even if suppressed a long time.

Damage & Mortality Agents

Damage and mortality agents affecting the major species common to aspen stands are summarized in Table 2.5. Aspen species have many insect and disease pests that cause minor damage, but rarely widespread mortality. Climate change may become a significant threat to aspen in the future. See Appendix A for a more detailed discussion of damaging agents that affect aspen.

Two diseases, **white trunk rot** and **Hypoxylon canker**, cause significant volume reductions and mortality in aspen, and are the most serious concerns for management. These diseases can render highly susceptible clones unproductive for fiber, and managers often schedule infected stands for early rotation.

White Trunk Rot

White trunk rot fungus causes a heart rot of aspen, and is responsible for more volume loss than any other disease of aspen. Severity of the disease increases with stand age. Incidence of white trunk rot is a major consideration in determining aspen rotations. Diseased stands are susceptible to loss of trees from breakage at points of stem decay. Resistance to decay varies among aspen clones on the same site. Although no consistent relationship exists between site and decay, generally less volume is lost in vigorous stands on good sites. On the same site, resistance to decay varies among aspen clones. Stands damaged by fire or storms are more subject to decay, often requiring shorter rotations.

The most reliable external indicator of decay is the presence of conks. Decay associated with conks in the first 16 feet of the bole accounts for nearly 70% of the total volume loss. Decay volume in trees with no conks averaged less than 2%, compared to 14% in trees with conks. In studying available external signs of decay in aspen, the most reliable indicator was *P. tremulae* conks with 80% of the conks accounting for 70% of the decay volume (Jones et. al., 1998).

Hypoxylon Canker

Hypoxylon canker is one of the most important killing diseases of aspen in eastern North America. In the Lake States, the total impact of Hypoxylon canker has been estimated to be 30% of the annual net growth of aspen. Resistance to Hypoxylon varies between clones.

Thinning aspen stands increases the incidence of Hypoxylon infection. If thinning is done, only fully stocked aspen stands with very low levels of the disease should be treated, and all infected trees should be removed, as they will die within 3 to 5 years anyway.

Wildlife Habitat Attributes

Aspen is a valuable habitat component for eleven featured species of wildlife including woodcock, beaver, black bear, elk, golden-winged warbler, moose, pileated woodpeckers, ruffed grouse, snowshoe hare, white-tailed deer and turkey.

For most of these species, aspen represents a significant portion of their diets or is a preferred food. They consume leaves, twigs, bark, buds, suckers, sprouts, and catkins, depending upon the species. Ungulates such as moose, elk and white-tailed deer browse heavily on young aspen stands where stems are within reach. Snowshoe hare favor particularly young aspen where the leaves, twigs and tender bark are relatively close to the ground. On the other hand, beaver can feed on all ages of aspen. For most of these species, aspen represents a critical food source to meet important life history needs, such as pre-winter fat accumulation, winter food or post-denning food.

Aspen is the preferred vegetative structural cover for ruffed grouse, golden-winged warbler and woodcock. Ruffed grouse use aspen stands of all ages; young stands are important brood-rearing cover, while older stands are important overwintering and breeding cover. Woodcock do best in young stands with high stem densities. Mature aspen is also important for cavity development, providing needed den and nest sites. Mature trees and soft-core snags are used by pileated woodpeckers and secondary nesters, eventually falling to the ground and becoming coarse woody debris.

Table 2.5 Damage/Mortality Agents for Aspen Association Species.

Species	Impact of Deer Browse Pressure	Susceptibility to Decay and Stain Fungi	Stem Cankers	Insects	Other Damage Agents
Bigtooth aspen	High	High; white trunk rot (*Phellinus tremulae*)	Hypoxylon, (but is more resistant than trembling aspen), root rots *Armillaria* & *Ganoderma.*	Forest tent caterpillar, large aspen tortrix, gypsy moth, poplar borer.	Fire, hail, sunscald, storm breakage.
Trembling aspen	High	High; white trunk rot (*Phellinus tremulae*)	Hypoxylon, Ceratocystis, Cytospora	Forest tent caterpillar, large aspen tortrix, gypsy moth, poplar borer.	Beaver, snowshoe hare, and other rodents. Fire, frost sunscald, and drought.
Balsam poplar	Moderate	High; white trunk rot (*Phellinus tremulae*)		Poplar and willow borer, bronze poplar borer, and poplar borer.	Stem damage from browsing moose, elk, deer, rabbits, mice, beaver. Fire, frost damage
Paper birch	Moderate/high	Medium; 12% at 100 years		Bronze birch borer	
Red Maple	Moderate-high	High; cull 40% at 100 years, 50% at 150.			Few serious agents
White spruce	Low			Spruce budworm	Few serious agents
Balsam fir	Moderate	High, especially in older trees regardless of size.		Spruce budworm	Few serious agents

Aspen Management Guidance

Introduction

This section contains recommendations for management of aspen on DNR administered state forest lands. This information is intended as guidance only. Management decisions should also be informed by local experience the Regional State Forest Management Plans, and input from DNR's inventory and compartment review process.

Management Objectives

Pulpwood production is the primary timber objective for most aspen stands, although sawlog production may be appropriate on better sites (dry-mesic to wet-mesic). Aspen vigor and growth potential may be reduced, if the chosen silvicultural system for stand management is modified to meet other management objectives. These objectives often include wildlife habitat and aesthetics. A common treatment may accomplish multiple management objectives for aspen stands (Table 2.6).

Table 2.6 Alternative Silvicultural Approaches for Regeneration & Management of Lake States Aspen (Adapted from Cleland et. al. 2000)

Silvicultural Treatment	Management Objective		
	Timber	*Wildlife Habitat & Biodiversity*	*Conversion to Aspen*
Harvest	Clearcut commercially mature stands	Clearcut or variable retention of other desirable species	Clearcut existing hardwood or conifer stand
Size of harvest units	Generally large (40+ acres) or entire stand	10-160+ acres depending on habitat objectives[1]	
Rotation or cutting cycle	30-70 years[2], depending on site and clone	20-80+[2] years depending on area age class distribution	Variable depending on existing forest type
Overstory composition	Pure stands preferred	Pure or mixed species, multistoried stands depending on habitat objectives	Pure or mixed stands; subsequent clearcut harvests can increase aspen component

[1] For grouse, optimum size may be 10-20 acres according to some habitat suitability indicies. Small harvest units like these are also valuable for deer and other wildlife.
[2] Very short (<20 years) and very long (>70 years) rotations may lead to deterioration of aspen root systems.

Silvicultural Systems and Treatments

Aspen is primarily managed on an even-age basis. The early-successional, shade intolerant nature of the species dictates that it is regenerated under full sun, with minimal competition.

General Management Recommendations

- To maximize stand growth and vigor, aspen should be grown in full sunlight in a fully stocked condition. Clearcut harvests achieve the best regeneration and growth.
- Economic rotation ages for pulpwood production are in the range of 50 to 60 years (Perala 1977) with typical biological rotation lengths ranging from 40 to 70 years, depending on site characteristics (Ruark 1990, Alban et. al. 1991, Pothier et. al. 2004).
- Rotation ages for sawtimber are typically 70 to 79 years (OMNR 2000), and generally can be justified only on the highest productivity sites, and where aspen sawlogs can command a market premium over pulpwood prices. These opportunities rarely occur on state forest lands.

- If sawtimber is an objective, thinning should be considered (See the Alternative Management Strategies section).
- Reserve tree harvests increase biodiversity and improve aesthetics following harvest (See the Alternative Management Strategies section).
- On wet to wet-mesic sites, retain some mature hardwoods and conifers in regeneration harvests to help maintain a portion of the normal evapo-transpiration process and stabilize water table levels during stand regeneration. Retained trees should be well distributed. Depending on residual stand density, this type of harvest could best be characterized as a seed tree or dispersed shelterwood.

Regeneration Standards

For purposes of DNR regeneration surveys:

- Optimum stocking is 12,000 well-spaced suckers per acre the first year.
- Minimum full stocking level is considered to be 6,000 suckers per acre.
- Minimum sucker density of 2,000 stems per acre (about 5x5 foot spacing between sprouts) at age 4 is the benchmark for evaluating regeneration success or failure (see Michigan DNR Regeneration Survey Manual, IC 4145).

Other factors also appear to influence sprouting response in aspen stands, including stand age, condition, season of harvest, soil disturbance and/or root compaction during logging, and soil saturation. In one study, the effect of summer harvests produced similar levels of sprouting as low levels of overstory retention. Recommendations for minimizing the effects of retention on aspen sprouting density and growth include:

- Scheduling harvest for late summer, fall or winter to help maximize sprouting potential;
- Consider lower levels of retention in aspen stands in general (e.g., 3-5% area retention or the equivalent);
- Use aggregate retention preferentially rather than dispersed retention in aspen stands, with ~ >2 acres patch sizes on large sales (>20 acres) to minimize edge effects while conserving mature forest micro-climate within the retained patch;
- Keep residual BA below 10 ft2/acre when using dispersed retention;
- Retain some mature aspen stems among the residual due to its value for cavity and den-using species and also as a food source for grouse;
- Consider modified retention (retention of just snags, CWD, tops and patches of shrubs) or only aggregate retention for stands with low vigor due to age (>70-80 years) or overall condition, narrow stands (<200 ft. wide), and those with high water tables.

Alternative Management Strategies

- **Reserve Tree Management.** The reserve tree management method is not used frequently on state forest, but has been employed with some success. In this context, reserve tree management is not a synonym for within-stand retention for biodiversity conservation. Instead, the reserve tree management method is an alternative that may be useful for ameliorating the aesthetic impacts of harvesting, increasing other hardwood or conifer species representation in the future stand, or to help meet other reserve tree requirements.

  The reserve tree technique may be used to favor reproduction of other species while maintaining an aspen component (e.g., to favor regeneration of birch components in stands that are predominantly aspen). To implement this technique, mark to retain 7 to 15 dominant or co-dominant aspen per acre at a uniform spacing of 50 to 66 feet in the regeneration area. The retained mature aspen will hormonally suppress, but not eliminate, root sprouts in the surrounding harvest area, and in theory reduce competition with other tree species reproducing from seed. Other species such as oak, hemlock, and pine may also be left, but the total basal area of all reserve trees should not exceed 25 ft^2/acre. The resulting stand will be a mix of aspen and other hardwood or conifer species. The aspen reserve trees should be retained until the regenerated stand reaches maturity. While this method may result in a modest reduction of aspen sucker density, growth and volume of aspen stands at maturity are not

seriously impacted (Ruark 1990, Stone et. al. 2001). Low levels of aspen retention (~10 ft^2/acre BA or ~10% canopy coverage) do appear to produce reductions in total sprout density relative to clearcut stands. However, in most studies, the resulting regeneration still met minimum regeneration thresholds for aspen stands. Higher levels of retention appear to reduce sprouting below acceptable levels for producing fully stocked aspen stands. Sprouting response also varies significantly with site quality; e.g., lower sprout densities result on low quality sites.

- **Conversion to Aspen**. This technique requires either an adequate aspen component in the overstory or a suitable seedbed with an adjacent seed source. However, natural regeneration from seedfall is infrequent and should not be relied on.

  On well-drained sites, coppice regeneration with as few as 50 trembling aspen per acre will normally create a fully stocked stand of suckers (Perala 1977). Minimum basal area equivalents of ~20 ft^2/acre produce minimum stocking in trembling aspen stands. However, greater stem density is needed to produce minimally stocked bigtooth aspen (OMNR 2000).

  To establish aspen regeneration from seed, a continuously moist mineral soil seedbed is essential. Successful seeding has occurred on a seedbed scorched with a hot fire, or scraped bare with a dozer blade so that the seedbed has mineral soil fully exposed to the sun and soil conditions are firm. Firm soil (not compacted) increases the moisture retention needed for seed germination.

Management Considerations

This section is organized as a series of queries and responses. Note that there is some overlap between the sections due to their inter-relatedness.

1) *How can habitat type be used to inform management decisions?*
2) *Why should I convert aspen on poor quality sites to other species?*
3) *Should I convert aspen stands on high quality sites to other species?*
4) *Should I manage for a mixed-species stand?*
5) *How do forest health considerations influence management?*
6) *How do I determine rotation age?*
7) *How do I enhance wood quality?*
8) *How do I favor/discourage specific clones?*
9) *How do I expand existing aspen clones, or discourage aspen components in stands to be managed as other cover types?*
10) *How do I enhance wildlife habitat and biodiversity?*
11) *How do nutrient management and soil compaction considerations influence management?*
12) *How do climate change considerations influence management?*

1) How can habitat type be used to inform management decisions?

In Michigan, aspen stands are found on almost all habitat types, but the associated species and growth potential vary (Tables 2.1 and 2.2). Habitat type is increasingly used, in addition to site index, soils information, and other measures of site potential to inform stand management choices. Habitat type can indicate the relative growth potential for aspen and associated species. A crosswalk of habitat type class to an estimated site index range is included in Tables 2.1 and 2.2. A site index curve for aspen is included in Appendix B.

Managers can use habitat type to help make stand management decisions on a site specific basis. Habitat type can be used to help identify options for management, including:

- Converting to other forest types;
- Diversifying stand structure and composition using group selection or shelterwood techniques;
- Maintaining even-aged stand structure via clearcutting or seed tree harvests; and

- Restoring species that are not currently present, but historically were important on the site (e.g., white pine and red pine).

In general, more mesic, nutrient rich habitat types support the best growth for aspen. On higher quality sites, however, shade tolerant and intermediate shade tolerant species have a competitive advantage over shade intolerant species. On the poorest habitat types, other intolerant species often perform better than aspen (jack pine, red pine, white pine, pin oak, etc.)

Specific recommendations by habitat type include:

- Very dry sites (PVDc, PVCx, PQE, PArV, PVE, PVCd):
    - Growth potential for aspen is fair to poor. Consider promoting jack pine, red pine, or pin oak on these sites.
- Nutrient-rich mesic sites (e.g., AFO, AFOCa, ATFD, AFOAs, AOCa):
    - Growth potential for shade tolerant northern hardwood species is good to very good and aspen can only be maintained by intensive management. Consider conversion to northern hardwoods on these sites.

2) Should I convert aspen stands on poor quality sites to other species?

Aspen growth rate, form, and product quality tend to be poor when grown on the lowest productivity sites (PVE, PVDc, PVCx, and PVCd). Aspen also tends to be more susceptible to disease such as Hypoxylon canker on these sites. Due to slower growth rates, it often takes 60 to 70 years for aspen on low productivity sites to reach merchantable sizes (generally only as pulpwood).

Managers should consider the opportunity to manage for species better suited to the site, such as jack pine and red pine. An alternative for continuing to manage for pure (albeit low quality) aspen stands on these sites is to encourage the development of mixed pine/aspen stands.

3) ***Should I convert aspen stands on high quality sites to other species?***

Current stand species composition, management objectives, and site quality may favor conversion of an even-aged aspen-dominated stand to shade tolerant hardwood or conifer species (specifically, on any of the “A” series habitat types). In some cases, ecological concerns may support conversion to other species such as northern hardwood. In other cases, a well-developed hardwood understory may be present that has higher fiber or wildlife habitat value, such as sugar maple or oak.

Bigtooth aspen grows well on some of these high productivity sites, and an argument can be made for maintaining it in some areas, particularly where the understory is predominately red maple, beech, or other species with low timber product values.

Use the decision key in Figure 2.6 to help decide whether to maintain aspen or convert to other species mixes.

To help identify which management options are appropriate, managers can evaluate each stand in light of habitat type information by answering the following questions:

1) What is the quality and vigor of current overstory, as a whole, and by species:
   - Will the stand regenerate to aspen if clearcut now?, or
   - Will aspen be a minor component of the future stand due to current vigor/density of the remaining aspen overstory?
2) If conversion is a possibility:
   - Is advanced regeneration density, height and species composition sufficient to produce the desired future stand?, or
   - Is there sufficient density of good quality dominant and co-dominant trees of appropriate species and vigor to serve as shelterwood seed trees?
3) What species are not currently present that the site could support (as predicted by habitat type)? For example, a poorer site currently dominated by low quality aspen can be converted to mixed pine-oak using a clearcut combined with artificial regeneration, if a seed source is not currently on site.
4) What are the current regeneration tendencies of the site?
5) Is there potential for maintaining aspen by clearcutting, based on its current presence in the overstory (see the section on conversion)? This could be a good option on some hardwood sites that contain some vigorous bigtooth aspen.

Figure 2.1 Decision Key for Aspen Maintenance Vs. Conversion (Adapted from Stone et. al. 1997)

4) Should I manage for a mixed-species stand?

In some situations, management for a mixed aspen-hardwood or aspen-conifer stand may be appropriate. As a practical matter, it may be possible to maintain or expand the aspen component in mixed deciduous and mixed conifer stands with 20 to 40% aspen canopy coverage by clearcutting. The aspen will regenerate from root sprouts, and should compete well with stump sprouts from red maple and other hardwood species, and regeneration of other hardwood or conifer species from seed. The resulting mixed-species stands could be managed on a 40 to 70 year rotation to maintain the aspen component, or eventually converted to another cover type through gradual thinning or merely allowing the aspen to senesce over time.

Management for mixed species stands containing a significant aspen component may be appropriate on the medium to higher quality sites. However, aspen in mixed species stands on the lowest quality sites arguably should be allowed to naturally senesce. See the discussion in **2)** above.

5) ***How do forest health considerations influence management?***

The most significant agents of aspen mortality and decay are white trunk rot and Hypoxylon canker. See the Aspen Silvics section discussion on Damage & Mortality Agents for a description of these diseases. Appendix A includes a more detailed description of other forest health problems affecting aspen. Management recommendations for white trunk rot and Hypoxylon canker are listed below:

White Trunk Rot of Aspen

White trunk rot of aspen (*Phellinus tremulae)* causes a heart rot of aspen responsible for more wood volume loss than any other disease of aspen.

Management Strategies (Schipper and Anderson 1978, and Jones and Ostry 1998):

a. Harvest aspen stands before decay becomes advanced. This usually means a maximum rotation of 50 to 60 years.
b. Look for conks. Trees with conks have a longer decay column and more decay than trees with open wounds or frost cracks.
c. Stands and trees damaged by fire, wind, and/or ice are especially susceptible to this fungus. Harvest damaged stands early.
d. Conduct regeneration harvests in overmature, defective aspen stands to bring these sites back to full production.
e. Manage aspen to get uniform, well- stocked stands in which natural pruning will reduce the number and size of potential infection sites.

Hypoxylon Canker

Hypoxylon canker (*Hypoxylon mammatum*) is one of the most important killing diseases of aspen in eastern North America. Resistance to Hypoxylon varies between clones. Aspen stands should be monitored for symptoms of decay or decline at ages 40 to 80 years (OMNR 2000).

