Chapter 41

Oak Cover Type

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1 TYPE DESCRIPTION

1.1 Stand Composition and Associated Species

Stand composition
Oak comprises 50% or more of the basal area in poletimber and sawtimber stands, or 50% or more of the stems in seedling and sapling stands. The five common upland oak species are: northern red oak (*Quercus rubra*), white oak (*Q. alba*), bur oak (*Q. macrocarpa*), black oak (*Q. velutina*), and northern pin oak (*Q. ellipsoidalis*). For information on swamp white oak (Q. *bicolor)*, see Bottomland Hardwood Cover Type Chapter 47.

Associated species
Overstory and understory composition of oak dominated communities varies significantly between southern and northern Wisconsin. Within each region, composition also varies across the range of sites where oak forests occur, from dry to mesic to wet. For each of the following site types, typical oak forests are described in terms of dominant trees and principal associates. These descriptions of characteristic overstory associations are derived primarily from analysis of Forest Inventory and Analysis (FIA) data (Schmidt 1997, Kotar et al. 1999) and the Forest Habitat Type Classification System (FHTCS – see Section B).

1.2 Silvical Characteristics

The primary source for the following descriptions and tabular summary is from *Silvics of North America* (Burns and Honkala 1990). Other sources: *The Ecology and Silviculture of Oaks* (Johnson et al. 2002), *Trees and Shrubs of the Upper Midwest* (Rosendahl 1955), and *North American Trees* (Preston 1976).

1.2.1 Black Oak

Flowers and fruiting
Black oak catkins emerge before or at the same time as the leaves in April or May. Black oak can hybridize with northern pin and red oak. Acorns occur singly or in clusters of 2-5, are about one-third enclosed in a scaly cup and mature in two years. Black oak acorns are brown when mature and ripen from late August to late October, depending on geographic location. It is a consistent seed producer with good crops of acorns every 2 to 3 years.

Germination
Black oak acorns germinate in the spring following seed fall. The most favorable conditions for germination occur when the acorns are in contact with or buried in mineral soil and covered with a light layer of litter. Acorns on top of the litter generally dry excessively during early spring and lose viability before temperatures are favorable for germination.

Seedling development
After harvesting, black oak seedlings will be present in approximately the same numbers as in advance reproduction prior to harvesting. New seedlings established at or just after harvest typically grow too slowly to compete with sprouts of other tree species and other vegetation.

Light intensity is critical to the survival and growth of black oak seedlings. Light intensity under undisturbed forest stands is often very low at the height of the new seedlings (about 6” high). Even-aged silvicultural systems satisfy the reproduction and growth requirements of black oak better than uneven-aged selection systems. Under the selection system, black oak is unable to reproduce because of inadequate light.

Black oak seedlings seldom remain true seedlings for more than a few years because drought, low light intensity, fire, animals, or mechanical agents kill the tops. Then dormant buds near the root collar produce new sprouts. The dieback and re-sprouting process can occur several times; thus the roots of black oak saplings may be 10 to 20 years older than the tops. If environmental conditions are favorable, these root systems can support rapid shoot re-growth when the shoots are broken off. Growth of black oak sprouts, like that of seedlings, is slow under forest canopies.

Vegetative reproduction

Small stumps of young trees on good sites (dry-mesic to mesic) sprout most frequently and large stumps of old trees on poor sites (dry) sprout least frequently. The probability a stump with a living 1-year old sprout will have at least one dominant or codominant sprout at 5 years is predictable based on stump diameter. It ranges from near 100% for 3” stumps to about 15% for 30” stumps (41.10).

Growth and development

Black oak is intermediate in shade tolerance. Seedlings usually die within a few years of establishment under closed canopies. Most black oak sprouts in mature stands develop crooked stems and flat-topped or misshapen crowns. After the overstory is removed, only the large stems are capable of competing successfully. Seedlings are soon overtopped. The few that survive usually remain in the intermediate crown class.

Fire

Wildfires damage black oak trees by killing the cambial tissue, creating an entry point for decay with the result of volume loss due to heart rot. Trees up to pole size are easily killed by fire, and severe fires may kill sawtimber. Many of the killed trees sprout and form a new stand, giving black oak a competitive edge over other tree species that do not readily sprout after a fire (Sander: Burns and Honkala, 1990).

Longevity

Black oak grow to heights of 60-80 feet, up to 24” to 36” dbh, become physiologically mature (the stage prior to the beginning of senescence) at about 100 years of age, with some living to 200 years.

1.2.2 Bur Oak

Flowers and fruiting

Bur oak flowers shortly after the leaves appear in mid-late May in Wisconsin. Pollen from one tree appears to germinate better on the stigmas of another, favoring cross pollination. Acorns ripen within the year and drop from the tree as early as August or as late as November.

Germination usually occurs soon after seed fall, but acorns of northern trees may remain dormant through winter and germinate the following spring.

Bur oaks up to age 400 years bear seed, older than reported for any other American oak. Good seed crops occur every 2 to 3 years, with no crops or light crops in intervening years.

Germination
Germination of acorns and early development of bur oak are often best where litter has been removed. When covered by litter, acorns are more susceptible to pilferage by rodents and the newly developed seedlings are more likely to be attacked by fungi and insects.

Seedling development
Root growth of juvenile bur oaks is rapid, and the taproot penetrates deeply into the soil before the leaves unfold. At the end of the first growing season, bur oak roots have been found at depths of 4.5 ft., with a total lateral spread of 30 inches. This strong early root development, along with high water-use efficiency, may explain why bur oak can pioneer on droughty sites and can successfully establish itself in competition with prairie shrubs and grasses.

Vegetative reproduction
Vigorous sprout growth follows the burning or cutting of pole-size or smaller bur oaks. Except for seedling sprouts, the quality and form of sprout stems are poor. In northwestern Wisconsin, bur oak often breaks bud before the last spring frosts, resulting in development of a shrubby form of the tree.

Growth and development
Bur oak is intermediate in shade tolerance. Bur oak is slow growing. In 12- to 16-year-old plantations on Iowa upland sites, average annual height growth ranged from 0.3 to 1.7 ft. and diameter growth from less than 0.1-0.25”.

Flood tolerance
Bur oak is relatively tolerant of flooding, compared to the other oaks (except swamp white oak). In open bottom lands, reproduction of bur oak may be prolific, but first-year mortality may be 40-50% when seedling submersion continues for two weeks or longer during the growing season. Although bur oak seedlings can endure flooding for up to 30 consecutive days during the growing season, root growth is greatly reduced, thus reducing drought tolerance after flood waters have receded.

Longevity
Bur oaks generally grow to heights of 80-100 feet, can range from 36-48” dbh, and live for 200 to 300 years. Maximum individual tree longevity can be 500 years.

1.2.3 Northern Pin Oak

Flowers and fruiting
Northern pin oak flowers open when leaves are half developed. Acorns ripen the second season and are either solitary or in pairs. Acorns are ellipsoidal, light brown, and usually

striped with darker lines. The cup covers 33-50% of the acorn, with the cup scales closely appressed.

Growth and development
Northern pin oak is the most shade intolerant of all the oaks and cannot reproduce in shade. Northern pin oak can hybridize with black and red oak. Growth form can be almost shrub-like where stems are frequently damaged from fire, frost, or browsing. Sprouts from smaller diameter stumps are prolific. Northern pin oak is distributed throughout the state and is frequently associated with jack pine in the north. It is common, and, in places, abundant on acid, sandy soils.

Northern pin oak reaches seed bearing age at about 20 years with optimum seed bearing at 40- 50 years, producing good seed crops every 2-4 years. It reproduces vegetatively by sprouting prolifically from stumps of cut trees or root collars of top killed trees.

Vegetative reproduction
Sprouts are an important component of the regeneration of northern pin oak. This species will produce a vigorous sprout nearly 100% of the time on small diameter stumps (< 4”) and very large diameter stumps (>18”) will produce sprouts up to 70% of the time. On average, 85% of all northern pin oak stumps will sprout (Mujuri and Demchik 2009).

Fire
The thick bark of older trees (>10 dbh) minimizes fire damage. Smaller trees are easily damaged by surface fires but commonly sprout vigorously from the root collar after top-kill.

Longevity
The largest northern pin oak known in Wisconsin is 92’ tall with a dbh of 52”. The average longevity of northern pin oak is 80-100 years.

1.2.4 Northern Red Oak

Flowers and fruiting
Red oak flowers emerge before or at the same time as the leaves in April or May. The acorn occurs singly or in clusters of 2-5, is partially enclosed by a scaly cup, and matures in 2 years. Northern red oak acorns are brown when mature and ripen from September to late October, depending on geographic location.

Good to excellent seed crops are produced at irregular intervals, usually every 2-5 years. Acorn production is highly variable among trees even in good seed years. Some trees are always poor producers (<8 acorns/branch tip) while others are always good producers (>17 acorns/branch tip) (Grisez 1975). Crown size seems to be the most important tree characteristic affecting acorn production. Dominant or codominant trees with large, uncrowded crowns produce more acorns than trees with small, restricted crowns.

Germination

Even in good years only about 1% of the acorns become available for regenerating northern red oak due to predation by insects and animals. To produce one 1-year old seedling in unmanaged situations, 500 or more acorns may be required.

Best germination occurs when the acorns are in contact with or buried in mineral soil and covered by a thin layer of leaf litter. Acorns on top of the leaf litter or mixed with litter become excessively dry during early spring and lose viability before temperatures are favorable for germination. Management practices, such as scarification, that protect acorns and improve the germination environment can increase the percentage of acorns available to produce seedlings.

Seedling development

Germination is followed by vigorous and rapid taproot development, and if the taproot is able to penetrate the soil, seedlings survive considerable moisture stress later in the growing season. Northern red oak seedlings are the least drought tolerant of the oak species.

Growth and development

Northern red oak is intermediate in shade tolerance. “Light intensity appears to be the most critical factor affecting not only first year survival, but also survival and growth in subsequent years” (Sander: Burns and Honkala 1990). Northern red oak reaches maximum photosynthesis at about 30% of full sunlight. Light intensity under undisturbed forest stands, at new seedlings height, is often much lower and results in poor growth.

Where red oak receives adequate sunlight, it is among the fastest growing upland oaks, with average radial growth rates of 1-1.5”/decade (Johnson et al., 2002). Growth and development are best on mesic habitat types, where trees in excess of 150 years of age have been observed with radial growth rates in excess of 1”/decade**.** Red oak can hybridize with pin and black oak.

Conditions such as fire, poor light, poor moisture conditions, or herbivory can kill the tops, but the roots often survive. Dormant buds near the root collar can produce new sprouts. This dieback and resprouting may occur several times; the result can be a crooked, flat-topped, or forked stem. Such stems have root systems that may be 10 or more years older than the tops. When the tops are broken off (such as may occur during logging) during favorable environmental conditions for oak, the older, larger root system can support rapid shoot re-growth. Stem form can often be improved when this occurs.

Growth of northern red oak seedlings and sprouts is slow and generally restricted to one growth flush under undisturbed or lightly disturbed forest canopies.

Vegetative reproduction

Northern red oak stumps sprout more frequently than black oak or white oak stumps. Sprouting frequency is related to parent tree size with more small stumps sprouting than large ones. More than 60% of stumps from 11” dbh or smaller trees will sprout, while 30% of 17+” dbh trees will sprout (Sander 1977). Sprouting ability is also influenced by tree age. In studies of northern red oak, 93% of trees 50-60 years old had live sprouts, while live sprouts occurred on less than 60% of 80-110 years old trees (Johnson 1975, Wendel 1975). Sprouts of low origin are much less likely to develop decay than sprouts that originate high on the stump, but they may develop severe crook or sweep at the base.

Fire
"Wildfires seriously damage northern red oak by killing the cambial tissue at the base of trees, thus creating an entry point for decay-causing fungi. Wildfires can be severe enough to top kill even pole- and sawtimber-size trees. Many of the top-killed trees sprout and thus create new even-aged stands, but the economic loss of the old stand may be great. Small northern red oak seedlings may be killed by prescribed fires, but larger stems will sprout and survive, even if their tops are killed." (Sander: Burns and Honkala, 1990)

Longevity
Typical size at maturity on good sites is 65-100' tall and 24-36" dbh. Maximum tree size recorded in Wisconsin is 112' tall and 85" at dbh. Maximum individual tree longevity is 400 years.

1.2.5 White Oak

Flowers and fruiting
White oak flowers in the spring at about the same time leaves appear. The time may vary from late March to late May depending on latitude. Physiological maturity of acorns, as indicated by normal germination, is reached when acorns change color from green to light brown.

White oak can produce seeds prolifically, but frequency of good acorn crops is inconsistent and occurs only every 4 to 10 years. Several studies have shown that only a small portion of the total mature acorn crop (sometimes only 18%) is sound and fully developed; the remainder is damaged or destroyed by animals and insects so seedlings may be established only during heavy crop years.

Germination
Seeds germinate in the fall soon after dropping in September or October, requiring no pretreatment for germination. For germination to occur, the moisture content of acorns must not fall below 30-50%. Germination is favored at soil temperatures between 50° and 60° F. When acorns germinate, their roots begin to grow but the shoot remains dormant. This trait serves to protect it from damage by freezing. After germination, root growth continues until interrupted by cold weather. Broken radicles are replaced on freshly sprouted seeds. Root and shoot growth resumes in the spring, and after the first growing season, seedlings 3-4" high normally develop a large taproot 0.25 - 0.50" in diameter and more than 12" long.

Seedling development
Under ideal growing conditions it is common for individual seedlings to grow 2' or more per year. However, white oak seedlings germinated in the year of overstory removal normally grow slowly and are frequently outcompeted by other species, so they are of little value in stand reproduction.

Vegetative reproduction

Small white oak trees sprout prolifically and vigorously when cut, or damaged by fire. The ability to sprout depends on the dbh of the parent trees. Trees less than 5” dbh will sprout 80% of the time, 50% of the trees 6-11” dbh will sprout, and 15% or less of trees larger than 12” dbh will sprout.

Growth and development

White oak is intermediate in shade tolerance and the most tolerant of the oaks. It is most tolerant during youth and becomes less tolerant as the tree grows larger. It is common to find white oak seedlings accumulating to high densities in an understory over time. White oak seedlings, saplings, and even pole-size trees are able to persist under a forest canopy for more than 90 years periodically dying back and resprouting from the root system (Burns and Honkala 1990).

White oak is deep rooted, a trait that persists from youth to maturity. White oak seedlings produce a conspicuous, well-developed taproot which gradually disappears with age and is replaced by a fibrous root system with well-developed, tapered laterals. Fine roots are typically concentrated in dense mats in the upper soil horizons usually close to tree trunks but occasionally lying beneath the base of neighboring trees. Root grafts between white oak trees can occur, especially among trees within 50’of each other, although root grafting among the white oak group is less common than among the red oak group.

Longevity

Typical size at maturity on good sites is 80-100’ tall and 36-48” dbh. Maximum tree size recorded in Wisconsin is 98’ tall and 64” at dbh. Oaks in general and white oak specifically, are long-lived trees. Under ideal conditions, white oaks can live to 600 years of age (Rogers: Burns and Honkala, 1990).

Table 41.1. Summary of selected silvical characteristics.

Species	**Black oak**	**Bur oak**	**Northern pin oak**	**Northern red oak**	**White oak**
Flowers (All monoecious)	April-May	April-May	April-May	April-May	April-May
Seed Ripens	2nd year, Sept.-Oct.	1st year, Aug.- Nov.	2nd year, Sept.-Oct.	2nd year, Sept.-Oct.	1st year, Sept.-Oct.
No. seeds/lb.	245	75	245	105	215
Seed dispersal	Fall. Rodents and gravity. Blue jays at larger distances.	Fall. Rodents and gravity.	Fall. Rodents and gravity.	Fall. Rodents and gravity. Blue jays at larger distances.	Fall. Rodents and gravity.
Minimum Seed-Bearing Age	20 years	35 years	15 years	25 years	30 years

Species	**Black oak**	**Bur oak**	**Northern pin oak**	**Northern red oak**	**White oak**
Optimum seed-bearing age	40-75 years	75-150 years	40-50 years	50+ years	50-200 years
Good Seed Years	Every 2-3 years	Every 2-3 years	Every 2-4 years	Every 2-5 years	Every 4-10 years
Average Seed viability	47%	45%	95%	58%	50-99%
Cold Stratification	30-60 days @ 20-30°F	In Wisconsin: 30-60 days @ 33-40°F	60-90 days @ 34-41°F	30-45 days @ 32-41°F	None
Germination Temp.	65-80°F	60-80°F	30-60°F	>34°F	50-60ºF
Seedbed Requirements	Mineral soil with cover of light leaf litter	Mineral soil contact	Mineral soil contact	Mineral soil with cover of light leaf litter	Light to moderate leaf litter
Seed Germinates	Spring after seed fall	In Wisconsin, remain dormant until spring.	Spring after seed fall	Spring after seed fall	Immediately after seed fall
Seedling development	Rapid root growth. Slow shoot growth compared to competition. Growth under forested condition is slow.	Rapid root growth compared to shoot growth. Slow shoot growth	Rapid root growth. Slow shoot growth compared to competition. Growth under forested condition is slow.	Rapid root growth. Slow shoot growth compared to competition. Needs >30% of full sunlight.	Rapid root growth, shoot remains dormant until next spring. > 35% full sunlight for best growth.
Vegetative reproduction	Poletimber and smaller sized trees sprout readily. Sawtimber-sized trees sprout less frequently	Poletimber and smaller sized trees sprout readily. Sawtimber-sized trees sprout less frequently	Sprouts prolifically.	Poletimber and smaller sized trees sprout readily. Sawtimber-sized trees sprout less frequently	Poletimber and smaller sized trees sprout readily. Sawtimber-sized trees sprout less frequently
Shade Tolerance	Intermediate. Less tolerant than white oak	Intermediate	Intolerant	Intermediate. Less tolerant than white oak	Intermediate. Most tolerant as seedling.
Maximum individual tree longevity	200 years	500 years	Unknown	400 years	600 years

2 MANAGEMENT GOALS, LANDOWNER OBJECTIVES

Management objectives should be identified in accordance with landowner goals within a sustainable forest management framework, which gives consideration to a variety of goals and objectives within the local and regional landscape. The silvicultural systems described herein are designed to promote the optimum quality and quantity of oak timber products. High quality sawlog and veneer production is the objective for most sites of fair (dry-mesic) to excellent quality (mesic), while sites of poor quality (very-dry to dry) will be managed for optimum health and vigor. Modifying these silvicultural systems to satisfy other management objectives could potentially result in reduced vigor, growth and stem quality. The habitat type is the preferred indicator of site potential. Other indicators of site potential include site index, aspect, position on the slope, and soil characteristics. In addition to clearly identifying landowner goals and objectives, in-depth and accurate stand assessment will facilitate discussion of management options and objectives in relation to realistic and sustainable management goals. Oak stand assessment should include quantifying variables such as present species composition, stand structure, stand quality (present and potential crop trees), stand age, ground layer competition, site quality, and herbivory potential.

3 LANDSCAPE, SITE, AND STAND MANAGEMENT CONSIDERATIONS

3.1 Landscape Considerations

Oak forests provide significant ecological, economic and social benefits. Although these forests are still very common, an increase in oak acreage on dry sites has offset recent decreases on more productive, mesic sites. There are concerns that select red and white oaks are declining as components of Wisconsin's forests. Forest and Inventory Analysis (FIA) data show a decline in acreage of oaks in the youngest and oldest age and size classes. Landscape-scale considerations for the oak cover type include concerns for the decrease in oak species' dominance on dry-mesic and mesic sites, a lack of regeneration, and a decline in representation of older oak (>100 years old). Possible reasons include land and forest management goals/objectives/practices, altered disturbance regimes, and herbivory. Forest fragmentation is another concern because of impacts on ecosystem function.

3.1.1 Historical Context

When the General Land Office Public Lands Surveys (PLS) were conducted in Wisconsin (1832-1866), oak-dominated cover types occurred on about 10.8 million acres, including 5.0 million acres of oak forest primarily composed of black, white and bur oaks, as well as 2.4 million acres of scrub oak/jack pine forest and barrens, and 3.4 million acres of oak openings (Finley 1976). In addition, red, white, and black oaks were a significant component, particularly in southern and central Wisconsin, of northern hardwood forests dominated by beech or sugar maple. The historic predominance of oaks was likely due to several factors, including natural disturbances (e.g., fire, wind), and Native American land use practices, particularly burning (Abrams and Nowacki 1992).

In northern and central Wisconsin, oaks were commonly found in scrub oak/jack pine forests and barrens on sandy soils with a frequent and severe fire disturbance regime. Oak species also occurred as a component of northern hardwood and northern pine forest communities. In the northern hardwoods, the oak component is believed to have been maintained by localized fire disturbances. Fires were significantly less frequent on loamy moraines, where northern hardwoods typically dominate, than in sandy outwash areas (Radeloff et al. 2000**).** The oak component would have developed where fire regimes were of low to moderate intensity, such as in transitional areas between outwash and moraines, or where till materials are intermingled with outwash sands. Severe fires that originated in outwash sands would occasionally run for some distance into loamy moraines if driven by strong winds, particularly during periods of drought. Some fire occurrences within northern hardwoods were associated with blowdowns which ignited after fuels had dried. Fire disturbance exposed mineral soils for seed germination, and reduced competition for oak seedlings.

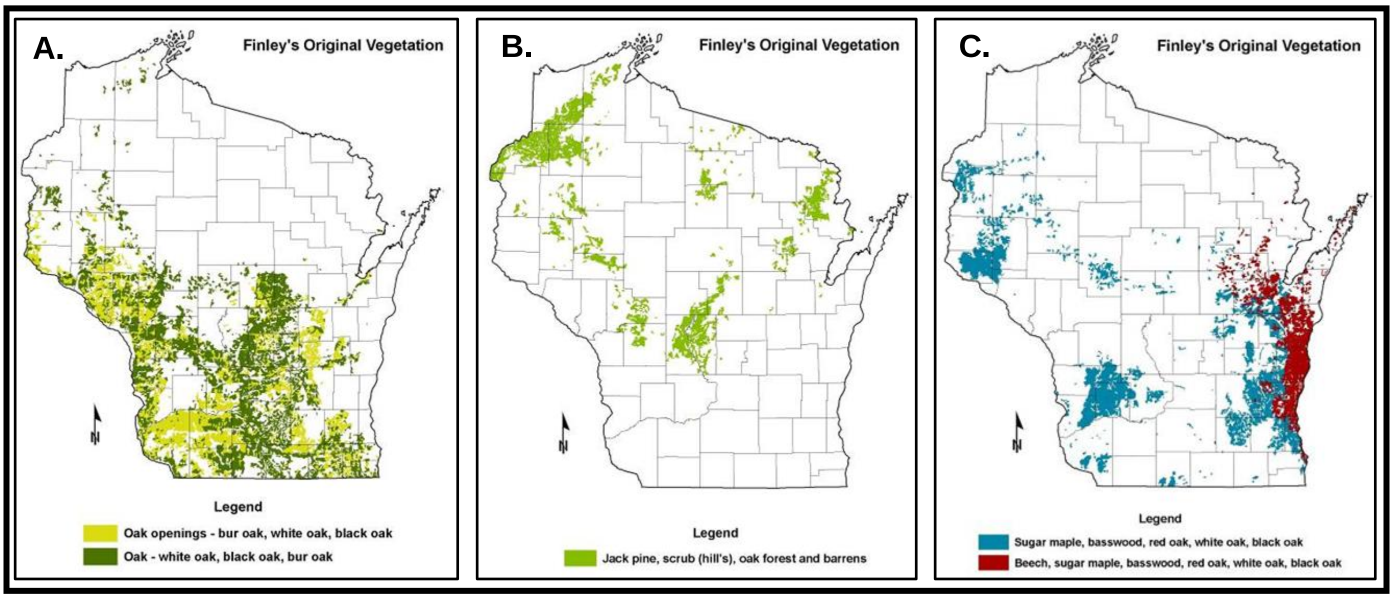

Figure 41.1. Finley's original vegetation maps for oak woodlands from 1832-1866. (A.) Pure oak stands and openings (white, black and bur oak), (B.) mixed stands in barrens conditions, (C.) mixed stands with northern hardwoods species.

The oaks of southern Wisconsin were commonly described by early explorers, missionaries, and settlers as open, "park-like" forests dominated by widely spaced oaks with a paucity of shrubs or saplings. Oak forests were more common in the Driftless Area, but savannas dominated the landscape of southeast Wisconsin. The oak forests and savannas were interspersed with prairies, wetlands, and maple-dominated forests. Oak woodland is sometimes defined as an intermediate structural stage between closed forests and savannas, with more canopy closure and an open understory. This structure would have been created by ground fires of relatively low intensity and shorter intervals.

The close association of fire and oak forests has led to some research on type, intensity, timing, frequency, and pattern (Brose et al. 2005). Evidence indicates that periodic fire disturbance played an important functional role in development and maintenance of pre-Euro-American settlement oak ecosystems (Abrams 2005). The frequency and severity of fire disturbance affects stand structure, composition, and ecosystem processes such as nutrient cycling. High frequency fires at less than 50-year intervals have been credited with creating and maintaining savannas and woodlands prior to European settlement (Reich et al. 1990; Anderson et al.1999).

Historically, most oak forests would have had a low intensity and less frequent interval of fire (>50 years). Variations in southern Wisconsin's fire disturbance regime, both spatially and temporally, led to the range of structural conditions of oak cover types. Low intensity fires with intervals of 5-15 years are defined as those with flames less than two feet long, which consume the leaf litter and small woody debris. Low intensity fires usually enhance oak regeneration. Historically, oak forests would have experienced these fires at less frequent intervals (>50 years) while fires in oak savanna were of low to moderate intensity with intervals estimated at 16 years (Peterson et al. 2001).

High intensity fires are defined as those with flame length greater than two feet or that kill significant numbers of overstory trees. Generally, these fires enhanced the competitive status of oak regeneration by increasing the amount of light reaching the forest floor. The scrub oak/ jack pine barrens likely experienced surface fires annually (Dorney 1981).

When Euro-American settlement began in southern Wisconsin in the early 1800s, land clearing for agriculture led to the loss of many oak forests and savannas. Oaks were used for fences, building materials, and fuels, and many were cut and burned to clear the land. As marginal agricultural areas reverted to forest, the combined effects of burning and pasturing led to suitable conditions for the establishment of oak.

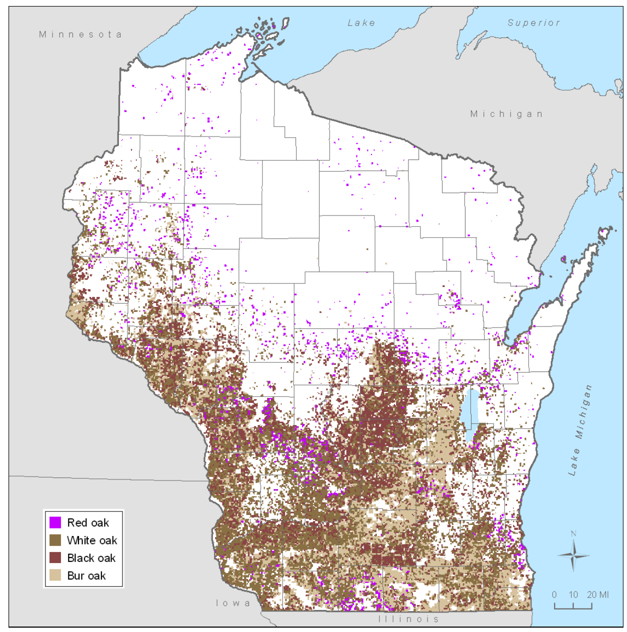

Figure 41.2. Distribution map of four oak species in Wisconsin.

3.1.2 Current Context

According to Forest Inventory and Analysis (FIA) data summarized in 2004, the oak-hickory forest type is still widespread in Wisconsin, occupying about 3.4 million acres (Schmidt 1997). The oak-hickory forest is the 3rd most abundant cover type in Wisconsin and represents about 21% of forestland. A distribution map of four oak species is shown in Figure 41.2. Today, oak forests are a result of post-Cutover era land management practices including clearing, short-term intense fires, farming, and pasturing, which favored oaks over more shade-tolerant species. In many areas, the canopy composition of the forest is now steadily shifting from oak dominance to more shade tolerant mesic hardwoods, primarily due to the absence of widespread fire disturbances and the selective removal of commercially valuable oaks. Today, competition from native and non-native species in the absence of fire is contributing to the succession of oak forests to central and northern hardwood species, including red and sugar maple, basswood, elms, green and white ash, black cherry, and ironwood.