Management Strategies (Anderson et. al. 1979):

a. If 15 to 25% of the aspen in a stand are infected, the stand should be harvested early, preferably in the dormant season, to encourage vigorous aspen reproduction.
b. If greater than 25% of the trees are infected, the stand should be harvested when merchantable, and the site converted to another species.
c. Lightly infected stands can be managed on rotations longer than 40 years.
d. Exercise caution if thinning is to be done in aspen to minimize the risk of infection resulting from damage to residual stems.
e. Manage to encourage resistant clones and discourage susceptible clones through selection harvest practices, wildlife opening creation or other means.
f. Allow either conversion to other species and/or encroachment by neighboring resistant clones by leaving susceptible clones in an aspen stand to breakup due to old age.
g. Another option is to create openings by treating susceptible clones with herbicide after harvesting, and planted with grasses or other tree species.

6) How do I determine rotation age?

The DNR typically uses a 50 to 60 year rotation age for aspen, but in some areas will manage up to a 70 year rotation. Bigtooth aspen can often be managed on a longer rotation than trembling aspen. In general, stands >80 years old are usually considered over-mature or declining (OMNR 2000). The Wisconsin DNR recommends a rotation of 45 to 60 years to maximize average annual volume growth (MAI) (WDNR 2002). Efforts to balance age classes on state forest lands may lend support to decisions to schedule some stands in the 30- and 40-year age classes for early harvest. Examiners should refer to the Regional State Forest Management Plan discussion on aspen management for each management area and consult the district timber management specialist.

7) How do I enhance wood quality?

Stem quality can be theoretically enhanced by selective removal of poorer quality clones. However, this technique has not been employed frequently on state forests. Where differences in disease susceptibility or stem form are noted between clones, it may be possible to remove the poorer quality clones' stems in a partial harvest such that enough residual overstory is retained to discourage or reduce sprouting of the inferior clones.

8) How do I favor/discourage specific clones?

Clone management is possible, but infrequently attempted, presumably due to difficulty distinguishing between clone boundaries in the field. Clones can sometimes be discerned by differences in stem quality between clones in a stand. Clone boundaries can sometimes be detected in spring due to differences in

bud break and leaf flush between adjacent clones, or by observing differences in leaf color change in the fall.

Reproduction of the most vigorous clones can be encouraged by clearcutting only the best clones, and retaining all mature stems from the less vigorous or more disease prone clone(s).

Conversely, the USDA Forest Service recommends retaining all of the stems from the best clone(s) and harvesting only the inferior clones' stems (USDA Forest Service, Aspen Web-Based Forest Management Guide; Perala 1977). This technique works best when the residual stand will remain fully stocked, through retention of stems of the desired clone(s) (and if necessary of enough stems of the undesirable clone) to maintain a fully stocked residual stand. In this way, sprouting of the inferior clone(s) is suppressed and most of the sprouts that develop die from shading. Herbicides can also be used in a cut stump application to suppress regeneration of the poorer clone(s). Multiple rotations may need to be treated in this fashion to eliminate the inferior clone(s).

9) How do I expand existing aspen clones, or discourage aspen components in stands to be managed as other cover types?

Objectives for some stands may include radial expansion of minor inclusions or patches of aspen, or in mixed hardwood or conifer stands may encourage greater dominance of aspen in the future stand. Aspen clones can be encouraged to spread up to one tree length by clearcutting an area one to two tree lengths beyond the boundary of existing stems at the end of each rotation.

Conversely, aspen's great sprouting ability is sometimes a problem when management objectives include reducing aspen dominance in a future stand. Where the goal is to discourage aspen re-growth in mixed hardwood or conifer stands, the best course of action may be to retain most of the mature aspen stems during stand entries (e.g., during selection harvests, group selection, shelterwood or seed tree harvests). Retained aspen stems will die over time, and while alive will continue to suppress sprouting in the immediate vicinity of the mature stems. Meanwhile, the declining aspen can serve as retention for wildlife habitat and biodiversity, future snags and den trees.

This strategy may not be appropriate for stands scheduled to be regenerated with red or jack pine via trenching and planting, as scattered aspen stems may inhibit trenching operations, and limit options for post-planting aerial release spraying. As an alternative, these stands could be clearcut (cut all aspen stems) and the resulting aspen regeneration suppressed via herbicide applications as part of site preparation, then trenched and planted. Sprouting density may also be somewhat suppressed by scheduling harvesting operations during late spring/early summer.

10) ***How do I enhance wildlife habitat and biodiversity?***

Aspen is an important habitat component and food source for many wildlife species. Guidance for management of aspen at the landscape scale has been included in the Regional State Forest Management Plans (RSFMP) for each Management Area (MA). Staff should consult their local biologist and review the guidance pertaining to wildlife habitat in the RSFMP MA summaries. The Within-Stand Retention Guidance (Michigan DNR 2012) provides recommendations for enhancing biodiversity and wildlife habitat at the stand level in the aspen cover type.

11) How do nutrient management and soil compaction considerations influence management?

Potential impacts on long-term productivity are a consideration when maintaining aspen through multiple regeneration and harvest cycles on the same site. Nutrient replacement following a typical harvest at full rotation age is relatively quick (less than 20 years for N, P, K, Mg and Ca), but is dependent upon site quality.

On medium-nutrient content sites, whole tree harvesting has had no significant effect on soil nutrition levels 5 years after logging (Alban and Perala 1990). Total tree harvesting of aspen on clay and loam soils had no negative effects on 5-year growth and productivity (Stone et. al. 1999). In contrast, results indicate potential

declines in aspen productivity with repeated total tree harvesting on sandy soils, where total tree harvesting was associated with reduced 5 year aspen growth and productivity. Retention of organic matter appears to be an important consideration to sustain long-term productivity of aspen stands on sandy soils. Limbing at the stump and retaining logging slash on site is recommended to decrease nutrient removal on sandy sites (Stone et. al. 1999, Stone et. al. 2001, Stone 2001).

The Woody Biomass Harvesting Guidance specifies that stands on nutrient poor sites should be prescribed for retention of >30% of the harvest residue (tops and branches <4 inches in diameter). This residue should be distributed relatively evenly across the harvest area.

Management activities that compact soil have been associated with declines in site productivity:

- Compaction treatments that increased soil bulk density by 15 and 30% had no consistent negative effects on 5 year aspen growth and productivity (Stone et. al. 1999, Stone et. al. 2001, Stone 2001). In further operational studies, excessive compaction at landings and rutting by careless logging operations significantly reduced sucker density and growth on fine textured soils.
- The physical effects of soil compaction, increased bulk density and decreased soil porosity, are long-term.
- Snow cover does not protect soils from compaction and rutting, but frozen soil conditions do. Recommendations to protect soils from excessive compaction and rutting when logging in deep snow include:
    - plowing and packing snow on skid trails and allow freezing before use, and/or
    - delaying skidding for 1 to 4 weeks following felling.
- On wet to wet-mesic soils (poorly drained and somewhat poorly drained), removing only commercial wood (retain some hardwoods and conifers) can result in less rutting and compaction. Harvesting on these sites on frozen or dry ground will minimize rutting. Rutting can impede water flow and alter existing drainage. Also, retention of a mature overstory component can help avoid significant elevation of the water table.

12) How do climate change considerations influence management?

Climate change is projected to negatively impact the aspen forest type as of this writing, however management guidance had not been developed. It will be incorporated in future revisions of this guidance.

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Appendix A. Forest Health Issues for Aspen Species

Quaking and bigtooth aspen are susceptible to damage from the agents listed below.

- Aspen are highly susceptible to fire damage. Fires may kill trees outright or cause basal scars that serve as avenues of entrance for wood-rotting fungi. Intense fires can kill or injure surface roots and thereby reduce sucker regeneration.
- Animal damage:
    - Young trees are sometimes killed by bark-eating mammals, such as meadow mice and snowshoe hares, which may girdle the stem at or near the ground line.
    - Beaver feed on the young tender bark and shoots of aspen and often cut down large numbers of trees near their colonies.
    - A high population of porcupines can greatly damage tree crowns both directly by feeding, and indirectly by increasing the trees' susceptibility to attack by insects and diseases.
    - Browse and mechanical damage from deer, elk and moose. These injuries often favor secondary attack by insects or pathogens.
- Vandalism by recreationists has caused aspen to deteriorate in many campsites.
- Stain and decay have the greatest direct impact of the many stem pathogens on wood production. Phellinus tremulae causes a white rot of the heartwood at first, but may eventually invade the entire stem. It causes the greatest volume of aspen decay and is so prevalent it conceals rot caused by other fungi. Fruiting bodies (knows as horseshoe conks) are the most reliable external indicator of decay. They provide a means to estimate present and future decay. Resistance to this fungus is strongly genetically controlled. Incidence and extent of infection increases with tree age or size, but is not strongly related to site.
- Root rots: Ganoderma applanatum and Armillaria mellea can cause extensive root decay in bigtooth aspen. Clones vary greatly in resistance to disease attack and damage.
- Stem cankers can kill a tree within a few years or persist for decades:
    - Hypoxylon canker caused by Hypoxylon mammatum is probably the most serious aspen disease east of the Rockies, killing 1 to 2 % of the aspen annually. Most canker infections seem to originate in young branches with scars or galls formed by twig-boring insects. Once infected, the host bark tissue is rapidly invaded and the fungus girdles and kills the tree in a few years.
    - Ceratocystis canker is a target-shaped canker caused by Ceratocystis spp. This canker is found throughout the range of aspen. *C. fimbriata* is the most common causal pathogen. These cankers seldom kill aspens, but can reduce usable volume of the butt log. Infection is primarily through trunk wounds and insects are the primary vectors.
    - Cytospora canker is caused by Cytospora chrysosperma, a normal inhabitant of aspen bark. The fungus is not considered a primary pathogen and causes cankers, lesions, or bark necrosis only after the host tree has been stressed, such as by drought, fire, frost, suppression, or leaf diseases. The disease is most serious on young trees and is found throughout the range of aspen.
- Insects: Quaking aspen hosts a wide variety of insects, but only a few are known to severely damage trees. They may be grouped into defoliators, borers, and sucking insects.
    - Defoliators:
        - Forest tent caterpillar *(Malacasoma disstria)* periodically defoliates large areas of aspen (> 100,000 mi²). Outbreaks usually persist for 2 to 4 years. Aspen growth losses during defoliation have been as high as 90% and may take as long as 3 or 4 years for total growth recovery. On good sites when defoliate coincides with other forest stressors such as drought and/or other defoliators, tree morality following aspen decline primarily affects suppressed trees.
        - Large aspen tortrix (Choristoneura conflictana) is found throughout the range of aspen. It has defoliated large areas of forest (10,000 mi²). Caterpillars predominantly infest the leaves of early flushing clones. Outbreaks normally collapse in 2 or 3 years and, although aspen growth is reduced, few trees are killed.
        - Aspen is a favored host for the exotic gypsy moth (Lymantria dispar), however, high population levels are generally not sustained for more than a year or two resulting in some associated growth loss, but little tree mortality on good sites.

- Wood-boring insects primarily include beetles of the Cerambycidae (round-headed borers or long-horned beetles) and Buprestidae (flatheaded borers or metallic beetles).
    - The poplar borer (Soperda calcarata) is the most damaging. The larvae tunnel in the bole, weakening and degrading the wood. Breakage by wind increases and the tunnels serve as infection courts for wood-rotting fungi
    - The root-boring saperda (Saperda calcarata) feeds on phloem and outer sapwood near the base of young aspen suckers. Oviposition incisions of the poplar gall saperda (S. inornata) frequently cause round galls to form on the stems of young suckers and on small branches of larger trees. These oviposition wounds can serve as infection sites for Hypoxylon that can then grow from a branch gall down into the bole of the tree causing a canker.
    - Two flatheaded borers, the bronze poplar borer (Agrilus liragus) and the aspen root girdler (A. horni), bore galleries that disrupt nutrient and water movement. The former attacks sucker stems and makes zig-zag galleries; the latter girdles the sucker with a spiral gallery from the lower trunk to the roots and back.

- Weather:
    - Early spring frosts may kill new leaves and shoots and, when especially severe, some of the previous year's shoots.
    - Overwinter freezing can cause frost cracks.
    - Strong winds can uproot or break mature aspen and even moderate wind can crack the bole of trees with lopsided crowns.
    - Hail can bruise the bark of young aspen and, in severe storms, kill entire sapling stands.
    - Aspen suffers little from ice storms or heavy wet snow, except when in leaf.
    - Drought-stressed trees become predisposed to secondary agents such as insects and disease. Drought also reduces tree vigor.
- Aspen suddenly exposed to full sunlight may suffer sunscald. Pole-size trees are more susceptible than saplings.

Appendix B: Site Index Curve for Aspen in Northern Wisconsin and Upper Michigan (Carmean et. al. 1989)

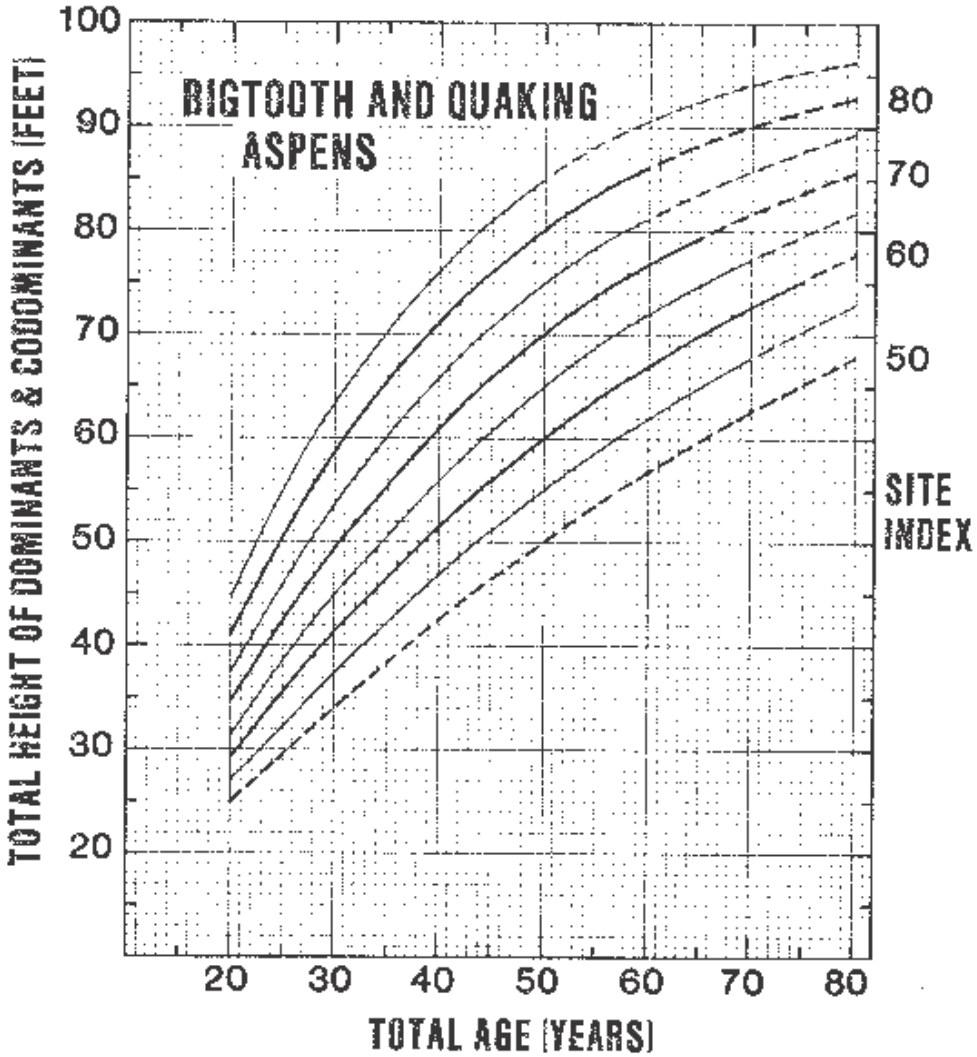

Figure 32.—Bigtooth and quaking aspens (Carmean 1978)
Northern Wisconsin and Upper Michigan
13 plots having 42 dominant and codominant trees
Stem analysis, nonlinear regression, polymorphic
Add 4 years to d.b.h. age to obtain total age (BH = 0.0)

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
HI	5.2188	0.6855	-0.0301	50.0071	-0.8595	0.99	1.58	4.5
SI	0.0612	1.4390	-0.0050	-3.9080	-0.4350	0.93	1.30	10.4

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Figure 2.6 Site Curve for Bigtooth & Quaking Aspen for Northern Wisconsin & Upper Michigan.

Appendix C: Common and Scientific Names for Species Cited

Common Name	Scientific Name
Trees	
American beech	*Fagus grandifolia*
balsam fir	*Abies balsamea*
balsam poplar, 'balm of gilead' or BAM	*Populus balsamifera*
basswood	*Tilia americana*
bigtooth aspen	*Populus grandidentata*
black oak	*Quercus velutina*
black spruce	*Picea mariana*
eastern hemlock	*Tsuga canadensis*
jack pine	*Pinus banksiana*
oak	*Quercus spp.*
paper birch	*Betula papyrifera*
red maple	*Acer rubrum*
red oak	*Quercus rubra*
red pine	*Pinus resinosa*
sugar maple	*Acer saccharum*
trembling aspen	*Populus tremuloides*
white ash	*Fraxinus americana*
white oak	*Quercus alba*
white pine	*Pinus strobus*
white spruce	*Picea glauca*
yellow birch	*Betula alleghaniensis*
Shrubs	
American fly honeysuckle	*Lonicera canadensis*
beaked hazelnut	*Corylus cornuta*
blueberry	*Vaccinium spp.*
bush honeysuckle	*Diervilla lonicera*
dogwood	*Cornus spp.*
raspberry	*Rubus spp.*
striped maple	*Acer pensylvanicum*
Forbs	
bracken fern	*Pteridium aquilinum*
large-leaved aster	*Eurybia macrophylla*
wild strawberry	*Fragaria vesca*
yellow beadlilly	*Clintonia borealis*

Common Name	Scientific Name
Animals	
beaver	*Castor canadensis*
black bear	*Ursus americanus*
elk	*Cervus canadensis*
golden-winged warber	*Vermivora chrysoptera*
moose	*Alces alces*
pileated woodpecker	*Dryocopus pileatus*
porcupine	*Erethizon dorsatum*
ruffed grouse	*Bonasa umbellus*
snowshoe hare	*Lepus americanus*
turkey	*Meleagris gallopavo*
whitetailed deer	*Odocoileus virginianus*
woodcock	*Scolopax minor*
Insects	
aspen root girdler	*Agrilus horni*
bronze poplar borer	*Agrilus liragus*
forest tent caterpillar	*Malacasoma disstria*
gypsy moth	*Lymantria dispar*
large aspen tortrix	*Choristoneura conflictana*
poplar borer	*Soperda calcarata*
poplar gall saperda	*Saperda inornata*
root boring saperda	*Saperda calcarata*
Fungi	
Ceratocystis canker	*Ceratocystis spp.*
Ceratocystis canker	*Ceratocystis fimbriata*
Cytospora canker	*Cytospora chrysosperma*
Hypoxylon canker	*Hypoxylon mammatum*
root rot	*Ganoderma applanatum*
shoestring fungus	*Armillaria mellea*
white trunk rot	*Phellinus tremulae*

3. Jack Pine

Preface and Acknowledgements

This document provides guidance for the management of jack pine stands in Michigan. General information on the ecological characteristics of the common tree species, wildlife and biodiversity values, and an overview of forest health concerns common to jack pine stands are presented in the Jack Pine Silvics section. Guidance for management of jack pine on Michigan Department of Natural Resources (DNR) administered state forest land is presented in the Jack Pine Management Guidance section. Both sections are intended to be used together.

The guidance was written over an 8-year period, by a core team of DNR Forest Resources Division and Wildlife Division staff, including Jim Bielecki, Don Kuhr, Keith Kintigh, Bob Heyd, and Roger Mech. The guidance was edited by David Neumann, Debbie Begalle, David Price, and Georgia Peterson.

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Jack Pine Silvics Guidance

Introduction

This treatment of jack pine silvics is written in general terms, intended as one of several aids for the practice of jack pine silviculture.

The discussion that follows is organized under the following general headings:

- Composition and Distribution of the Forest Type;
- Associated Species;
- Historical Influences;
- Common Stand Conditions;
- Site and Succession Characteristics;
- Reproductive Characteristics, Ranging from Seed Production to Growth Responses of Established Saplings;
- Damage/Mortality Agents; and
- Wildlife Habitat Attributes.

Range and Composition of the Jack Pine Cover Type

Jack pine stands comprised about 688,000 acres in 2010 or about 3% of Michigan forests (FIA, 2010). Jack pine is a small-to-medium sized coniferous tree native to northern and boreal forests of North America that reaches the southern end of its range in the northern United States. It usually grows in even-aged pure or mixed stands on less fertile and drier soils than those required by other native species in its range.

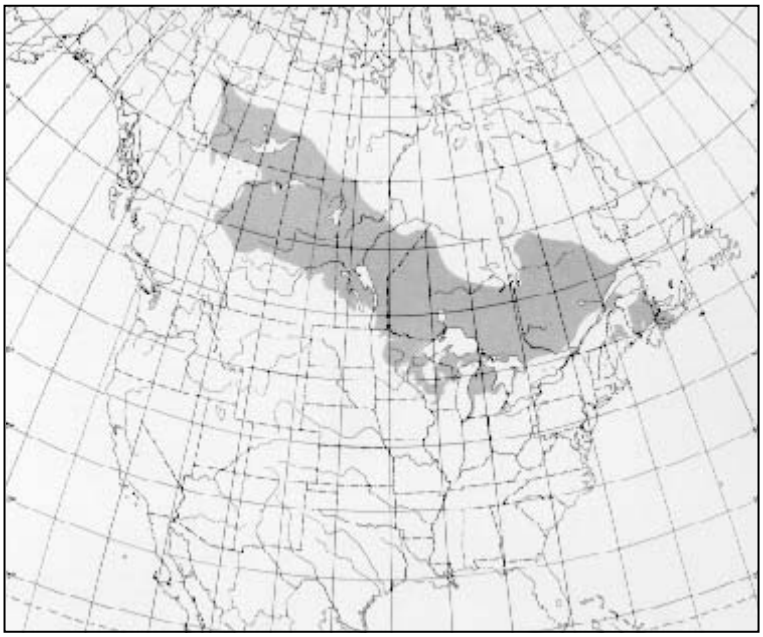

Figure 3.1 Native of Jack Pine Forests in N. America (Rudolph & Laidly 1990)

Jack pine stands commonly grow on dry, level to gently rolling sand plains, usually of glacial outwash, fluvial or lacustrine origin. Natural stands of jack pine are confined largely to soils of the podzolic regions. Jack pine grows on a wide range of sites, from very dry sandy or gravelly soils where other species have difficulty surviving, to loamy soils and wet sandy soil sites that may have standing water during spring. Jack pine also occurs on dune sands and on lowland sites dominated by peat soils in the Upper Peninsula (UP) and parts of the Northern Lower Peninsula (NLP). It can also be found on rock outcrops and rock ridges.

Jack pine stands generally reach their best growth and development on very dry to dry-mesic sites with well-drained loamy soils where the water table is within 4 to 6 feet below the surface in the summer months. Growth potential is good to very good for all but the lowest habitat type sites (Table 3.1) On these sites, PVDc and PVCx in the WUP, growth potential is rated as “fair”.

Associated Species

Jack pine usually grows in even-aged pure or mixed stands. Common overstory associates include red and white pine, aspen, paper birch, oak, and red maple, but tend to vary by site and habitat type (Table 3.1).

Understory and ground flora associates are important in determining jack pine regeneration options. Upland jack pine typically occurs with ground cover dominated by sedge, or by blueberry, lichen, and moss, or by mixtures of sedge, blueberry, lichen and moss. On wet sites, ground cover may be dominated by leatherleaf.

Historical Influences

Most of the older natural jack pine that currently exists in Michigan can trace its origin back to the uncontrolled forest fires that followed the pine-logging era of the late 1800’s/early 1900’s. Large parts of northern Michigan that were originally comprised of mixtures of white, red and jack pine are now nearly pure jack pine (GLO and state forest inventory data).

The relatively pure, thick stands of young jack pine that regenerated following the fires became ideal nesting habitat for the Kirtland’s warbler. As a result, the Kirtland's warbler population reached its peak between 1885 and 1900. With the advent of modern fire protection and suppression efforts, there was a drastic decline of available warbler nesting habitat, and its numbers plummeted. To address this population decline, during the mid-1970’s, some 134,000 acres of jack pine were designated for management as Kirtland's warbler nesting habitat within 24 management areas of state and national forests. Additional lands were added through the 1990’s to bring the total public land specifically set aside for the Kirtland's warbler to more than 150,000 acres. Today, more than 190,000 acres are dedicated to Kirtland’s warbler habitat in Michigan (Huron Manistee National Forest website).

Common Stand Conditions

The jack pine cover type comprises about 688,000 acres in Michigan, or about 3.4% of total forestland acreage (2010 FIA data). Of this, about 45% is located on state forest land, 33% on national forest land and the remaining 22% on private ownership. Figure 3.2 shows the age-class distribution of jack pine in Michigan (all ownerships).

Even-aged management of jack pine is common, usually through clearcutting on a 50- or 60-year rotation. Statewide, the age-class structure of jack pine is more balanced than many even-aged forest types in Michigan, with relatively few acres older than 70 years (Figure 3.2). Intensive management for the Kirtland’s warbler on state and national forest land during the past few decades is reflected by the number of acres in the 0 to 30 year classes (Figure 3.2 and Figure 3.3). In addition, in recent years on state forest land, there has also been a substantial effort to harvest a large quantity of jack pine in older age-classes before mortality and damage related to jack pine budworm and other insect pests, or succession occurs. This effort is also reflected in the total acreage in the 0 to 19 year age classes as these stands are regenerated (Figure 3.3), often through planting. Jack pine on private ownership appears to be skewed toward the older age classes, and more toward younger age classes on state and local government ownerships (Figure 3.4).

Jack pine stands tend to be medium- to fully-stocked per Table 3.2. However, a greater percentage of stands on private lands were rated as poorly stocked than on public ownerships.

Table 3.1 Typical Jack Pine Sites by Nutrient Regime, Habitat Type, Typical Overstory Species, and Growth Potential for Jack Pine.

	Moisture Regime	Nutrient Regime	Region	Habitat Type	Typical overstory associates in mixed stands[1]	Jack Pine Growth Potential	Jack Pine Site Index[2]
Wet Sites	wet-mesic to mesic	poor	NLP	PArVCo	red maple, white pine, aspen, red oak	variable	65-75
	dry-mesic to dry	medium-poor	WUP	PArVAa[w]	white pine, red pine, aspen, red oak, red maple	very good	70-80
			NLP	PArVVb	red oak, red maple, bigtooth aspen	very good	65-75
		poor	WUP	PArVAa	red pine, red maple, white pine	very good	70-80
			EUP	PArVAa	red pine, red maple, white pine	very good	70-80
Dry Sites	dry	poor	WUP	**PArV[w]**	pine (jack, red, white) and aspen	very good	65-75
				PArV-Co	pine (jack, red, white), red maple, and paper birch	very good	60-70
	dry to very dry	poor	NLP	**PArVHa**	red oak singly or mixed with white oak, black oak, bigtooth aspen, red maple, white pine	very good	55-65
		poor-very poor	WUP	**PQE, PArV**	jack pine (PQE); red & white pine (PArV)	good	55-65
			EUP	**PArV, PArV-Ao**	red and white pine with red maple on PArV, plus jack pine on PARV-Ao	very good	55-65
	very dry	poor-very poor	EUP	**PVE**	jack and red pine stands	good	55-60
		very poor	WUP	**PVDc**	jack and red pine stands	fair	50-55
				PVCx			55-60
			NLP	**PVCd**	jack pine	good	50-55

Bold font = jack pine is commonly found as a significant overstory component, or can dominate stands

[1]Typical dominant overstory species composition. Species are listed in decreasing order of abundance (left to right).

[2]Estimated site index base 50 years, adapted from Coffman et al. (1980).

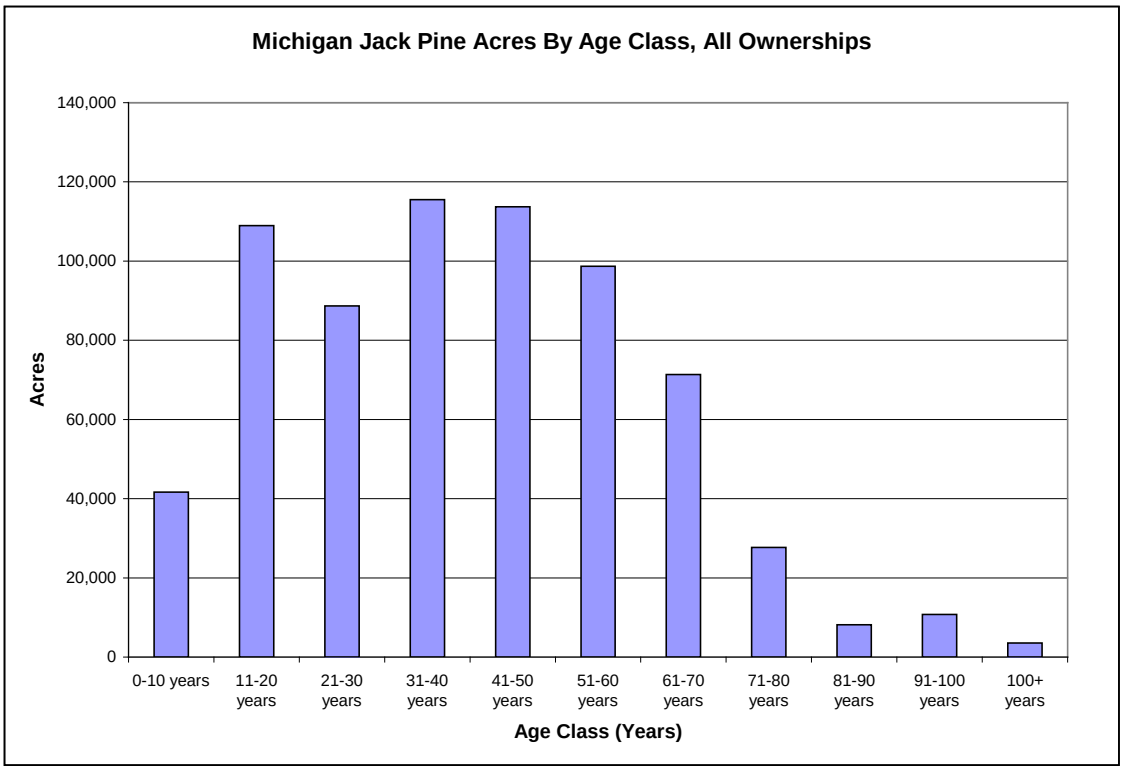

Figure 3.2 Michigan Jack Pine Acres by Age Class, from 2010 FIA Data.

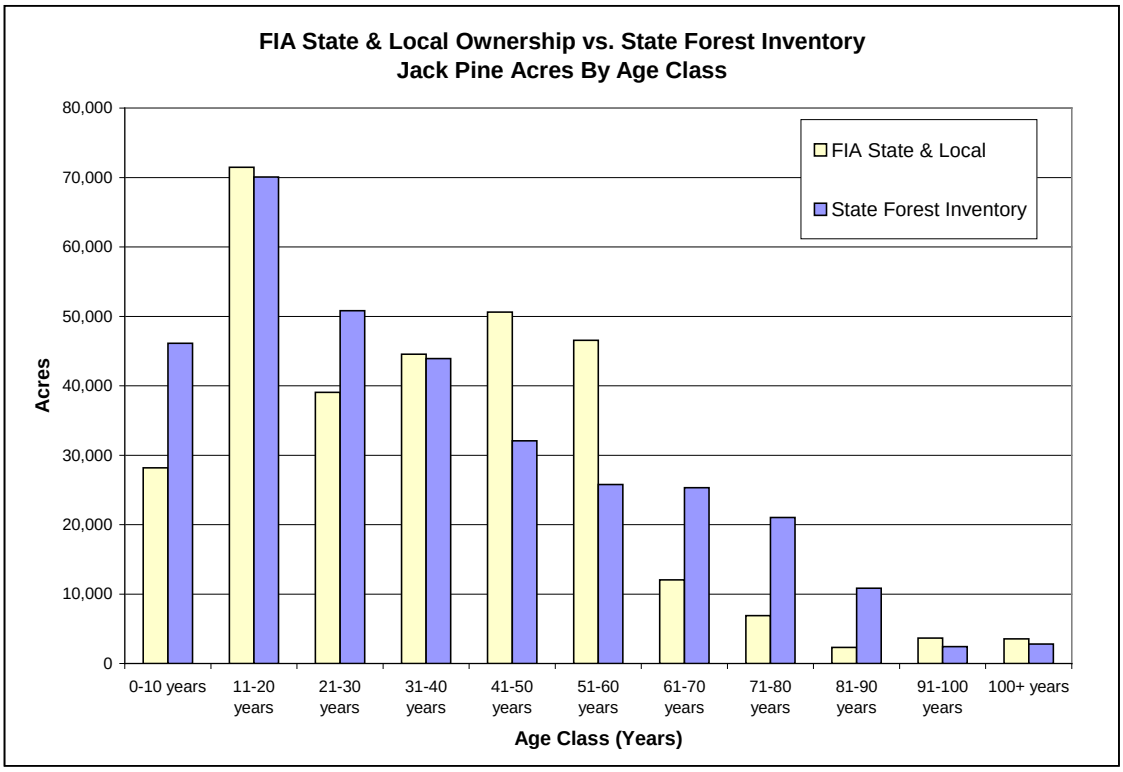

Figure 3.3 Jack Pine Acres by Age Class for State & Local Gov't Ownerships vs. DNR State Forest Lands (from 2010 FIA Data & unpublished 2011 DNR inventory data).

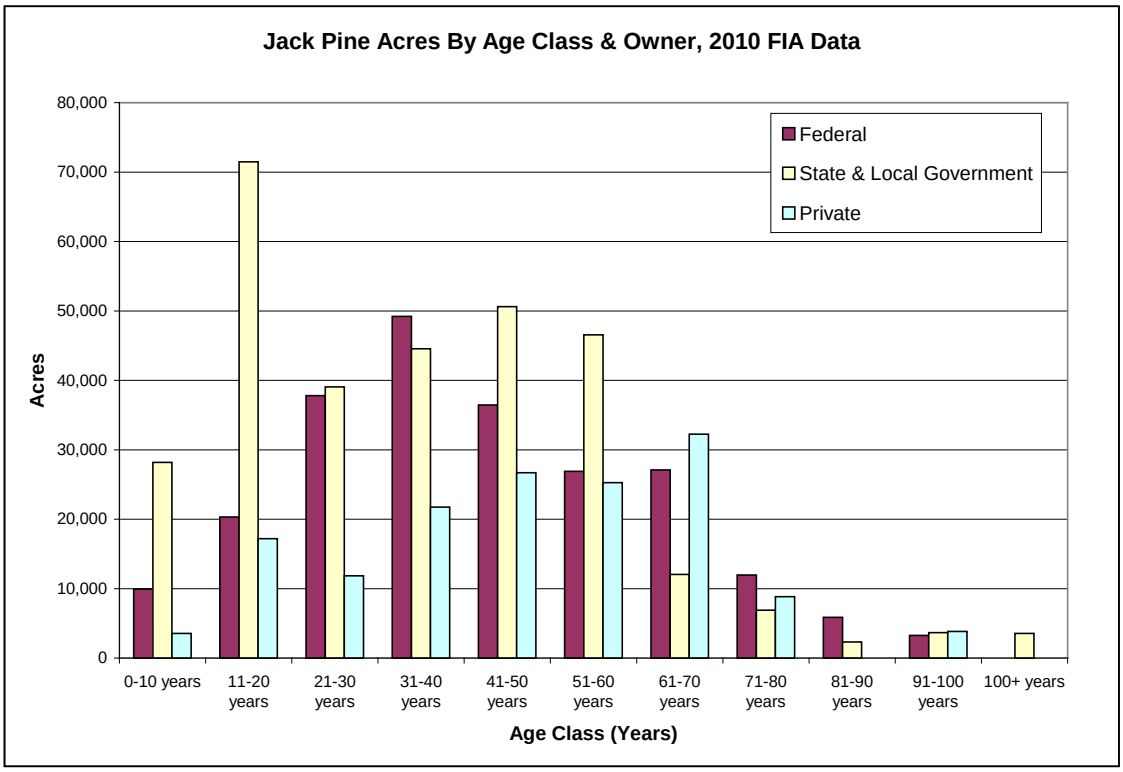

Figure 3.4 Jack Pine Acreage by Ownership & Age Class (2010 FIA Data).

Table 3.2 Michigan Jack Pine Acres by Ownership & Live Stocking Class, from 2010 FIA Data.