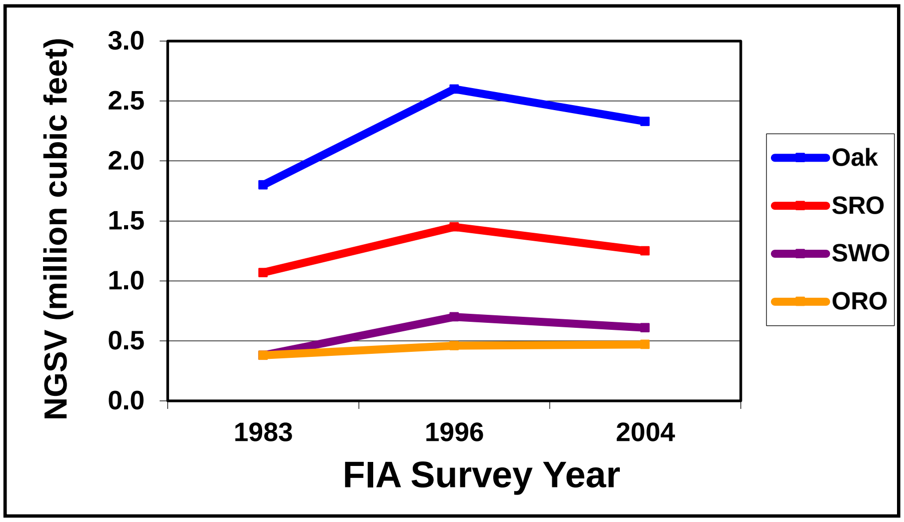

Figure 41.3. Change in net growing stock volume (NGSV) of select oaks: SRO (northern red oak), SWO (white, swamp white and bur oaks), and ORO (northern pin and black oaks) (site index > 60 sq. ft.) on timberland.

FIA data reveal a downward trend in net growing stock of oak in stands with site index >60 (Figure 41.3) between 1996 and 2004. Implications for the decline in this category suggest the removal of high value trees can leave a degraded forest and possibly an imbalance in size or ages class within the stand.

Figure 41.4 shows a decline in acreage of young oak-hickory stands and stands older than 100 years between the 1996 and 2005 inventories, leading to concerns that representation of oak forests will continue to decline in the future. A decline in the young age class may reflect the difficulty in regenerating oak. This may contribute to a gradual succession of oak forests to other forest types (mixed central hardwood, red maple, northern hardwood). A decline in the older age class may affect habitat available for certain plant and animal species and overall biodiversity in older oak forests.

The future representation of oak forests on dry-mesic and mesic sites is uncertain. Oak regeneration is uncommon and succession of oak forests to other community types is widespread. Primary factors that may be contributing to the decline of oak in some age classes on the landscape are forest management goals/objectives/practices, altered disturbance (particularly fire) regimes, and herbivory.

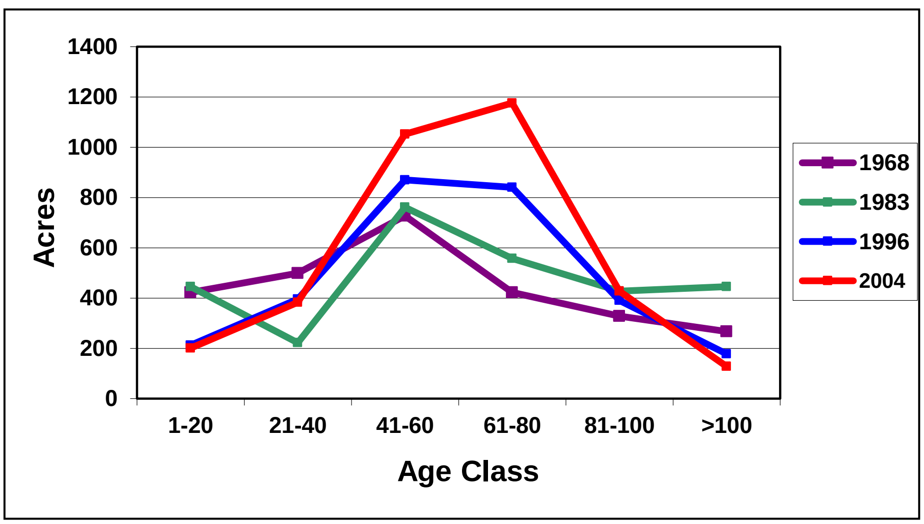

Figure 41.4. Forest age-class distribution for the oak-hickory forest type group in Wisconsin, from FIA measurements taken in 1968, 1983, 1996 and 2005.

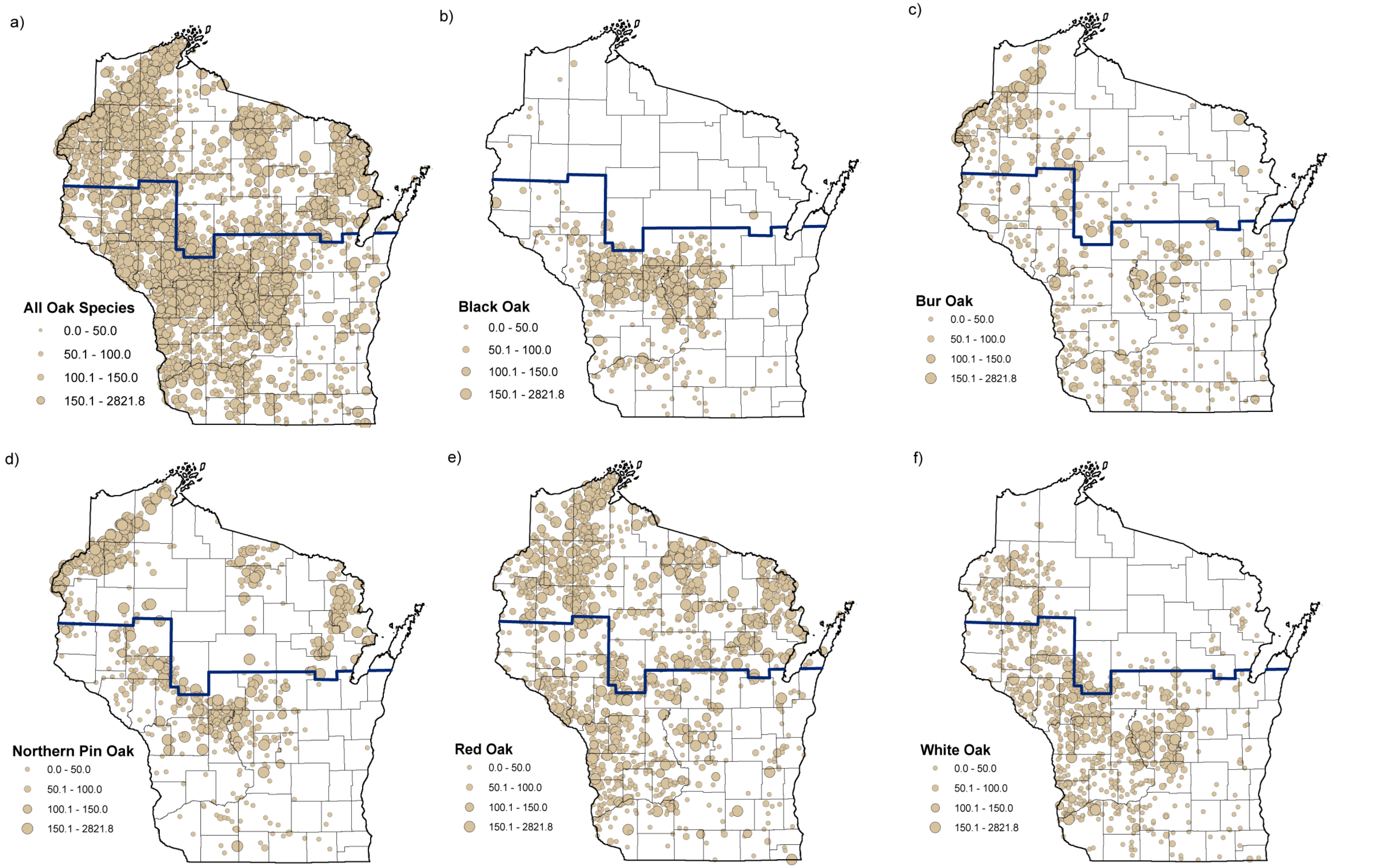

Figure 41.5. Volume of oak from Wisconsin FIA plots (USDA-FS 2009). Figures are for a) all oaks b) black oak c) bur oak d) northern pin oak e) red oak and f) white oak. The blue line on each map separates the northern and southern habitat type regions.

3.1.4 Fragmentation

Fragmentation is a term used to describe certain kinds of landscape structure and is often characterized as permanent versus habitat fragmentation. “Permanent” fragmentation refers to a long-term conversion of forest to urban, residential or agricultural uses. “Habitat” fragmentation refers to a shorter-term disruption of habitat continuity caused by creation of a mosaic of successional stages within a forest tract. Habitat fragmentation represents a short-term loss of habitat for some species and a gain for others. Some animals and plants can be negatively affected by fragmentation, particularly those that are area-sensitive, or subject to impacts associated with forest edges. Dispersal can be affected if species or their propagules cannot cross or get around the open land. In Wisconsin and elsewhere, the loss of forest habitat has a larger impact on species than shorter-term habitat fragmentation.

Considerable forest fragmentation has occurred during the past 150 years, especially in the oak-hickory forests of southern Wisconsin. Due to increasing human population and associated development pressure, there are few large tracts of southern forest remaining. The remaining southern forests are located in areas where development has been limited by public ownership, low commercial value, or relative inaccessibility (e.g., rough topography, susceptibility to flooding).

Edge effects can benefit some species while negatively impacting others, and effects vary depending on the type of edge. “Hard” edges occur at abrupt habitat boundaries, such as when agricultural fields or residential developments adjoin forests. “Soft” edges occur where forests are adjacent to shrubby riparian zones or patches of younger forest. Hard edges are a common condition in southern Wisconsin, where most of the mesic oak forests occur. As fragmentation progresses and forest patch sizes become smaller, more of the area is edge-affected. Small patch sizes and hard edges are associated with cowbird parasitism and nest predation, which are limiting factors for many bird populations in southern oak forest fragments. However, species such as ruffed grouse and small mammals benefit from edge habitat.

Forest fragmentation and edge effects have been associated with declines in populations of neotropical migratory songbirds (NTMB’s). Edge effects on other wildlife species are not as well documented. NTMB’s are considered “indicators of ecosystem health” in part because of the insect pests they consume (Robinson et al. 1995). During the 1980’s, research studies identified increases in predation and nest parasitism along forest edges (Brittingham and Temple 1983, Wilcove 1985). These effects are more harmful to songbirds in areas where agricultural and urban land uses predominate (Small and Hunter 1988). Nest parasitism from cowbirds has been shown to be less of a problem in areas where the forested matrix is dominant, as in northern Wisconsin, although parasitism can be “locally common in forest areas that are fragmented by agricultural or urban environments, especially if livestock or horses are present” (Howe et al. 1995). With the mixed ownership pattern that exists in southern Wisconsin, cowbird parasitism is of large concern for NTMB’s. Predation from small mammals, crows, jays, raccoons, skunks, domestic pets, and feral cats and dogs is also associated with fragmentation and edges.

Some species are “area-sensitive”, requiring large patches of relatively contiguous forest cover. Mossman and Hoffman (1989) summarized a number of breeding bird surveys, noting that isolated forest patches of 40-80 acres in size were dominated by generalist species, while interior forest specialists such as Cerulean Warbler and Acadian Flycatcher occurred in patches of 100 acres or larger. Among the interior forest species, the Worm-eating Warbler, Kentucky Warbler, and Hooded Warbler only bred consistently in forest patches larger than 500 acres. As larger forest patches become increasingly scarce in southeast and south-central Wisconsin, smaller patches of mature oak or mixed oak-central hardwoods may be important if they are located near large forested tracts, especially if there is potential for restoring connectivity or increasing patch size in the future. These smaller tracts may also be important as migratory stopovers, and as habitat for amphibians.

3.1.5 Non-Native Invasive Species

The ecology of the oak-hickory forests is also being affected by non-native species. Unlike the northern forests, the southern oak forests have been widely colonized by troublesome invasive plants, including non-native buckthorns (*Rhamnus* spp.), honeysuckles (*Lonicera* spp.), multiflora rose (*Rosa multiflora*), and garlic mustard (*Alliaria petiolata*). Other problematic forest invasive species include Japanese barberry (*Berberis thunbergii*) and Oriental bittersweet (*Celastrus orbiculatus*)*.* When abundant, invasive plants alter forest composition and structure, and can ultimately affect successional patterns and future forest conditions (WDNR 1997). Plants like buckthorn suppress regeneration, while vines like Oriental bittersweet climb and girdle trees. Honeysuckles and garlic mustard are implicated in impacting forest growth rates.

Woody shrub species may be the most widespread and problematic invasive plants currently affecting our forests, and they are expensive to control. Two buckthorn species and four bush honeysuckle species have already invaded large acreages of forest understory. One WDNR forester in southern Wisconsin reported that treatment costs for buckthorn on several oak sites resulted in about $200/acre (WDNR 2005). Other invasives such as autumn olive and multiflora rose are common in areas where agriculture has been practiced, and Japanese barberry is gaining a hold in the southeast and southcentral parts of the state. Few herbaceous species can compete in the shade of a forest understory, but garlic mustard is an exception and is rapidly spreading across the state. The WDNR Best management Practices for Invasive Species have additional guidance on management planning and mitigation of invasive species before timber harvesting is conducted (WDNR 2009).

3.1.6 Summary of Landscape Considerations

When deciding whether to actively manage for oak-hickory stand assuming the habitat type is suitable, consider the following factors:

- What are the characteristics of the broad-scale ecological unit (Landtype Association (LTA) or Subsection) around the stand?
- Is the prospective management area already fragmented by either habitat or permanent fragmentation?
- In even-aged management, are there opportunities to aggregate individual cuts to reduce the overall amount of edge?

- Is there an abundance of invasive plants in the stand being managed? Is there an opportunity to control them before harvesting?
- Is the forest patch large enough to support bird species uncommon at the landscape or regional scale, and how is the proposed management likely to affect them?
- Large forest patches with older age-class structure are scarce and managing for interior NTMB's such as cerulean warbler or Acadian flycatcher may be an important consideration.
- Can the management activity be designed to limit fragmentation that may be caused by development of infrastructure (e.g., roads and landings)?
- Is there an opportunity for extended rotation, to increase or partially maintain the extent of older oak forest?
- Are there problems with herbivory in the vicinity (e.g., lack of oak regeneration, excessive browsing of herbaceous vegetation)? If so, consider methods of limiting post-harvest damage to regeneration.
- Is there an opportunity to incorporate prescribe fire into the management plan to retard competition and enhance oak regeneration?
- Is there an opportunity to develop structure through canopy gaps?

3.2 Site and Stand Considerations

3.2.1 Soils

Characteristic soil textures are also identified in the FIA data (Schmidt 1997, Kotar et al. 1999) and the FHTCS. Northern and southern regions and site types are derived from the FHTCS. Exceptions to these typical conditions should be expected.

Oak stands grow on a variety of soils, but individual oak species are associated with soils of a particular moisture and nutrient status.

Northern red oak, and to some extent, white oak and bur oak, occur on loamy soils, as evidenced by their association with dry-mesic Northern and dry-mesic to mesic Southern Habitat Type Groups (Table 41.2 and Table 41.4). Vehicle traffic on loamy soils can cause detrimental soil compaction. A number of studies of conifer species have found that soil disturbances including compaction, rutting, and surface displacement decreased tree growth (NCASI 2004, Table 3.1). Growth decreases have also been documented in experimentally compacted aspen stands on clay and loam soils in the Lake States, but growth increased on compacted sand soils (Stone 2001). It is likely that compaction and associated soil disturbances have detrimental impacts to oaks growing on loamy soils. These disturbances cannot be avoided entirely during a harvest but can and should be minimized. A system of pre-planned skidding routes and landing areas can be designed to meet the needs of the harvest while impacting as little of the stand area as possible. As a general rule, less than 15% of a harvest area should be devoted to haul roads, skid trails, and landings (WDNR 2011b). Soils are most susceptible to compaction and rutting when they are saturated, so harvesting when the soil is frozen or dry can reduce the potential for compaction. Increasing the interval for re-entry into stands may partially mitigate and reduce the amount of compaction and rutting, although soil compaction is not readily ameliorated and effects can persist for several decades (NCASI 2004).

Many northern red oak, white oak, and bur oak stands, and mixed stands, are located in southwest Wisconsin's "Driftless Area", which is characterized by steep, easily eroded hillsides, and shallow bedrock. In these areas, soil compaction, displacement, and erosion are a particular concern. Shallow soils can be squeezed between equipment and bedrock, increasing the likelihood of compaction and rutting, and damaging soil structure so that rainfall can transport and erode the soil more readily. Roads should be designed with a consideration for slopes, and operations during periods of rainfall should be carefully monitored to ensure that compaction, rutting, and erosion do not exceed guidelines. See "Wisconsin Forest Management Guidelines" (WDNR 2011b). An additional concern on shallow soils is the decreased volume of soil available to supply nutrients. In a deep soil, 95% of tree roots occur in the upper 40", and this is the depth generally considered to supply most of the nutrition for tree growth (Gale and Grigal 1987). A site on shallow soils has a lower amount of nutrients and could become nutrient-depleted by harvest removals in fewer rotations than a site with deep soils. Shallow soils over sandstone bedrock, or hard bedrock of volcanic origin, tend to have less nutrient capital than soils that overlie limestone or dolomite.

Oak species that typically grow on sandy sites include northern pin oak and black oak. Table 41.2 and Table 41.4 indicate these species are most associated with very dry to dry Northern, and dry Southern Habitat Type Groups. On these sandy sites, displacement of the surface mat of vegetation is a concern. If the surface is removed or worn away on roads and skid trails, bare mineral soil is exposed and new vegetation is often slow to establish. Erosion by wind and water can keep these areas open, and bank slumping can prevent road cuts from stabilizing. Cumulatively, these impacts make parts of the stand non-productive.

Another concern regarding oaks on sandy sites is the potential for nutrient depletion over repeated rotations. Sites accrue nutrients through mineral weathering and atmospheric deposition. Nutrients can be lost from a site through leaching, volatilization (in the case of nitrogen), and removals in harvested wood. If losses are greater than inputs over the course of a rotation, nutrient depletion occurs. If losses are relatively small and the site is "rich", or has a large amount of nutrient capital, then concerns are minimal. However, if the site is sandy and has little nutrient capital, losses may be significant. There is uncertainty in predicting the exact amount of potential nutrient losses, and more research is needed in this area, particularly as there are not published data for nutrient concentrations of northern pin oak. Nutrient concentrations for mixed oak stands in three studies were compiled and averaged (Tritton et al.1987, for stands with 40-50% of basal area in northern red, chestnut, white and black oaks; Johnson et al. 1982, for stands with 70% of above-ground biomass in chestnut, white, northern red, and black oaks; Rolfe et al. 1978, for stands with 85% of total biomass in white and northern red oak). Average calcium concentrations were applied to biomass data for northern pin oak stands (Reiners 1972), and nutrient balance calculations using these estimates suggested a potential for net losses of around 150-200 lbs. calcium/acre for an 80-year rotation with whole-tree harvesting.

3.2.2 Site Quality

3.2.2.1 *Range of Habitat Types*

See Chapter 12 – Forest Habitat Type Classification System for information summarizing the system and the habitat type groups. Habitat type regions 1-5 (northern Wisconsin) contain the northern habitat type groups; these represent 67% of the total forest land acres and 70% of the total net growing stock volume statewide. Habitat type regions 6-11 (southern Wisconsin) contain the southern habitat type groups; these represent 33% of the total acres and 30% of the total net growing stock volume on forest land statewide. However, the southern habitat type groups contain 74% of the oak cover type acres and 61% of the oak volume statewide (1996 FIA). The oak cover type currently is much more common in southern than in northern Wisconsin.

Another useful resource is *Vegetation of Wisconsin* (Curtis 1959) which divides Wisconsin into two floristic provinces based on climatic conditions and plant species distribution. Within each province, five to six forested community types are defined based on overstory associations. These forest types are further characterized, including understory associations and site characteristics. Most oak forests are classified into one of four groups: dry and dry-mesic southern hardwoods, and dry and dry-mesic northern hardwoods.

The different oak species are distributed differently across the state (Figure 41.5). Northern red oak demonstrates the most even geographic distribution with about 56% of its total statewide net growing stock volume occurring within the northern habitat type groups (and 44% in the south). In contrast, about 81% of northern pin oak and black oak combined volume occurs within the southern habitat type groups. However, whereas black oak occurs almost exclusively within the southern groups, northern pin oak occurs in both southern and northern Wisconsin. White oaks (white, bur, swamp white) are much more common in southern Wisconsin, where about 78% of their statewide volume occurs (1996 FIA).

<u>Northern Wisconsin habitat types</u>
In northern Wisconsin, the occurrence and relative growth potential of the oak cover type, and of the individual species comprising the type, vary by habitat type groups and habitat types.

Oak is currently the predominant cover type occurring on very dry to dry sites in northern Wisconsin; oak occurs on about 28% of the total area occupied by these dry sites. Oak is a common cover type on dry to dry-mesic (15% of the area) and dry-mesic (21% of the area) sites but is less abundant than the aspen and maple-basswood cover types. It is a minor cover type on the mesic (4%) and mesic to wet-mesic (2%) habitat type groups. The oak cover type rarely occurs on wet-mesic to wet sites (<1%) in northern Wisconsin.

The distribution of oak volumes by site type contrasts with the distribution of oak cover type acres. The greatest volume (both net volume and average volume per acre) of oak occurs within the dry-mesic habitat type group. Mesic sites also contain a large net volume of oak; mesic acres are extensive and high-quality oak occurs as a common associate within the maple-basswood cover type. In northern Wisconsin, about 75% of the total oak volume is northern red oak, 15% white oaks (mostly white and bur), and 10% northern pin oak (with a little black oak).

Northern dry (very dry to dry and dry to dry-mesic habitat type groups): Oak is a common cover type. Characteristic dominants in oak forests are northern pin oak and red oak, although white and bur oaks can be locally important. Common associates include aspen, white pine, red pine, jack pine, red maple, and white birch. Typical surface soil textures are sand and loamy sand.

Northern dry-mesic (dry-mesic habitat type group): Oak is a common cover type. The characteristic dominant in oak forests is northern red oak, although white oak can be locally important. Common associates include aspen, red maple, sugar maple, white birch, white pine, and basswood. Typical surface soil textures are loamy sand and sandy loam.

Northern mesic (mesic habitat type group): Oak is a minor cover type. The characteristic dominant in oak forests is northern red oak, although white oak can be locally important. Common associates include sugar maple, basswood, red maple, aspen, white birch, and ashes. Typical surface soil textures are sandy loam and silt loam.

Northern wet-mesic and wet (mesic to wet-mesic and wet-mesic to wet habitat type groups)[1]: Oak is a minor to rare cover type on these sites. Soils exhibit impeded drainage (any texture).

Table 41.2 shows the relative representation of oaks within northern habitat type groups (based on volume) and trends across groups. Table 41.3 and Figure 41.6 are useful to evaluate potential growth and productivity for oaks.

<u>Southern Wisconsin Habitat Types</u>
In southern Wisconsin, the occurrence and relative growth potential of the oak cover type, and of the individual species comprising the type, vary by habitat type groups and habitat types.

In southern Wisconsin, oak is currently the predominant cover type occurring on dry, dry-mesic, dry-mesic to mesic, dry-mesic to mesic phase, and mesic phase habitat type groups (site types). It occupies 50-60% of total acres within each of these groups, except for dry sites where it occupies about 43% of total acres. On mesic sites, oak is the second most common cover type (32% of total acres) following maple-basswood. On mesic to wet-mesic and wet-mesic to wet sites, the oak cover type commonly occurs (about 11% of the area of each) but is much less abundant than maple-basswood and elm-ash-soft maple.

The greatest net volumes of oak occur on dry-mesic and dry sites (many acres and many oak trees). However, the most productive sites with abundant oak and high average standing volumes per acre are dry-mesic, dry-mesic to mesic, dry-mesic to mesic phase, and mesic phase. In southern Wisconsin, about 39% of the total oak volume is northern red oak, 34% white oaks (white, bur, swamp white), and 27% other red oaks (black and northern pin).

Southern dry (dry habitat type group): Oak is a predominant cover type. Characteristic dominants in oak forests are black oak and northern pin oak, although white, bur, and red oaks sometimes exert dominance. Common associates include aspen (*Populus* spp.), white pine (*Pinus strobus*), red pine (*Pinus resinosa*), jack pine (*Pinus banksiana*), and red maple (*Acer rubrum*). Typical surface soil textures are sand and loamy sand.

Table 41.2. Oak species – abundance within each northern habitat type group. Values are % of the total volume for all species (net volume and average volume per acre) represented by each oak species group within each habitat type group (1996 FIA).

Northern Habitat Type Groups	% Volume of Oak Species within Habitat Type Groups			
	N. Red Oak	N. Pin Oak[1]	White Oak & Bur Oak[2]	Total – All Oaks
Very Dry to Dry	11	10	<1	22
Dry to Dry-mesic	11	3	2	16
Dry-mesic	24	<1	5	29
Mesic	7	<1	1	8
Mesic to Wet-mesic	3	<1	1	5
Wet-mesic to Wet	<1	<1	<1	1

1 – Includes a small amount of black oak
2 – Includes a small amount of swamp white oak

Southern dry-mesic (dry-mesic habitat type group): Oak is a predominant cover type. Characteristic dominants in oak forests are red oak, white oak, bur oak, and black oak. Common associates include aspen, red maple, white birch (*Betula papyrifera*), and white pine. Typical surface soil textures are loamy sand and coarse or shallow loams.

Southern mesic (dry-mesic to mesic and mesic habitat type groups): These sites can be subdivided based on historic disturbance regimes and the current representation of mesic hardwoods in current communities. Typical surface soil textures are loams.

1. Phases – occur in extreme southern and southwestern Wisconsin
    a. Oak is a predominant cover type. Characteristic dominants in oak forests are white oak and red oak. Common associates include: bur oak, black oak, hickories (*Carya* spp.), elms (*Ulmus* spp.), black cherry (*Prunus serotina*), black walnut (*Juglans nigra*), and aspen.

2. Typical sites – mesic hardwoods usually represented
    a. Oak is a common cover type. Characteristic dominants in oak forests are red oak and white oak. Common associates include sugar maple (*Acer saccharum*), basswood (*Tilia americana*), ashes (*Fraxinus* spp.), aspen, red maple, elms, hickories, bur oak, and black oak.

Table 41.3. Oak cover type – estimated relative growth potential by northern habitat type group and type.

Northern Habitat Type Groups	Estimated Relative Growth Potential for Oak Cover Type[1]				
	Very Poor	Poor	Fair	Good	Excellent
Very Dry to Dry	PQE PQG	PQGCe PArV PArV-U PArVAo QAp			
Dry to Dry-mesic			PArVHa PArVAm PArVAa PArVAa-Vb PArVAa-Po PArVPo		
Dry-mesic				TFAa AVCl AVVb AVDe AVb-V ACl AVb	AAt ATFPo
Mesic					AFVb ATM ATFD ATFSt AAs ATD ATDH AHVb AFAd AFAl ACaCi AOCa AH
Mesic to Wet-mesic[2]		PArVRh ArAbVC ArAbVCo ArVRp ArAbSn	ArAbCo TMC ASnMi AAtRp	ATAtOn ASaI ACaI AHI	

1 – Estimation of relative growth potential for oak cover type based on: oak cover type average volume/acre, oak site index, potential tree vigor and form, and oak species typically present.
2 – See Table 41.2; oak occurs infrequently on most habitat types within this group.