Jack Pine - All Live Stocking						
Owner	**Total**	**Over-stocked**	**Fully stocked**	**Medium stocked**	**Poorly stocked**	**Non-stocked**
All Owners	688,847	13%	26%	45%	16%	0%
Federal	228,773	14%	28%	47%	11%	0%
State & Local	308,833	14%	31%	40%	15%	0%
Private	151,241	7%	14%	52%	27%	0%

The rate at which jack pine stands develop into sapling, pole and sawlog size classes is highly dependent on stand density and site quality. Seedlings reach breast height in 5 to 8 years, depending on site quality. Stands may take up to 40 years to reach average diameters of 5 inches on sites with site index of 40 or 50, compared to about 30 years for higher quality sites. Tree size and quality tend to vary with the uniformity of stand density--stands with more uniform stand density tend to have more uniform tree size (Benzie 1977). Stands on higher quality sites may reach an average diameter of 9+ inches within 60 to 70 years. Mature trees tend to average 8 to 10 inches dbh, and 55 to 65 feet in height. Stand basal areas seldom exceed 160 ft^2/acres of basal area. Jack pine stands start to disintegrate at ages ranging from 60 years to 80 years, depending on site quality (Rudolph and Laidly, 1990).

Site and Successional Characteristics

Jack pine is an early successional or “pioneer” species that dominates sites where mineral soil has been exposed by major disturbances such as wildfire or logging. Jack pine is one of the least shade-tolerant trees in the Great Lakes area. In the absence of fire or other major disturbances, jack pine is usually replaced by more shade-tolerant species listed in Table 3.1, if suitable seed sources are present. However, on the poorest, driest

sites, jack pine may persist as an edaphic climax. These sites were most likely historically dominated by mixed pine stands or jack pine barrens.

Jack pine seedlings may be relatively more shade-tolerant as germinants and during initial establishment (Rudolph and Laidly,1990), but quickly become shade intolerant. Established seedlings and later stages of development can stand considerable crowding, but little overhead shade (Rudolf, 1958).

Jack pine is a short lived tree -- individual stems can live up to 100 years, although stands start to break up at between 60 and 80 years. Some individual trees have been reported reaching ages of 200+ years.

Reproductive Characteristics

Among all Michigan tree species, jack pine is uniquely adapted to exist and reproduce on the hottest and driest sites in Michigan. It is called a "fire species" mainly because of its sealed “serotinous” cones which only open in the extreme heat produced by a forest fire. Fire running through mature, uncut stands of jack pine, or jack pine mixed with red pine, white pine or other species, encourages reproduction of jack pine at the expense of other species due to jack pine’s unique seeding habits.

Most jack pine have serotinous cones that are sealed with a special resin which prevents the cones from drying out and only allows the cones to open under high temperature conditions (110 to 140°F) that usually occur during a forest fire. Although a fire sweeping through a jack pine stand kills nearly all of the vegetation, the insulation afforded by the thick cone scales leaves most of the seed unharmed. The heat of the flames, usually of too brief a duration to destroy the cones, opens the cones and releases the seed onto soil that is practically bare. The fire thus simultaneously prepares a favorable seedbed, reduces plant competition, and releases an immense number of seeds (Eyre and LeBarron, 1944).

In the absence of fire, most serotinous cones on standing trees will remain closed. However, cones on logging slash will open when heated by sunlight over the course of a summer. Also a portion of the cones on standing trees may open when heated by sunlight. Seeds in closed cones remain viable for many years, but viability is reduced after 5 to 10 years.

A variety of jack pine that bears non-serotinous cones also occurs at the southern end of the species range. In Michigan, this variety occurs in some parts of the NLP. The mature cones on these trees may open in any season, but often open in September and October when the air temperature reaches 75 to 80°F.

Cones are produced beginning at ages as young as 5 to 10 years, and production tends to be fairly regular thereafter. Good cone crops are produced every 3 to 4 years, but some cones are produced in almost every year. Seed production is best at ages 40 to 50. Seeds can disperse up to 2 to 3 tree lengths, but most seedlings are found within 1 tree length (Laidly 1990).

Jack pine germinates best on bare mineral soil exposed by severe disturbances like fire or scarification caused by whole-tree skidding, anchor chain scarification, or trenching. Stands can be regenerated naturally, or via direct seeding; however, success is highly dependent on competing vegetation, depth to water tables, occurrence of drought, and availability of suitable seedbeds. Established seedlings are highly sensitive to shading by competing vegetation. Drought occurring during germination and early seedling establishment causes significant mortality (Benzie 1977). Natural regeneration following scarification of logging slash following a timber sale is a technique that has had great success in parts of the UP. Direct seeding has also been used with good results in both the UP and LP. However, the majority of upland stands today are regenerated via aggressive site preparation and planting of seedlings.

Jack pine grows moderately rapidly as a seedling. Average heights of wild seedlings are about 2 inches at year 1, 6 inches after 2 growing seasons, and 1 to 3 feet tall after 4 years. For several years thereafter, growth will average 1 to 1½ feet on medium sites.

Jack pine is well adapted to thrive in droughty conditions. Seedlings quickly develop a tap root and wide lateral root system relative to its above ground height. During the first season, the root system penetrates to a depth of about 5 to 10 inches. By the end of the second growing season, jack pine seedlings usually have roots about 11 to 13 inches deep with a lateral spread of 18 to 24 inches (Rudolf, 1958).

Damage & Mortality Agents

Jack pine is subject to many agents that cause damage or mortality; however, the most significant agents of wide-spread mortality and damage in stands are the jack pine budworm and the ips bark beetle.

Jack Pine Budworm:

The jack pine budworm is the most significant defoliator of jack pine in the northeastern United States. Trees over 50 years of age are at greatest risk of top kill and mortality. Overstocked and under stocked stands are at higher risk than optimally stocked stands, and volume losses can be higher on better sites following outbreaks. Two-storied stands and plantations adjacent to mature jack pine stands are at particular risk. In addition, stands with jack pine that have a large number of staminate cones support larger, healthier budworm populations, which can prolong outbreaks. In Michigan, outbreaks occur every 5 to 12 years on average, and last from 2 to 4 years.

Ips Bark Beetle:

Trees weakened by jack pine budworm become susceptible to attack by bark beetles. Outbreaks of bark beetle can also occur when populations build to high levels in fresh slash or on trees weakened by drought, defoliation or mechanical damage from storms or logging. At high population levels, bark beetles attack adjacent healthy trees.

Climate change impacts on the jack pine forest type are unclear at this time.

Wildlife Habitat Attributes

Jack pine is a dominant or associate tree species in several natural communities including interdunal wetland, poor conifer swamp, boreal forest, dry northern forest, oak-pine barrens, pine barrens, and Great Lakes barrens. Several plants and animals of special concern occur in these communities including pale agoseris (state threatened), rough fescue (state threatened), Canada rice-grass (state threatened), dusted skipper (state threatened), persius duskywing (state threatened), Great Plains spittlebug (state threatened), Kirtland's warbler (federally endangered and state endangered), and prairie warbler (state endangered). Refer to MNFI Community Abstracts and Wildlife Action Plan for more complete lists of special concern species.

Jack Pine can function as nesting cover for numerous bird species including pine siskin and golden-crowned kinglet. Additionally, jack pine, like other pine species, can be important habitat for winter migrants because of the energetic advantage provided by dense foliage. Mature stands, in landscapes lacking significant lowland conifer, can function as important thermal cover for white-tailed deer as well. In addition, mature stands with significant numbers of snags can attract woodpeckers including the northern flicker and black-backed woodpecker. Jack pine seeds are eaten by a number of species including red crossbill, red squirrel, red-backed vole, and white-footed mouse. Jack pine needles are an important food source for the spruce grouse. Jack pine also serves as a fall and winter browse for ungulates and snowshoe hare. Blueberry is a common understory species in jack pine stands in some parts of the state, and in good berry production years, these sites can be an important food source for black bear and other soft mast foragers.

Jack Pine Management Guidance

Introduction

This section contains recommendations for management of jack pine on Michigan DNR administered state forest lands. This information is intended as guidance only. Management decisions should also be informed by local experience and input from the DNR's inventory and compartment review process.

Management Objectives

Pulpwood production is the primary timber objective for most jack pine stands; however, sawlog production may be appropriate on better sites, particularly in the WUP. Other common objectives include management for Kirtland's warbler, other wildlife species habitat, and aesthetics. Maintaining jack pine may meet stand objectives determined during the compartment review process, or conversion to another cover type may be better. Alternative cover type objectives for current jack pine stands are listed by habitat type in Table 3.3.

Table 3.3 Alternative Cover Type Objectives for Jack Pine Stands by Habitat Type. (Adapated from Burger & Kotar 2003)

Productivity Rating	Moisture Regime	Nutrient Regime	Habitat Type	Management Options
Low	very dry to dry	poor to very poor	NLP-- PVCd, 'low end' PArVHa EUP-- PVE, PArV, PArV-Ao WUP—PVDc, PVCx, PArV, PQE,	• Maintain jack pine, manage for pulpwood or low-grade sawtimber • Convert to barrens • Manage for mixed pine/hardwood or mixed conifer
Medium	dry to dry-mesic	medium to poor	NLP--PArVHa EUP-- PArVAa WUP-- PArV(w), PArVAa, PArVAa(w), PArV-Co	• Maintain jack pine where timber production is not the priority, manage for pulpwood or low-grade sawtimber • Convert to another species via natural regeneration • Manage for mixed pine/hardwood or mixed conifer • Convert to red pine where timber production is the priority
Medium	dry-mesic	medium to poor	NLP—ParVVb	• Convert to red pine
High	mesic	medium to high	Any of the 'A' series habitat types, e.g., AFO	• Convert to hardwoods • Convert to red pine
Variable	wet	poor	NLP-- PArVCo OR any very dry to dry site within 5 miles of Great Lakes, or adjacent to water OR any site with water table <4 to 6 ft.	• Consider conversion to other species on NLP PArVCo • Maintain jack pine, manage for pulpwood or low-grade sawtimber

Silvicultural Systems and Treatments

Jack pine is primarily managed on an even-age basis. The early-successional, extremely shade intolerant nature of the species usually requires it to be regenerated under full sun, with minimal competition. However, for some sites, use of the seed tree or shelterwood technique may be appropriate, with timely removal of the overstory once regeneration is established.

Recommendations in this section are summarized under the following headings. Site specific regeneration options are also summarized as flow charts in Appendix C.

- General Recommendations
- Commonly Used Silvicultural Systems
- Other Silvicultural Treatments
- Regeneration Standards
- Recommendations by Habitat Type and/or Site Moisture Class
- Appendix C: Regeneration Option Flowcharts for Jack Pine on State Forest Lands

General Management Recommendations

- Maintain stands until they reach maturity.
- Thinning is not commonly recommended in jack pine due to low average product value, risk of damage to the residual trees and subsequent pest outbreaks, and poor response to thinning in terms of crown response and diameter growth.
- Regenerate stands on a 40 to 70 year rotation. In areas with a history of jack pine budworm outbreaks, use rotation age = (Site Index minus 5 years).
- Select a regeneration method with consideration of:
    - habitat type
    - depth to water table
    - proximity to the Great Lakes influence zones or other surface water
    - whether the stand has serotinous, or non-serotinous cones
    - harvest method (e.g., whole tree skidding & chipping, vs. bole wood only harvest).
- Use regeneration methods that will produce fully stocked stands.
- Use natural regeneration whenever it is cheaper than artificial regeneration.
- Natural regeneration, furrow seeding, and direct seeding have best success on sites that have adequate soil moisture, such as:
    - Water tables within 4 to 6 feet of the surface during summer.
    - Moderating climate conditions that occur within 5 miles the Great Lakes, or immediately adjacent to other large water bodies.
    - Standing water during part of the year, often with leatherleaf understories.
- If natural regeneration or direct seeding fails, consult the district timber management specialist regarding regeneration options. Trenching and planting may be necessary.

Commonly Used Silvicultural Systems

A. Clearcut

Clearcutting **is the most common harvest method** used in jack pine management. Jack pine grows best in a full-light environment, although initial germination and establishment may be higher under partial shade conditions created under shelterwood (see the shelterwood discussion below). Clearcutting is most often followed by additional regeneration treatments to create a bare mineral soil seed bed, suppress competing vegetation, and facilitate planting or seeding.

Clearcut sites are most often regenerated via planting, although furrow seeding, direct seeding (whole area) and natural regeneration from seeds born in cones on logging slash, work well on sites with adequate soil moisture or lake effect climate.

B. Seed Tree

The seed tree system can be used to regenerate jack pine on wet sites, and low-lying areas that often have standing water during part of the year. Historically, jack pine on these sites originated following wildfires in the 1920's and 1930's. These sites often have an understory dominated by leatherleaf, and offer unique problems for regeneration. The combination of wet site conditions and tough leatherleaf brush make trenching difficult. On some sites, seed tree harvests have been used followed by prescribed burning to naturally regenerate jack pine.

In practice:

- It is essential that the fire specialist, fire officer and timber management specialist be consulted in compartment review planning and for preparing timber sale specifications.
- Seed trees are marked prior to harvest, leaving 15 to 25 trees per acre, well-distributed across the site.
- Seed trees should be of good form and have full crowns, capable of producing large amounts of cones.
- Harvests should be bole-wood only; all logging slash must be left on-site in order to provide adequate fuel to remove the leatherleaf and herbaceous ground cover, expose bare mineral soil seed bed, and provide sufficient heat to open the serotinous cones on the seed trees.
- Burns should be scheduled for late summer/early fall, and when site and fuel conditions will allow creation of a mineral soil seed bed.
- Seed trees are often left on-site and not removed, as part of a release cut after the regeneration is established. In some cases, the seed trees end up being killed or severely damaged during the prescribed burn and die shortly afterward.

Logging slash that is left to carry a prescribed burn will hamper backup regeneration treatments (trenching and planting or trenching and furrow seeding), if the prescribed fire component of the seed tree system cannot be completed within the timeframe for regeneration requirements.

C. Shelterwood

Shelterwood systems can be used to regenerate the non-serotinous cone-variety of jack pine (WDNR, 1995; Caveney and Rudolph, 1970; Michigan DNR unpublished guidance) that occurs only in some areas in the NLP on PVCd and PArVHa sites. On these trees, a portion of the mature cones tend to open and disperse seed in September and October when air temperatures reach 75 to 80°F. Some sources indicate that initial abundance of jack pine seedlings may be higher under partial shade --10 to 30% of full light-such as may be provided under shelterwood conditions (Rudolph 1965). However, this technique should only be used for stands with:

- groundcover dominated by blueberry, lichen and moss; and
- a water table <4 to 6 feet of the surface.

In practice:

- Mark 10 to 20 ft2/acre BA of open-cone jack pine trees evenly scattered across the site;
- Schedule the harvest for summer and specify whole tree skidding to help scarify the site, or scarify the site using anchor chains to expose bare mineral soil as a seed bed after the timber sale is complete;
- Remove the shelterwood overstory via release cut when the site is successfully regenerated (2 or 3 years after timber sale completion) to release the seedlings. Schedule the release cut for winter to help minimize damage to the regeneration.
- Usually only in areas that it has previously worked.

It is critical that the shelterwood overstory be removed promptly to avoid suppression and/or shade induced mortality, as jack pine seedlings become more intolerant of shade as they mature. Retention of a mature or over-mature jack pine overstory also increases the risk of jack pine budworm outbreak.

Other Silvicultural Practices

A. Trenching and Furrow Seeding

Trenching is the practice of exposing bare mineral soil in shallow linear furrows or trenches, generally at about 8-foot spacing, about 1.5 to 2 feet wide, and 4 to 8 inches deep. Trenching is used as a means of site preparation for hand planting seedlings on dry sites, and in combination with furrow seeding on moist sites.

For operator safety, timber sale specifications should restrict stump heights to 6 inches or less. Harvest residue retention should be restricted to the minimum of 1/6 of harvested tops and limbs (per the Woody Biomass Harvesting Guidance), as heavy slash accumulations reduce the quality of the trenches produced (and correspondingly reduce seedling survival). If heavy slash accumulations result from harvesting operations, then the site may require prescribed burning to reduce the volume of slash prior to planting.

In furrow seeding, a pneumatic seeder mounted on the trencher blows jack pine seed into the furrows immediately behind the disks. Seed is planted at a rate of 1/3 lb. per acre.

Furrow seeding is used on dry-mesic sites:

- With water tables < 4 to 6 feet of the surface;
- Immediately adjacent to inland lakes;
- Within 5 miles of the Great Lakes; or
- With leatherleaf-dominated ground flora and standing water present during part of the year.

B. Planting

Planting is often used to regenerate dry sites, or as a backup regeneration method when natural regeneration attempts fail. Sites are prepared for planting by trenching. Bare root 2-0 seedlings are hand-planted in Spring. Fall plantings have had relatively poor survival using bare root stock, likely due to inadequate soil moisture in the weeks following planting. Preferred planting densities are 900 seedlings per acre in the UP, and 1,000 seedlings per acre in the NLP. Areas that are planted for Kirtland's warbler habitat are usually planted at ~1,200 seedlings per acre.

C. Scarification

Scarification is frequently used to facilitate natural regeneration of jack pine on sites with sufficient soil moisture or presence of moderating weather to aide establishment. It may also be used to prepare sites for direct broadcast seeding. Scarification may be accomplished as part of the timber sale by requiring the producer to whole-tree skid. If this is not possible, scarification can be accomplished using a roller chopper and/or use of anchor chains. For operator safety, timber sale specifications should restrict stump heights to 6 inches or less.

Scarification for natural regeneration is recommended for the following sites:

- Where water tables are < 4 to 6 feet of the surface;
- Sites immediately adjacent to lakes; and
- Sites within 5 miles of the Great Lakes.

As windthrow is a risk on these wetter sites, scarification should be completed within 2 years of timber sale completion to help ensure that adequate seed trees remain to achieve the desired stocking.

D. Herbicide Applications

Herbicide applications for site preparation preceding trenching and planting of jack pine are common in the WUP, but rare elsewhere on State Forest lands. In the WUP, applications are made to suppress competing herbaceous and woody vegetation including sedge, red maple, and aspen.

E. Direct seeding

Direct seeding can be used to regenerate jack pine following scarification or prescribed burning that exposes bare mineral soil. Scarification should expose bare mineral soil on at least 50% of the site for seeding to be effective. Jack pine seed should be broadcast at a rate of about ½ lb. per acre, using a snowmobile or ATV modified to carry a cyclone seeder. Direct seeding is best done in late winter or early spring on hard packed snow.

F. Prescribed burning

The local fire specialist, fire officer, and timber management specialist should be consulted early in the compartment review planning process when developing treatment prescriptions involving prescribed burning.

Prescribed burning is recommended in some situations to reduce logging slash, expose a bare mineral soil seedbed conducive for jack pine natural regeneration or direct seeding, and to suppress competing vegetation. Jack pine is susceptible to fire damage at all stages of development; even mature trees are susceptible to scorching or crowning due to ladder fuels characteristic of its growth pattern.

An under-burning following seed tree harvest has been used to facilitate natural regeneration on wet sites where sufficient serotinous cones are present on the retained trees. However, these burns require additional preparation and care to prevent unintended consumption of the seed source, while burning hot enough to expose bare mineral soil.

G. Thinning

Thinning is theoretically possible in jack pine on high productivity sites (jack pine SI >60); however, this practice is rarely used, and there is very little site index 60 acreage on state forest lands. Thinning has value mainly for stands that will be managed for production of poles and small sawlogs. Candidate stands should be at least 20 years from rotation age to justify the cost of thinning.

For stands with an initial BA >120 ft^2/acre, recommendations (Benzie,1977) include:

- Thin to a target BA of about 80 ft^2/acre;
- Do not remove more than 1/3 of the basal area to minimize post-logging mortality;
- In dense stands (initial BA >120 ft^2/acre), use two or more thinnings to reduce BA to 80 ft^2/acre;
- In plantations, remove every third row, only if individual tree marking is impractical or not cost effective;
- Mark as a thinning from below; remove the smaller, poorly formed or low quality trees, along with all high risk and/or damaged trees;
- In mixed stands, favor the more valuable species (just about everything else).

Regeneration Standards

For purposes of DNR artificial and natural regeneration surveys:

- Minimum stocking level is considered to be 600 seedlings per acre.
- Seedlings should be well-distributed across the site. At least 60% of the stand area should be well-stocked with seedlings.
- Re-evaluate stands falling below the minimum stocking and/or with less than 60% of the site well-stocked. Replanting or modification of the stand prescription to accept lower stocking may be necessary.

Recommendations by Habitat Type and/or Site Moisture Class

Recommendations for specific habitat types and site moisture classes are summarized in the groups listed below:

Low Productivity, Dry Jack Pine Sites
Medium Productivity, Dry Jack Pine Sites
Medium Productivity, Dry-Mesic Jack Pine Sites
High Productivity, Dry Jack Pine Sites
Moist Sites and Lake Effect Zones
Wet Sites
Jack Pine with Non-Serotinous Cones

A. Low Productivity, Dry Jack Pine Sites:

- NLP: PVCd and "low end" PArVHa
- EUP: PVE, PArV and PArV-Ao
- WUP: PVDc, PVCx, PArV and PQE

Management Alternatives:

1) Maintain the Jack Pine Cover Type:

- Silvicultural system - clearcut or clearcut with reserves on a 40 to 70 year rotation.
- Regeneration by planting is recommended due to droughtiness. Poor survival and stocking typically result from natural regeneration attempts in the absence of wildfire.
- In the NLP: plant at 1,000 seedlings per acre due to white pine weevil issues.
- In the UP: plant at 900 seedlings per acre.

2) Conversion to Oak:

It is very common to find pin oak, black oak and white oak regeneration beneath stands of jack pine. Seedlings in this category usually respond to release so recommended management is to clearcut once the stand is mature. Pin oak, black oak and white oak also produce viable stump sprouts which can help augment the oak regeneration in these stands.

- Silvicultural system - clearcut or clearcut with reserves on a 40 to 70 year rotation. Note that better advanced oak regeneration may be obtained by scheduling regeneration harvests toward the end of this range, or in some cases by extending rotation beyond 70 years. However, risk of jack pine budworm damage or outbreak may be higher on some sites with longer rotations.
- Regeneration – rely on oak stump sprouts and established advanced regeneration to produce a fully stocked stand.

3) Conversion to Aspen:

Quaking aspen can be found growing with jack pine in both the NLP and the UP, and stands can be converted to aspen by clearcutting. However, it is ill-suited to low productivity sites like PVCd, PVE, PVDc, PVCx, and PQE.

- Silvicultural system - clearcut or clearcut with reserves on a 40 to 70 year rotation.
- Regeneration – rely on aspen root sprouts to produce a fully stocked stand.

4) Mixed Species Management—Jack Pine/Oak:

Northern pin oak, black oak and white oak are common associates of jack pine on PVCd sites in the NLP, and managing for a mixture of oak and jack pine is acceptable.

- Silvicultural system - clearcut or clearcut with reserves on a 40 to 70 year rotation.
- Regeneration –plant jack pine at a stocking of 1,000 trees/acre. Rely on stump sprouting to regenerate the oak component.

5) **Mixed Species Management—Jack Pine/Aspen:**
Quaking aspen can be managed in mixed stands with jack pine; however, it is ill-suited to low-end sites like PVCd, PVE, PVDc, PVCx, and PQE . These stands would be allowed to revert to a relatively pure stand of jack pine.
   - Silvicultural system - clearcut on a 40 to 70 year rotation.
   - Regeneration –the aspen will root sprout; evaluate the site after 2 years, then trench and plant jack pine in the areas that have not regenerated at a stocking of 1,000 trees/acre.

B. Medium Productivity, Dry Jack Pine Sites:

- NLP: PArVHa
- EUP: PArVAa
- WUP: PArV(w), PArVAa, PArVAa(w), PArV-Co

Management Alternatives:

1) **Maintain the jack pine cover type:**
   - Silvicultural system - clearcut or clearcut with reserves on a 40 to 70 year rotation.
   - Regeneration alternatives:
     - Planting seedlings:
       - In the NLP: plant at 1,000 seedlings per acre due to white pine weevil issues.
       - In the UP: plant at 900 seedlings per acre.
     - Furrow seeding: some of these sites may have sufficient soil moisture to make them good candidates for furrow seeding. Furrow seeding has had success on sites:
       - With water tables within 4 to 6 feet of the surface
       - Immediately adjacent to water
       - Within 5 miles of the Great Lakes

       Germination rates will be increased if the furrow seeding is done during wet periods.

2) **Conversion to Oak:**
Same as for Low Productivity, Dry sites, except red oak is often a common associated species.
   - Silvicultural system – clearcut or clearcut with reserves on a 40 to 70 year rotation, and replant with jack pine.
   - Regeneration – rely on stump sprouts and advanced regeneration to reproduce the oak component.

3) **Conversion to Aspen:**
Bigtooth and quaking aspen can be found growing with jack pine in both the NLP and the UP, and stands can be converted to aspen by clearcutting. Bigtooth and quaking aspen are both well suited to these sites.
   - Silvicultural system - clearcut or clearcut with reserves on a 40 to 70 year rotation.
   - Regeneration – rely on aspen root sprouts to produce a fully stocked stand.

4) **Mixed Species Management—Jack Pine/Oak:**
Same as for Low Productivity, Dry sites, except associated oak species include red oak.
   - Silvicultural system – clearcut or clearcut with reserves on a 40 to 70 year rotation.
   - Regeneration – plant jack pine at a stocking of 1,000 trees/acre. Rely on stump sprouting to regenerate the oak component.

5) **Mixed Species Management—Jack Pine/Aspen:**
Same as for Low Productivity, Dry sites, except associated species include bigtooth aspen.
   - Silvicultural system - clearcut on a 40 to 70 year rotation.
   - Regeneration –the aspen will root sprout; evaluate the site after 2 years, then trench and plant jack pine in the areas that have not regenerated at a stocking of 1,000 trees/acre.

6) **Convert to Red Pine:**

Red pine is well suited to these sites and converting stands of jack pine to red pine is a viable management option. Jack pine also regenerates very well on these sites, and often additional site preparation treatments may be necessary before trenching and planting. Consider using harvesting methods that do not disturb the soil.

- Silvicultural system - clearcut or clearcut with reserves on a 40 to 70 year rotation.
- Regeneration –trench and plant red pine at 900 seedlings/acre.

C. Medium Productivity, Dry-Mesic Jack Pine Sites:

- NLP: PArVVb

Management Alternatives:

1) Convert to Red Pine:

Red pine is well suited to these sites and converting stands of jack pine to red pine is a viable management option. Jack pine also regenerates very well on these sites, and often additional site preparation treatments may be necessary before trenching and planting. Consider using harvesting methods that do not disturb the soil.

- Silvicultural system - clearcut or clearcut with reserves on a 40 to 70 year rotation.
- Regeneration –trench and plant red pine at 900 seedlings/acre.

D. High Productivity, Dry Jack Pine Sites:

- (Any of the “A”- series habitat types)

Management Alternatives:

1) Conversion to Northern Hardwoods:

Jack pine stands are relatively rare on sites of this quality and are probably remnants of past fires or are plantations. In most, if not all cases, a well-developed northern hardwood understory is present. AFO sites, and better, are highly productive and should be managed for northern hardwood instead of jack pine.

- Silvicultural system - clearcut or clearcut with reserves on a 40 to 70 year rotation.
- Regeneration – rely on existing advanced regeneration to produce a fully stocked stand.

2) Convert to Red Pine:

Conversion to red pine may be a viable option when planted jack pine stands on these sites have a poorly stocked understory or undesirable understory species composition. Red pine grows well on these sites.

- Silvicultural system – clearcut or clearcut with reserves on a 40 to 70 year rotation.
- Regeneration – trench and plant red pine at 900 seedlings/acre. Herbicide applications may be necessary for site preparation and/or as a release spray 1 or 2 years post-planting.

E. Moist Sites, and Lake Effect Zones:

- NLP: PArVCo
- Any site in either peninsula immediately adjacent to water
- Sites with water tables within 4 to 6 feet of the surface in summer months
- Sites within 5 miles of the Great Lakes shoreline

Management Alternatives:

1) Maintain the jack pine cover type:

The PArVCo site class is very moist which makes them ideal candidates for furrow seeding. Adequate soil moisture on these sites, sites with high water tables, and sites adjacent to water also permits scarification to facilitate natural regeneration from seed on cones born in slash.

"Lake effect" can modify atmospheric conditions by lowering air temperature and increasing humidity providing conditions that are very favorable for jack pine seed germination. The greatest "lake effect" is found in the eastern UP within 5 miles of both Lake Superior and Lake Michigan. Similar "lake effect" zones also exist along Lake Michigan and Lake Huron in the NLP.

Planting can also be used on all of these sites as a primary regeneration method or as a backup method, if furrow seeding or natural regeneration following scarification treatments fail.

- Silvicultural system - clearcut or clearcut with reserves on a 40 to 70 year rotation.
- Regeneration alternatives:
  - Planting seedlings:
    - In the NLP: plant at 1,000 seedlings per acre due to white pine weevil issues.
    - In the UP: plant at 900 seedlings per acre.
  - Furrow seeding
  - Scarification – scarification to facilitate natural regeneration from seed on cones in logging slash can be accomplished using:
    - Whole tree skidding as part of the timber sale – bare mineral soils is exposed and cones are scattered in the process of dragging the trees to the landing, and often results in successful jack pine regeneration.
    - Roller chopping and anchor chain scarification – can be prescribed as a post-harvest treatment to break down slash, expose bare mineral soil, and scatter cones on sites where slash is left onsite or at the stump.
  - Direct seeding may also be an option on moist sites and within the lake effect zones.
    - Scarify first as part of whole tree skidding during the harvest, or as a post-harvest treatment using anchor chains. Scarification should expose bare mineral soil on at least 50% of the site for seeding to be effective.
    - Prescribed burning may also be used to expose bare mineral soil.
    - Direct seeding is best done in late winter or early spring on hard packed snow.
    - Broadcast jack pine seed at a rate of ½ lb./acre, using a snowmobile or ATV modified to carry a cyclone seeder.

F. Wet Sites:

Certain areas of the state have large areas of "wet" jack pine, or jack pine growing in low areas where standing water is common during parts of the year (lowland, so no habitat type designation). Some of these stands were established in the 1920's and 1930's following wildfires. These sites are characterized by well developed ground cover of predominantly leatherleaf, and offer unique problems for regeneration.

Management Alternatives:

1) Maintain the jack pine cover type:

Clearcutting or clearcut with reserves are the preferred harvest methods on these sites. Natural regeneration may be adequate on some sites without any additional scarification, if tops are retained -- consult the district timber management specialist regarding local experience on these sites. Furrow seeding has been used with success on these sites also when tops are not retained during harvests. Also, the seed tree harvest system has been used with some success, if followed by prescribed burning.

- Silvicultural systems:
  - Clearcut or clearcut with reserves on a 40 to 70 year rotation. Scarification may not be necessary on some sites if tops are retained.
  - Seed tree harvest using the same rotation length.

        - Leaving seed trees and burning slash produced in a timber sale has also proven to be a successful technique of regenerating jack pine on wet sites.
        - Marking between 15 and 25 jack pine per acre will leave enough trees for seed without impacting sale volumes significantly.
        - Seed trees should be of good form and have full crowns capable of producing large amounts of cones.
    - Regeneration alternatives:
        - Furrow seeding is recommended for use with clearcuts. The time of the year is very important when furrow seeding and should only be tried in late summer when the water table has dropped to its seasonal low.
        - Prescribed burning to facilitate natural regeneration
            - Logging slash should be left onsite in order to provide the fuel necessary to remove the thick herbaceous groundcover common to these sites.
            - The burn should be hot enough to expose bare mineral soil, and open the serotinous cones on the seed trees, but not so hot that the cones are consumed (not a crown fire).
            - Late summer and early fall are the best times for a burn and should only be attempted when the drought index allows for a mineral seedbed producing fire.

G. Jack Pine With Non-Serotinous Cones:

A variety of jack pine exists in some parts of the NLP that has non-serotinous cones. The mature cones on these trees open in September and October when the air temperature reaches 75 to 80°F. When this type of Jack Pine is found on PVCd and PArVHa site classes, the shelterwood system can be used to regenerate the stand. In this situation, approximately 10 to 20 square feet of open-cone jack pine are left evenly scattered throughout the sale area. Logging should be restricted to the summer months in order to take advantage of scarification through logging. Once successfully regenerated (2 or 3 years after the sale), the overstory should be removed.

Management Considerations

This section is organized as a series of queries and supporting information by way of response. Note that there is some overlap between the sections due to their interrelatedness.

1) *How does habitat type affect management?*
2) *Should I manage for jack pine or red pine?*
3) *How do I manage for mixed pine/hardwood and mixed conifer stands?*
4) *How do I manage for mixed jack pine/conifer stands?*
5) *How does stand structure and condition influence jack pine management?*
6) *How do I manage old strip cuts or strip plantations?*
7) *How do I convert jack pine to oak or mixed jack pine/oak stands?*
8) *How do forest health considerations influence management?*
9) *How do I determine rotation age?*
10) *How do I improve jack pine stand or average stem quality over time?*
11) *How do I manage for jack pine barrens?*
12) *How do I manage stands for Kirtland's warbler habitat?*
13) *How do I enhance wildlife habitat and biodiversity in other stands?*
14) *How do nutrient management concerns influence management?*
15) *How do climate change considerations influence management?*

1) ***How can habitat type be used to inform management decisions?***

In Michigan, jack pine stands are most commonly found on the habitat types listed in Table 2.3.1. Habitat type is increasingly used in addition to site index, soils information, and other measures of site potential to inform stand management choices. Habitat type can also indicate the relative growth potential for jack pine

and associated species. Estimates of site index values corresponding to habitat types are included in Table 3.1. A site index curve for jack pine in Michigan is also included in Appendix B.

Managers can use habitat type to help make stand management decisions on a site specific basis. Habitat type can be used to help identify options for management, including:

- conversion to other forest types;
- suitability for mixed pine/hardwood management;
- regeneration method; and
- restoration of species that are not present currently, but historically were important on the site (e.g., white pine, red pine).

Jack pine attains its best growth on dry to dry-mesic sites with well-drained sand or loamy-sand soils, and where the water table is within 4 to 6 feet of the surface. These sites also are often well suited to management for oak, aspen, red pine or white pine. Conversion to other cover types on these sites may be possible via natural regeneration, or if red pine and white pine seed sources are lacking, planting may be required.

On higher productivity sites, other species have a competitive advantage and often succeed jack pine, unless intensive site preparation and replanting are undertaken. Planted stands occur on some of these high productivity sites on state forest lands, and they often contain well-established hardwood understories.

On the poorest habitat types, jack pine usually co-dominates or has a competitive advantage over other shade intolerant species (red pine, white pine, pin oak, aspen, etc.) While jack pine growth potential is rated only as “fair” on these sites (PVDc, PVCx), other species perform worse. Jack pine barrens may be the climax community on these sites. Natural regeneration can often be accomplished, although planting is usually necessary for sites dedicated to Kirtland’s warbler management.

Specific recommendations for potential management objectives are summarized by habitat type in Table 2.3.2.

2) ***Should I manage for jack pine or red pine?***

Jack pine is generally well suited to sites classified as poor- and medium-productivity dry site habitat types listed in Tables 2.3.1 and 2.3.3. Red pine also is well suited to the medium productivity site, and is better suited to the dry mesic medium productivity sites (PArVVb).

Where timber production is the primary goal on these medium productivity sites, red pine should be regenerated. Unpublished economic analyses (Vasievich 2007) indicate that investments in red pine outperform jack pine on similar sites by a factor of 100 to 1. Alternative investments in common timber types on state forest lands were evaluated using DNR costs and region-specific average stumpage prices under no-thinning management scenarios, including red pine and jack pine on site index 50 and 60 sites. Present net values calculated using a 4% discount rate were negative for jack pine investments in the NLP and EUP, and barely positive for the WUP. By comparison, unthinned red pine stands had present net values ranging from ~$80 to $200+. The author concluded:

“Evaluation of jack pine plantations showed low performance in all regions except the Western UP where (present net values) barely passed the 4% hurdle rate. Relatively slow growth and weak markets hamper returns for jack pine… Recommendations here are to convert these sites to other species, such as red pine, if the management objective is primarily for timber revenues and the site is suitable for conversion. Alternatively, less costly measures of regenerating jack pine through direct seeding and less-costly site preparation could increase returns for these stands.”

Where wildlife habitat is the primary objective, medium productivity sites should be maintained as jack pine. Jack pine is often preferred as wildlife habitat over red pine because:

- Its branch retention is better,
- stands tend to be more open in older stands, and often have a well developed shrub understory,
- more wildlife species use jack pine.

3) How do I manage for mixed jack pine/hardwood stands?

Mixed jack pine and oak, jack pine and aspen stands occur naturally, and can be managed on low to medium productivity with a dominant or co-dominant jack pine component as described below. However, these stands should be regenerated or converted to other cover types when the jack pine component reaches 40 to 70 years. As the jack pine component is very shade intolerant, even-aged management techniques must be used that leave very little residual overstory (i.e., clearcutting). Leaving a jack pine residual overstory is usually discouraged due to forest health concerns.