Southern wet-mesic and wet (mesic to wet-mesic and wet-mesic to wet habitat type groups): Oak is a common cover type. The characteristic dominant in oak forests is swamp white oak, although bur oak, white oak and black oak can occur. Common associates include red maple, silver maple (*Acer saccharinum*), ashes, elms and basswood. Soils exhibit impeded drainage.

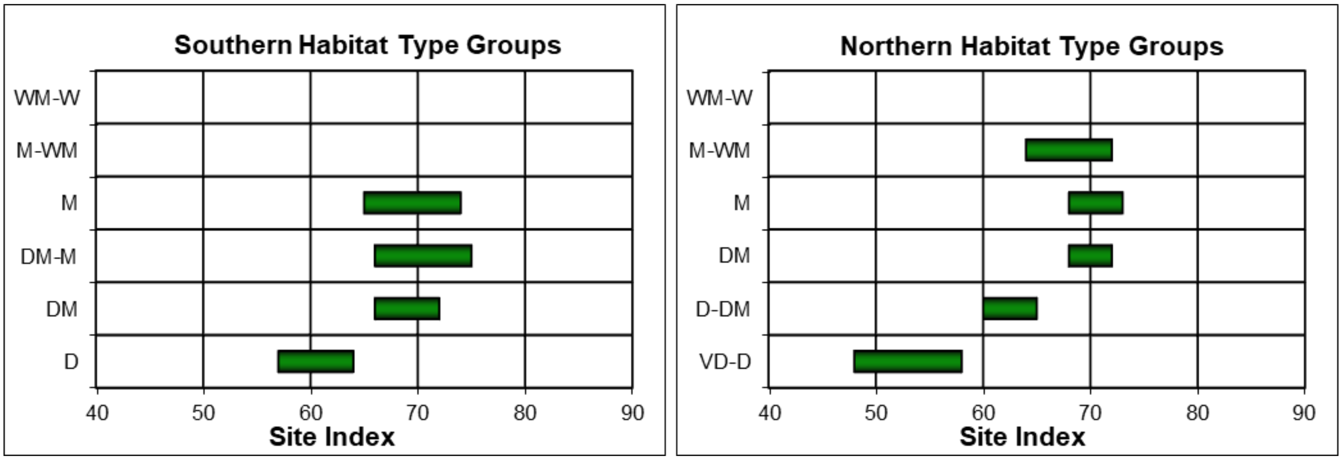

Figure 41.6. Site index for northern red oak across northern and southern habitat type groups (1996 FIA). Bars indicate 95% confidence limits for the mean.

Table 41.4 shows the relative representation of oaks within southern habitat type groups (based on volume) and trends across groups. Table 41.5 and Figure 41.6 are useful to evaluate potential growth and productivity for oaks.

Table 41.4. Oak species – abundance within each southern habitat type group. Values are percent of the total volume for all species (net volume and average volume per acre) represented by each oak species group within each habitat type group, (1996 FIA data).

Southern Habitat Type Groups	% Volume of Oak Species within Habitat Type Groups			
	N. Red Oak	Black Oak and N. Pin Oak	White Oaks[1]	Total – All Oaks
Dry	8	25	7	41
Dry-mesic	21	13	17	51
Dry-mesic to Mesic	21	4	21	45
Dry-mesic to Mesic (phase)	16	7	24	47
Mesic (phase)	16	7	20	43
Mesic	17	1	10	29
Mesic to Wet-mesic[2]	2	7	9	17
Wet-mesic to Wet[2]	<1	2	7	9

1 – White, bur, and swamp white oaks
2 – All sites – Habitat types not defined

Table 41.5. Oak cover type – estimated relative growth potential by southern habitat type group and habitat type.

Southern Habitat Type Groups	Estimated Relative Growth Potential for Oak Cover Type[1]				
	Poor	Fair	Fair to Good	Good	Excellent
Dry	PEu PVGy PVCr	PVG PVHa			
Dry-mesic			ArDe-V ArDe	AArVb ArCi ArCi-Ph AQVb-Gr AArL	
Dry-mesic to Mesic					AFrDe AFrDeO ATiFrCi ATiFrVb ATiDe ATiDe-Ha ATiDe-As
Dry-mesic to Mesic (phase)					AFrDe(Vb) ATiFrVb(Cr) ATiCr(O) ATiCr(As) ATiDe(Pr)
Mesic (phase)					ATiFrCa(O) ATiAs(De)
Mesic					ATiSa-De ATiSa ATTr AFTD AFH ATiFrCa ATiCa-La ATiCa-Al ATiCa ATiH AFAs-O AFAs
Mesic to Wet-mesic	PVRh	No habitat types defined			

1 – Estimation of relative growth potential for oak cover type based on: oak cover type average volume/acre, oak site index, potential tree vigor and form, and oak species typically present.

3.2.3 Forest Health

The numerous pests of oak are summarized in Forest Health Protection Guidelines (Appendix). There are three oak pests with significant impact to the oak in Wisconsin and warrant an expanded discussion.

Oak Wilt

Oak Wilt is a vascular disease caused by the fungus *Ceratocystis fagacearum*. There is no cure, but there are several preventive measures. Site-specific guidelines on oak harvesting in the forest setting were developed and implemented in 2007. These guidelines were designed to provide information on the relationship between the risk of introduction of oak wilt and the timing of any activities that may wound oaks or leave oak stumps, based on site factors in a stand. The guidelines incorporate information such as the proximity of a stand to a county where oak wilt is confirmed, preharvest BA of oak, terrain, and soil texture and give a site-specific risk level of introduction and spread in a particular stand when a stand is harvested in the spring, summer, or fall-winter. The guide should be used to help make decisions about when harvesting may occur. For the oak cutting guidelines in the forest setting, refer to the Forest Health Protection Guidelines (Appendix). The guidelines can be viewed and downloaded at https://dnr.wisconsin.gov/topic/foresthealth/oakwilt/ An interactive user-friendly version is also available at the website.

Gypsy Moth

Gypsy moth is an invasive pest that periodically increases to very high numbers, causing significant defoliation similar to the native forest tent caterpillar. Oak is a favored host of gypsy moth larvae and typically sustains greater damage from this pest than less favored species such as maples or conifers. Where gypsy moth is established, outbreaks can occur about every 10 years in mesic forests or as frequently as every 5 years in dry, oak dominated forests. Some deciduous forests of the state have yet to be impacted by gypsy moth despite its presence in them for nearly 20 years. For a current map of counties where gypsy moth is established, go to http://gypsymoth.wi.gov/ and view the quarantine map. Counties are quarantined when this pest becomes established, though populations may be low.

Population outbreaks can typically last 1-3 years before collapsing. A rule of thumb is that following heavy defoliation, the amount of mortality that would have occurred in a stand over the following 10 years will be compressed into 3 years as suppressed and stressed trees die. Individual tree mortality can occur for up to 3 years following heavy defoliation. Tree mortality is usually highest following the first outbreak in an area and is greatest among overmature, weakened or suppressed trees of preferred species. Mortality rates of 5-25% can be expected in stands dominated by preferred species. Avoid multiple simultaneous stress agents. Heavy or catastrophic mortality is likely to occur if defoliation coincides or occurs within a year of another significant stress such as recent prior defoliation, drought or thinning. In Wisconsin, 50-95% mortality has occurred following heavy defoliation of stressed, overmature northern pin oak, in northern pin oak stands thinned the year prior to defoliation, and in stressed white oak defoliated during a drought. Do not conduct thinning in susceptible stands 1 growing season before or after heavy defoliation occurs or is predicted. On dry sites leave 2 growing seasons to allow trees to recover vigor.

There are several options for reducing or preventing losses from gypsy moth. Increasing species diversity and reducing the proportion of preferred species can reduce the frequency and intensity of outbreaks. A preferred species composition of 50% or less is suggested where practical. Improving stand vigor by thinning more than 2 years before defoliation can improve survival of the remaining trees. Harvest susceptible trees before overmature unless left for green tree retention. Aerial spraying can prevent heavy defoliation and associated tree stress and may be appropriate if a stand is already under stress and harvest is not desirable. Autumn egg mass surveys are used to predict the size of the pest population and the level of potential damage the following spring, allowing ample time to plan for a spray of the stand if appropriate. For directions on how to conduct a predictive survey, silvicultural guidance, and how to arrange for an aerial spray of a woodlot, go to http://gypsymoth.wi.gov/.

<u>Herbivory by Deer</u>
High deer densities are significantly altering forest composition through herbivory, impacting the herbaceous layer, and reducing regeneration success of some tree species (WDNR 1995). Rooney Waller (2003) showed that deer limit oak regeneration in Wisconsin forests. Both young oak branches and acorns are browsed, leading to poor seedling establishment, slow growth, and high mortality.

High density deer populations in oak-dominated forests cause significant regeneration failure, reduced plant species richness and biomass, and loss of structural diversity through shifts in species composition (McShea and Healy 2002). Although oak has a long re-initiation phase and can compete with other species over long periods of time, oak regeneration will eventually succumb to continuous browsing, especially in combination with competition from shade tolerant species. Methods of protecting regenerating areas include fencing, tube shelters, bud caps and repellents. These techniques are costly and labor intensive but offer some relief from browse impacts.

In general, Wisconsin experience suggests deer populations at or below 50% of maximum “natural” carrying capacity for the deer management unit will not prevent oak regeneration. Natural carrying capacity is average deer carrying capacity that is not artificially inflated by baiting, feeding, or agricultural practices designed to increase deer populations. Researchers in Pennsylvania (DeCalesta and Stout 1997) have advanced a conceptual framework for relating deer population levels to a variety of potential management goals. Under this framework, management of deer in a forested system managed for timber in Pennsylvania would hold the population near 30% of maximum carrying capacity and hold deer populations below 20% of maximum carrying capacity to make deer impacts negligible. Wisconsin experience suggests that successful silviculture can usually be practiced where herds are maintained at 50-65% of natural carrying capacity.

Regardless of goals and population levels on a deer management unit basis, herbivory is a local and seasonal phenomenon. Foresters must assess site-specific indicators of deer density when planning silvicultural treatments. Recent browse damage to trees and shrubs within reach of deer is the most indicative sign of potential deer problems. The extent of recent browse damage and growth form, e.g., “brooming”, of woody browse present in the stand should be assessed as part of the stand examination when prescribing a regeneration treatment. This assessment is best done in late winter or early spring before leaf break.

Preferred species of woody browse commonly associated with oak include red maple, white pine, oak, aspen, alternate-leaved dogwood, and juneberry. Severe browsing (>2/3 of available twigs browsed) on these species indicates a potential problem. Some browsing pressure should be expected on these preferred food species. If these species are present in the stand understory, less than 1/3 of the available twigs are browsed, and some individuals are 4’ tall or greater, oak regeneration techniques that result in sufficient seedling establishment should be successful.

Intermediate browse pressure is indicated when >1/3 and < 2/3 of the available twigs are browsed. This indicates a potential problem. Regeneration may be possible under these conditions, but it will require an excellent seedling establishment and possibly a treatment area greater than 10 acres.

Beech, red pine, ironwood, and walnut are generally avoided by deer. Any noticeable level of browsing by deer on these species indicates a potential problem. Oak regeneration may not be possible until local deer numbers are reduced or other measures are used to prevent browsing.

Hunting can be effective in reducing overabundant deer populations to achieve forestry goals. Individual landowners may not control enough land to affect local deer populations but should be encouraged to allow harvest of deer if herbivory is a problem. Females display more philopatry than males and shooting does is more likely to reduce local populations than shooting bucks. Local deer populations must be held at sustainable levels relative to forestry objectives for an extended period of time to allow forest regeneration to occur.

In areas where high deer numbers are likely to contribute to a regeneration failure, several techniques have been used to protect seedlings and saplings. Fencing, shelters, and repellents are available in a variety of types. Area fencing can be used to protect regeneration by excluding deer from a site. A woven wire or polypropylene fence at least 8' tall is the best barrier to deer entry into a regenerated stand. These fences are costly to install and require inspection and maintenance. Multiple strand electric fences are less costly to install but require more maintenance. Individual tree shelters are generally used in artificial regeneration applications but could be placed on select advance regeneration in a natural regeneration treatment. A variety of shelters are commercially available and additional types can be constructed. Installation and maintenance requirements vary by shelter type. Repellents function by inducing fear in deer or by reducing the palatability of plants to which they are applied. Products vary in effectiveness and may require frequent repeat applications. Any of these options are rather costly means to achieve regeneration compared to herd reduction. A review of available techniques is available on the WDNR Forestry website. www.dnr.state.wi.us/forestry/Publications/articles/ManagingDeerBrowse.pdf

Experience shows food plots and feeding will not buffer plant communities from deer herbivory but will exacerbate the problem by concentrating deer activity in proximity to the "artificial" food source (Brown and Cooper 2006; Donier et al. 1997). Deer herd reproductive response to supplemental food also leads to higher deer densities. Foresters should be aware small areas of regeneration in a landscape with limited deer preferred food sources may concentrate deer activity. Similarly, increasing timber management on a landscape scale has been proposed as a means of providing additional browse availability to mitigate deer impacts on desired regeneration. This is a solution that works only if the deer population is not allowed to respond (increase) to the improved habitat. Absolute numbers of deer must remain constant as habitat improves for this strategy to succeed.

3.2.4 Interfering Vegetation

Site factors influence oak regeneration potential and vary by habitat type (group). The potential for and success of oak regeneration is strongly influenced by the density, size, and type of competing vegetation. This level of competition is influenced by habitat type and disturbance history. On most sites, significant oak regeneration is unlikely unless competing vegetation is limited through natural disturbance (e.g., fire) or controlled by human cultural activities (e.g., release). In general, the necessary intensity and frequency of control of competing vegetation is greatest on the more mesic sites, because of the presence and vigorous growth of shade tolerant advance regeneration. Often, on drier sites competition is less intense which can facilitate the success of targeted oak regeneration practices. Identification and interpretation of habitat types can provide an indication of how vegetation will respond to silvicultural treatments (Table 41.6).

Table 41.6. Oak regeneration – typical level of competition and primary competitors.

Northern Habitat Type Groups	Typical Level of Competition	Most Common Competitors
Very Dry to Dry	Low – Medium	White pine, Red maple, Shrubs
Dry to Dry-mesic	Low – Medium	Red maple, White pine, Shrubs
Dry-mesic	Medium	Red maple, Mesic hardwoods
Mesic	High	Mesic hardwoods[1]
Southern Habitat Type Groups		
Dry	Low – Medium	Red maple, White pine, Shrubs
Dry-mesic	Medium	Mixed hardwoods2, Mesic hardwoods, Shrubs
Dry-mesic to Mesic	High	Mesic hardwoods, Shrubs
Dry-mesic to Mesic (phase)	High	Mixed hardwoods, Shrubs (mesic hardwoods)
Mesic (phase)	High	Mixed hardwoods, Shrubs (mesic hardwoods)
Mesic	High	Mesic hardwoods

1 – Mesic hardwoods include: sugar maple, beech, basswood, white ash, yellow birch, and ironwood.
2 – Mixed hardwoods include: red maple, elms, hickories, and black cherry.

Stand disturbance history (type, severity, and timing) can significantly alter expected levels of competition. For example, dense shrub layers (e.g., hazel) can develop following successive thinnings and exclude oak regeneration on dry sites. Shrubs and invasive exotic plants can become abundant and provide intense competition across a wide range of habitat types; this problem is particularly prevalent on sites that were previously non-forested (e.g., agricultural lands or historic savannas). Aggressive shrub and herb layers can out-compete oak seedlings; intensive management techniques may be required to control competition and establish regeneration. Within each stand being managed, established competition and potential control measures should be evaluated.

3.2.5 Wildlife

Oak forests are found on a wide variety of habitat types throughout the state. Several species of oak with different silvical characteristics and habitat requirements produce a diversity of oak habitat for wildlife. However, all oak species share some characteristics that make them attractive to wildlife. Consumption of acorns may be the most noticeable wildlife use of oak stands but the growth characteristics and associated tree, shrub, and ground layer species found in the oak type also contribute to the value.

The sapling stage of an oak stand resulting from a regeneration cut provides food and cover to many early-successional specialists. Regenerated stands in the sapling stage have a high population of birds, peaking 5-6 years after stand initiation on good sites. Ground layer specialists such as flickers colonize the site. As the regeneration grows, shrub-nesting specialists dominate the site. Opportunities to manage for ruffed grouse nesting and brood rearing habitat become important in some portions of the state during this phase of stand development. A series of different species and foraging guilds are present as the stand matures. The original assemblage of bird species stabilizes at around 40-50 years of age and is maintained as stand structural development continues. Extended rotation in this type benefits bark gleaners and cavity nesters.

Breeding bird populations in oak as well as other forest types are enhanced by treatments that increase structural complexity of stands, increase the variety of stands, or increase the rotation age. Oak forests have from 28 species of breeding birds present in dry, nutrient-poor northern stands to 41 species of breeding birds present in more mesic southern stands. Structural development and complexity of all levels of the stand is more important in determining the bird assemblage than is the geographic area of the state. In other words, the habitat type on which oak is found determines its use by wildlife in general and breeding birds in particular. Regardless of this, persistence of oak snags and den trees extends the usefulness of this important wildlife feature.

Shelterwoods and thinnings may increase use of the type by flycatchers and orioles. These birds forage by using the high canopy trees to set out in search of prey. Foraging by midlayer or ground specialists may be available if a midlayer of shrubs or small residual remains in the stand.

Acorns are high in fats and metabolizable energy but low in sodium and calcium and relatively low in protein. The nutritive value of acorns is affected by phenols which interfere with digestion. The red oak group has higher concentration of phenols than the white oak group. Other differences such as acorn size and shell thickness from different oak species affect wildlife use of this food source. As an example, ruffed grouse tend not to eat acorns with the caps on. Animals on an acorn diet usually need to supplement with other foods although the fats present in acorns and the potential for weight gain can outweigh the nutritional deficiencies of acorns. It is a popular belief that white oaks are more beneficial to wildlife than red oaks. While the palatability of white oak acorns and the nutritive value of the nuts may be higher, white oaks do not provide as dependable a source of acorns as do red oaks. Additionally, the timing of acorn drop and germination affects availability of the acorns for foraging wildlife. Management should be directed toward providing representatives from both oak groups wherever possible if wildlife habitat is a concern.

Small mammal populations can be sensitive to the nutritional benefits provided by acorns. Overwinter survival and breeding rate of squirrels depend mainly on fall mast crop. The age at which gray squirrels become sexually mature and the breeding rate in gray squirrels is directly affected by the mast crop. Small mammals also benefit from cavities in oaks for protection.

As with small mammals, large mammals such as black bear and deer take advantage of the nutritional benefits of acorns when available. Survival of bear cubs and breeding success are impacted heavily by the nutritional status of female bears. Oak stands represent an important food source remembered and monitored yearly by bears. Knowledge of the location of oaks may be transmitted from female bears to their offspring. While browse is the primary source of food for deer, they take advantage of acorn crops and benefit greatly from them. A good mast crop can also positively affect winter survival of deer and subsequent fawn production and survival. However, high deer populations can affect regeneration of oak (refer to Herbivory by Deer section of Appendix C: Forest Health Management Guidelines).

Wild turkey populations fluctuate with food production, and adverse food conditions affect winter survival and reproduction. Mast production of any kind is important but not reliable and turkeys rely on other sources of food. When available, acorns are a major food source in every season. If managing for turkeys, an interspersion of oak and other hardwoods with openings provides good habitat.

Acorns are the mainstay of the diet for wood ducks in fall and winter. Wood ducks will leave the water to forage on upland sites, but these sites must be relatively free of undergrowth. Wood ducks forage on all types of acorns but prefer smaller nuts with thin shells. Tannin concentration within the nuts does not seem to affect wood ducks as much as it does other animals.

Cavity promotion and protection may be as important to wood ducks as the mast production. Natural cavities used by wood ducks are almost always in live trees. Most wood duck nests are located within 200 yards of water. The trees or the portion of the trunk containing the cavity should have a diameter of 12" to provide for an inside diameter of the nest cavity of 7” or greater. Cavities with a roof are better than cavities without and an entrance of 3.5-4” is preferred. Small cavity entrances provide better protection from predators. High cavities are more readily found and provide some protection from predation. In general, cavities higher than 30’ are preferentially used over cavities located closer to the ground. As with entrance size, predator exclusion may be the major factor determining suitability. Cavities in which the wood duck hen is successful in nesting are more likely to be used in subsequent years. Other cavity users will have different requirements. Cavity development and retention in oak trees is an extremely important wildlife consideration because of the potential for large cavities and the persistence of this attribute. Many large-bodied cavity users in Wisconsin need cavities of 18” or larger. Examples of large-bodied cavity users include vultures, barred owls, and bears.

Maintaining oak wherever possible will benefit a wide array of wildlife. The benefits of the type extend from thermal protection to nesting habitat to a food resource. Many Wisconsin wildlife species will spend at least a portion of their annual cycle in oak. If oak is not a major component of the forest in the area, any stand may be particularly important to local wildlife populations. When regenerating a stand in this situation, consider adjusting the rotation to take some portions of the stand early or late, so that 25-40% of the stand can be maintained in acorn production at all times. If possible, a diversity of oak species in a stand or closely associated in a landscape will benefit wildlife particularly if representatives of both the white oak and red oak groups can be maintained.

Summary of oak recommendations to benefit wildlife:

- Maintain and encourage oak
- Promote a diversity of oak species
- Maintain cavity trees
- Maintain acorn production
- Consider oak stand contribution in landscape

3.2.5.1 *Deer and Herbivory Effects*

Deer can have a significant impact on the success or failure of regenerating oak. A survey conducted of DNR foresters in 2006 identified deer browsing as the most common reason for lack of natural oak regeneration. Success of oak regeneration will vary across the state depending on local deer densities and carrying capacity. It is projected that regeneration of oak will be successful where deer densities are at or below 50% of carrying capacity. Oak regeneration where deer densities are above 50% carrying capacity will most likely require protection from deer to be successful. Fencing or individual tree protection has been shown to be the most successful. (Dey et al. 2008). Brose et al. (2008) recommend that up to 8 times the number of smaller established seedlings (less than 3’ tall) may be needed in areas of high deer numbers. See the discussion on deer herbivory in the Forest Health section.

3.2.6 Endangered, Threatened and Special Concern (ETS) Species

Oaks can be dominant in at least 10 different natural community types, including some globally rare types, and these are associated with many rare species. Maintaining oak on the landscape will be important for many species, and there are often opportunities to maintain habitats for rare species while managing for high quality timber and other objectives.

From a biodiversity perspective, a challenge with oak-dominated ecosystems is determining where to attempt regeneration versus where to try to keep existing oak on the landscape for as long as possible. Even for sites where biodiversity is the primary management objective, there are decisions regarding where to manage for closed canopy forest versus maintaining rare, fire-dependent community types such as Oak Openings or Oak Barrens communities that support many rare plant and animal species.

Stand conversion, in general, is an important issue. For example, a site classified as oak based on basal area could have a heavy component of young jack pine and be located next to a known population of the federally listed Kirtland’s warbler (*Dendroica kirtlandii*), a species that uses scrubby jack pine for its breeding habitat. Another oak stand could contain the largest block of mature oak forest in the county and be extremely important for an entirely different group of species. Issues such as these are best addressed using a broad, landscape-scale examination that includes the species present, as well as the site’s context, viability, and the feasibility of maintaining the site at the desired stage, among other considerations. See the

Landscape Considerations section, as well as the Ecological Landscapes of Wisconsin Handbook (WDNR 2011a) for more information.

Some of the rare species associated with oak can be found in closed-canopy forests such as Cerulean warbler (*Dendroica cerulea*) or autumn coral root (*Corallorhiza odontorhiza*), while others require much more open conditions such as red-headed woodpecker (*Melanerpes erythrocephalus*), slender glass lizard (*Ophisaurus attenuatus*) or kitten tails (*Besseya bullii*). As oak has a major role in so many different habitats with an extremely wide range of structure, composition, moisture, nutrients, and geography, it would be impossible to cover all the important rare species considerations in this brief section. Instead, the major themes are highlighted here, and the reader is encouraged to use the Bureau of Endangered Resources Web pages (*dnr.wi.gov/org/land/er/*), as well as other sources for more information.

There are several general considerations related to rare species and oak management. These include special microsites, developmental stages, the size of forested blocks and their context, special natural communities and habitats, and important structural features within stands. Although direct harm or “take” of rare species can often be avoided through simple prescription modifications such as changes to the timing of harvests, there are often opportunities to provide long-term sustainable habitat for species through more comprehensive planning and management.

Rare species are under threat from shrinking habitat, the direct/indirect effects of invasive species, and other factors. Using ecosystem management principles (WDNR 2011a), habitat can be maintained for rare species and produce a sustainable timber supply within a given planning unit/group of planning units. The best management plans will include considerations for a broad suite of plant and animal species, with information regarding how a given stand fits into the ecological context of the larger landscape.

<u>Identify special habitats</u>
Special microsites for rare species can be important during oak management, as many rare species are limited to these small areas within larger blocks of forested habitat. For example, cliffs, ephemeral ponds (vernal pools), seeps or springs, or rock outcrops, as well as prairie, savanna, or barrens remnants may harbor rare species. Most areas have not been thoroughly surveyed for rare species, so it is important to maintain these habitats, proactively, so undocumented species can continue to persist and/or additional species can begin to colonize these areas in the future.

Cliffs and bedrock glades: These features may require one of two different approaches, depending on their physical characteristics and the species present. For moist cliffs, which sometimes exhibit seepage, modify harvests near the feature to retain shade and provide moisture for species requiring those characteristics. For dry cliffs or bedrock glades with species requiring more open conditions, the removal of shade, especially by removing trees from the base of the cliff, may greatly improve conditions.

Ephemeral ponds (vernal pools): Small seasonally flooded areas that add significant biological diversity to forest stands. Although usually found on mesic sites, these features can sometimes be found in dry-mesic forests. They are especially important breeding sites for amphibians which are, in turn, an important food source for other wildlife. Shade should be retained on these ponds whenever possible, and harvesting should avoid felling trees into or skidding through them. Some species can also benefit from maintaining additional coarse woody debris in the stands surrounding the ponds. Conversely, in dry habitats, such as places in the Northwest Sands, oak forests or savannas may be located on former prairie or barrens sites that had been regularly affected by fire in the past. These ponds are not well-understood in the Lake States, but there may be benefits to greatly reducing the shade around them, as they can contain species adapted to more open conditions.

Native prairie and savanna remnants: Native prairies cover less than 8,000 acres statewide, and over half of these acres are protected and managed to expand and enhance the prairie community. Most of the remaining prairies are very small and continue to decrease in size every year through woody species encroachment. Virtually all of the known remnants are adjacent to, or near, an oak forest. These fire-dependent communities, once identified, are often maintained at the size at which they were found. However, these prairies have often been greatly reduced in size over the past several decades, and there are opportunities to expand these areas.

Oak openings: Oak savannas are now globally rare and often contain many of the same herbaceous species found in prairies, along with others adapted to partial shade conditions. These areas require active restoration, and there can be benefits to managing them as part of a prairie/savanna/oak forest continuum. Enlarging the prairie and softening the edges enhances habitat and improves viability for rare species populations. Depending on landowner objectives, a shift in management direction toward non-forest community management could be needed to maintain larger areas of savanna habitat, although limited timber production could be a viable part of the management plan. At a minimum it would be best to manage the oaks and hickory at savanna densities (i.e., 1 to 17 trees per acre) next to the prairie whenever possible.

Sand blows and barrens remnants: These communities are primarily found in sandy nutrient-poor to very nutrient-poor habitat types. Characteristic features are bowl-shaped areas of open sand, scrubby oaks with multiple short stems, and a sparse ground layer with an abundance of foliose lichens. These areas can harbor numerous rare species such as tiger beetles, skippers, reptiles, and plants. Most often basal area would need to be kept near or at the minimum stocking level to maintain habitat for these sand-loving species. Reduction of tree density by thinning or treating oaks, use of prescribed fire, and avoidance of open sand areas as landing sites or logging roads can increase both economic and ecological benefits. These areas might best be managed from a non-commercial perspective to continue to support light-demanding species. Often times, however, these areas will be small patches that could be managed compatibly with the larger surrounding forest through simple modifications. Where these patches exist, it is important to use care during site preparation activities by avoiding spraying herbicides on understory plants (other than exotics) and being careful with mechanical site preparation.

Riparian habitats: Wisconsin’s Best Management Practices for Water Quality have greatly improved our protection of riparian areas in an effort to maintain water quality. However, additional considerations may be needed to sustain rare species habitats. For example, wood turtles spend portions of the year foraging in the forest well away from the rivers, so harvest timing considerations would be needed, at a minimum. Acadian Flycatchers (*Empidonax virescens*) sometimes prefer deep, shady ravines along streams, so a broader landscape approach might be best for determining how to best accommodate that species. The best approach to maintain rare species habitats is to look at the habitat needs of the species in question, the topography and hydrology of the area, and the relationship of the riparian area to the surrounding landscape.

Biological “hotspots”: In addition to the special habitats already mentioned, bird rookeries, bat hibernacula, herptile hibernacula, migratory bird concentration areas, and cave/sinkhole systems can harbor many rare species. These hotspots can be permanent such as caves, or temporary like bird rookeries. Different strategies may apply, depending on the characteristics of the site and the species in question. Consultation and advice from wildlife or endangered resources specialists should be sought when these hotspots are encountered.

<u>Retain and enhance structure to managed forests</u>
Structural retention is modeled on the biological legacies that remained after natural disturbances, and these legacies are largely missing from much of our actively managed forests. After windstorms, tornadoes, or even the most intense forest fires, many tree individuals and clumps could be expected to survive. Old retained trees can provide numerous ecological benefits, such as current and future cavities, distinctive architecture with large branches that are used as movement corridors or the foundation for large nests, and diverse habitats for insects and spiders. Retaining large vigorous trees, decadent trees, snags, and downed logs enhances structural complexity and provides specialized habitats for numerous species. This also contributes to the food web of the forest ecosystem and helps to maintain diverse fine root and fungi systems in the soil.

Recent literature has also highlighted the importance of cavities, as well as large trees with loose bark for several forest-dwelling bat species (Lacki et al. 2007), and many other species have long been known to use these features like northern flying squirrels, lizards, and several bird species. Consider retaining these features whenever possible. For example, include scattered large trees and snags in clearcut/coppice harvests, or remove only a portion of the oak in the second stage of a shelterwood operation.

Little data exists on how much structure should be retained to benefit rare species in the Lake States. Chapter 24, Marking Guidelines, provides the general retention guidelines recommended by the department. These guidelines could be exceeded for stands where management goals include maintaining or enhancing biodiversity such as High Conservation Value Forests (HCVFs).

Remnant patches of late developmental forest: Maintenance of long-rotation forest with high canopy closure can greatly benefit certain rare species. For example, cerulean warbler prefers old mixed hardwood forest, especially with oaks, that occurs in large patches (>250 acres) with at least 70% crown closure. Planning for this species requires examining its life history to develop a management strategy. By using a landscape approach, a forest management plan could consider forest size, age, and crown closure within the various units of the property or group of properties for which plans are being developed. See the Old Growth Handbook (WDNR 2006a) for a discussion of managed old-growth and extended rotation forestry techniques.

Utilizing alternative approaches

Prescribed burning: Fire is now routinely used for restoring savanna, prairie, and barrens habitats, and there is potential to increase its use as a silvicultural tool in Wisconsin (see Prescribed Fire, Management Alternatives Section). Regular fire was applied to Wisconsin's landscape for at least a few thousand years. This long period of fire followed by fire suppression and decades of grazing provided the unique conditions that led to much our present-day oak forest. Several rare species were well-adapted to the filtered sunlight and low shrub competition that resulted from these conditions, and these species could now benefit from the use of fire along with understory removal in many cases.

Artificial habitats: In some instances, a critical habitat requirement for a species is largely missing from the landscape, and there is often a high degree of competition for the few remaining habitats. For example, the cavity-dwelling Eastern Bluebird (*Sialia sialis*), known historically from savanna habitats, and the Prothonotary Warbler, known from bottomland hardwoods along water, both may lose competition battles with other more aggressive birds. Erecting and monitoring suitable nest boxes in favorable locations can greatly increase the chances for these birds' survival. Nest boxes may also be useful for augmenting populations of northern flying squirrel (*Glaucomys sabrinus*), a Species of Greatest Conservation Need, at sites where there are not ample opportunities to provide large cavity trees, snags, and woody debris (WDNR 2006b). Although this work may not always be practical from an operational standpoint, landowners could be encouraged to erect and monitor these structures with good chances for success.

Adaptive management and monitoring: Many aspects of endangered and threatened species management are not well-understood, yet management activities are being carried out by hundreds of foresters across the state. Managers often have to rely on scarce information for species life history or ecological disturbance patterns, and information on species' responses to silvicultural techniques is often notably lacking. It is very important, therefore, to learn from foresters' shared experiences by monitoring the results of the various management trials and techniques currently in use. As we learn more about rare species and how they respond to our activities, the practice of sustainable forestry can continue to evolve along with our knowledge base.

Table 41.7. Select rare vertebrates that can be associated with oak stands, general habitat preferences, and sample beneficial management considerations. Scores are from the Wildlife Action Plan (WDNR 2006b) and indicate the species' affinity with a particular natural community type on a scale from 1-3, with 3 being the highest. There is potential for species to occur in natural community types not indicated in the Wildlife Action Plan; good examples of this are indicated with an "X," rather than a numerical score. The considerations column is provided for broad planning purposes, and these are not avoidance measures. Please consult additional sources for life history information. The species list is not exhaustive, as other rare species may be found in oak-dominated ecosystems.

	oak often dominant								oak can be common					
Species / State Status *	**Central Sands Pine–Oak Forest**	**Northern Dry Forest**	**Northern Dry-Mesic Forest †**	**Oak Barrens**	**Oak Opening**	**Oak Woodland**	**Southern Dry Forest**	**Southern Dry-Mesic Forest**	**Floodplain Forest**	**Northern Mesic Forest**	**Pine Barrens**	**Southern Mesic Forest**	**Habitat**	**Considerations**
Rare Birds														
Acadian flycatcher (*Empidonax virescens*) – THR						X	1	3	2			3	Mature hardwood forest, with semi-open understory and a preference for deep, shaded ravines.	Extended rotation and landscape planning. Maintain large blocks of forest where possible.
Black-throated blue warbler (*Dendroica caerulescens*) - SC/M			2							3			Mature hardwood forest with areas of dense understory in	Maintain large blocks of mesic forest where possible. Group selection patches and blowdown

	oak often dominant								oak can be common					
Species / State Status *	**Central Sands Pine–Oak Forest**	**Northern Dry Forest**	**Northern Dry-Mesic Forest †**	**Oak Barrens**	**Oak Opening**	**Oak Woodland**	**Southern Dry Forest**	**Southern Dry-Mesic Forest**	**Floodplain Forest**	**Northern Mesic Forest**	**Pine Barrens**	**Southern Mesic Forest**	**Habitat**	**Considerations**
													northern Wisconsin.	patches could be beneficial.
Cerulean warbler (*Dendroica cerulea*) - THR						2	1	3	3	1		2	Full-canopied mature to old oak, central hardwoods, and floodplains.	Extended rotation and landscape planning. Maintain large blocks of forest where possible.
Great egret (*Ardea alba*) - THR									2				Floodplain Forests and other riparian forests.	Maintain large blocks of floodplain and riparian forest where possible. Consult with department biologists/ecologists regarding active colonies.
Hooded warbler (*Wilsonia citrina*) - THR								3				3	Brushy gaps in large blocks of oak and other hardwood forests.	Group selection management and landscape planning.

	oak often dominant								oak can be common					
Species / State Status *	**Central Sands Pine–Oak Forest**	**Northern Dry Forest**	**Northern Dry-Mesic Forest †**	**Oak Barrens**	**Oak Opening**	**Oak Woodland**	**Southern Dry Forest**	**Southern Dry-Mesic Forest**	**Floodplain Forest**	**Northern Mesic Forest**	**Pine Barrens**	**Southern Mesic Forest**	**Habitat**	**Considerations**
Kentucky warbler (*Oporornis formosus*) – THR								2	3			3	Large blocks of mature hardwood forest usually near streams or in ravines w/ a dense understory.	Extended rotation and landscape planning.
Lark sparrow (*Chondestes grammacus*) - SC/M				3							2		Oak Barrens, sand Prairies, and some shrub, old field, and open grassland areas w/ bare soils or sand blows.	Barrens management and landscape planning.
Louisiana waterthrush (*Seiurus motacilla*) - SC/M								3	X	X		3	Large blocks of mature hardwood forest usually near streams or in ravines.	Riparian BMPs on small streams and extended rotation. Maintain large blocks of forest where possible.

	oak often dominant								oak can be common					
Species / State Status *	**Central Sands Pine–Oak Forest**	**Northern Dry Forest**	**Northern Dry-Mesic Forest †**	**Oak Barrens**	**Oak Opening**	**Oak Woodland**	**Southern Dry Forest**	**Southern Dry-Mesic Forest**	**Floodplain Forest**	**Northern Mesic Forest**	**Pine Barrens**	**Southern Mesic Forest**	**Habitat**	**Considerations**
Northern goshawk (*Accipiter gentilis*) - SC/M		1	2							3			Mature deciduous, coniferous, or mixed forest types, mostly in the northern 2/3 of the state.	Maintain large forested blocks through landscape planning. Follow department guidance around nest trees.
Prothonotary warbler (*Protonotaria citrea*) - SC/M									3				Bottomland hardwoods in the southern 2/3 of the state, typically in truncated snags among flooded timber.	Retain trees with nest cavities and/or retain snags and stumps in floodplain forests. Can benefit from nest boxes.
Red-shouldered hawk (*Buteo lineatus*) - THR		1	2					2	3	2		2	Floodplain forest and mature to old-growth hardwoods are preferred.	Riparian BMPs and extended rotation.
Worm-eating warbler (*Helmitheros vermivorus*) – END							2	3				2	Prefers wooded slopes within mature	Extended rotation and landscape planning.

	oak often dominant								oak can be common					
Species / State Status *	**Central Sands Pine–Oak Forest**	**Northern Dry Forest**	**Northern Dry-Mesic Forest †**	**Oak Barrens**	**Oak Opening**	**Oak Woodland**	**Southern Dry Forest**	**Southern Dry-Mesic Forest**	**Floodplain Forest**	**Northern Mesic Forest**	**Pine Barrens**	**Southern Mesic Forest**	**Habitat**	**Considerations**
													to old blocks of hardwoods.	
Yellow-billed cuckoo (*Coccyzus americanus*) - SC/M						1	1	2	3	1		2	Prefers floodplains and mature hardwoods.	Riparian BMPs and extended rotations
Yellow-crowned night-heron (*Nyctanassa violacea*) – THR									3				Bottomland hardwoods in southern Wisconsin.	Maintain large blocks of Floodplain and riparian forest where possible. Avoid disturbance during breeding season.
Yellow-throated warbler (*Dendroica dominica*) – END								2	3				Bottomland hardwoods in extreme southern Wisconsin (usually associated with sycamores).	Maintain large blocks of Floodplain Forest. Conserve and restore large sycamore trees.
Rare Reptiles and Amphibians														

	oak often dominant								oak can be common					
Species / State Status *	**Central Sands Pine–Oak Forest**	**Northern Dry Forest**	**Northern Dry-Mesic Forest †**	**Oak Barrens**	**Oak Opening**	**Oak Woodland**	**Southern Dry Forest**	**Southern Dry-Mesic Forest**	**Floodplain Forest**	**Northern Mesic Forest**	**Pine Barrens**	**Southern Mesic Forest**	**Habitat**	**Considerations**
Blanding's turtle (*Emydoidea blandingii*) – THR				3	3	2		2	2		3	2	Variety of aquatic marsh habitats, but they occupy terrestrial habitats for nesting or commuting to nest sites.	Protect nest sites which are usually in open, sunny areas on well-drained soils and probably reused annually.
Eastern massasauga (*Sistrurus catenatus catenatus*) – END ‡				3					3		3		Strongly associated with floodplain habitats along medium to large rivers in very few locations.	Consult department biologists / ecologists. Protect wetland hydrology.
Four-toed salamander (*Hemidactylium scutatum*) - SC/H									3	3		3	Hardwood forests and to a lesser degree, conifer swamps. Require dense mosses near	Maintain forest cover around isolated wetlands. Provide buffers around known wetland habitats, and maintain large

	oak often dominant								oak can be common					
Species / State Status *	**Central Sands Pine–Oak Forest**	**Northern Dry Forest**	**Northern Dry-Mesic Forest †**	**Oak Barrens**	**Oak Opening**	**Oak Woodland**	**Southern Dry Forest**	**Southern Dry-Mesic Forest**	**Floodplain Forest**	**Northern Mesic Forest**	**Pine Barrens**	**Southern Mesic Forest**	**Habitat**	**Considerations**
													fishless water for breeding.	forest blocks wherever possible. Avoid negatively impacting moss habitats.
Gophersnake (*Pituophis catenifer*) - SC/P	2			3	3	3	2	2			3	2	Open upland habitats with dry, sandy soils such as prairies, oak savannas, barrens pastures, and meadows.	Barrens/savanna/prairie management. Reduce cover on dry bluff habitats.
Gray ratsnake (*Pantherophis spiloides*) - SC/P					2	3	3	3	2			3	Oak forest and savanna habitats in southwest counties.	Maintain forest and savanna habitats. Reduce cover near known overwintering habitat.
North American racer (*Coluber constrictor*) - SC/P				2	X		2	2			2		Prairie and savanna habitats.	Manage to minimum stocking levels or convert to

	oak often dominant								oak can be common					
Species / State Status *	**Central Sands Pine–Oak Forest**	**Northern Dry Forest**	**Northern Dry-Mesic Forest †**	**Oak Barrens**	**Oak Opening**	**Oak Woodland**	**Southern Dry Forest**	**Southern Dry-Mesic Forest**	**Floodplain Forest**	**Northern Mesic Forest**	**Pine Barrens**	**Southern Mesic Forest**	**Habitat**	**Considerations**
														barrens/savanna/prairie native community management.
Ornate box turtle (*Terrapene ornata*) – END	3			X	3	3	3	3				2	Sand prairies, sand barrens, and sandy, open oak woods.	Manage to minimum stocking levels or convert to barrens native community management.
Pickerel frog (*Lithobates palustris*) - SC/H									2	2		2	Riparian habitats along streams and rivers especially springs and spring runs.	Protect riparian areas, including habitats surrounding ephemeral ponds.
Prairie ring-necked snake (*Diadophis punctatus arnyi*) - SC/H	2			2	3	2	2	2					Variety of open or partially open habitats such as prairies or savannas.	Manage to minimum stocking levels or convert to barrens/savanna/prairie native community management.

	oak often dominant								oak can be common					
Species / State Status *	**Central Sands Pine–Oak Forest**	**Northern Dry Forest**	**Northern Dry-Mesic Forest †**	**Oak Barrens**	**Oak Opening**	**Oak Woodland**	**Southern Dry Forest**	**Southern Dry-Mesic Forest**	**Floodplain Forest**	**Northern Mesic Forest**	**Pine Barrens**	**Southern Mesic Forest**	**Habitat**	**Considerations**
Prairie skink (*Plestiodon septentrionalis*) - SC/H		2	2	3	3	2	2	2			3		Barrens, savanna, and grassland habitats w/ sandy soils.	Manage to minimum stocking levels or convert to barrens/savanna/prairie native community management.
Six-lined racerunner (*Aspidoscelis sexlineata*) - SC/H				3	3								Savanna and dry prairie habitats w/ sandy soils.	Manage to minimum stocking levels or convert to barrens/savanna/prairie native community management.
Slender glass lizard (*Ophisaurus attenuatus*) – END				3	2						3		Sandy oak woods, oak barrens, and sand barrens.	Manage to minimum stocking levels or convert to barrens native community management.
Timber rattlesnake (*Crotalus horridus*) - SC/P					3	3	3	3	2			3	Steep, rocky prairies and adjacent oak woodlands.	Manage near minimum stocking levels and use of prescribed fire.

	oak often dominant								oak can be common					
Species / State Status *	**Central Sands Pine–Oak Forest**	**Northern Dry Forest**	**Northern Dry-Mesic Forest †**	**Oak Barrens**	**Oak Opening**	**Oak Woodland**	**Southern Dry Forest**	**Southern Dry-Mesic Forest**	**Floodplain Forest**	**Northern Mesic Forest**	**Pine Barrens**	**Southern Mesic Forest**	**Habitat**	**Considerations**
														Protect known hibernacula.
Upland sandpiper (*Bartramia longicauda*) - SC/M				X	2	1	2				X		Tallgrass prairies, sedge meadows, unmowed fields, barrens, and scattered woodlands.	Grassland / barrens management, if possible. Highly area-sensitive, manage at landscape level.
Western ribbonsnake (*Thamnophis proximus*) – END				2	1								Along rivers and adjacent to marshes.	Consult department biologists / ecologists.
Western wormsnake (*Carphophis vermis*) - SC/H							2	2					Bluff prairies, adjacent savannas and open woodlands. Known only from Grant County.	Extremely fossorial snake, maintain CWD. Consult department biologists / ecologists. Protect known sites.

	oak often dominant								oak can be common					
Species / State Status *	**Central Sands Pine–Oak Forest**	**Northern Dry Forest**	**Northern Dry-Mesic Forest †**	**Oak Barrens**	**Oak Opening**	**Oak Woodland**	**Southern Dry Forest**	**Southern Dry-Mesic Forest**	**Floodplain Forest**	**Northern Mesic Forest**	**Pine Barrens**	**Southern Mesic Forest**	**Habitat**	**Considerations**
Wood turtle (*Glyptemys insculpta*) – THR				3	2	2			3	3	3	2	Clean rivers and streams with moderate to fast flows and adjacent riparian wetlands and upland deciduous forests.	Protect riparian areas, adjacent upland forest, and avoid locating landings on sandy openings near rivers where nest sites are located.
Rare Mammals														
Franklin's ground squirrel (*Spermophilus franklinii*) - SC/N				3	3	2					3		Brushy and partly wooded barrens areas, dense grassy, shrubby marshland, and prairie edges	Barrens/savanna/prairie management. Protect known sites.
Northern flying squirrel (*Glaucomys sabrinus*) - SC/P	1	2	3				1	1	2	3	1	1	Northern forests, often, but not always, with conifers.	Retain current or future large cavity trees, snags, and coarse woody debris.

	oak often dominant								oak can be common					
Species / State Status *	**Central Sands Pine–Oak Forest**	**Northern Dry Forest**	**Northern Dry-Mesic Forest †**	**Oak Barrens**	**Oak Opening**	**Oak Woodland**	**Southern Dry Forest**	**Southern Dry-Mesic Forest**	**Floodplain Forest**	**Northern Mesic Forest**	**Pine Barrens**	**Southern Mesic Forest**	**Habitat**	**Considerations**
Northern long-eared bat (*Myotis septentrionalis*) – THR	2	2	2	2	1	2	2	2	2	2		2	Colonies in tree cavities and crevices, under exfoliating bark, in live trees, and bridges (expansion joints). Most prefer trees over man-made structures. Most often feeds within the forest and can forage in more cluttered vegetation than other bats.	Maintain forest cover. Retain large cavity trees, and large diameter living trees whenever possible. Consider extended rotation or managed old-growth.
Prairie vole (*Microtus ochrogaster*) - SC/N				2	2						1		Dry open areas; seldom in sparsely wooded areas	Manage to minimum stocking levels or convert to barrens / savanna /

	oak often dominant								oak can be common					
Species / State Status *	**Central Sands Pine–Oak Forest**	**Northern Dry Forest**	**Northern Dry-Mesic Forest †**	**Oak Barrens**	**Oak Opening**	**Oak Woodland**	**Southern Dry Forest**	**Southern Dry-Mesic Forest**	**Floodplain Forest**	**Northern Mesic Forest**	**Pine Barrens**	**Southern Mesic Forest**	**Habitat**	**Considerations**
														prairie management.
Water shrew (*Sorex palustris*) - SC/N									2	2		2	Marshes, bogs, swamps, and cold, small streams with cover along the banks.	Protect riparian areas.
Woodland jumping mouse (*Napaeozapus insignis*) - SC/N		1	1						2	3	1	2	Forested or brushy areas near water, wet bogs, stream borders.	Protect riparian areas.
Woodland vole (*Microtus pinetorum*) - SC/N	2			1	3	3	3	3	1			1	A variety of habitats, but most often found in hardwood forests.	Maintain a component of dead and down woody material.

* State status definitions: THR = Wisconsin Threatened, END = Wisconsin Endangered, SC = Wisconsin Special Concern with following modifiers SC/P = fully protected; SC/N = no laws regulating use, possession, or harvesting; SC/H = take regulated by establishment of open closed seasons; SC/M = fully protected by federal and state laws under the Migratory Bird Act

† Typically dominated by red and white pine, but oak may be dominant where pines have been removed.

‡ Also a candidate for federal listing

Table 41.8. Select rare invertebrates that can be associated with oak stands, general habitat preferences, and sample beneficial management considerations. These are meant as broad considerations for planning purposes, rather than avoidance measures; please consult additional sources for life history information. The species list is not exhaustive, as other rare species may be found in oak-dominated ecosystems.

Species / State Status *	Habitat	Considerations
A looper moth (*Euchlaena milnei*) – SC/N	Dry prairie and oak savanna	Prairie management, expansion and feathered savanna edge
A tiger beetle (*Cicindela patruela patruela*) - SC/N	Sand Blows and sand barrens	Sand blow and sand barrens
Frosted elfin (*Callophrys irus*) - THR	Oak barrens - host larval plant is lupine	Manage to minimum stocking levels or convert to sand barrens native community management
Henry’s elfin (*Callophrys henrici*) - SC/N	Oak forest edges and sandy oak woods	Manage to minimum stocking levels or convert to sand barrens native community management
Hickory hairstreak (*Satyrium caryaevorum*) - SC/N	Host plant is hickory	Retention of hickory
Phlox moth (*Schinia indiana*) - THR	Sand prairies, sand barrens and sandy open oak woods	Manage to minimum stocking levels or convert to sand barrens native community management
Pink sallow (*Psectraglaea carnosa*) - SC/N	Sandy oak barrens	Manage to minimum stocking levels or convert to sand barrens native community management
a tiger beetle (*Cicindela patruela huberi*) - SC/N	Sand blows and sand barrens	Sand blow and sand barrens
Whitney’s underwing (*Catocala whitneyi*) - SC/N	Dry prairie and oak savanna	Prairie management, expansion and feathered savanna edge

* State status definitions: THR = Wisconsin Threatened, END = Wisconsin Endangered, SC = Wisconsin Special Concern with following modifiers SC/P = fully protected; SC/N = no laws regulating use, possession, or harvesting; SC/H = take regulated by establishment of open closed seasons; SC/M = fully protected by federal and state laws under the Migratory Bird Act

Table 41.9. Select rare plants that can be associated with oak stands, general habitat preferences, and sample beneficial management considerations. These are meant as broad considerations for planning purposes, rather than avoidance measures; please consult additional sources for life history information. The species list is not exhaustive, as other rare species may be found in oak-dominated ecosystems.

Species / State Status	Habitat	Considerations
Brittle prickly pear (*Opuntia fragilis*) - THR	Grows in sand barrens and on open rock outcrops.	Open bedrock management, sand barrens – no landings
Clustered sedge (*Carex cumulata*) - SC	A species of grass found mostly on sandy soils and rocks	Open bedrock management or sand barrens conversion.
Fragrant sumac (*Rhus aromatica*) - SC	Prairie edges, oak openings and woodlands.	Manage near minimum stocking levels or convert to oak savanna native community management and prescribed fire.
Hairy-jointed meadow parsnip (*Thaspium barbinode*) - END	Oak woodlands near loess capped crests or in ravines.	Manage near minimum stocking levels or convert to oak savanna native community management and prescribed fire.
Hoary tick-trefoil (*Desmodium canescens*) - SC	Rich oak woodlands	Manage near minimum stocking levels or convert to oak savanna native community management and prescribed fire
Kittentails (*Besseya bullii*) - THR	Oak savanna	Manage to minimum stocking levels or convert to oak savanna native community management and prescribed fire
Mullein foxglove (*Dasistoma macrophylla*) - SC	Found in rich oak and hardwood forest mostly southwest.	Extended rotation or old-growth management, especially near shaded rocks.
October ladies-tresses (*Spiranthes ovalis*) - SC	Found in oak and central hardwood forests.	Extended rotation or old-growth management.
Oval-leaved milkweed (*Ascelpias ovalifolia*) - THR	Sand prairie, sand barrens open sand oak forests	Manage to minimum stocking levels or convert to sand barrens native community management
Prairie fame-flower (*Talinum rugospermum*) - SC	A rare species in Wisconsin growing on bedrock or in sand prairies and sand barrens.	Open bedrock management, sand blows, sand barrens

Species / State Status	Habitat	Considerations
Prairie trillium (*Trillium recurvatum*) - SC	Rich oak and central hardwoods in the southern two tiers of counties	Extended rotation or old-growth management.
Purple milkweed (*Asclepias purpurescens*) - THR	Rich oak woodlands and wet-mesic prairie	Manage to minimum stocking levels or convert to oak savanna native community management and prescribed fire
Rocky Mountain sedge (*Carex backii*) - SC	A species of grass found mostly on sandy soils and rocks.	Open bedrock management or sand barrens conversion.
Sand violet (*Viola fimbrulata*) - END	Sand Barrens and sand prairies	Convert to sand barrens management
Slender bush clover (*Lespedeza virginica*) - THR	Rocky oak woodland glades.	Partially shaded bedrock with oak canopy and prescribed fire.
Three birds orchid (*Triphora trianthophora*) - SC	Rich oak and central hardwood forests.	Extended rotation or old-growth management
Upland boneset (*Eupatorium sessilifolium*) - SC	Rich oak woodlands	Manage near minimum stocking levels or convert to oak savanna native community management and prescribed fire
Wafer-ash (*Ptelea trifoliate*) - SC	Habitat is oak central hardwood forest edges and gaps	Prescribed fire.

* State status definitions: THR = Wisconsin Threatened, END = Wisconsin Endangered, SC = Wisconsin Special Concern

Other rare species may occur in oak-dominated stands. Many of these species will be found in specialized habitats such as rock outcrops, cliffs, ephemeral ponds, prairie/savanna openings, and seeps. If a rare species is known to be present in an area, including Element Occurrences from the NHI Database, refer to the department screening guidance for avoidance and contact the appropriate staff, as needed. Information for NHI Working List species and their habitats can be found through the Bureau of Endangered Resources Web pages (*dnr.wi.gov/org/land/er/*).

Figure 41.8. Ephemeral Pond (vernal pool) in an unusual location: a dry-mesic forest. Sauk County, Photo by Drew Feldkirchner, WDNR.

Figure 41.9. Slender glass lizard a species associated with Wisconsin oak savannas. Adams County, Photo © Nick Walton.

Figure 41.7. Dwarf milkweed (Asclepias ovalifolia), a species associated with barrens that can be found in patches of dry oak-dominated forests. Monroe County, Photo by Eric Epstein, WDNR.

4 STAND MANAGEMENT DECISION SUPPORT

4.2 Key/Checklist for Evaluation Cover Type Stand Management Options

Note: The following recommendations assume the management objective is to maximize quality and quantity of oak sawtimber.