Jack pine-oak stands on dry, poor to medium quality sites typically contain northern pin oak, black oak and white oak. Red oak is also a common associate on medium quality sites. Stands are usually clearcut once the jack pine component is mature, and replanted with jack pine at 1,200 seedlings per acre. Rely on stump sprouting for regeneration of the oak component. On many sites, natural regeneration by itself is not usually reliable enough to produce fully stocked stands on these sites. However, natural regeneration has been successful on some sites in the western NLP with retention of 20 to 30 ft^2/acre oak, in combination with tree length skidding to scarify the site and help regenerate jack pine from cones dispersed from logging slash. Average annual snow depth may be a factor contributing to success on these sites.

Jack pine-aspen stands on very dry, poor quality sites (PVCd, PVE, PVDc, PVCx, PQE) often contain quaking aspen. These sites are often clearcut once the jack pine component reaches 40 to 70 years. The aspen usually regenerates via root sprouting in patches; jack pine can then be planted in the areas that are poorly-stocked, at stocking equivalent to 1,000 seedlings per acre.

Note that growth potential for quaking aspen on these sites is often poor, or at best fair, and form and stem quality also tend to be poor. When this is evident, these sites should be allowed to succeed to pure jack pine by using techniques that discourage aspen (i.e., not harvesting low quality clones).

Jack pine-aspen stands on dry to dry-mesic sites often contain bigtooth aspen. Aspen is usually well suited to these sites, and can be managed in mixture with jack pine by clearcutting when the stand reaches 40 to 70 years. The aspen will regenerate from root suckers; jack pine can then be planted in the poorly stocked areas at densities equivalent to 1,000 stems per acre.

4) How do I manage for mixed jack pine/conifer stands

Single-storied mixed conifer stands containing jack pine are often an acceptable management objective when they originate from natural regeneration. Natural mixed conifer stands can range from those with a minor but significant jack pine component to stands with a plurality of jack pine. For example, natural mixed jack pine-black spruce stands occur on moist sand soil sites in the marsh complexes in the EUP, where black spruce is often present as advanced regeneration. In these locations, scarification to enhance natural regeneration is often unnecessary due to the ideal moisture conditions (water tables within 1 foot of the surface).

Where jack pine forms a plurality, natural mixed stands should be managed on a 40 to 70 year rotation. The jack pine component should be harvested at maturity, and two or more regeneration alternatives may be available depending on the site. Upland sites could be converted to red and/or white pine via shelterwood or seed tree harvest systems, or the stand should be clearcut and regenerated with an objective to regenerate a mixed conifer stand dominated by jack pine. In this situation, clearcutting should be followed by trenching and planting, or on sites with adequate soil moisture or moderating lake effect, by scarification and direct or furrow seeding. Note that managers should avoid creation or perpetuation of 2-

storied hard pine stands (red, white and jack pine) due to the increased risk of sphaeropsis and jack pine budworm outbreak.

Natural jack pine-black spruce stands could be regenerated as mixed stands by clearcutting with retention of the black spruce component, relying on natural regeneration of the jack pine from cones in the slash. Alternatively, the site could be clearcut without retention to shift species dominance in the future stand toward jack pine.

Mixed **planted** stands of jack pine and other species in equal proportions should be avoided due to the poor success of these plantings on state forest lands and high cost of artificial regeneration. The lower stand values that result make artificial regeneration inefficient. Experience indicates that planting equal mixtures jack pine and red pine on state forest lands have higher mortality, disease, and poorer form and stem quality than single species plantings. Mixed red and jack pine planted stands often develop a 2-aged structure (or the appearance of one) due to differential growth rates, and jack pine's propensity to become suppressed by adjacent or over-topping competitors. As the stands mature, the jack pine component has high mortality from competition, disease and insect damage resulting in poorly stocked stands, and often poor form and stem quality develop in both species.

Instead, managers should rely on adjacent local seed sources or advanced regeneration to compliment planting of either jack pine or red pine. The stands that result are often dominated by the planted species, and contain a lesser component of other conifers. If local seed sources or advanced regeneration of other conifers are not present, a minor component of another species could be planted to increase biodiversity and help develop a future seed source, however, equal mixtures should be avoided.

5) How does stand structure and condition influence jack pine management?

About 50% of state forest jack pine is <30 years old, and about 74% is less than 50 years old (Figure 2.3.5). Little of the cover type (~18%) currently falls in age classes that could be considered over-mature (e.g., 60+ years old).

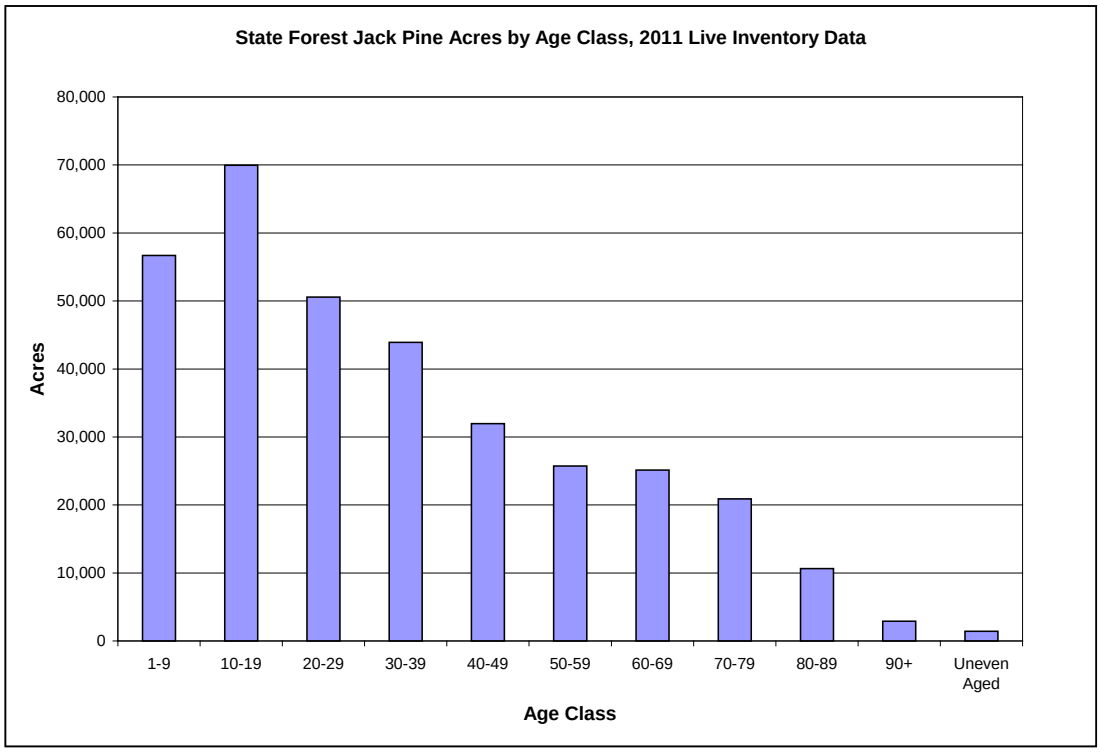

Figure 3.5 State Forest Jack Pine Acres by Age Class (Unpublished DNR Live Inventory Data, dated 8/31/2011).

Likewise, poorly stocked stands (stands <30 ft2 BA/acre at 40 years, or <60 ft2 BA/acre at 50 years) should be scheduled for early harvest, as they create conditions favorable to jack pine budworm outbreaks, and because they will not reach full stocking before normal rotation age Benzie 1977). The minimum and maximum recommended stocking is:

- Minimum for stands averaging:
  - 4 inches dbh = 600 trees and 50 ft^2 BA/acre
  - 12 inches dbh = 100 trees and 80 ft^2 BA/acre
- Maximum for stands averaging:
  - 5 inches dbh = 800 trees and 110 ft2 BA/acre
  - 9 inches dbh = 300 trees and 140 ft2 BA/acre

Two-aged and multi-aged jack pine stand structure should be avoided, as these structures favor budworm population buildup.

6) How do I manage old strip cuts or strip plantations?

Strip plantings are a legacy of past reforestation practices that are no longer recommended. Alternating narrow strips of jack pine and red pine were planted at the same time in the 1950's and 1960's. Often the jack pine would have high mortality, as a result of shading from the adjacent red pine, and poor form in the trees that survived. Narrow strip plantings should be avoided, as the open conditions and "wolfy" tree form in edge trees favor for budworm population outbreaks.

Managers should consider options to consolidate the strips in a new stand, by harvesting the adjacent red pine early along with the jack pine at 40 to 50 years, or by holding the jack pine stand until the adjacent red pine is mature (e.g., harvest at 80+ years). Consolidation is logistically desirable when preparing timber sales, and also from a forest health standpoint. Creation of 2-storied stands should be avoided to minimize the risk of sphaeropsis shoot blight related pine seedling mortality.

7) How do I convert jack pine to oak or mixed jack pine/oak stands?

On low productivity sites containing a mixture of northern pin oak, black oak and jack pine, consider clearcutting when the jack pine component reaches ages 40 to 70 years. Note that better advanced regeneration of oak may be obtained if the rotation is extended to the upper end of this range. Rely on oak stump sprouts and the release of any advanced oak regeneration to regenerate the site. On dry sites, utilize a whole tree chipping harvest, followed by trenching and planting of jack pine seedlings in any resulting under-stocked areas. A mixed oak-jack pine stand will result, hopefully dominated by oak.

On higher productivity sites, follow the recommendations in the oak silvics & management guidance.

8) How do forest health considerations influence management?

Appendix A includes a comprehensive list and brief description of forest health problems affecting jack pine. However, the most significant agents of mortality are jack pine budworm and Ips bark beetles. Risks of infestation can be mitigated by:

- Generally scheduling stands for final harvest at ages 50 to 69, and closer to 50 in high risk areas. As a rule of thumb for high-risk areas, stands should be harvested at age (Site Index – 5 years).
- Avoiding heavy slash accumulation and decking freshly cut wood during May through mid-July.
- Avoiding creation of poorly stocked stands, since they are at higher risk of budworm attack. In high risk areas for budworm, consider replanting young stands, and consider harvesting older stands that have become poorly stocked.
- Avoid creation of two-aged stands in high risk areas – do not use shelterwood or seed tree regeneration techniques in these areas, and limit retention for biodiversity purposes.
- Monitoring jack pine plantations adjacent to high-risk jack pine stands for budworm activity. Defoliation can destroy a higher percentage of needles on small trees than on mature trees, leading to top kill or mortality after just one event.

9) How do I determine rotation age?

Typical biological rotation ages for jack pine range from 40 to 70 years, with 60 years being the standard DNR recommendation. Most stands will be managed for pulpwood production; cordwood mean annual increment (MAI) peaks as early as 40 years in dense stands on good sites. Stands on better sites (SI > 60) may also be managed for poles or small sawtimber in rotations up to 70 years.

10) How do I improve jack pine stand or average stem quality over time?

Jack pine's great genetic diversity makes it possible to improve average stem quality and form in stands over time by selective retention of the better formed individuals as seed trees, where stand and site conditions are conducive to regeneration via seed tree or shelterwood harvest systems. In these situations, bushy or poorly formed stems can be removed during the shelterwood or seed tree harvest, in conjunction with scarification via whole-tree skidding or anchor chain scarification after the timber sale is complete.

However, for most stands, any improvement in the future stand will have to be achieved by planting improved seedling stock originating from seed collected at DNR's jack pine seed orchards located at Wyman Nursery and Brighton Tree Improvement Center. At this time, stock from the current orchards appear to demonstrate a ~10% improvement in diameter growth rate and volume.

11)How do I manage a stand for jack pine barrens?

Jack pine barrens historically occupied the poorest sites, and were maintained by periodic severe and low intensity wildfire. Barrens were predominantly grassland, mostly poorly stocked or unstocked, with a minor component of scattered jack pine and other tree species. Potential Pine Barrens sites include areas where:

- barrens are currently present, or
- barrens have historically occurred, and it is desirable to restore them. Typically, these sites occur on the following habitat types (Burger & Kotar, 2003):

Table 3.4 Typical Habitat Types Associated with Pine Barrens. (DNR Published Draft Guidance)

NLP	EUP	WUP
PVCd	PVE	PQE
		PVCx
		PVDc

Historic disturbance regimes should be mimicked using prescribed fire, timber harvests, and modified wildfire suppression tactics. Low intensity prescribed fire should be used to mimic ground fire return intervals of 15 to 50 years. Stand replacing fires should be mimicked at 50 to 60 year intervals using high intensity prescribed fire (primarily on grass-dominated sites) or timber harvests followed by prescribed burns. Replication of stand replacing fire on medium- to fully-stocked sites may only be an option in limited circumstances.

The size of historic disturbance patches to mimic using timber harvests or prescribed fire could range between a few acres and several thousand acres. If historic wildfire disturbance is mimicked using prescribed fire or timber harvests, patch sizes should generally range between 20 and 200 acres.

Managers should attempt natural regeneration, using prescribed fire for site preparation, or scarification, if fire is not feasible. Monitor regeneration, and consider limited planting, if needed to maintain landscape-level ratios of fully stocked to poorly stocked stands.

In practice, convert stands to grass and sedge dominated cover type, with a few scattered individual stems and clumps of jack pine:

- Final harvest with retention of an average of 8 trees per acre, arranged in scattered clumps.
- Use prescribed fire and/or seeding to restore native grasses/sedge.
- Retain some snags.
- Encourage representation of other overstory species of importance by retaining some red pine, white pine, pin oak, pin cherry, and aspen, if present.
- Scarify sites during harvesting via whole tree skidding, or if that is not possible, prescribe scarification using anchor chains within 2 years of sale completion.
- Prescribed burn, or scarify to facilitate natural regeneration at ~50-year intervals thereafter to maintain the jack pine component.
- Other low-intensity prescribed burns may be necessary to maintain the grass and forb components.

12)How do I manage stands for Kirtland's warbler habitat?

Currently, about 25% of state forest jack pine is managed for Kirtland's warbler (KW) (~87,000 acres, per unpublished inventory data from August 2011). Currently, all of the KW jack pine is located in the NLP, where it comprises ~40% of the jack pine on state forest. Age-class distribution of KW jack pine does not differ significantly from non-KW jack pine, state forest-wide or by region (Figure 3.6).

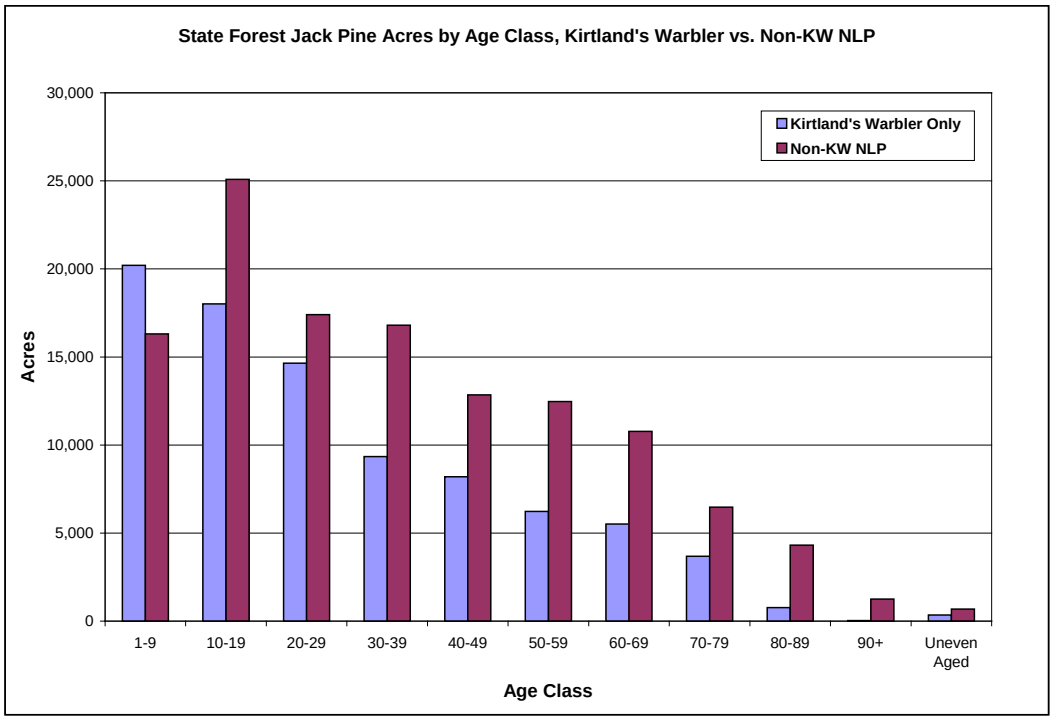

Figure 3.6 NLP State Forest Jack Pine Acres by Age Class for Kirtland's Warbler (KW) vs. Non-KW Areas (Unpublished DNR inventory data).

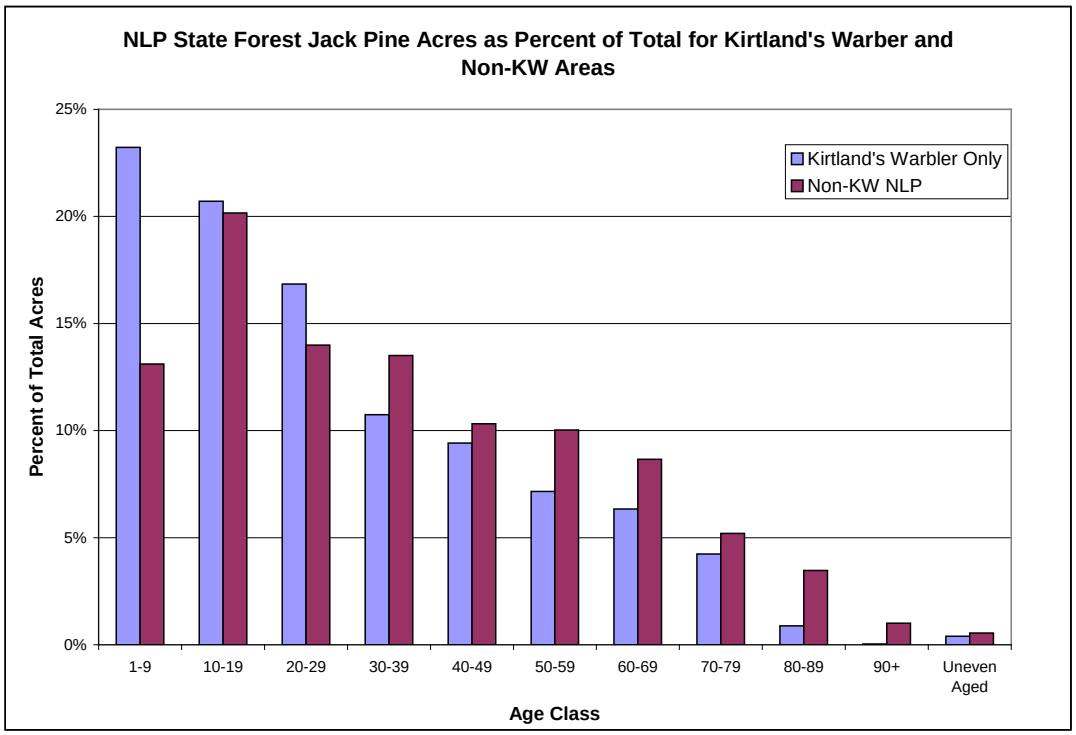

Figure 3.7 NLP State Forest Jack Pine Acres as Percent of Total for KW vs. Non-KW Areas (Unpublished DNR inventory data).