1. Seedling and saplings	2
1. Pole and/or sawtimber	4
2. Adequate stocking (see appendix to evaluate stocking)	3
2. Inadequate stocking (see appendix to evaluate stocking	Plant to bring up to adequate stocking.
3. Poor site (typically < 50 site index) (Table 41.3 and Table 41.5) (includes most northern pin oak)	Grow to rotation
3. Fair to excellent sites (typically > 50 Site Index) (Table 41.3 and Table 41.5)	Evaluate need for release
4. Poor site (typically < 50 site index) (Table 41.3 and Table 41.5) (includes most northern pin oak)	5
4. Fair to excellent sites (typically > 50 site index) (Table 41.3 and Table 41.5)	7
5. Stocking slightly below, at or above B-line	6
5. Stocking significantly below B-line (≤ 40 to 50 ft^2 basal area)	Conduct a regeneration harvest (overstory removal, coppice, clearcut, or combination thereof
6. Not at rotation age	Let grow
6. At rotation age	Conduct a regeneration harvest (overstory removal, coppice, clearcut, or combination thereof
7. Stand not degraded: Stand quality and stocking levels sufficient for continued management: >40 crop trees per acre	8
7. Stand degraded: stand quality and stocking levels insufficient for continued management: <40 crop trees per acre	11
8. Age less than 75% of rotation	9
8. Age greater than 75% of rotation	10

9. Stocking below B-line	Let grow
9. Stocking above B-line and operable	Intermediate thinning to no lower than B-line
10. Not at rotation age	Let grow
10. At rotation age	11
11. Adequate advanced regeneration not present	Apply shelterwood
11. Adequate advanced regeneration present	Overstory removal

5 SILVICULTURAL SYSTEMS

A silvicultural system is a planned program of vegetation treatment during the entire life of a stand. Silvicultural systems typically include three basic components: intermediate treatments (tending), harvesting, and regeneration. With the oak type, silvicultural systems are frequently adapted to meet site-specific and species-specific conditions. As generally accepted in Wisconsin, oak regeneration is accomplished using even-aged methods.

The even-aged regeneration methods generally accepted and supported by literature are:

- Coppice
- Overstory removal
- Shelterwood

5.1 Seedling / Sapling Stands

The first 10-20 years of stand development is called the stand initiation stage and occurs immediately after the disturbance. During this stage, there are typically thousands of trees and shrubs per acre. Competition between trees and shrubs is intense during this period of rapid change. As few as 100 shade-tolerant stems per acre may be a concern at this time (e.g., ironwood, red maple, hazel, prickly ash, etc.). If allowed, these stems could out-compete oak and may eventually dominate the main canopy. Initiation of oak is slow compared to other hardwood trees and shrubs.

If existing seedling/sapling stands do not contain sufficient numbers and/or adequate size of preferred species, one option is to interplant the stand with desirable species. Mechanical or chemical competition control will improve the long-term survival and viability of planted trees.

As a forest progresses through the stand initiation stage to the stem exclusion stage (Frelich 2002, Oliver and Larson 1996), oaks have a higher chance of becoming dominant on low to average quality sites than on higher quality sites (Johnson et al. 2002). On high quality sites, without management intervention, intermediate and codominant oaks have a low probability of becoming more dominant as the stand advances toward maturity. Stocking of dominant, competitive oak can be increased on high quality sites by cleaning (thinning) to release potential crop trees (Dey et al. 2008).

In young stands, release is an important consideration and is often critical to put oak in a competitive position. The best time to apply release treatments is between when the canopy begins to close to within 10-15 years after canopy closure. Canopy closure will vary by site quality and generally occur between 8-15 years of age. Opportunities to improve long term composition of quality oak in the overstory is greatest in young stands that are less than 25-30 years old (Dey et al. 2008).

The number of oak stems required to provide a fully stocked stand for the final harvest is determined by following the evaluation method in Appendix B. Dominant and co-dominant oak stems should be encouraged and released from direct crown competition. Delaying more than 4-5 years could result in reduced growth and possible loss of reproduction. Where oak is not overtopped, defer thinning until crop trees are at least 25' tall (Lamson and Smith 1978).

Locally high populations of whitetail deer are a serious threat to forest regeneration throughout Wisconsin. It is important for foresters prescribing treatments in oak stands to anticipate and plan for this additional problem when establishing seedlings and saplings. In areas of extremely high deer populations, regeneration should be protected against browsing (Marquis et al. 1992).

5.2 Intermediate Treatments

5.2.1 Stem Quality

Factors affecting stem quality include stand history (such as over cutting, high grading, long periods of overstocked conditions), site capability, stand age, genetic variability and damage due to factors such as grazing, insects, disease, ice, wind, and poor harvesting practices and techniques. Hybridization among species within the red oak group has also been observed and can have an impact on quality. Stem characteristics such as forks, epicormic branches, seams, cankers, rot, and logging damage all contribute to lower log grades (See Forest Health Protection Guidelines, Appendix). Damage during harvest should be avoided at all times of the year. Root damage is more common when soils are not dry or frozen. Short cutting cycles combined with frequent entries for thinnings can increase the potential for damage during logging operations, and may also stress the stand due to repeated disturbances.

<u>Site selection</u>
Development of stand quality is the primary focus on sites that are classified as fair to excellent (Table 41.3 and Table 41.5). The focus on quality should occur from establishment of seedlings and saplings through harvest and regeneration treatments. Developing stand quality is not a primary concern on poor sites. Generally, these sites are limited in their capability to produce stands of high-quality oak sawtimber but are managed to maximize vigor.

<u>Density</u>
Stand density should be maintained at or above recommended residual levels to maintain bole quality. Stem form problems, such as epicormic branching, are directly related to stand density and crown development. Epicormic branch sprouts originate from dormant buds embedded in the bark. Bud dormancy is controlled by growth regulators (auxins) which are produced by the terminal buds. Trees lacking a healthy, vigorous, large crown, such as suppressed and intermediate trees in the understory or crowded overstory trees in unmanaged stands, do not

produce sufficient regulators to prevent epicormic sprouting. White oak produces more epicormic branches than red oak within the same crown class (Miller 1996). Dominant trees are less likely to produce epicormic branches than trees in lower crown classes.

Heavy thinnings that subject trees to sudden exposure to high light intensities increase the risk of epicormic branching and can reduce quality. “Trees around the perimeter of openings created by harvesting may also develop many epicormic branches, because the boles of northern red oak in fully stocked stands contain numerous dormant buds.” (Johnson et al. 2002) However, most epicormic branches on dominant and codominant trees develop in the upper stem just below the crown, which is of less concern as this area of the stem typically produces lower quality products.

Branches that result in forking are a stem defect increasing the risk of crown or stem breakage and can subject the stand to greater risk of oak wilt infection if breakage occurs during the growing season.

Crop Trees

Thinning regimes focus on the recognition, selection, and development of high-quality future crop trees. Evaluation of risk, vigor, and attention to future crop trees should be incorporated into the use of recognized marking guidelines. Crop trees are released by following the standard order of removal. Development of stand quality may be a long-term process involving three or more entries, on a cycle of 10-15 years.

The following criteria are generally used to select crop trees (see specifications in Chapter 24):

- Low risk – Tree has little (<10%) or no signs of defect and is likely to live through the cutting cycle to the next entry
- Good crown vigor – Tree is dominant or co-dominant with a good silhouette, healthy foliage, and a full concentric crown.
- Good timber quality – Tree has usable lengths commensurate with site, dbh/length ratio is good, there are no defects that reduce usable length, and any slight crook or sweep can be cut out. Tree has potential for at least one 16’ butt log of tree grade 2 or better.
- Desirable species – Tree is of a species well adapted to the site and of good commercial value with consideration given to landowner objectives.

The process of crop tree selection and management is described in greater detail in Chapter 24, Tree Marking and Retention Guidelines. Also described is the selection and management of residual trees for non-timber benefits.

5.2.2 Non-Commercial Intermediate Treatments

On fair to excellent sites, it is often necessary to enhance stand development with non-commercial intermediate treatments or timber stand improvement practices (TSI). These sites are capable of producing a greater yield and have a greater potential to develop stand quality. On poor sites, after the overstory removal has been completed, it is not necessary to conduct intermediate cuttings.

Where enhancement of stand development and quality are warranted, several methods are available to treat competing vegetation. Stand conditions must be evaluated when deciding which method to use.

5.2.2.1 *Methods to Control Competing Vegetation*

<u>Herbicides</u>
Herbicides can be effectively used against vegetation that competes with oak. The specific herbicide is dependent upon several factors such as the target species and preferred application technique. Stand conditions must also be considered when selecting between application techniques. These techniques include broadcast spraying; cutting the oak and broadcast spraying target species; stem injection; basal application; and cut stump treatments. All techniques require adherence to herbicide labels, appropriate safety clothing and equipment, and following applicator laws, licensing, and applicable forest certification standards.

<u>Mechanical Treatments</u>
Mechanical treatments include cutting, lopping, girdling, ripping, and other use of mechanized equipment. This method usually doesn’t kill the competitor species; however, it can put oak in a more advantageous position to grow through the competitor species. Sometimes this method can be included in a timber sale contract and completed as part of the conditions of the timber sale.

<u>Prescribed Burning</u>
Prescribed burning is an effective means of controlling oak competitors. Oak is more resistant to burning because of its thicker bark and larger root systems as compared to competing species (e.g., maple). Timing the burn to late spring or summer will increase efficacy of the burn, because root reserves are at their lowest and the burn is more lethal. Burning should be conducted when advance regeneration has developed, generally about 3-5 years after a shelterwood cut. More than one burn may be needed, depending on the burn intensity. All burns should be evaluated afterward to determine the need for follow-up treatments. Avoid burning when an acorn crop has just occurred or when oak seedlings are small, of low vigor, or recently established. Care must be taken to avoid basal damage to the seed trees. These trees are of the highest quality and contain the greatest value in the stand. Consideration must be given to the effect the burn may have in future marketing of the seed trees. See Prescribed Fire in Management Alternatives section.

5.2.2.2 *Practice of Release*

<u>Weeding</u>
Weeding eliminates or suppresses undesirable vegetation (trees, shrubs, vines, herbaceous vegetation, and invasive species) regardless of crown position within a stand. Most often these undesirables are fast-growing tree, aggressive shrub, or herbaceous species that retard advance regeneration or prevent the establishment of desirable regeneration. Intensive management techniques may be required to control competition and establish regeneration.

Cleaning
Cleaning releases desirable seedlings and saplings from undesirable tree species in the same age class that overtop them or are likely to do so. It is used to control a stand's species composition and to improve growth and quality of crop trees. Studies show that cubic foot yields of oak stands are more than 50% greater when cleaning (thinning) is begun at age 10 than when thinning is begun at age 60 (Gingrich 1971).

Liberation
Liberation frees favored trees from competition with older, overtopping trees. It is applied when a young crop of desirable seedlings and/or saplings are overtopped by less desirable, older competitors. Overtopping can reduce growth, cause stem deformations, and increase mortality due to excessive shade. In instances where cutting competitors would excessively damage the understory oak, girdling or applying herbicides to overtopping standing trees will accomplish the objective of the release while providing other benefits by creating snags. To achieve multiple benefits and ecological objectives, consider leaving reserve trees.

5.2.3 Thinning

5.2.3.1 *Non-Commercial Thinning and Improvement*

Crown release thinnings in young non-commercial pole stands will favor crop trees by removing adjacent crown competitors. This allows crop trees to develop full, vigorous crowns necessary for improving growth and quality. It is sometimes referred to as "crop tree release". If small diameter wood markets exist, non-commercial thinning and improvement may be deferred until a timber sale is viable, but there is a risk of losing potential oak crop trees due to competition. However, if a delay is feasible, a commercial intermediate thinning may allow residual trees to maintain or increase their growth and quality without the expense of a non-commercial practice.

Management should focus on improving stand composition and growth (Smith and Lamson 1983). Even when desired species are present in sufficient numbers, growth is often slow and mortality high due to intense competition from herbaceous vegetation and less preferred species. Early, intensive release can be used to improve stand species composition and growth by reducing competition (Della-Bianca 1969). Individual release of selected stems can facilitate adequate stocking of preferred species as the stand matures. Select 50-100 trees/acre, approximately 20-30' apart, and remove all trees whose crown touches the crown of the selected tree. At this stage, be conservative, creating spaces no more than five feet wide on 3 or 4 sides of selected crop trees (Sampson et al. 1983). This should occur when a stand is 10-20 years old or when tree height averages 25'. Delaying cutting until trees are 25' high may allow for better access into the stand and there will be fewer trees to cut. Stump sprouts of undesirable trees will not be a problem as they will be in the understory of these young dense stands. However, apply the release cut **before** selected crop trees fall below the codominant size class.

Thinning clump (stump) sprouts that originate from a single stump is a consideration in young stands. This practice can maximize residual stem growth and quality when thinned to one stem before reaching 3" dbh (age 12-15) (Johnson and Rogers 1984). Thin stump sprouts only on fair to excellent sites. Simulations indicate that thinning clumps to 1 stem at 5 years of age in stands of site index 70 can produce boles 11.6" dbh at age 25 when coupled with periodic thinnings around crop trees to a spacing that approximates B-level stocking. See Chapter 23, Intermediate Treatments for more detailed information on clump thinning.

General clump (stump) thinning guidelines (Lamson et al. 1988):

1. Thin clumps when 10-20 years old and only on good sites
2. Select crop stems that are dominant or codominant, straight, and free of forks and other defects and originate not more than 6" above the ground line.
3. Retain the best 1-2 crop trees/clump. If two crop stems are retained, the stems should be far enough apart so the stems do not fuse together at a common base (Roth 1956, Stroempl 1983)
4. Remove all intermediate or codominant trees if the crowns touch the crop stem crown, or if the crowns are above the crop stem crown.
5. Thin around thinned clumps in about 10 years to sustain maximum diameter growth.

5.2.3.2 *Commercial Thinning and Improvement*

Intermediate thinning is used in oak stands on fair to excellent sites (Table 41.3 and Table 41.5) to control stand density and structure. Regeneration is not an objective of thinning. The primary objectives of intermediate thinnings in oak stands are:

- To capture losses that would occur as a result of competition and suppression
- To improve overall stand quality by concentrating growth on the most desirable trees
- To improve stand vigor, growth and health
- To improve species composition
- To generate income during the stand rotation

Stocking charts have been developed for many timber types to determine how much basal area to remove with an intermediate thinning. These charts identify a stand's relative density when stand basal area and the number of trees per acre are known (see Chapter 23 – Intermediate Treatments).

Relative density is a measure of tree crowding that accounts for both the size of the tree and the amount of space typically occupied by a tree of that size and species, so it is an especially useful measure in mixed species stands (Stout and Nyland 1986). A relative density of 100% implies the growing space is fully occupied; growth will slow and some trees will be crowded out and die. On most stocking charts, 100% relative density is represented as the A-line. If relative density is at least 60% and below 100%, trees can fully occupy the growing site. The optimum relative density to retain after a thinning is a compromise between an individual tree's rate of growth, quality, and the number of trees needed to fully utilize available growing space (Gingrich 1967). The lower limit of stocking necessary to reach 60% (B-line) stocking in ten years on average sites is represented as the C-line and corresponds roughly to 40-50% relative density. Typically, thinnings are implemented at 80-100% stocking (usually economically operable), and density is reduced to 60-70% stocking to optimize sawtimber growth and quality.

Intermediate thinnings control stand density to maximize both stand growth and quality. Yields of high-quality crop trees are increased dramatically if stands are thinned early and regularly, particularly on good sites. Pole-size trees respond well to thinning. Diameter growth of released trees for a 20-year period can be expected to be about double that of non-released trees. Oak stands grown for quality timber should be kept fairly dense until the lower 20-25' of the boles are relatively free of branches. This will generally be when the trees are 40-50' tall (30-45 years old). Crop trees released at age 45 can average a 40% increase in diameter growth over unreleased trees in the 10 years immediately following release.

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

1. Risk – Cut high risk trees likely to die between cuttings (unless retained as a wildlife tree)
2. Release crop trees – Cut poorer quality competitors to provide crown growing space around crop trees to promote growth and quality development
3. Vigor – Cut low vigor trees, based on crown size and condition, crown class, and potential stem decay
4. Stem form and quality, based on usable log length and potential decay
5. Less desirable species (determined by landowner objectives)
6. Improve spacing

Free thinnings are generally recommended in oak. Removing trees of the lower crown class facilitates the utilization of trees likely to die due to suppression and captures income that would otherwise be lost. Thinning should be heavy enough not only to remove suppressed and intermediate stems but also the poorer, codominant trees as well. Follow crop tree selection and order of removal guidelines. Even though crown thinning is most applicable in stands of shade tolerant hardwoods, some degree of crown thinning is conducted in practice to provide release of codominant and dominant crown class. Ideally, crop trees should be 20-25' apart, however if they are unevenly distributed, leaving two crop trees close together and treating them as one tree is recommended. Note: spacing is last on the order of removal. Improving stand quality is a primary objective.

Thinning young stands offers the best opportunity to influence stand species composition and increases the growth rate of residual trees. If thinning is applied in a timely fashion to a young stand, the first thinning should be heavy, reducing stocking to approximately 50% (see stocking charts fig. 41.11a and b). Thinned stands should be allowed to grow to an operable stocking level before thinning again, generally 8-15 years. To maximize diameter-growth rates of crop trees, it is recommended that all subsequent thinnings should target a residual of 60 to 70% stocking.

First thinnings applied late (in overstocked stands) should take a more conservative approach, reducing the residual stocking to 60% for poletimber and 70% for sawtimber but removing no more than one-third of the stocking (see stocking chart, fig. 41.11a and b). Thinning lightly and more frequently will more safely develop tree vigor and strength until target residual densities can be achieved.

As a general guideline, if site preparation techniques are used to control understory development, thinning may continue until the time of regeneration. Refraining from thinning during the last 20% of the rotation may reduce development of a brushy understory that could interfere with desirable regeneration at stand rotation. This may reduce the need for site preparation (competition control) to ensure adequate regeneration of oak.

The thinning systems described above are not suitable for high graded stands with an abundance of undesirable growing stock. Assuming adequate good growing stock still exists; several improvement cuts may be applied in order to rehabilitate these stands (see degraded stands).

Cutting cycle intervals

The cutting cycle re-entry interval generally ranges from 8-15 years based on landowner objectives. Shorter cutting cycles can maintain higher tree growth rates, but operability (costs and benefits) must be considered. Shorter, more frequent re-entries may increase the potential for degrading stand quality through stem damage, root damage, and soil compaction. Conversely, shorter cutting cycles will allow for capture of more high risk and low vigor trees that would otherwise succumb to mortality. Longer cutting cycles can maximize tree quality and reduce negative impacts, such as damage to residual trees, soil compaction, aesthetic impacts (reduced slash), and ecological impacts (habitat disruption).

5.3 Natural Regeneration Methods

Two important rules of oak regeneration apply to most methods of oak regeneration for successful representation of oak in a future stand: 1) there must be competitive sources of oak regeneration in advance of the final overstory harvest, and 2) the advance oak regeneration must be adequately and timely released (Loftis 2004) especially on fair to excellent sites. Regenerating oak stands, especially on better quality sites, should be thought of as a process rather than an event. Several years to decades may be required to properly implement multiple practice prescriptions (preharvest site preparation to release of saplings). A commitment to long term management will be required to successfully regenerate and establish new oaks. On dryer habitat types, where competition is less intense, adequate natural advanced regeneration is sufficient, and tree diameter is smaller, regeneration can be accomplished with one harvest operation relying on a combination of systems (i.e., overstory removal, coppice, and clearcut).

Regeneration systems recommended to regenerate oak vary by habitat type due to variation of oak species, maximum tree size, and competition across ranges of habitat conditions. Table 41.11 and Table 41.12 indicate regeneration systems by habitat type groups that can be successfully applied in Wisconsin.

Table 41.10. Northern habitat type groups – generally accepted regeneration methods.

Habitat Type Groups	Coppice	Overstory Removal	Shelterwood
Very Dry to Dry	GAP	GAP	X
Dry to Dry–Mesic	GAP	GAP	GAP
Dry-Mesic	X	GAP	GAP
Mesic		GAP	GAP
Mesic to Wet–Mesic		GAP	GAP

GAP – Generally Accepted Practice
X – Method may have potential for application (See discussion under specific regeneration method)

Table 41.11. Southern habitat type groups – generally accepted regeneration methods.

Habitat Type Groups	Coppice	Overstory Removal	Shelterwood
Dry	GAP	GAP	X
Dry–Mesic	XX	GAP	GAP
Dry-Mesic to Mesic, and Mesic inc. phases	XX	GAP	GAP
Mesic to Wet–Mesic		GAP	GAP

GAP – Generally Accepted Practice
X – Method may have potential for application. (See discussion under specific regeneration method)
XX - On steep slopes in the Driftless area with small diameter trees where shelterwood is not practical.

5.3.1 Even-Age Regeneration Methods

<u>Advanced reproduction, stump sprouts and regeneration potential</u>
The key to successful regeneration of oak is to have sufficient numbers of large advance reproduction and/or potential oak stump sprouts to provide adequate oak stocking at the end of the regeneration period. Oak stands will depend on regeneration from new seedlings, seedling sprouts and/or sprouts from the stumps of overstory trees cut during harvesting (Johnson 1993). Seed origin trees are preferred for producing high-quality sawtimber.

Advanced reproduction exists either as true seedlings (recent germinants) or seedling sprouts. The root systems of seedling sprouts are usually considerably older than the stems and are capable of supporting much greater stem growth than those of true seedlings.

The size of advance regeneration is important, with taller stems having a greater chance of surviving and competing to be part of a future stand of oak. Jacobs and Wray (1992) developed a system for determining the regeneration potential of oak stands (Appendix B).

Jacobs and Wray defined competitive oak seedlings taller than 4’ as those with the greatest potential to contribute to the future stand. Quantity can make up for seedling size but requires greater number of smaller seedlings to contribute to the future stand. Guidelines indicate that twice as many seedlings 2.1- 4.0’ tall are needed, or, six times the seedlings 1.1- 2.0’ tall, or, thirty times the seedlings <1.0’ tall. Based on this system, a minimum of 515 seedlings (>4’ tall) per acre are needed to produce a fully stocked stand of oak by the time the stand reaches an average diameter of 9”.

In many of the drier oak forests of Wisconsin, advanced oak reproduction naturally accumulates to sufficient numbers over time prior to reaching rotation age. In dry-mesic or better site oak forest, accumulation of sufficient advance oak reproduction may take up to a decade or more to amass after initiating a disturbance or series of disturbances (shelterwood system).

Sprouting of overstory oaks after harvesting is an important source of regeneration and should be considered if there is a need to compensate for seedling oak regeneration deficiencies. The sprouting probability of oak species varies considerably, but generally decreases as tree size and age increase. Figure 41.10 shows the estimated sprouting probability for oak stumps in relation to site index and parent tree diameter. Table 41.16 lists the potential (percentage) of oak sprouts expected by species, site index, and age class. Deer have shown a preference for stump sprouts over seedlings.

Prior to the final overstory removal for any of the recommended oak regeneration systems, the adequacy of oak advance regeneration and/or potential of oak stump sprouting to compensate for oak advance regeneration deficiencies needs to be evaluated. See Appendix B for a procedure to evaluate the adequacy of advance oak regeneration and stump sprout potential.

The publication, “Prescribed Regeneration Treatments for Mixed–Oak Forests in the Mid-Atlantic Region” (Brose et al. 2008) provides an alternative method of evaluating the adequacy of oak seedlings that may have some application in Wisconsin based on height and/or root collar diameter. This publication defines “competitive” oak seedlings as being at least 3’ tall with a root collar diameter greater than 0.75”, which are highly likely to be dominant or codominant at crown closure of the new stand following harvest.

“Established” oak seedlings (0.5-3.0’ tall with a root collar diameter of 0.25-0.75”) are too small to compete on their own but with silvicultural treatments designed to give them a competitive edge they may develop.

“New” oak seedlings (< 0.5’ tall with a root collar < 0.25”) are considered too small to be determined established and should not be counted on for advance regeneration while implementing regeneration practices. Although this method of evaluating oak seedlings may have application in Wisconsin, further testing and development will be needed to adapt it to Wisconsin’s oak forest.

5.3.1.1 *Coppice*

Coppice regeneration relies on a mixture of seedling sprouts and stump sprouts for oak regeneration. It is most applicable on dry sites. On dry-mesic northern sites, coppice has potential to augment regeneration with advance seedling established at the time of overstory removal. Typically, regeneration will also be supplemented with advance regeneration, and potentially with acorn germination at the time of the harvest.

Frequency of sprouting is related to species, tree diameter, age, and site index (Johnson 1977, Weigel and Johnson 1998). In general, sprouting decreases with increasing diameter and age (Figure 41.10 and Table 41.18).

Follow-up thinning treatments of stump sprouts may be a consideration on dry-mesic and better sites to improve quality of stems (see Non-Commercial Thinning and Improvement section and Chapter 23).

Newly regenerated oak stands should be evaluated for competition after five years. If overtopping competition is present and becomes detrimental to the oak seedlings, mechanical control, herbicide, or a prescribed burn may be required to release seedlings (see Non-Commercial Intermediate Treatment and Prescribed Fire sections).

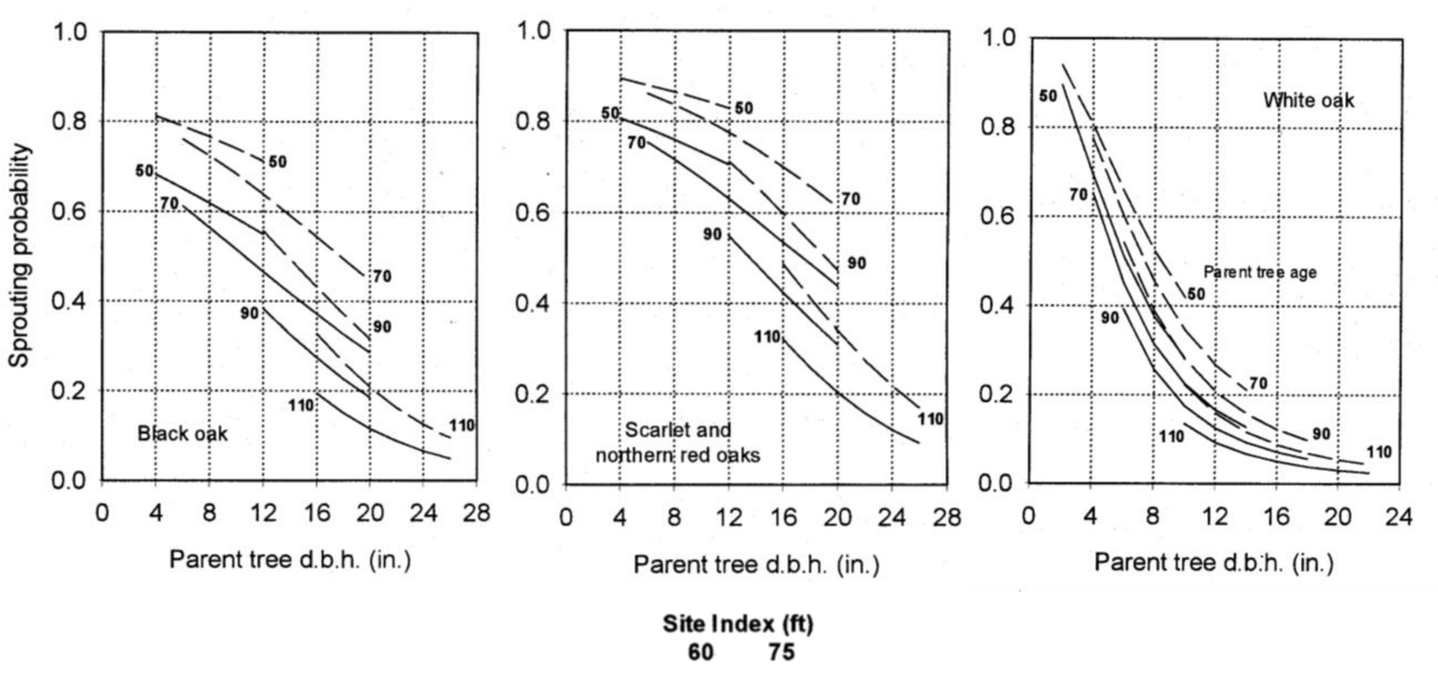

Figure 41.10. The estimated probability that an oak stump will have at least one living sprout one year after the parent tree is cut, by species, and parent tree age and dbh (Weigel and Johnson 1998).

5.3.1.2 *Overstory Removal*

This even-aged regeneration method removes all the overstory trees to release existing advanced oak regeneration beneath it. Success depends on adequate advance oak regeneration as described in Appendix B: Advance Reproduction and Regeneration Potential. Acceptable regeneration can generally be defined as a minimum of 515 seedlings/saplings per acre that are greater than 4' tall, to as many as 3100 seedlings/acre that are 1-2' tall. Damage to regeneration should be minimized by limiting the extent of skid trails and/or conducting operations during winter or fall. Overstory removal is used more frequently as the sole regeneration method on drier oak sites where adequate advance regeneration is established and is used in combination with shelterwood harvests on better sites. In practice, regeneration may also be supplemented with seedling and stump sprout development, as well as acorn germination at the time of harvest.

Newly regenerated oak stands should be evaluated for competition after five years. If overtopping competition is present and becomes detrimental to the oak seedlings, then mechanical control, herbicides, or a prescribed burn may be required to release seedlings (see Non-Commercial Intermediate Treatment and Prescribed Fire sections).

5.3.1.3 *Shelterwood*

This even-aged regeneration system involves 2-3 cutting treatments extended over a 5-30 year period and may include a preparatory cut or burn, or scarification to encourage the development of advanced reproduction, a seeding cut with site preparation, and an overstory removal cut. Table 41.10 and Table 41.11 identify site types where the shelterwood method is commonly applied. Although the shelterwood method may have potential on dry sites, generally it is not needed due to the presence of advance regeneration, the potential for stump sprouting, and because competition is less of a factor. Establishing oak on better quality sites (mesic) will entail greater effort and costs.

Three key aspects of applying a shelterwood system are controlling the amount of light, controlling competition, and incorporating acorns into mineral soil. The primary purpose for retaining a partial overstory after the first seeding cut is not to modify the understory but rather to provide a seed source to help establish advance regeneration. Results of present studies suggest it is the shade cast by the development of shade-tolerant midstory and ground layers, rather than the main canopy (shelterwood canopy) itself, that hinders the survival and growth of oak seedlings (Lorimer et al. 1994). Thus, controlling understory and midstory vegetation prior to and following a shelterwood cut is as important as the shelterwood cut itself. Thorough evaluation of potential competing vegetation (e.g., ferns, shrubs, small tress) is essential and may be accomplished by methods described in Appendix B for evaluating oak regeneration potential. If greater than 30% of the plots have competing vegetation, treat with herbicides, prescribed fire, or mechanical removal.

An optional preparatory cut may be needed in oak stands not previously thinned. A preparatory cut may be applied 10-15 years prior to rotation designed to remove non-oak and poor-quality trees and facilitate crown expansion of residual good phenotype oak trees to increase seed production.

Recommended crown closures for the first of a two stage shelterwood cut is approximately 40-60%. Retained trees should:

- have a dominant, large, vigorous crown
- have a high-quality bole
- be evenly spaced

An important component of the shelterwood system is evaluation of the acorn crop (see Appendix A) (Grisez 1975). Mature acorn crops are best evaluated in August or for one-year acorns in the red oak group, any time after the first growing season. Time site preparation treatments with a good or bumper acorn crop (August to November). If there is a thick duff layer, scarification may be necessary at the time of acorn drop, or shortly after, to incorporate the acorns into mineral soil. Scarify at least 50% of the stand area.

Successful shelterwood cuts have been accomplished with either of two separate methods.

1. The first method involves establishment of the shelterwood harvest and either:
    a. Timing the harvest (August to November) with a good or bumper acorn crop or
    b. Scarifying the harvest area (August to November) at the time of a good or bumper acorn crop, and then harvesting that winter or the following winter. Experience has shown a salmon blade works well for preharvest scarification. Scarification should emphasize mixing of the top 6” of soil, incorporating the acorns and uprooting undesirable competition.
2. The second method involves completing the seed cut of the shelterwood without regard for timing or size of the acorn crop. After the seeding cut is completed, the site will require monitoring as above for a good or bumper acorn crop. All site preparation treatments are timed to the occurrence of a good acorn crop. Chemical application and prescribed burning to control competing vegetation should occur prior to acorn drop (generally in August to September). Scarification is done during or shortly after the acorn drop. Silviculture field trials in Wisconsin have shown that use of an anchor chain works well for post-harvest scarification.

Under shelterwood methods, once adequate advance oak regeneration is present (within 3-5 years after germination) (see Appendix B on Evaluating Adequacy of Oak Regeneration), remove the residual overstory while maintaining reserves. If there is not adequate oak regeneration, consider planting oak to supplement natural regeneration or repeating site preparation for natural oak regeneration. Protection from deer may be necessary.

Newly regenerated oak stands should be evaluated for competition after 5 years. If overtopping competition is present and becomes detrimental to the oak seedlings, mechanical control, herbicide, or a prescribed burn may be required to release seedlings (see Non-Commercial Intermediate Treatment and Prescribed Fire sections).

5.3.1.3.1 Shelterwood and Plant

Shelterwood and plant is an alternative used on good to excellent sites (dry mesic or better) when scarification and other site preparation techniques are impractical due to site limitations (e.g., steep slopes, rocky, etc.). A 19-year study of various oak regeneration treatments concluded that underplanting on mesic sites is necessary to achieve established dominant oaks (Povak et al. 2008). Planting under the shade of a shelterwood can give the seedlings time to overcome planting stress before overstory removal. The residual overstory trees also provide some natural seeding and oak establishment to supplement planting. Cut from below to leave approximately 40-60% stocking in dominant and codominant trees. Control of mid-story competition and stump sprouts of undesirable species is essential. Plant large seedlings (at least 3/8" stem diameter) from a known source with fibrous root system (at least six permanent, first order laterals). Plant twice as many seedlings as needed to supplement natural regeneration. If oak stock is smaller than recommended, plant 3x as many seedlings as needed to supplement natural regeneration. Planting the "extra" seedlings assures the establishment of the desired number of trees. Remove the overstory during the dormant season in 3-6 years when planted seedlings are at least 2' tall (Jacobs and Wray 1992). See Appendix B: Evaluating the Adequacy of Oak Regeneration.

Newly regenerated oak stands should be evaluated for competition after 5 years. If overtopping competition is present and becomes detrimental to the oak seedlings, mechanical control, herbicide, or a prescribed burn may be required to release seedlings (see Non-Commercial Intermediate Treatment and Prescribed Fire sections).

5.3.1.4 *Clearcutting*[1]

Clearcutting is the process of removing most or all of the woody material creating an open area leading to the establishment of an even-aged stand. Regeneration is natural seeding from the trees cut in the harvest operation. If attempted, timing of cut is critical and must occur after August coinciding with an abundant, mature acorn crop (See Appendix A, Evaluation of Acorn Crop), control of competing tree saplings, and scarification. This method is silviculturally risky because there is only a single opportunity to naturally regenerate the stand.

Planting large oak seedlings in combination with clearcutting can help improve regeneration success. It is essential to control undesirable hardwood trees, preferably with spot treatment with herbicides to prevent hardwood sprouting. Plant large seedlings (at least 3/8" stem diameter) from a known source with fibrous root system (at least 6 permanent, first order laterals). Plant 3x as many trees as desired to supplement natural regeneration in the established stand. Planting the "extra" seedlings assures the establishment of the desired number of supplemental oak trees. Evaluate the stand for competition to planted oak after 5 years. If overtopping competition is present and becomes detrimental to the oak seedlings, mechanical control, herbicide, or a prescribed burn may be required to release seedlings (see Non-Commercial Intermediate Treatment and Prescribed Fire sections, and Artificial Regeneration guidance in Chapter 22). Refer to the Chapter 21 for more details on artificial regeneration.

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[1] Management practice that may have potential for application in managing oak but has not been widely utilized and tested.

5.3.2 Uneven-Age Regeneration Methods

5.3.2.1 *Patch Selection*[2]

Trees are periodically removed in patches greater than 0.5 acres to typically less than 2 acres in size to create conditions favorable for the regeneration and establishment. The smallest canopy openings are larger than 0.5 acre, which is equivalent to a 167' diameter circular opening (approximately 2x tree height). This system generally favors regeneration and maintenance of shade mid-tolerant species; however, relatively intolerant or tolerant species can be encouraged. Shading effects will vary across the canopy opening, ranging from completely open at the center to shaded at the edge. The distribution of canopy openings may be regular, or irregular depending on variations in stand condition, such as the age, size, vigor, quality, composition, and health of patches of trees.

Acreage regulation determines the number of canopy openings. Patches of trees are harvested at rotation age creating new canopy openings. In addition, site preparation and follow-up release may be needed to establish desired regeneration, and regeneration recruited by past cutting may require release, while the remainder of the stand is thinned (see tending section). Many cohorts of trees must be tracked to evaluate rotation, site preparation and regeneration, release, and thinning of different aged patches. Patch selection is a system to manage uneven-aged stands essentially composed of many small even-aged patches. Both even-aged and uneven-aged silvicultural techniques are employed. Note: patch selection differs from group selection. Under group selection, openings are smaller, ranging from 0.2-0.5 acres in size. Group selection applications to date have proven unsuccessful in regenerating oaks.

5.5 Rotation Lengths and Cutting Cycles

<u>Rotation Definition</u>
In even-aged silvicultural systems a rotation is defined as the period between regeneration establishment and final cutting. The length of rotation may be based on many criteria, including culmination of mean annual increment (CMAI), target size, attainment of a physical or value growth rate, and biological condition.

<u>Choosing an appropriate rotation age</u>
Selecting when to rotate a stand is based on multiple considerations, including landowner goals, stand condition, and expected future growth. The rotation ages provided are guidelines based on literature, empirical data, and professional experience. In application, foresters will need to regularly review stands in the field and exercise professional judgment concerning tree vigor and mortality and stand growth and productivity. Different rotation lengths can result in increased production of some benefits and reduced production of others. Landowner goals and objectives, along with accurate stand assessment, will help evaluate the benefits and costs (ecological, economic, social) associated with different forest management strategies.

[2] Management practice that may have potential for application in managing oak but has not been widely utilized and tested.

Below are rotation age guidelines based on three different management emphases to accommodate a variety of landowner goals.

Table 41.12. Biological and extended rotation age (years) recommendations for oak by Habitat Type groups and species groups (1st and 2nd numbers represent the biological rotation age range, and the 2nd and 3rd numbers represent the extended rotation age range).

Habitat Type	**Black/N. Pin Oaks**	**Red Oak**	**White Oak**
Dry	70-90-110	70-100-120	80-110-150
Dry-mesic	80-110-140	80-120-150	80-140-250
Mesic	90-120-150	100-140-200	100-160-300

5.5.1 Economic Rotation (Maximum Net Present Value)

The economic rotation age maximizes the net present value of the stand. It may only include financial aspects but could also include non-timber benefits. The inclusion of non-timber benefits may shorten or lengthen the optimal rotation depending on the non-timber benefits included. Landowners who choose economic rotation ages generally want to maximize the financial performance of the stand. Economic rotations will vary depending on the target discount rate and factors such as estimated costs and revenues. In practice, there can be significant overlap between economic and biological rotations, but economic rotations are often shorter. For more details on the factors that affect economic rotation age, please refer to the Economics Chapter (Chapter 62).

Oak is an important timber species in Wisconsin, however the products and associated financial returns vary widely by species and site quality. On very dry/nutrient-poor sites (Tables 41.2 and 41.4) with fair to poor potential productivity (SI<50), oak is managed primarily for pulpwood, firewood, and low grade sawtimber. On dry-mesic/medium sites (Tables 41.2 and 41.4) with good productivity (SI ~ 50-60), oak is managed primarily to produce sawtimber with occasional trees reaching veneer quality. On mesic/medium-rich sites (Tables 41.2 and 41.4) oak is managed to produce sawtimber and veneer where relative potential productivity is very good to excellent (SI>60). A recent study found that the best economic returns were found by thinning oak stands before age 50, however later thinning of previously unthinned stands between 60-78 years still increased volume growth rates and provided economic benefits (Demchik et. al. 2016).

Economic rotation data for oak in Wisconsin are very limited (Buongiorno and Hseu 1993, Demchik et. al. 2018). A few studies in the eastern United States calculated the maximum NPV for red oak rotations ranging from 80-125 years, depending on factors such as discount rate, stand quality, thinning regime, and logging system (Hibbs and Bentley 1983, Michie and McCandless 1986, LeDoux 2007). Alternatively, economic rotations can be based on a target rotation size. An economic rotation based on an optimal stem size attempts to capture the greatest stand-level value once the overall dominant/codominant cohort has achieved the highest value product class. The rotation sizes given are based on the average stand diameter of the primary size class, which can be determined from basic cruise data. Rotations based on a size target still must consider appropriate silviculture and regeneration methods for managing oak stands. On medium-rich sites managed for grade 1 and veneer logs, the economic rotation size can typically range from 18”-22” DBH. On poor-medium sites managed for logs grade 2 and below, the economic rotation size can range from 16”-20” DBH (Trimble and Mendel 1969, Hibbs and Bentley 1983, Demchik et. al. 2018). Financial returns on the very dry/nutrient-poor sites are minimal, so rotations are most often based on stand health/vigor and other landowner goals.

5.5.2 Biological Rotation (Culmination of Mean Annual Increment)

The biological rotation seeks to maximize long-term sustained yield, or volume production, and is defined by the age at which maximization or culmination of mean annual increment (CMAI) growth occurs. Biological rotation should therefore not be confused with the term “biological maturity” which is based on a species’ life expectancy. Refer to Table 41.13 for recommended biological rotation ages by Habitat Type groups and species groups. In this guideline, the range in rotation ages is defined at the lower end by CMAI and at the upper end by the average stand life expectancy. The recommended rotations provided are our best estimates of these endpoints based on the literature, Forest Inventory and Analysis (FIA), and other empirical data. On the very dry/nutrient poor sites, the shorter rotation ages are due to expected reduced quality, reduced growth rates, and increased mortality. On medium to rich sites, well-managed stands are often capable of growing longer and maintaining productivity.

5.5.3 Extended Rotation

Extended rotation involves growing stands beyond typical biological rotation ages yet younger than average tree life expectancy, with the objective of managing for both commodity production and the development of some ecological and social benefits associated with older forests. Refer to Table 41.13 for recommended extended rotation ages by Habitat Type groups and species groups. Ecological benefits of extended rotations can include an abundance of large trees, more diverse vertical structure, and greater levels of standing snags and coarse woody debris that support organisms associated with these structures.

5.6 Other Silvicultural Considerations

5.6.1 Prescribed Fire

Fire has played a major role in the regeneration and development of oak-dominated forests. Until recently, prescribed fire has been used infrequently in maintaining open oak-hickory forests and in facilitating regeneration of these species (Lorimer 1993). In the absence of such a disturbance, competition by other species can lead to loss of oak and conversion to a more mesic forest. Past research on prescribed fire in oak has produced mixed results. More recent studies, however, have documented effective ways of applying prescribed burning along with silvicultural methods.

Prescribed fire, especially in dry mesic and mesic oak forests, is used for several reasons, including reducing competition (release burn), preparing seedbed (site preparation burn), and controlling invasive species (Brose et al. 1999). Oak-dominated stands on better quality sites often have considerable competition from more shade-tolerant hardwood species, and if left untreated, establishment of oak seedlings is difficult. If site preparation and release techniques are not used, then further recruitment of oak typically will be minimal. Prescribed fire is a tool that can be applied to enhance the recruitment and establishment of oak regeneration.

Oaks have many fire-resistant adaptations. Mature white oaks tend to be more resistant than mature red oaks due to differences in bark characteristics and ability to compartmentalize (Lorimer 1985). The adaptations are as follows (Savanna Oak Foundation 2010):

- Mature oaks have thicker bark than most other hardwood species and can tolerate moderately intense ground fires.
- Oak regeneration can increase its root to shoot ratio following disturbance and can resprout after top kill.
- Acorns have hypogeal germination, which means that cotyledons are often located well below the soil surface and can survive fire.

Planning the timing and intensity of prescribed fires is important in achieving the desired results. Fire intensity (low and high), number of burns, seasonal timing and stand conditions are factors monitored in recent studies (Brose, 2006). Most research suggests spring understory fire effectively reduces competition and enhances regeneration and establishment of the more fire-resistant oaks. Timing the fire to late spring or summer will increase efficacy of the fire, because root reserves are at their lowest and the fire will be more lethal. High intensity fires (flames greater than 2') decrease dense understory competition more quickly than low intensity fires. When conducting prescribed fires, care must be taken to protect residual oak trees from basal fire damage. Slash and other fuels must be removed from the base of residual oaks to prevent fire damage (Van Lear and Watt 1993).

Two types of prescribed fires recommended for oak are release burns and site preparation burns (Brose et al. 2006):

1. **Release burns** are used to treat competing, undesirable vegetation. Burning can be done after the first removal harvest of the shelterwood or after the final removal cut in mid to late spring during bud-swell and before leaf expansion of canopy trees. Fire intensity should be moderate to high intensity to ensure complete top kill of the undesirable vegetation.
2. **Site preparation burn** is a method to prepare an oak stand for seedling establishment. Timing with a good acorn crop is recommended. The objective is to reduce dense competition and litter so an acorn crop can successfully germinate. Burning can be done in late spring or fall, preferably in spring with a moderate to high intensity fire to top kill competition. Multiple fires at 2-5-year intervals may be needed to reduce competition and enhance the accumulation of oak seedlings over time. It is best to avoid burning if an acorn crop has just fallen or new oak seedlings have just established (Van Lear and Watt 1993).

In Wisconsin, there are examples of using fire in combination with shelterwood harvest. The objectives of the fire are to reduce competition and prepare the seed bed. The technique is attractive because of the relatively low cost of prescribed burning (Becky Marty, MN DNR, personal communication).

The shelterwood-burn method is a 3-step process (Brose et al. 1999):

1. First, the shelterwood seed cut, removes about half of the overstory basal area, retaining the best quality dominant and codominant oaks for further acorn production. This partial harvest is followed by a period of up to 5 years during which the stand is allowed to recover after harvest. During this period the shelterwood stand continues to produce litter, and fine fuel from the harvest dries out in preparation for the effective burn. Also, residual overstory trees continue to develop vigorous crowns and produce a good seed crop.
2. Second, a spring (growing) season burn is applied to set back competition and enhance the seedbed for more oak recruitment. The burn must be considered with regard to impacts on marketability of harvested seed trees, avoiding basal damage to the valuable seed trees. Oak regeneration is then evaluated over a period of 2-4 years.
3. Third, the overstory removal harvest is conducted when oak regeneration is established and of adequate density. Remaining trees can be harvested, leaving up to 15% residual crown closure for green tree retention.

Monitoring and documenting prescribed burn trials is recommended during pre- and post-burn application. The intent is to assess and document fire effects on competition, seed bed enhancement, regeneration stocking, and fire conditions. Recommendations for monitoring include:

- Document pre-burn and post-burn forest conditions – density, size and vigor of regeneration, competition, and crown cover
- Measure fire conditions – fuel load, fire intensity/severity, flame length, rate of spread
- Document the cost – equipment time and labor
- Examine the site the first year and then 3-5 years after the burn - document density, size and vigor of regeneration, competition, and crown cover

5.6.2 Managing “Degraded” Stands

Many stands throughout Wisconsin have been “degraded” or reduced in stand quality due to a multitude of factors including grazing, poor harvesting techniques, high-grading, fire, and other biotic and abiotic agents (e.g., disease, insects, wind, ice). Many of these oak stands have either an abundance of poor-quality stems or some poor-quality larger diameter stems overtopping a younger stand (poles, saplings or seedlings) containing potential crop trees. Some historically oak stands have converted to other hardwood types. If oak is no longer the management objective, refer to the handbook chapter of the new timber type for management guidelines.

Thorough stand assessment is required to determine the site quality, species composition, stand age, number of potential crop trees, and management potential. If a minimum of 40 well-distributed, potential crop trees/acre exist on sites with “fair” or better growth potential (Table 41.3 and Table 41.5) the stand can be managed to rotation length using systems described in this chapter. If remaining crop trees are of poor quality and/or low vigor, consider managing at the lower end of the rotation length for the site. If less than 40 potential crop trees/acre exist and natural regeneration is lacking, the stand could be allowed to reach seed bearing age and then follow the process to conduct a two-step shelterwood to regenerate a new stand. If adequate established regeneration is present, then follow the guidelines for Overstory Removal. Depending on present species composition and the landowner’s objectives, the stand could be considered for artificial regeneration following generally accepted practices (Chapters 21 and 22).

Stands growing on sites with “very poor” to “poor” growth potential (Table 41.3 and Table 41.5) are not capable of producing quality crop trees. Stands at or near b-line on stocking chart should be grown to rotation. Stands younger than rotation and significantly below b-line (basal area of 40-50’^{2}), should be regenerated following guidelines in this chapter.

8 APPENDICES

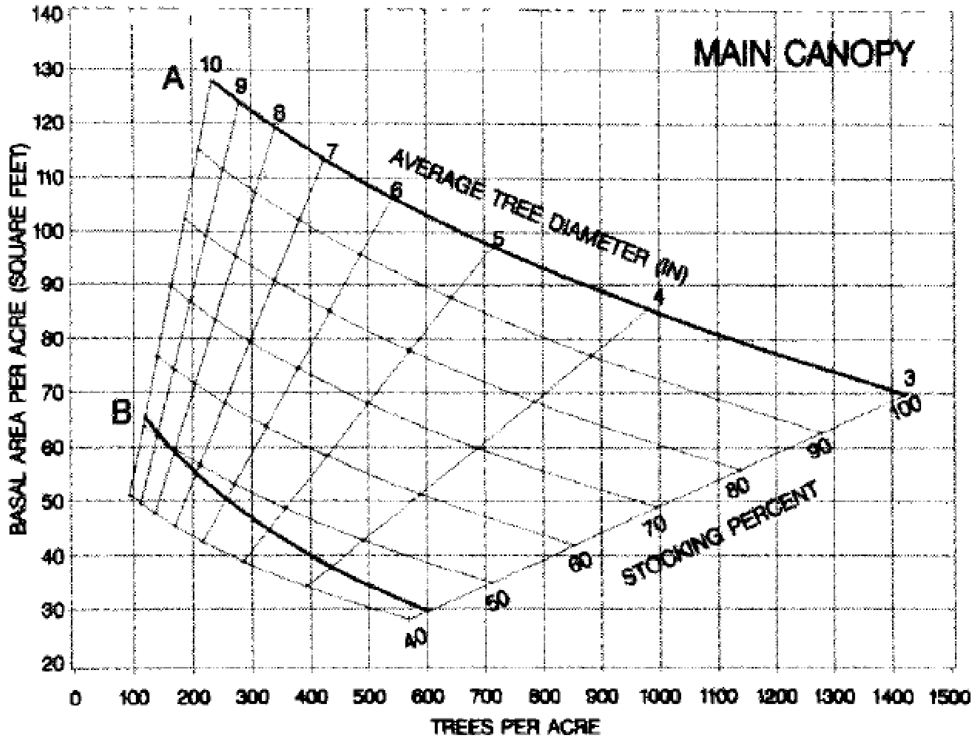


Figure 41.11. Stocking guide for northern red oak stands (average dbh 3-10") in Wisconsin (McGill et al.1999).

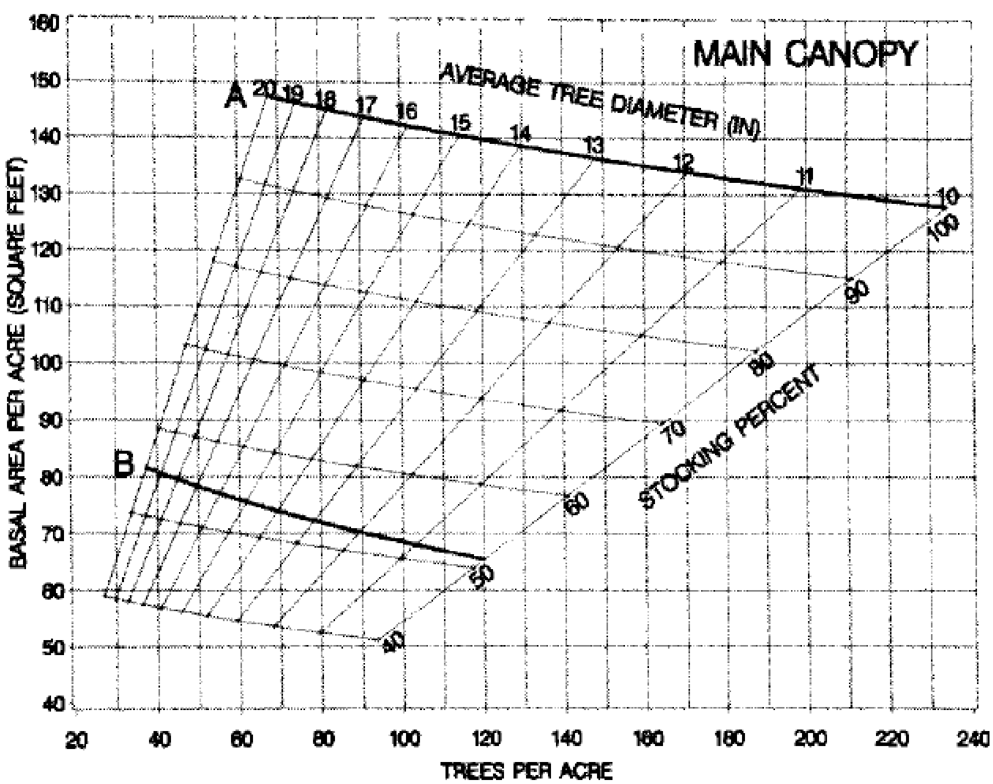


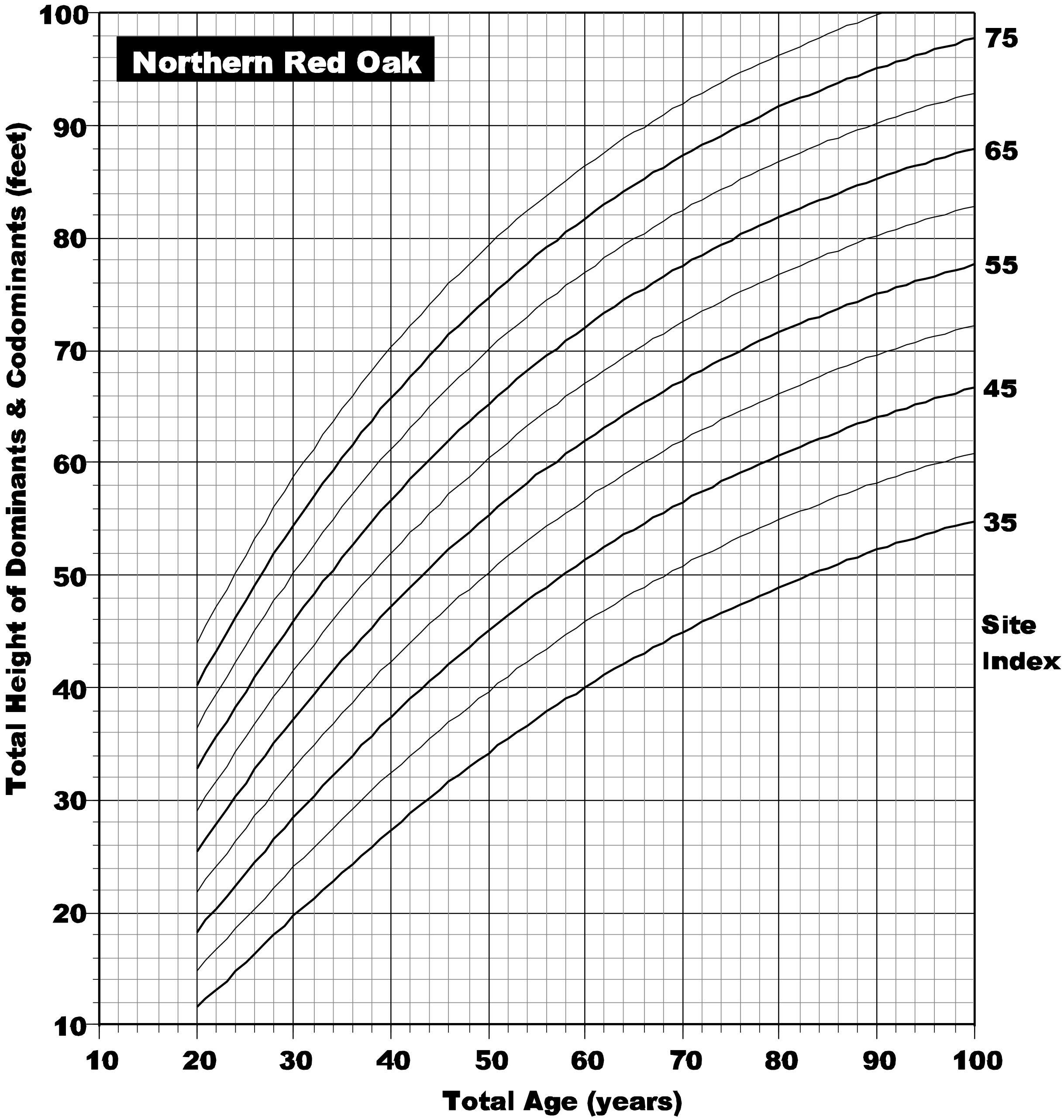
Figure 41.12. Stocking guide for northern red oak stands (average dbh 10-20" in Wisconsin (McGill et al. 1999).