Stands have been generally managed on a 50-year rotation in large (>200 acre) blocks. Most stands will be regenerated by trenching and planting at ~1,200 seedlings per acre, following the "weave" pattern to simulate the openings that would have occurred as fire skips under the historic catastrophic wildfire disturbance regime. To improve merchantability and/or reduce cost, other plantings and treatment options will be tried. See the Kirtland's Warbler Management Guidelines for more information at (from the Michigan DNR intranet page, search for "Kirtland's warbler"):

http://michigan.gov/dnr/0,1607,7-153-10370_12145_12202-32591--,00.html

13) How do I enhance wildlife habitat and biodiversity in other jack pine stands?

Jack pine provides important habitat for the KW and many other species. Guidance for management of jack pine at the landscape scale has been included in the Regional State Forest Management Plans (RSFMP) for each Management Area (MA). Staff should consult their local biologist and review the guidance pertaining to wildlife habitat in the RSFMP MA summaries. The Within-Stand Retention Guidance (Michigan DNR 2012) provides recommendations for enhancing biodiversity and wildlife habitat at the stand level in the jack pine cover type.

For stands to be converted to jack pine barrens dominated by sedge and prairie grasses, see the MNFI community abstracts for more information on restoration and maintenance of barrens habitat at:
http://web4.msue.msu.edu/mnfi/abstracts/ecology/Pine_barrens.pdf

14) How do nutrient management concerns influence management?

Nutrient management concerns in jack pine appear to be less of a concern than in other cover types, such as aspen. Jack pine appears to accumulate lower nutrient concentrations in foliage, branches, bark, and bole wood than aspen and red pine (Perala and Alban, 1982). Calcium is often a focus in discussions on potential nutrient depletion resulting from harvesting as a nutrient most likely to be depleted in the northeastern U.S. (Federer et. al. 1989). Nutrient budgets for calcium in jack pine in Wisconsin indicate neutral or slight positive balances for rotations longer than 40 years, based in part on this apparent low nutrient demand, Wisconsin soil nutrient capital, and assumed nutrient input rates from weathering and precipitation (WDNR 2008). Consequently, WDNR does not restrict biomass harvesting for jack pine in its woody biomass harvesting guidance.

However, researchers studying northern Ontario jack pine have concluded that there may be concern for potential nutrient depletion in jack pine, if nutrient budgets do not take mineral soil nutrient capital into account (e.g., depletion of mineral soil resources could be considered mining). Kopra and Fyles (2005) have estimated replacement times of 87 to 125 years for calcium removed in bole wood only vs. whole tree harvests.

Michigan DNR Woody Biomass Harvesting Guidance generally recommends retention of 1/6 to 1/3 of the tops of harvested trees, but allows an exception for jack pine. In jack pine stands, less than 1/6 of the tops may be retained, particularly where sites will be regenerated via planting. However, for stands prescribed for natural regeneration, managers should consider harvesting methods, equipment and timing to ensure that enough cones remain scattered on-site on retained slash or as seed trees to produce a fully stocked stand.

15)How do climate change considerations influence management?

Projected climate change impacts on the jack pine forest type were uncertain as of this writing, and management guidance will be developed in future silviculture guidance revisions.

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Appendix A. Forest Health Issues for Jack Pine

Other typical agents of damage affecting jack pine include fire, drought, browse by ungulates and rodents, shoot and needle feeding insects, fungi, and cone and seed damaging agents. These agents can cause significant damage, but less frequently wide-spread mortality in stands.

Fire Damage: Jack pine stands of all stages of development are damaged by fire. Young jack pine are especially susceptible to early spring fires.

Drought: Severe drought may kill many seedlings, particularly on coarse soils. Mortality is most pronounced on sites where the water table is greater than 6 feet deep during the growing season.

Browse: Heavy populations of white-tailed deer can kill young jack pines up to 2.1 m (7 ft) tall, retard total height growth to 1/2 its potential, and deform trees so they have little future value for timber products. Snowshoe hares sometimes severely damage jack pine reproduction, particularly in dense stands in trees less than 4 cm (1.5 in) dbh. Porcupines can cause extensive damage in older stands.

Shoot and needle feeding insects: The white pine weevil (Pissodes strobi) attacks and destroys the terminal and upper whorls of young jack pine in Michigan. Repeated attacks slow growth and can affect form, but trees can outgrow the damage by the time they reach pole-size. When average terminal diameter exceeds 1 inch, incidence and severity of attacks decrease significantly. The jack pine tip beetle (Conophthorus banksianae) causes extensive shoot tip mortality, preferring sapling-size trees, but rarely causes serious growth loss or damage. Several sawflies attack jack pine, including redheaded pine sawfly (Didiprion lecontei). Trees often die or are top-killed because the sawflies feed on both old and new needles. Diplodia shoot blight (Diplodia pinea) frequently results in a shoot blight of jack pine under nursery conditions or in plantation jack pine suffering drought stress, hail damage or other stressors. Two-storied stands or young plantations adjacent to mature jack or red pine stands are at highest risk because the disease builds up on female cone scales. Sirococcus shoot blight (Sirococcus strobilinus) has caused seedling losses in Michigan's UP. Scleroderris canker (Gremmeniella abietina) causes serious losses in young plantations along Lake Superior in the central UP.

Rusts, Root and Stem Decay Fungi: The pine-oak (eastern) gall rust (Cronartium quercuum) may infect up to 50% of young jack pine in plantations or natural stands, killing branches, or when galls occur on the main stem, entire branches. This disease is heaviest in stands or plantations with an oak component, which the fungus requires as a host for part of its life cycle. In recent years, the pine-to-pine (western) gall rust (Endocronartium harknessii) has been found throughout the Lake States in young jack pine stands. This species does not require an alternate host.

The major root-rot fungi include the shoestring fungus (Armillaria mellea) and annosum root rot (Heterobasidion annosum). The principal wood decay organisms are Phellinus pini, Phaeolus schweinitzii, and Fomitopsis pinicola.

Cone Damaging Agents: Red squirrels and other rodents destroy cones and consume seeds. Low-vigor trees may produce much pollen, but little seed. Pine-oak (eastern) gall rust damages trees resulting in smaller and aborted ovulate cones. Birds may be important consumers of jack pine seeds that fall to the ground or are directly sown. Cone and seed insects may cause serious losses. In one study in northeastern Wisconsin, numerous insect species were found attacking conelets and cones. The jack pine budworm (Choristoneura pinus pinus) destroyed 12% of the conelets. The most prevalent insect attacking cone was the cone borer (Eucosma monitorana) which killed 10% of the cones. Other insects responsible for a total of about 4% cone mortality were the webbing coneworm (Dioryctria disclusa), red pine cone beetle (Conophthorus resinosae), jack pine budworm, and cone midges (Lestodiplosis graddator, Resseliella silvana, and Asynapta hopkinsi).

Appendix B: Site Index Curve for Jack Pine in the Lakes States (Carmean et. al. 1989)

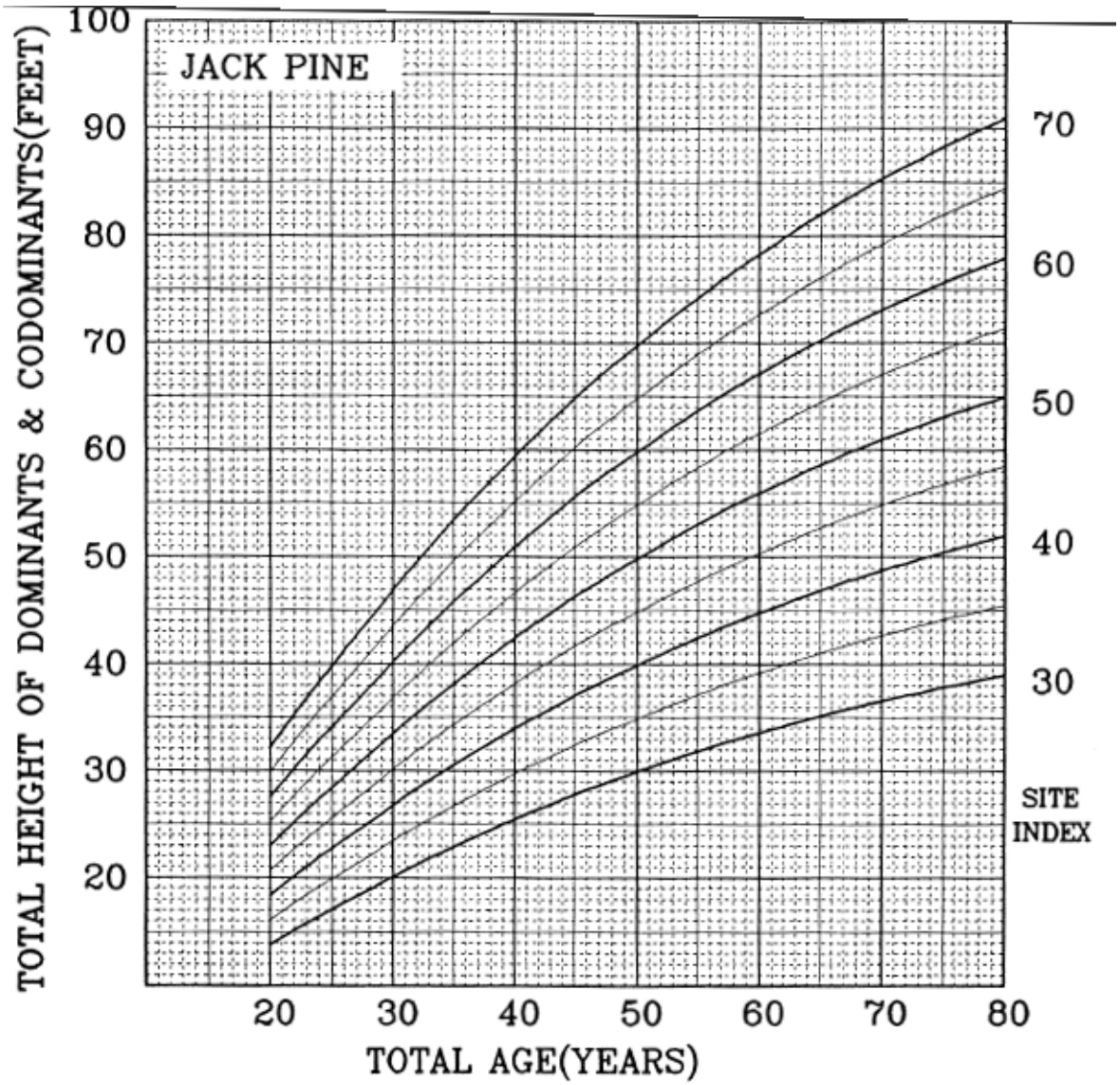


Figure 74.—Jack pine (Gevorkiantz 1956c, derived from Wackerman *et al.* 1929, and from Eyre and LeBarron 1944)
Lake States
Number of plots and number of dominant and codominant trees not given
Total height and total age, anamorphic, equation not given
Convert d.b.h. age to total age by adding years according to site index (BH = 0.0):

SI:	30	40	50	60	70	80	90
Years:	9	8	7	6	5	4	4

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
H	1.6330	1.0000	-0.0223	1.2419	0.0000	0.99	0.50	1.1
SI	0.6124	1.0000	-0.0223	-1.2419	0.0000	0.99	0.50	1.1

Figure 3.8 Site Index for Jack Pine in the Lake States (Carmean et. al. 1989).

Appendix C. Regeneration Option Flowcharts for Jack Pine on State Forest Lands

Regeneration options are summarized conceptually in the 6 flow charts that follow. The first flowchart, Figure 2.3.8, serves as a key partitioning recommendations by specific habitat type/site moisture class groups. Recommendations for each habitat type group/site moisture class are described in further detail in Figures 2.3.9 to 2.3.13.

Jack Pine Regeneration Option Flow Charts:

Figure 3.9 Key for habitat type groups/site moisture classes
Figure 3.10 Low-productivity, dry sites
Figure 3.11 Medium productivity, dry sites
Figure 3.12 High productivity, dry sites
Figure 3.13 Moist sites and lake effect zones
Figure 3.14 Wet sites

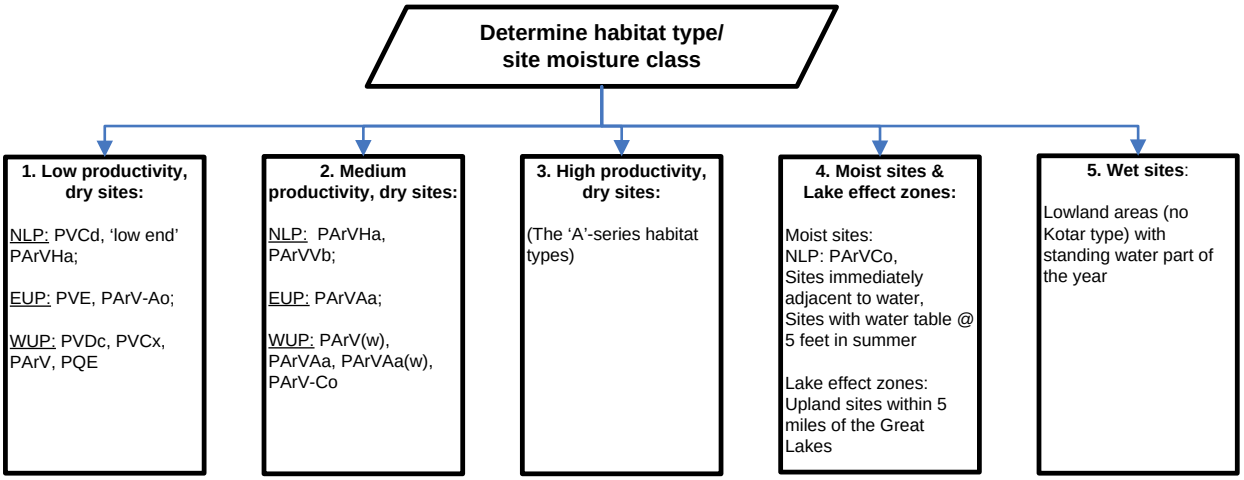
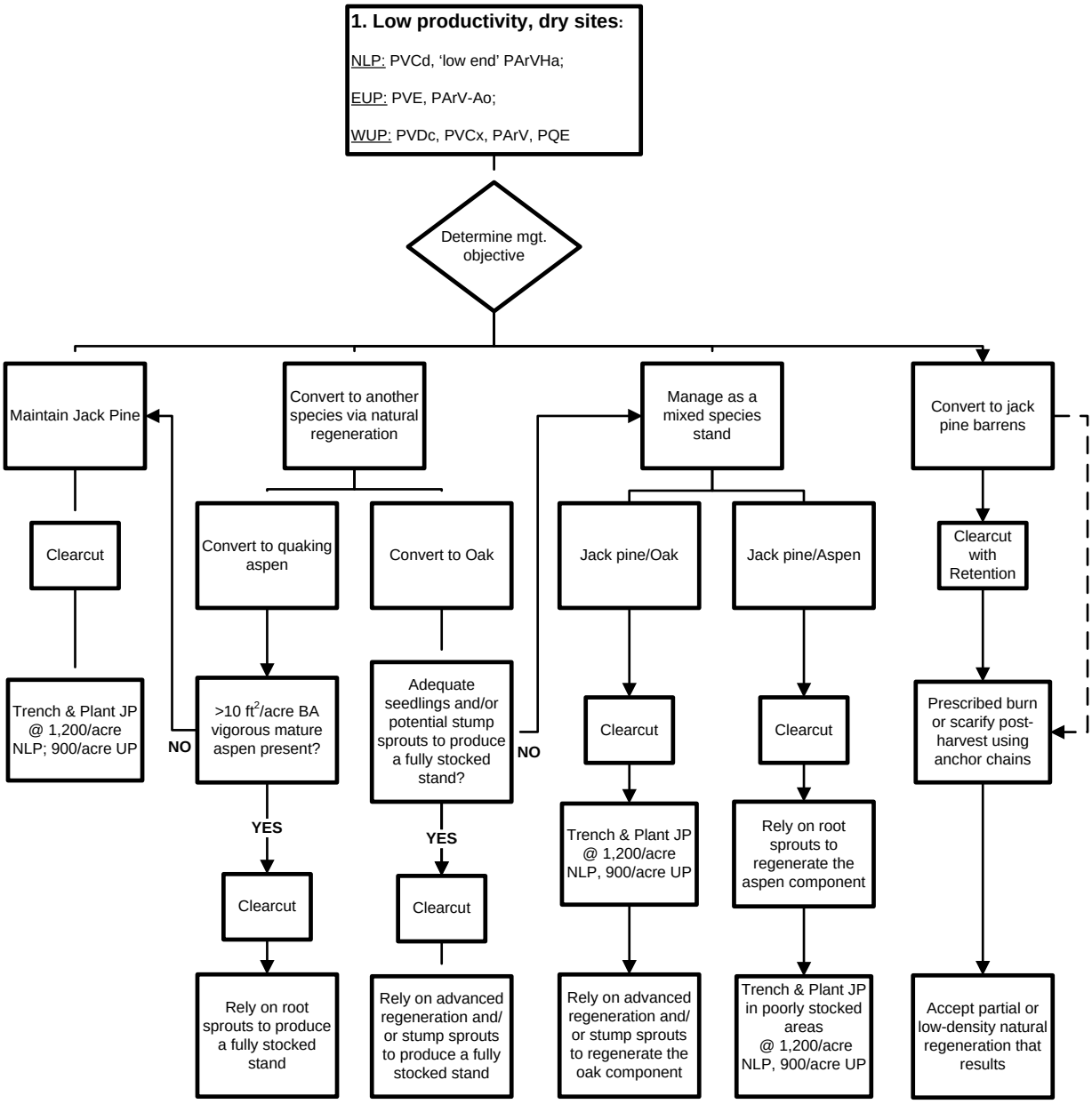


Figure 3.9 Key for Habitat Type Groups/Site Moisture Classes.