The Northern Red Oak Stocking Guides (Figure 41.11 and Figure 41.12) display the relationship between basal area, number of trees, mean stand diameter, and stocking percent. They provide a statistical approach to guide stand density management (see Chapter 23).

- To utilize the stocking guides, statistically accurate estimates of at least two stand variables must be obtained, including basal area per acre, number of trees per acre, and/or mean stand diameter. For the oak stocking guides, these variables are measured only for main canopy trees (dominant, codominant, and intermediate crown class trees)
- The area between the A-line and B-line indicates the range of stocking where optimum stand growth and volume yield can be maintained.
    - The A-line represents maximum stocking. Maintaining stocking levels near (but below) the A-line will produce comparatively more trees, but of smaller diameter.
    - The B-line represents minimum stocking. Maintaining stocking levels near (but above) the B-line will produce larger diameter trees faster, but comparatively fewer trees.
- When designing and implementing a thinning regime for a stand, do not reduce stand density to below the B-line or allow it to surpass the A-line.
- Thinning can occur at any time as long as stand density is maintained between the A-line and B-line. The A-line is not a thinning “trigger.” When to thin depends on management objectives, stand conditions, and feasibility.

Typically, thinning is implemented when average stand stocking is halfway or more between the B-line and A-line. Stocking is reduced to slightly above the B-line. Crop tree concepts are applied to retain and focus growth on desirable trees, and order of removal concepts are applied to select which trees will be cut to achieve stand management objectives.

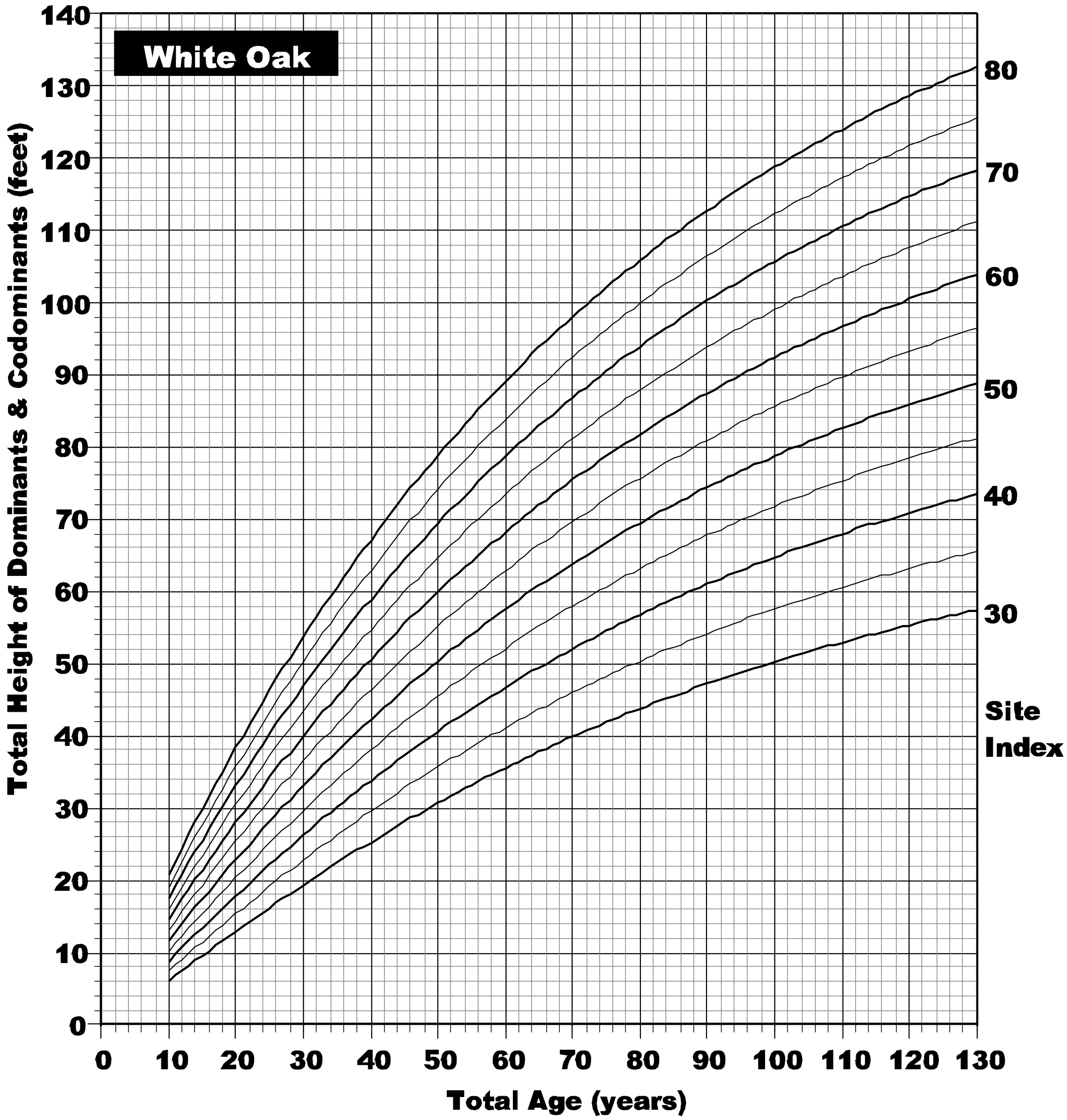
In overstocked stands, thin lightly and frequently, with increasing intensity, for the first several thinnings, to safely develop tree crown vigor and stem strength, and until target residual densities (near the B-line) are achieved. A general rule of thumb is do not remove >33% of the basal area in any one thinning operation.



Northern Wisconsin and Upper Michigan
37 plots having 136 dominant and codominant trees
Stem analysis, nonlinear regression, polymorphic
Add 4 years to DBH age to obtain total age (BH=0.0)

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
H	6.1785	0.6619	-0.0241	25.0185	-0.7400	0.99	1.32	4.9
SI	0.1692	1.2648	-0.0110	-3.4334	-0.3557	0.97	2.09	7.8

Figure 41.13. Site index curves for northern red oak (Carmean 1971, 1972).

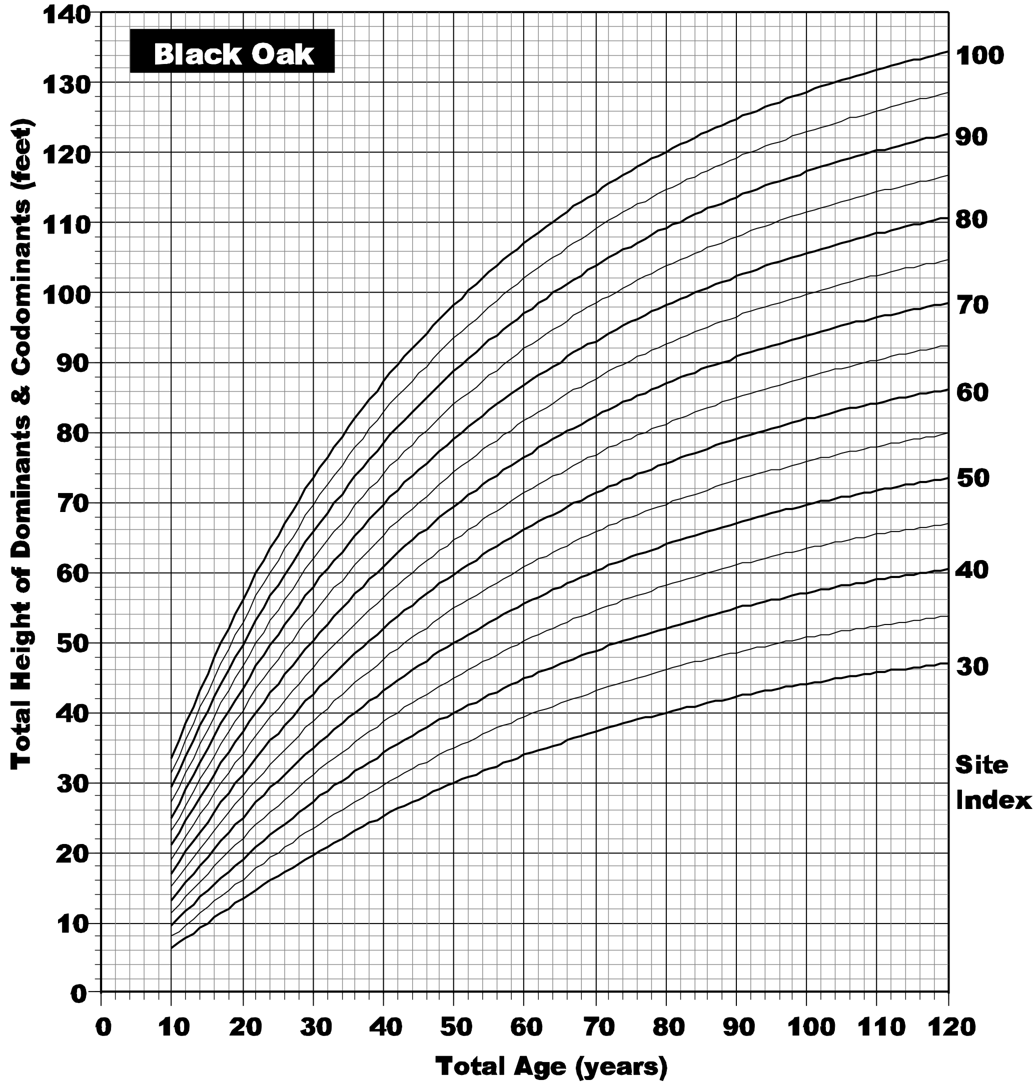


Unglaciated uplands of southeastern Ohio, eastern Kentucky, southern Indiana, southern Illinois, and southern Missouri; 41 plots having 112 dominant and codominant trees, Stem analysis, nonlinear regression, polymorphic. Add 3 years to DBH age to obtain total age (BH=0.0)

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
H	4.5598	0.8136	-0.0132	2.2410	-0.1880	0.99	2.69	(x)
SI	0.3387	1.0135	-0.0076	-0.9644	-0.0176	0.99	2.90	(x)

(x) Value not calculated because model was fitted to original data rather than to site index curves.

Figure 41.14. Site index curves for white oak (Carmean 1971, 1972).



Unglaciated uplands of southeastern Ohio, eastern Kentucky, Southern Indiana, southern Missouri

120 plots having 300 dominant and codominant trees

Stem analysis, nonlinear regression, polymorphic

Add 3 years to DBH age to obtain total age (BH=0.0)

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
H	2.9989	0.8435	-0.0200	3.4635	-0.3020	0.99	4.09	(x)
SI	0.2598	1.1721	-0.0107	-2.3272	-0.2825	0.99	4.42	(x)

(x) Value not calculated because model was fitted to original data rather than site index curves.

Figure 41.15. Site index curves for black oak (Carmean 1971, 1972).

8.1 Evaluation of Acorn Crops

A ranking system has been developed to help quantify the size of the acorn crop. Natural oak regeneration treatments (e.g., harvesting, mechanical and/or chemical site preparation, fire) should be timed with a good to bumper crop of acorns to maximize oak regeneration. Evaluating the size of the mature acorn crop is best done in August, when the acorns can be seen with the use of binoculars or a spotting scope. Since acorns in the red oak group require two years to mature, seed crops can be estimated after the first year of development to allow time for pre-planning of regeneration treatments. Developing ovules (i.e., acorns) are located on the current year's growth of the upper crown. The small 1-year ovules are 1/32-1/8" in size, singly or in clusters, on a short stalk. This early evaluation alternative can be misleading however if there are significant losses during the 2nd year of acorn development or if the sampled trees (i.e., cut tree from a nearby timber sale) are significantly different than the stand of trees to be regenerated, therefore the acorn crop should be verified again shortly before the regeneration treatment.

Procedure for evaluating acorn crops:

1. For fully developed acorns (i.e., August, second year for red oak group), binoculars or a spotting scope may be used to observe the acorns in the crown. For early estimates of 1-year developing red oak acorns, choose a nearby timber sale that was cut during the current fall or winter that is representative of the stand you wish to regenerate. Red oak ovules are too small to view from the ground, so you need to make these counts from representative trees that have been recently felled.
2. Randomly select at least three terminal branches from the upper one third of the crown on a dominant oak.
3. Count all the mature or developing acorns on the last 24" of each terminal (including all lateral branchlets). See Figure 41.16 (Early Evaluation of Acorn Crops from the Red Oak Group). Calculate the tree average from the three branches.
4. Due to tree to tree variation, repeat the procedure on several trees and then average all trees sampled on a site.
5. Determine the seed (acorn) crop rating from Table 41.13.

Table 41.13. A ranking of acorn production for individual trees (Johnson 1994).

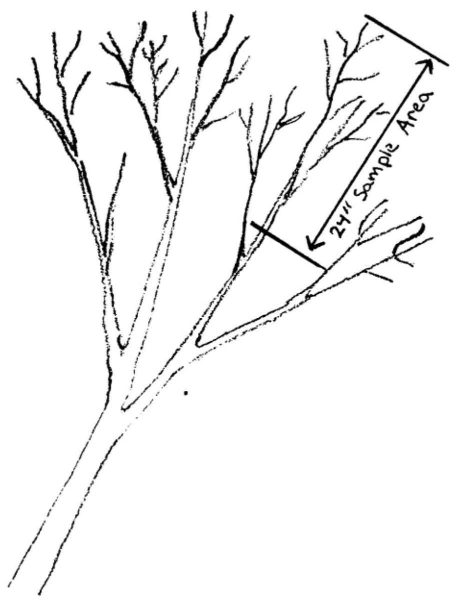
Ranking	White Oak Group	Red Oak Group
	Average number of acorns per branch[1]	
Excellent or Bumper	18+	24+
Good	12-17	16-23
Fair	6-11	8-15
Poor	<6	<8

[1]Based on the terminal 24" of healthy branches in the upper one-third of the crown.

According to Grisez (USFS Res. Pap. NE-315, 1975) the following table can serve as a guide to classifying next fall's crop. Remember, this is an estimate. These developing acorns are still susceptible to heavy insect losses and drying during a summer drought.

Seed Crop Rating	Average Number of Acorns Per 24-inch Branch Tip
Bumper	>24
Good	17-24
Fair	9-16
Poor	4-8
Trace to None	<3

Terminal Branch Sample Area:



First Year Red Oak Acorns:

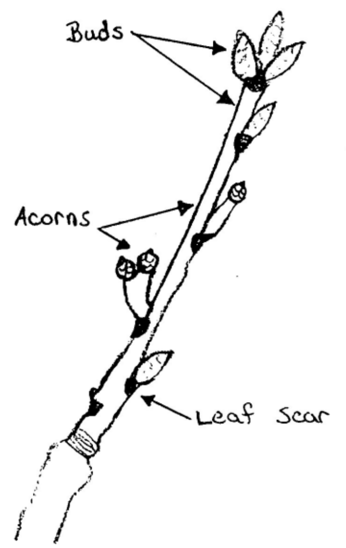


Figure 41.16. Early evaluation of acorn crops from the red oak group.

8.2 Evaluating the Adequacy of Oak Reproduction and Stump Sprouting

Adapted from Managing Oak in the Driftless Area, Jacobs and Wray 1992; Sander et al. 1984

To determine the potential ability of an oak stand to reproduce, conduct an inventory of the advance reproduction and the overstory oaks. If the advance reproduction does not meet the minimum stocking standards, the overstory inventory is used to determine whether there will be enough stump sprout potential to make up the difference.

The advance reproduction is evaluated in terms of the potential contribution of understory stems, after release, to stand stocking at age 20-25. The potential contribution of an individual stem is rated according to its height; this rating is called Stocking Value (SV). Ratings range from SV 1 for stems less than 1 foot tall to SV 30 for stems more than 4' tall:

Table 41.14. Stocking value by height.

Height		Stocking value of each stem	Adequate stocking (no. of stems)
(Class)	(Feet)		
A	<1.0	1	30
B	1.1-2.0	5	6
C	2.1-4.0	15	2
D	4.1+	30	1

An aggregate stocking value (SV) of 30 for stems in any combination of height classes in a reproduction plot indicates adequate stocking for that plot. For example, 3 class B stems (3 stems x 5 SV = 15) plus 1 class C stem (1 stem x 15 SV = 15) total 30.

An SV of 30 for all reproduction plots sampled indicates a potential minimum stocking of 220 4.5" dbh dominant or codominant oak stems per acre. However, a stocking of 154 dominant and codominant trees per acre (70% of reproduction plots stocked) is considered adequate. Although this is less than B-level stocking (30% stocked), if the trees maintain their crown position, either naturally or by thinning, there will be enough stems to reach B-level stocking when the average diameter reaches 9" and A-level when average diameter is 12". Presumably, total stocking will include the projected stocking of dominant and codominant oaks as well as other species and additional oaks in the subordinate crown classes.

A less or more restrictive minimum standard for oak reproduction can be set depending on the management objective for the stand. For example, if other desirable species (e.g., walnut, maple, and basswood) are present and, in combination with oak advance reproduction, meet the suggested minimum standard, fewer oaks may be acceptable as long as oaks represent 50% of the SV. Moreover, if competition remains under control after establishment of the seedlings, acceptable stocking value can be reduced by half to SV 15. This means that a reproduction plot can be considered stocked if it contains at least one oak 2' or more in height, at least three oaks 1' or more, or at least 15 oaks less than 1' tall.

Field procedures

1. Inventory all oaks 1.6” dbh and larger on 10 or more 1/20-acre plots (26.3’ radius). Record these data by species and size class on the “plot tally” lines of the Oak Overstory Tree Inventory form (Figure 41.16a). This information may be used to determine stump sprouting potential. Also record the ages to the nearest 20 years of both the overstory (dominant and codominant crown classes) and the understory (intermediate and suppressed) oaks and enter the oak site index.
2. Select the number of 1/750-acre plots (4.3’ radius) reproduction plots required from Table 41.15 according to the acreage of the stand being examined:

Table 41.15. Reproduction plots needed by stand acreage.

Stand area (acres)	No. 1/750-acre plots
<10	25
10-30	40
30-50	60

3. Distribute the reproduction plots uniformly throughout the stand. On each plot, count the advance reproduction and record by height on the Advance Reproduction Inventory form (Figure 41.19).
4. For each reproduction plot, determine the aggregate SV for oaks. If it is 30 or more, check column E on the Advance Reproduction Inventory form (Figure 41.19).
    a) To simplify the procedure:
        i. Begin with the tallest stems (column D). If at least one stem of this size is present (SV 30; see SV at the head of columns A-D), record as stocked in column E and look no further (see example). If no column D (4.1’+) stems are present, go to column C; two stems this size indicate a stocked reproduction plot. And so on. Check column E when SV totals 30 or more. Also record the number of stems by height class, which together provided the SV 30 sum.
        ii. If the SV for oak is less than 30 (but at least 15) and other species are acceptable to the owner, repeat the above process for the other desirable species. When SV is 30 or more for the combination of species, including oak, check column F.
        iii. If undesirable vegetation is preventing the establishment of desirable reproduction or hindering its growth, enter in column G:
            - F for ferns,
            - S for shrubs and trees less than 6 feet tall, and
            - T for taller shrubs and trees.
            - Use judgment in evaluating potential competition – look for an understory “canopy layer” or the potential for one developing after the stand is opened up. Base your decision on density, height, and vigor of interfering vegetation.

Example (based on the sample data in Figure 41.20)

Assume the inventory has resulted in the entries shown in Figure 41.20. We see reproduction plot 1 has 1 tree taller than 4'. This immediately gives plot 1 an SV of 30, so check column E and go on. Plot 2 has 1 tree in the 2.1-4.0' class with an SV of 15. It also has more than 3 trees (3+) in the 1.1-2.0'class. Three times the SV for that class (5) is 15. The total for plot 2 is at least 30, check column E again and continue in a similar manner throughout the form.

CALCULATIONS

1. Determine the potential stocking from advance reproduction by adding the entries in columns E (and F, if used) and dividing by the number of reproduction plots sampled. If 70% or more of the plots are stocked, advance reproduction is adequate and no further calculations are needed.
2. If fewer than 70% of the reproduction plots are stocked, stump sprouts are needed to supplement the advance reproduction. Calculate the projected stocking from advance reproduction by multiplying the percent of reproduction plots stocked by 220 (100% stocking). Subtract the result from 154 to find the number of stump sprouts needed to bring projected stocking up to minimum.
    a) Referring back to the example (Figure 41.17), divide the total number of entries in column E (12) by the number of reproduction plots (20) for a stocking percent of 60. Multiply 60% by 220 = 132 projected stems per acre, 22 less than the 154 needed for minimum stocking. Thus, the stand will be inadequately stocked with advance reproduction and at least 22 stump sprouts will be needed to bring stocking up to minimum.
3. The number of sprouts available to supplement advance reproduction is calculated from the "plot tally" data on the Oak Overstory Tree Inventory form (Figure 41.17). For each species and dbh class, convert the plot tally to number of trees/acre by dividing the plot tally sum by the area sampled. Determine the number of potential sprouts by applying the appropriate percentages from Table 41.16 to the stems/acre figures. Total the resulting numbers to get the number of sprouts/acre.
4. Add the projected number of stump sprouts to the projected stocking from advance reproduction. If the sum is >154, the stand has adequate oak regeneration potential; if < 154 take steps to recruit additional oak reproduction or consider planting to supplement natural oak regeneration.

Example (based on the sample data in Figure 41.18)

a. Assume 10 1/20-acre plots, site index 60, understory age 20, and overstory age 90.
b. Divide the red oak plot tally for 2-5" dbh trees (14) by the area sampled (1/2-acre) to get 28 stems per acre.
c. Multiply this number by the appropriate percentage for trees less than 60 years old from Table 41.16 (86) to find the number of stumps expected to produce dominant or codominant trees at age 20, i.e., 28 x 86% = 24 (rounded to the nearest whole number). Record this number in the appropriate cell in Figure 41.18.
d. Compute the corresponding numbers for the other species and diameter classes (age greater than 60 years).

e. Add the numbers across for each species and then add the sums for a grand total of 29 expected stump sprouts per acre.

To determine whether the number of stump sprouts is adequate to bring stocking up to minimum, add this number to the projected stocking (132) based on the Advance Reproduction Survey form (Figure 41.20). The result is 161, more than 154, so stocking is adequate.

Table 41.16. Percentage of stumps that will produce at least one codominant or larger stem at age 20-25 years (Sander et al. 1984).

Species	Site Index	Age Class (years)	dbh (inches)			
			2-5	6-11	12-16	17+
			%			
Red oak	All	< 60	86	86	86	86
		> 60	49	46	38	24
Black oak	50	all	30	10	3	2
	60	all	45	15	5	2
	70	all	60	20	7	2
White oak	50	40	47	18	6	0
		60	25	10	4	2
		80	12	6	3	1
		100	5	3	2	1
	60	40	63	26	9	0
		60	38	16	7	3
		80	19	9	5	2
		100	8	5	3	2
	70	40	81	36	15	0
		60	55	25	11	5
		80	31	16	8	4
		100	15	9	6	4

(Trees 1.6+ inches DBH)

1/20 Acre Plots (26.3-foot radius) Age: Understory oaks: __________
Overstory oaks: __________
Number of Plots ____________ Site Index: Oaks _________

	DBH Class-inches				
	2-5	**6-11**	**12-16**	**17+**	**Total**
Red Oak **Plot tally**					
Stems/acre					
Sprouting%					
Sprouts/acre					
White Oak **Plot tally**					
Stems/acre					
Sprouting%					
Sprouts/acre					
Black Oak **Plot tally**					
Stems/acre					
Sprouting%					
Sprouts/acre					
Other Oak **Plot tally**					
Stems/acre					
Sprouting%					
Sprouts/acre					
Other Oak **Plot tally**					
Stems/acre					
Sprouting%					
Sprouts/acre					
All Oaks **Sprouts/acre**					

Figure 41.17. Oak overstory tree inventory.

(Trees 1.6+ inches DBH)

1/20 Acre Plots (26.3 foot radius)

Number of Plots ⊠ 10

Age: Understory oaks: 20

Overstory oaks: 115

Site Index: Oaks 60

	DBH Class-inches				
	2-5	**6-11**	**12-16**	**17+**	**Total**
Red Oak Plot tally	⊠ ∷ (14)	⁖ (3)	⁖ (3)	· (1)	21
Stems/acre	28	6	6	2	
Sprouting%	86%	46%	38%	24%	
Sprouts/acre	24	3	2	0	29
White Oak Plot tally					
Stems/acre					
Sprouting%					
Sprouts/acre					
Black Oak Plot tally					
Stems/acre					
Sprouting%					
Sprouts/acre					
Other Oak Plot tally					
Stems/acre					
Sprouting%					
Sprouts/acre					
Other Oak Plot tally					
Stems/acre					
Sprouting%					
Sprouts/acre					
All Oaks Sprouts/acre	24	3	2	0	29

Figure 41.18. Oak overstory tree inventory example.

1/750 Acre Plot (4.3-foot radius)

Column

	A	B	C	D	E	F	G
Plot Number	**Height Class – Feet**				**Plot Stocking**		
	<1.0	**1.1-2.0**	**2.1-4.0**	**4.1+**			
	Stocking Value (SV)				**Oak**	**Desirable Species**	**Understory Competition**
	1	**5**	**15**	**30**			
	Number of Stems measured						
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
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18							
19							
20							

Figure 41.19. Advance reproduction inventory.

Calculations

1. Percent stocking: no. of plots stocked ÷ total no. of plots x 100.

2a. If **more** than 70% of plots are stocked, no further calculations are needed; there is adequate regeneration potential.

2b. If **fewer** than 70% of plots are stocked, continue calculations.

3. Projected stocking from advance reproduction: 220 x % stocking.
Projected number of stump sprouts from Oak Overstory Tree Inventory: ______.
Total projected stocking: ______.

4a. If total is greater than 154, there is adequate regeneration potential.

4b. If total is less than 154, supplemental natural or artificial oak reproduction is needed.

	Column						
	A	B	C	D	E	F	G
Plot Number	Height Class – Feet				Plot Stocking		
	<1.0	1.1-2.0	2.1-4.0	4.1+			
	Stocking Value (SV)						
	1	5	15	30	Oak	Desirable Species	Understory Competition
	Number of Stems measured						
1				1	✓		
2		3+	1		✓		
3					X		
4			2+		✓		
5		6+			✓		
6	5				X		
7					X		
8	15+	3			✓		
9			2+		✓		
10		3+	1		✓		
11					X		
12	15+		1		✓		
13					X		
14				1	✓		
15	2				X		
16		3+	1		✓		
17		3+	1		✓		
18					X		
19		6+			✓		
20			1		X		
21							
22							
23							
24							
25							

Calculations;

1. Plots Stocked: 12 ÷ total no. of plots: 20 x 100 = Percent of plots stocked: 60.

2a. If **more** that 70% of plots are stocked, no further calculations are needed; there is adequate regeneration potential.

2b. If **fewer** than 70% of plots are stocked, continue calculations. ✓

3. Projected stocking from advanced reproduction: 220 x percent stocking (1) 60 = 132.
Projected number of stump sprouts from Oak Overstory Tree Inventory = …………… 29.
Total projected stocking ………………………………………………………… = 161.

4a. If total is greater than 154, there is adequate regeneration potential. ✓

4b. If total is less than 154, supplemental natural or artificial oak reproduction is needed.

Figure 41.20. Advance reproduction inventory example.

8.3 Forest Health Guidelines - Forest Health Protection (FHP)

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
DEFOLIATING INSECTS			
Fall cankerworm – Alsophila pometaria Occasional outbreaks of repeated heavy defoliation in early spring may cause twig/branch dieback and mortality.	Oaks	Maintain healthy forests through proper forest management	
Oak leafroller – Archips semiferanus The larva rolls one leaf and ties it with strands of silk to feed and rest within the rolled leaf. It is a spring defoliator.	Northern red, black, northern pin, scrub oaks	Maintain healthy forests through proper forest management	How to Distinguish Oak LEAFTIERS From LEAFROLLERS. USDA FS NA-FR-16 (http://www.na.fs.fed.us/spfo/pubs/howtos/ht_oakpests/oakpests.htm)
Oak leaf tier (Oak leaf shredder) – Croesia semipurpurna The larva ties two or more leaves together with strands of silk to feed and rest between the leaves. It is a spring defoliator.	Oaks	Maintain healthy forests through proper forest management	How to Distinguish Oak LEAFTIERS From LEAFROLLERS. USDA FS NA-FR-16 (http://www.na.fs.fed.us/spfo/pubs/howtos/ht_oakpests/oakpests.htm)

Disturbance Agent and Expected Loss or Damage	**Host**	**Prevention, Options to Minimize Losses and Control Alternatives**	**References***
Gypsy moth – *Lymantria dispar* Feeding occurs from mid to late May through late June to early July. Widespread heavy defoliation occurs periodically at intervals of 5-15 years. Two or more years of heavy defoliation may stress trees to allow secondary pests, such as Armillaria root rot or two-lined chestnut borer to attack and kill trees. HAZARD ZONE: South of Eau Claire, Wausau, Marinette. HIGH RISK SITES: Upland, droughty sites with favored food trees in low-vigor, open-grown stands.	Oaks	ON HIGH RISK SITES: 1. Reduce oak and favored component to 25% or less. 2. Convert to unfavored type or non-timber type. 3. Accept risk of defoliation. ON LOW RISK SITES: 1. Maintain proper stocking levels. 2 Remove “wolf” trees. Monitor high-risk sites for rising populations. Spray rising populations to prevent outbreak. Allow population to rise and spray to protect foliage. Accept defoliation and monitor for decline	Gypsy Moth Silvicultural Guidelines for Wisconsin. C. Brooks and D. Hall. 1997. DNR PUB-FR-123
Forest tent caterpillar – *Malacosoma disstria* Feeding occurs in May through early June. Widespread heavy defoliation occurs periodically at intervals of 5-15 years. An outbreak usually lasts 2-5 years.	Oaks	Maintain healthy forests through proper forest management During an outbreak, insecticide applications can be an option to minimize the damage on highly valuable stands.	Forest Tent Caterpillar in the Upper Midwest. 2001. USDA FS NA-PR-02-01 (http://na.fs.fed.us/spfo/pubs/infosheets/tentcat/index.htm) Forest Tent Caterpillar. USDA FS FIDL 9. (http://na.fs.fed.us/spfo/pubs/fidls/ftc/tentcat.htm)
Late season defoliators **Oak skeletonizer – *Bucculatrix ainsliella***	Oaks	Maintain healthy forests through proper forest management	

Disturbance Agent and Expected Loss or Damage	**Host**	**Prevention, Options to Minimize Losses and Control Alternatives**	**References***
Orange-striped oakworm – *Anisota senatoria* **Red-humped oakworm – *Symmerista canicosta*** **Variable oak leaf caterpillar – *Heterocampa manteo*** Infrequent outbreaks of late summer defoliation seldom last more than one year. Normally late season defoliation does not damage trees significantly. However, complete defoliation may initiate branch dieback and decline of low-vigor trees, especially on droughty sites.		No chemical control is necessary	
FOLIAGE DISEASES			
Anthracnose – ***Apiognomonia quercina (Gnomonia quercina)*** The fungus causes irregular dead blotches on the leaves. Heavily infected leaves prematurely fall, and cause growth reduction. Heavy infection may occur during wet cool spring.	Oaks	Direct control is impractical and usually unnecessary. Silvicultural measures to encourage air circulation may reduce infection.	Anthracnose Diseases of Eastern Hardwoods. F. Berry. 1985. USDA FS Forest Insect & Disease Leaflet 133 (http://na.fs.fed.us/spfo/pubs/fidls/anthracnose_east/fidl-ae.htm)
Tubakia leaf spot – *Tubakia dryina (Actinopelte dryina)* The fungus produces circular, reddish-brown spots on the	Oaks	Maintain healthy forests through proper forest management	Late-Season Leaf Discoloration of White and Bur Oak: Drought/Tubakia Leaf

Disturbance Agent and Expected Loss or Damage	**Host**	**Prevention, Options to Minimize Losses and Control Alternatives**	**References***
leaves. Severely infected leaves fall prematurely. It occurs in late summer, and usually does not affect the health of trees significantly. However, recently, dieback and mortality of bur and white oaks, associated with Tubakia leaf spot and other disease/insect factors, have been reported in Wisconsin (see Oak Decline below).			Spot? Two-lined Chestnut Borer. WI DNR FHP. 2004.
Oak tatters – cause unknown It affects expanding new leaves in early spring. Affected leaves appear lacy or tattered. The causal agent is not determined, though frost, cold temperatures, and herbicides are among suspected.	Primarily the white oak group (bur, white, swamp white oaks) Red oaks are occasionally affected	Direct control is impractical and usually unnecessary.	Pest alert: Oak Tatters. 2000. USDA FS NA-PR-02-00 (http://www.na.fs.fed.us/spfo/pubs/pest_al/oaktatters/oaktatters.htm)
SCALE INSECTS			
Lecanium scale – *Parthenolecanium spp.* Adult females are circular to ovoid, and reddish to dark brown. This insect sucks plant juice, causing twig and branch dieback, and growth loss.	Oaks	Chemical control is impractical, and usually unnecessary.	Scale Insects of Trees and Shrubs. R. Wawrzynski and M. Ascerno. 1999. Univ. Minn. Ext. FO-01019.

Disturbance Agent and Expected Loss or Damage	**Host**	**Prevention, Options to Minimize Losses and Control Alternatives**	**References***
Kermes scale – *Kermes spp.* Adult females are globular or gall-like, and yellow to light brown. This insect sucks plant juice, causing twig and branch dieback, and growth loss.	Oaks	Chemical control is impractical, and usually unnecessary.	Scale Insects of Trees and Shrubs. R. Wawrzynski and M. Ascerno. 1999. Univ. Minn. Ext. FO-01019.
CANKERS/CANKER ROT			
Nectria canker – *Nectria cinnabarina* Trunk deformity and growth loss (all ages). Although it rarely causes mortality, a tree may break off at the point of canker.	Oaks	Silvicultural control measures are based on percent of infected trees in stand (see reference). Most infections occur when trees are 12-20 years old. Conduct improvement cut after age 20.	How to Identify and Control Nectria Canker of Hardwoods. R. Anderson. 1978. USDA FS
Strumella canker – *Strumella coryneoieda (Urnula craterium)* Trunk deformity and growth loss (all ages). Although it rarely causes mortality, a tree may break off at the point of canker.	Oaks	Avoid wounding. Cankered trees should be considered for removal during thinning	Strumella Canker. USDA FS FHP Southern Region. (http://www.fs.fed.us/r8/foresthealth/idotis/diseases/strmella.pdf)
Botryosphaeria twig dieback and canker – *Botryosphaeria quercuum* The fungus attacks tips of twigs and causes twig flagging. The disease may progress to a branch or to a	Oaks	Since the fungus appears to attack stressed trees more often, maintain healthy forests through proper forest management	

Disturbance Agent and Expected Loss or Damage	**Host**	**Prevention, Options to Minimize Losses and Control Alternatives**	**References***
stem and cause a branch dieback and tree decline.			
WILT DISEASES			
Oak wilt – *Ceratocystis fagacearum* The fungus attacks trees' vascular system to induce plugging of the vessels. Leaves of an infected tree will wilt and prematurely fall and an entire tree may die. Once wilting symptoms become visible, a tree in the red oak group (northern red, northern pin, black, scrub oaks) dies within a month. The disease spreads through insect vectors (overland spread) or through connected root system (underground spread). Wilting occurs most often in July and August, and occasionally in spring or fall.	Oak wilt symptoms progress much more quickly with trees in the red oak group compared to trees in the white oak group.	Avoid thinning, harvesting, or wounding oaks during critical time of oak wilt overland infection (for site-specific oak harvesting guidelines, refer to XXX). Cut root with a vibratory plow or trencher and remove trees of the same group within the root graft barrier. Consider conversion to alternate species if valuable species such as red or white pines are growing under oak.	Oak wilt: What are the options? 2005. UW Extension (G3590). (http://cecommerce.uwex.edu/pdfs/G3590.PDF) How to identify, Prevent, and Control Oak Wilt. 2000. USDA FS NA-PR-03-00. (http://www.na.fs.fed.us/spfo/pubs/howtos/ht_oakwilt/toc.htm) How to Collect Field Samples and Identify the Oak Wilt Fungus in the Laboratory. 1999. USDA FS NA-FR-01-99. (http://www.na.fs.fed.us/spfo/pubs/howtos/ht_oaklab/toc.htm)
WOOD BORERS			
Two-lined chestnut borer – *Agrilus bilineatus* The larva feeds on nutrient and water conducting tissues beneath the bark and girdles and kills a branch or an entire	Oaks	Maintain healthy forests through proper forest management. Maintain well-stocked stands. Consider insecticide applications to reduce the	Oak disorder: Two-lined chestnut borer. 1997. UW Extension A2902. Two-lined chestnut borer. USDA FS FIDL 168. 1992.

Disturbance Agent and Expected Loss or Damage	**Host**	**Prevention, Options to Minimize Losses and Control Alternatives**	**References***
tree. Dieback usually starts at the top and progresses downward. Trees may be killed within a year or in 2-3 years. This insect mainly attacks trees that are already stressed from defoliation, drought, or some other causes.		damage from outbreaks of a defoliating insects	(http://na.fs.fed.us/spfo/pubs/fidls/chestnutborer/chestnutborer.htm)
Other borers			
Red oak borer – *Enaphalodes rufulus* **White oak borer – *Goes tigrinus*** The young larva feed on phloem and sapwood, and the second-year larvae tunnel into heartwood.	Oaks	Maintain healthy forests through proper forest management.	Red Oak Borer. USDA FS FIDL 163. 1980. (http://www.na.fs.fed.us/spfo/pubs/fidls/Red%20Oak%20Borer/redoak.htm)
ROOT DISEASE			
Armillaria root disease (Shoestring root rot) – *Armillaria spp.* Stringy white rot. Dieback and mortality, especially during drought years or following 2 or more years of defoliation (all ages).	Oaks	Maintain stand in healthy condition. Harvest declining trees before mortality and decay take place.	Armillaria Root Disease. R. Williams, et al. 1986 USDA FS FIDL 78 (http://na.fs.fed.us/spfo/pubs/fidls/armillaria/armillaria.htm)

Disturbance Agent and Expected Loss or Damage	**Host**	**Prevention, Options to Minimize Losses and Control Alternatives**	**References***
ABIOTIC and MECHANICAL DAMAGE			
Storm damage Limb and trunk breakage. Decay and discoloration through wounds.	Oaks	Add FHP Table for specific recommendations related to impact?	Caring for ice-damaged woodlots and plantations. 1999. Ontario Extension Notes
Cold injury Cold injury occurs when the winter temperature falls to approximately -35° F or colder. Species' sensitivity varies. Injury is typically manifested by patches of dead (brown and black) cambium. In spring, affected trees will have reduced bud break and may have epicormic sprouts.	Oaks	Monitor for dieback in upper and outer crown. If more than 50% of the crown dies, expect decline to continue to mortality.	
Late spring frost damage This phenomenon is unpredictable and occurs when temperatures dip below freezing during bud expansion, break and when foliage is just emerging. Foliage turns black and wilts. Twig dieback can occur. New lateral buds can break within 4 weeks after damage.	Oaks	In frost pockets, expect injury to new expanding growth during years with late spring frost. Monitor for dieback in upper and outer crown. If more than 50% of crown dies, expect decline to continue to mortality.	
Drought Symptoms of drought include premature defoliation, thin	Oaks	Monitor for dieback in upper and outer crown. If more than 50% of crown dies, expect	

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
crowns, subnormal leaf size and in severe cases, wilting foliage. If drought persists for more than one year, dieback of the upper and outer crown may occur.		decline to continue to mortality. Hardwoods take longer to recover from drought than conifers. Improvement in crown may not be noticeable for a year after normal precipitation returns.	
Iron deficiency/chlorosis Interveinal yellowing of leaves of one branch or entire tree caused by inability of roots to take up iron because of high soil pH, soil disturbance, or root damage. Seriousness varies year to year. Some growth loss is common, and in extreme cases branch and tree mortality occur. Older trees are more susceptible.	Oaks, especially on northern pin oaks	Chemical control is impractical in forests, and usually unnecessary. In extreme cases, convert to a less susceptible type.	Oak and Other Trees Disorder: Iron Chlorosis. 1975. UW Extension. A2638 (https://cecommerce.uwex.edu/pdfs/A2638.PDF)

Disturbance Agent and Expected Loss or Damage	**Host**	**Prevention, Options to Minimize Losses and Control Alternatives**	**References***
Logging damage Wounds. Limb and trunk breakage. Decay and discoloration through wounds.	Oaks	Careful felling/skidding, directional felling techniques, careful harvest plan layout. Limit harvest activities to times when soil is frozen or dry enough as to minimize soil compaction. See FHP Table 2 for specific recommendations related to impact.	
DECLINE			
Oak decline It is considered to be caused by a complex of environmental, insect and disease factors. Trees are stressed by frost, drought, insect defoliations, foliar diseases, etc., then later attacked by opportunistic pests, such as two-lined chestnut borers and/or Armillaria root rot.	Oaks	Maintain healthy forests through proper forest management. Monitor stands for possible salvage.	Oak decline. 1983 USDA FS FIDL 165 (http://www.na.fs.fed.us/spfo/pubs/fidls/oakdecline/oakdecline.htm)

INVASIVE PLANT SPECIES	Conditions	Prevention, Mitigation Options	References*
Autumn olive – *Elaeagnus umbellate* A small shrub or tree introduced to the U.S. for landscaping and wildlife. Once established can be highly invasive and can disrupt native plant communities.	Disturbed areas, open woods and forest edges. Oak and red pine forests.	Young plants and seedlings can be pulled. Herbicide application with glyphosate or triclopyr via cut stump treatment is effective.	http://na.fs.fed.us/fhp/invasive_plants/weeds/autumn-olive.pdf http://dnr.wi.gov/invasives/classification/pdfs/LR_Elaeagnus_umbellata.pdf
Black locust – *Robinia pseudoacacia* A deciduous tree in the Legume family which was introduced extensively for soil erosion control. Dense stands can shade out native vegetation and is suspected of producing chemical compounds that prevent other plants from growing.	Forest, pastures, roadsides also found in oak and red pine forests.	Cutting without herbicide application can result in sprout and spread. Basal bark application with triclopyr herbicide or cut stump treatment with glyphosate. When treating with herbicide, all stems must be treated.	http://dnr.wi.gov/invasives/fact/black_locust.htm http://www.dnr.state.wi.us/invasives/publications/pdfs/black_locust_brochure.pdf
Burning bush – *Euonymus alatus* A deciduous shrub from Asia introduced as a cultivar. Spread by seeds and sprouts.	Forest edges, within oak, maple, and pine forests.	Cut stump treatment with Glyphosate or triclopyr herbicides can be effective. Avoid impacts to non-target vegetation.	http://dnr.wi.gov/invasives/photos/index.asp?mode=detail&Code=Euoala
Bush honeysuckles – (*Lonicera spp.*) Forms dense shrub thickets that outcompete and displace other flora. Seeds are spread by birds, and in mud on equipment.	Oak forests and open lands.	Monitor to ensure early detection. Clean equipment before entering the forest. Small plants: eradicate by hand pulling Large shrubs: mechanically remove or cut and stem-treat.	http://dnr.wi.gov/invasives/fact/honeysuckle_tart.htm http://dnr.wi.gov/invasives/fact/japanese_honeysuckle.htm http://dnr.wi.gov/invasives/fact/honeysuckle_bella.htm http://dnr.wi.gov/invasives/fact/honeysuckle_morrow.htm

INVASIVE PLANT SPECIES	**Conditions**	**Prevention, Mitigation Options**	**References***
		Foliar spray with glyphosate in spring, prior to native plants emergence. In high water table areas, use herbicides labeled for over water.	http://dnr.wi.gov/invasives/fact/amur_honeysuckle.htm
Common buckthorn and smooth (glossy) buckthorn – (*Rhamnus cathartica* and *R. frangula*) Tall shrubs form dense thickets that outcompete and displace other flora. There is some evidence that they are also allelopathic. Seeds are spread by birds, and in mud on equipment.	Oak forests and open lands. Smooth buckthorn is more restricted to wet and wet-mesic and mesic areas.	Monitor to ensure early detection. Clean equipment before entering the forest. Small plants: eradicate by hand pulling and prescribed burning. Large shrubs: mechanically remove, cut and stump-treat, or control with basal bark application. Restrict foliar sprays to fall months when buckthorn is actively growing but other species are dormant, to avoid impacts to non-target vegetation. Trichlopyr may be more selective than glyphosate. In areas with high water tables, use herbicides labeled for use over water. Continued monitoring and follow-up are needed after treatment.	http://dnr.wi.gov/invasives/fact/buckthorn_com.htm
Dames rocket – *Hesperis matronalis* Dame's rocket is a showy, short-lived perennial. Dame's rocket is planted as an	Forest edges, openings, cultivar escape. Found in oak and maple forests.	Plants can be pulled in the spring before going to seed. For larger infestations, use glyphosate foliar spray.	http://dnr.wi.gov/invasives/fact/dames_rocket.htm

INVASIVE PLANT SPECIES	**Conditions**	**Prevention, Mitigation Options**	**References***
ornamental, but quickly escapes cultivation because of its prolific seed set. Invasive success is attributed to wide distribution in "wildflower" seed mixes.			
Field bindweed – *Convulvulus arvensis* A Wisconsin state-listed "noxious weed" that can outcompete and displace other flora.	Oak forests.	Little is known about control in forests. Herbicide or hand-pulling on a regular basis (perhaps only once per year), may be used where control is needed.	http://tncweeds.ucdavis.edu/esadocs/documnts/convarv.html
Garlic mustard – *Alliaria petiolata* A major invasive plant that outcompetes herbaceous flora and tree seedlings. There is evidence of allelopathy to beneficial mycorrhizae. Small seeds spread easily on equipment and clothing, and on animal fur.	Oak forests. One of the few invasive understory plants to thrive in full shade.	Use preventative measures; clean equipment and clothing before entering the forest. Monitor to ensure early detection. Small infestations can be eradicated by hand pulling. Spray with glyphosate in spring or fall to kill basal rosette; avoid non-target species.	http://www.dnr.state.wi.us/invasives/publications/pdfs/garlic_mustard_brochure.pdf
Japanese barberry – *Berberis thunbergii* Has potential to limit forest regeneration as it becomes more abundant. With a concerted effort, potential remains to suppress this species. It can outcompete and displace other flora. Its thorns make it difficult to work	Forests and semi-open areas, including oak forests. Tolerates full shade.	Mechanical removal in early spring is recommended for small infestations. Wear thick gloves. Glyphosate or triclopyr herbicides can be effective. Avoid impacts to non-target vegetation.	http://dnr.wi.gov/invasives/fact/barberry.htm http://www.imapinvasives.org/GIST/ESA/esapages/berb_spp.html

INVASIVE PLANT SPECIES	**Conditions**	**Prevention, Mitigation Options**	**References***
or recreate in an infested area.			
Japanese knotweed – *Polygonum cuspidatum* Outcompetes and displaces other flora. Early emergence, height, and density allow it to shade out other vegetation and limit tree regeneration. Not yet widespread in Wisconsin. Difficult to eradicate once established.	Oak forests, riparian forests, open lands with mesic or wet-mesic conditions.	Repeated cutting (3x per growing season) provides control but may not eradicate a stand. The herbicide glyphosate can be effective, especially applied in fall. Continued monitoring and follow-up are needed after treatment.	http://www.imapinvasives.org/GIST/ESA/esapages/polycusp.html
Multiflora rose – *Rosa multiflora* Forming dense thickets that exclude other vegetation. Seed remains viable for up to 20 yrs. Spreads by stolons, shoots and seed.	Old fields, pastures and oak forests, full or partial sun.	Mowing and controlled burns. Cut stump and treat with glyphosate or basal bark spray stem with triclopyr.	http://dnr.wi.gov/invasives/fact/rose.htm
Oriental bittersweet – *Celastrus orbiculatus* A perennial vine that can climb and kill trees. Reduces photosynthesis, causes breakage due to additional weight, increases susceptibility to wind and ice damage, and can girdle trees. Birds spread seeds. Closely resembles the native American bittersweet (C. scandens), with which it hybridizes; Oriental	Oak and other forests.	Cut vine and pull up small infestations. Treat cut stem with triclopyr herbicide.	http://www.imapinvasives.org/GIST/ESA/esapages/celaorbi.html

INVASIVE PLANT SPECIES	Conditions	Prevention, Mitigation Options	References*
bittersweet has fruits originating from leaf axils, while American bittersweet fruits are borne at branch tips.			
Pennsylvania sedge – *Carex pennsylvanica* This native sedge can impact northern hardwood regeneration by forming impenetrable mats on the forest floor. Physical impedance is the mechanism by which damage occurs. Past management may have contributed to development of existing sedge mats; increases in size and density after opening the forest canopy have been observed.	Oak and mesic forests.	There is limited information on control. Herbicide, scarification, or tilling (particularly on roadbeds or landings) may be effective in some situations.	http://web4.msue.msu.edu/mnfi/abstracts/ecology/pine_barrens.pdf http://www.ecologyandsociety.org/vol7/iss2/art10/main.html http://www.fs.fed.us/database/feis/plants/graminoid/carpen/all.html
Siberian elm – *Ulmus pumila* This small to medium-sized tree has an open, round crown of slender, spreading branches. The fruits develop quickly and are disseminated by wind, allowing the species to form thickets of hundreds of seedlings in bare ground. Seeds germinate readily and seedlings grow rapidly.	Forest edge and within oak, maple and pine forests.	Young plants and seedlings can be pulled. Herbicide application with glyphosate or triclopyr via cut stump treatment is effective	http://dnr.wi.gov/invasives/fact/elm.htm

DEFECT	High Probability of Mortality or Failure (high risk)	High Probability[1] of Degrade due to Defect
Canker Localized area of dead bark and cambium; wood behind canker may or may not be decayed. Commonly caused by fungi. Fungal cankers are a source of spores that may infect healthy trees.	• Canker affects >50% of the stem's circumference or >40% of the stem's cross section. Common canker diseases on oak: Botryosphaeria canker (*Botryosphaeria quercuum*); Nectria canker (*Nectria cinnabarina*); Strumella canker (*Urnula craterium*) Strumella canker pathogen decays wood behind the cankers. • Horizontal crack on a canker face.	• Decay associated with large canker (affects >50% of stem's circumference). Fruit body visible in the canker's face. Extent of decay and discoloration will vary depending on organisms involved.
Wounds Any injury to tree that exposes the cambium or wood beneath cambium.		• >2 large (>5") branches broken close to the stem. • Codominant ripped from stem. • Fire scars affecting ≥ 20% of tree's circumference (red oak)
Decay Wood that is missing or structurally compromised. Canker rot fungi are not compartmentalized and will cause significant decay.	• Decay in main stem results in <1" of sound wood for every 6" in diameter; must have 2" of sound wood for every 6" dbh if there is also a cavity present. • Decay or cavity affects >40% of the stem's cross-section. • Tree infected with a canker-rot fungus (see next column).	• Tree infected with a canker-rot fungus including but not limited to: *Cerrena unicolor* *Phellinus everhartii* *Inonotus hispidus* *Spaniels' paydown (Ripe molly's)*

DEFECT	High Probability of Mortality or Failure (high risk)	High Probability[1] of Degrade due to Defect
Canker Localized area of dead bark and cambium; wood behind canker may or may not be decayed. Commonly caused by fungi. Fungal cankers are a source of spores that may infect healthy trees.	• Canker affects >50% of the stem's circumference or >40% of the stem's cross section. Common canker diseases on oak: Botryosphaeria canker (*Botryosphaeria quercuum*); Nectria canker (*Nectria cinnabarina*); Strumella canker (*Urnula craterium*) Strumella canker pathogen decays wood behind the cankers. • Horizontal crack on a canker face.	• Decay associated with large canker (affects >50% of stem's circumference). Fruit body visible in the canker's face. Extent of decay and discoloration will vary depending on organisms involved.
Cracks Open crack: A split through the bark, extending into the wood approximately 1 or more inches. Wood fibers are not fused. Stems or branches with open cracks cause the affected area to act as 2 or more separate beams, weakening mechanical support. Open cracks are more likely to be associated with decay and discoloration. Closed crack: A split through the bark that has fused back together.	• Open crack goes completely through a stem or is open for >4' (length). • Two open cracks occur on the same stem segment. • The stem has an open crack in contact with another defect such as decay, a canker, or weak union.	• >1 face with open or closed crack • open or closed spiral crack.

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

DEFECT	High Probability of Mortality or Failure (high risk)	High Probability[1] of Degrade due to Defect
Galls Abnormal growths on stems and branches. Galls are typically sound but may cause degrade in a localized area around the gall.		• Galls on main stem (Phomopsis galls)
Weak Union Union with ingrown bark between stems; wood fibers are not fused. Weak unions are characterized by an acute angle between stems.	• Stump sprouts joined above ground in V-shaped union and associated with a crack, showing failure has already begun.	• Large (>8" diameter stems) tight union that is either cracked or decayed or associated with another defect. Could result in failure; stain/ decay will vary.
Structural Compromise Unusual form typically initiated by storm damage.	• Leaning tree with recent root lifting. • Leaning tree with a horizontal crack, long vertical crack, or buckling wood on the underside of the tree. • New leader formed in response to a dead or broken top. Risk increases as top gets larger and stem decays at break point.	
Root Defects Loss of structural support due to root rot, wounding, severing or any other factors that cause root mortality.	• More than 33% of roots severed, decayed or otherwise compromised. • Stump sprouts with a tight union where root structure is not sufficient to support stems.	• >3 root wounds within 4' of the main stem; each wound encompasses >30% of root diameter.

DEFECT	High Probability of Mortality or Failure (high risk)	High Probability[1] of Degrade due to Defect
Crown Density/Dieback/Leaf Condition Crown symptoms are often showing a response to poor root health, stress such as defoliation or drought or infestation by cambium-mining beetles. Large dead branches/tops/codominants keep wound "open"; decay will advance more rapidly with an open wound. Failure of dead wood is unpredictable. Could cause damage upon failure.	• 50% of the crown dead unless loss of crown is due to stem breakage. • 75% of leaves subnormal in size or abnormal in color. (excluding iron chlorosis.) • Signs of cambium miners such as the two-lined chestnut borer.	• Multiple large (>5" diameter) dead branches, dead top or codominant (>10" diameter).

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

Summary of principles related to discoloration and decay development

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

Table 41.17. Summary of guidelines related to fire scars and decay development.

Issue	Species	Rule of Thumb
Wound size associated with fire scars	Black oak Northern red oak	Dormant season fire - Wound height = Height of bark scorch x 0.9; Wound width = Width of bark scorch x 0.6 Growing season fire - Wound height = Height of bark scorch x 1.2; Wound width = Width of bark scorch x 0.7
Wound size associated with fire scars	White oak	Dormant season fire - Wound height = Height of bark scorch x 0.7; Wound width = width of bark scorch x 0.6 Growing season fire - Wound height = Height of bark scorch x 1.0; Wound width = Width of bark scorch x 0.7
Decay associated with fire scars		Fire scars are common entries for decay fungi. Ten years after fire injury, decay may extend .5 – 1 foot above the top of the fire scar. Avg. rate of decay development = 1.25'/ decade.

Oaks (both red and white oaks) tend to decay at a slower rate with less discoloration with a same wound size/severity (see the diagram below).

Slower decay → **Faster decay**

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

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

Hickory, Ash **Basswood** **White Birch** **Sugar Maple** **Red Maple**
Oak **Yellow Birch**

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