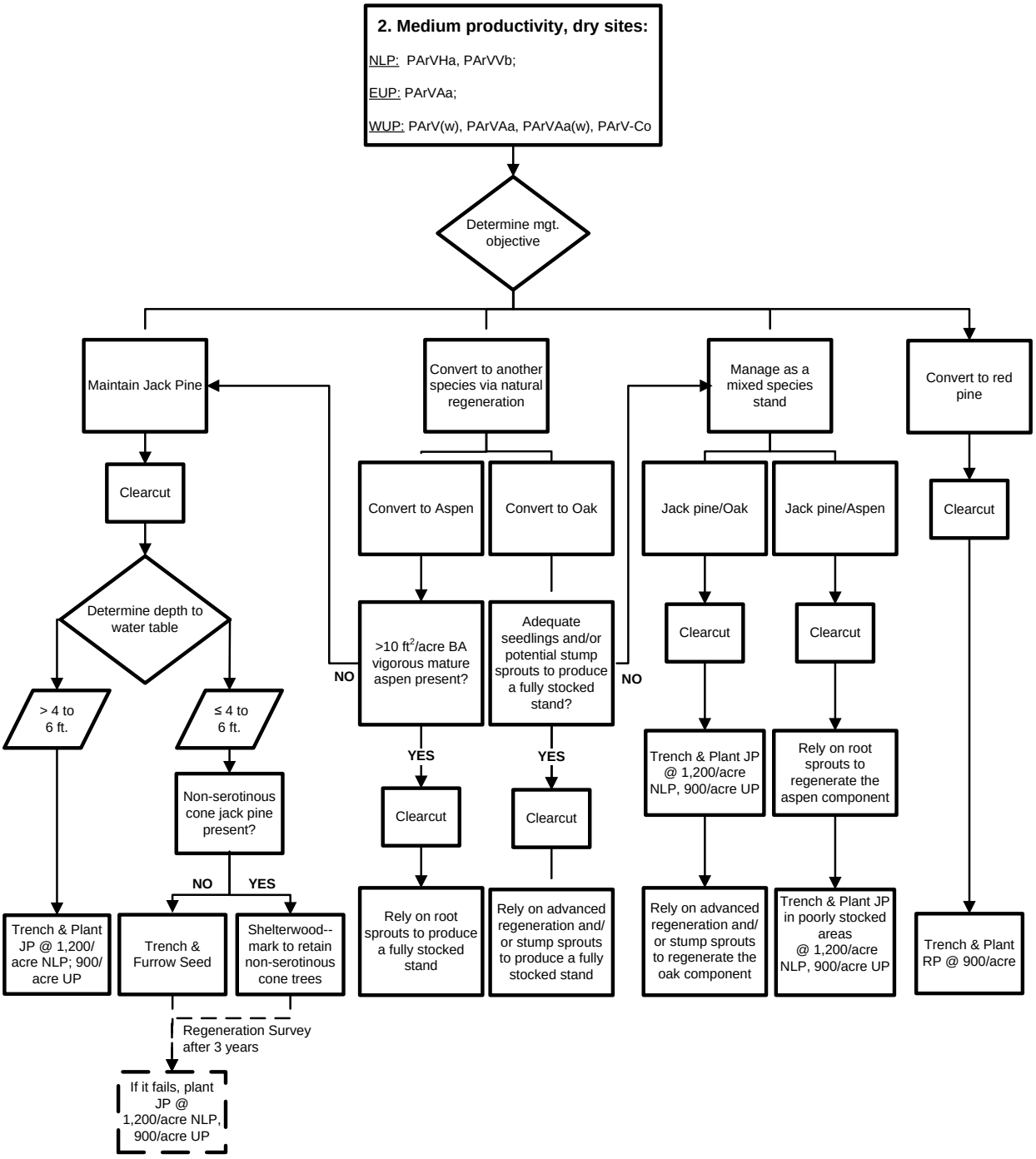
See the corresponding flow chart for a conceptual description of recommended regeneration treatments by habitat type/site moisture class.



NOTE: Type of ground cover is not as important on these very dry sites.

Also, aspen tends to have poor growth potential, form, and quality on these sites. An argument can be made in favor of letting it senesce on these sites, and replant jack pine.

Figure 3.10 Low Productivity, Dry Sites.



NOTE: Type of ground cover is not as important on these sites. Bigtooth and quaking aspen are often well suited to these sites and can be an alternative to jack pine. However, 'low end' PArVHa in the NLP is not as good a site for quaking aspen.

Red pine is also grows well on these sites and is also an alternative to jack pine.

Figure 3.11 Medium Productivity, Dry Sites

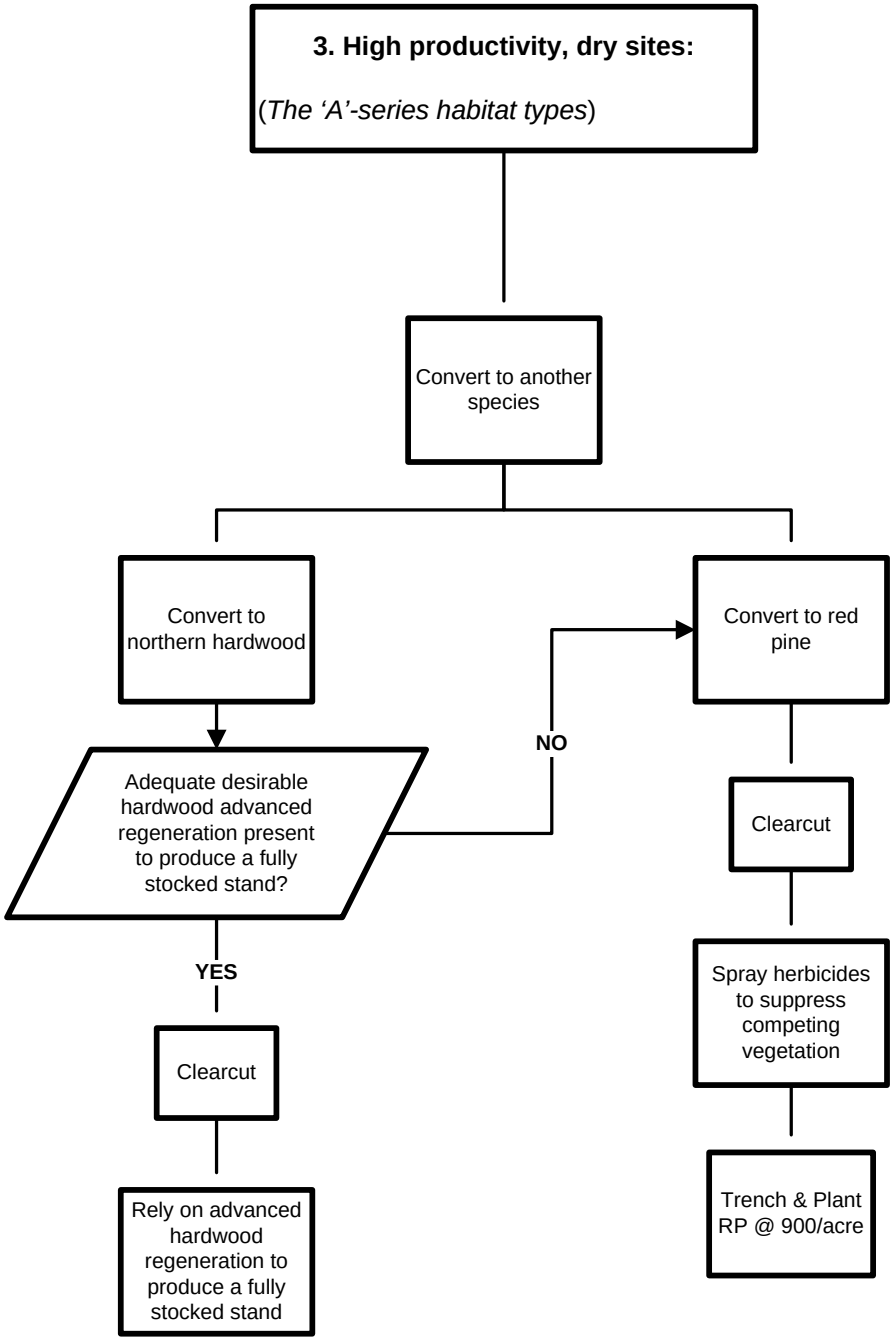


Figure 3.12 High Productivity, Dry Sites.

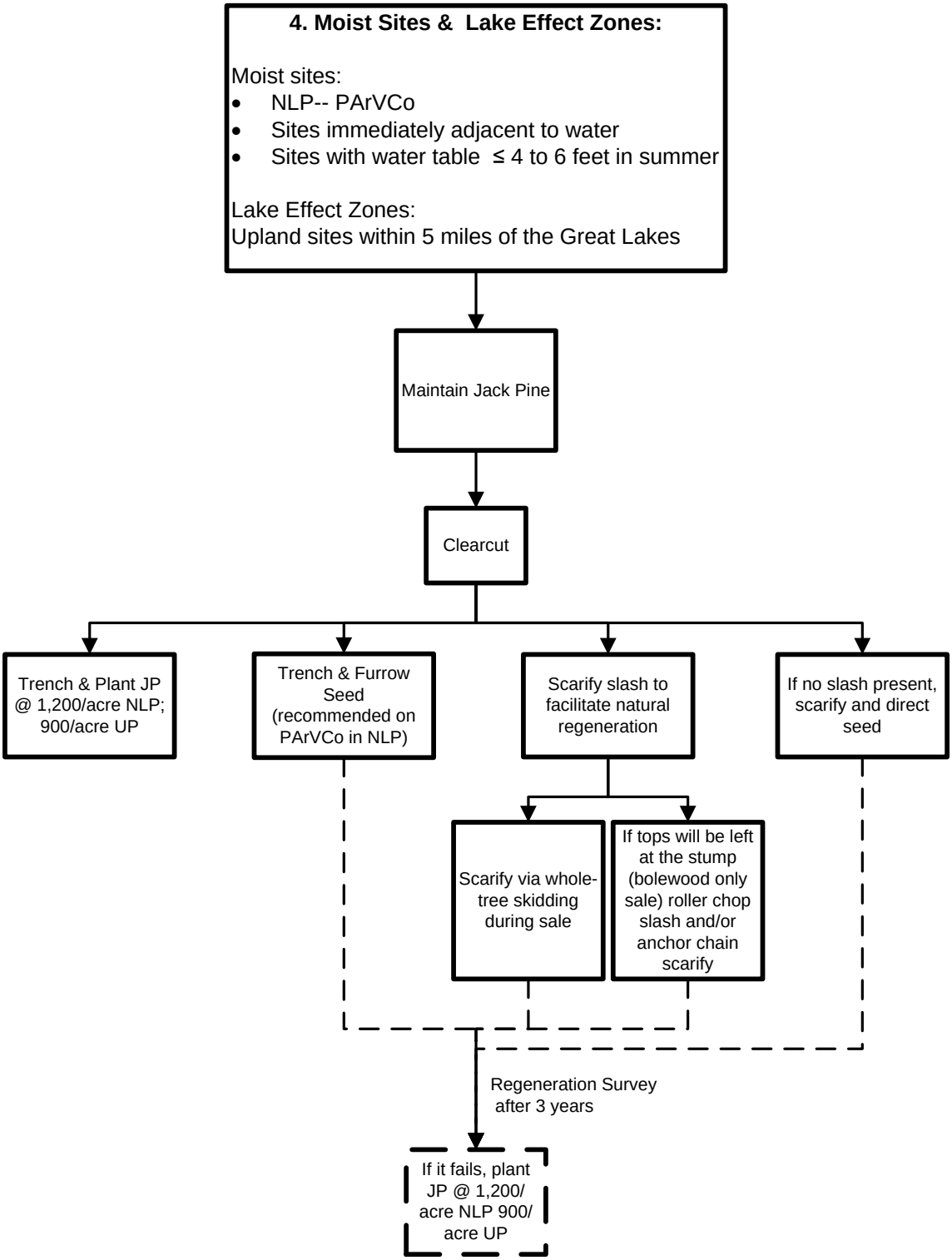


Figure 3.13 Moist Sites & Lake Effect Zones.

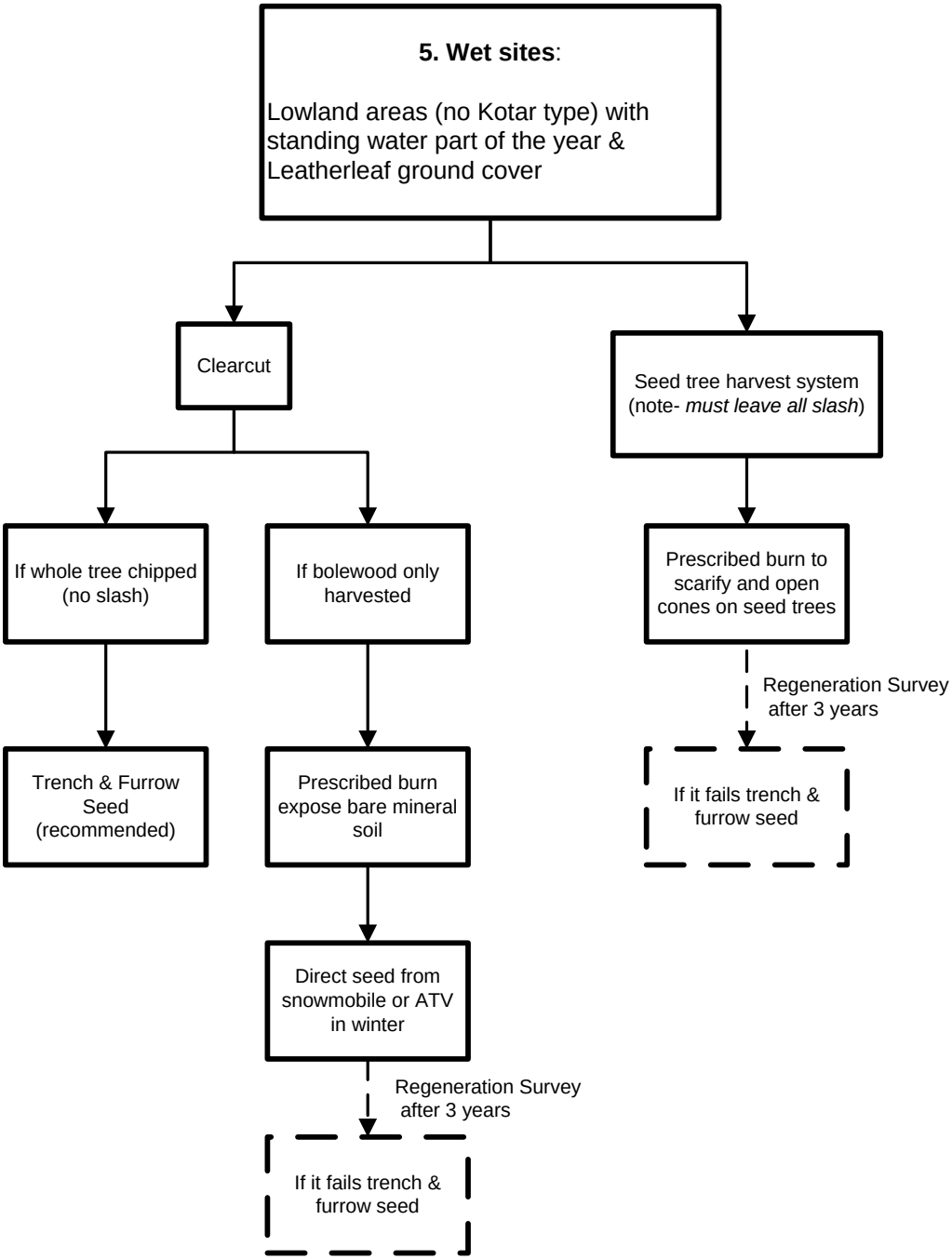


Figure 3.14 Wet Sites

Appendix D: Common and Scientific Names for Species Cited

Common Name	Scientific Name
Trees	
bigtooth aspen	Populus grandidentata
black oak	Quercus velutina
black spruce	Picea mariana
jack pine	Pinus banksiana
northern pin oak	Quercus ellipsoidalis
oak	Quercus spp.
paper birch	Betula papyrifera
red maple	Acer rubrum
red oak	Quercus rubra
red pine	Pinus resinosa
trembling aspen	Populus tremuloides
white oak	Quercus alba
white pine	Pinus strobus
Shrubs	
blueberry	Vaccinium spp.
leatherleaf	Chamaedaphne calyculata
Forbs	
Canada rice-grass	Oryzopsis canadensis
pale agoseris	Agoseris glauca
rough fescue	Festuca scabrella
sedge	Carex spp.
Animals	
black bear	Ursus americanus
black-backed woodpecker	Picoides arcticus
golden-crowned kinglet	Regulus satrapa
Kirtland's warber	Dendroica kirtlandii
northern flicker	Colaptes auratus
pine siskin	Carduelis pinus
prairie warbler	Dendroica discolor
red crossbill	Loxia curvirostra
red squirrel	Tamiasciurus hudsonicus
red-backed vole	Myodes spp.
snowshoe hare	Lepus americanus
spruce grouse	Falcipennis canadensis
white-footed mouse	Peromyscus leucopus
whitetailed deer	Odocoileus virginianus

Common Name	Scientific Name
Insects	
cone borer	Eucosma monitorana
cone midge	Lestodiplosis graddator
cone midge	Resseliella silvana
cone midge	Asynapta hopkinsi
dusted skipper	Atrytonopsis hianna
Great Plains spittlebug	Lepyronia gibbosa
ips bark beetle	
jack pine budworm	Choristoneura pinus pinus
jack pine tip beetle	Conophthorus banksianae
persius duskywing	Erynnis persius
red pine cone beetle	Conophthorus resinosae
red-headed pine sawfly	Didiprion lecontei
webbing coneworm	Dioryctria disclusa
white pine weevil	Pissodes strobi
Fungi	
pine-oak gall rust	Cronartium quercuum
root rot	Phellinus pini
root rot	Phaeolus schweinitzii
root rot	Fomitopsis pinicola
Scleroderris canker	Gremmeniella abietina
shoestring fungus	Armillaria mellea
Sirrococcus shoot blight	Sirococcus strobilinus
sphaeropsis	Diplodia pinea
western gall rust	Endocronartium harknessii