Appendix D

Range of Natural Variability, Old Growth, and Silvicultural Systems

Range of Natural Variability

Tree Characteristics

During the 1600s southeast Ohio was inhabited by the Shawnee Nation. It is believed that Native Americans frequently burned the forests of eastern North America to facilitate game hunting and to enhance the growth of herbaceous plants (Goebel and Hix, 1996). Berry and mast production also benefited from fire. The clearing of land for agriculture was probably restricted to fertile floodplains of larger river systems.

When the first European settlers viewed the forests of the Ohio Valley in the late 1700s, they found "hills clothed with a thick forest of trees, consisting of white, red, and black oak, hickory, ash, chestnut, sassafras, dogwood, and grape vine" (Goebel and Hix, 1996). The forests of southeast Ohio at the time of European settlement were dominated by white oak, which accounted for 40 percent of all witness trees documented by the original land surveyors of the Ohio Company Purchase from 1796 to 1802. American beech, sugar maple, and yellow poplar were frequently recorded in the "bottoms" (stream valleys) but they were not abundant overall (Dyer, 2001).

Although southeastern Ohio was almost entirely forested at the onset of Euro-American settlement (ca. 1800), written accounts of the landscape prior to 1800 describe more open conditions in some areas, as summarized in Sutherland and Hutchinson (2003). In several accounts, forests were described as open and park-like. In 1765, George Croghan, an Indian agent, frequently described "clear Woods" in eastern Ohio. Thaddeus Harris, traveling from Marietta, Ohio, to Wheeling, W.Va., in 1802 wrote "There is but little underwood; but on the sides of the creeks and near the river, the paw paw, spice bush or wild pimento, and dogberry grow in greatest abundance". Traveling west from Pittsburgh, Penn., David McClure in 1772 noted that "the woods were clear from underbrush, the oaks and black walnut do not grow very compact, and there is scarcely anything to incommode a traveler in riding, almost in any direction, in the woods of the Ohio. The Indians have been in the practice of burning over the ground, that they may have the advantage in seeing game at a distance among the trees."

In southeast Ohio, frequent burning is believed to have favored the more fire resistant oaks and eliminated understories of mesic species such as American beech and sugar maple (Goebel and Hix, 1996). The forest conditions were predominated by oaks because they have several biological adaptations to fire. Oak stems have thick, corky bark, a tenacious ability to repeatedly resprout following top-kill due to high root:shoot ratio and dormant buds near the root collar, and the ability to compartmentalize wounds. In addition, oaks benefit from post-fire conditions, such as the open understory and reduced impact of fire intolerant competitors, and the xerification of the site through consumption of some of the duff and exposure of soil to greater solar radiation, allowing oak to dominate the advanced regeneration pool (Ruffner and Groninger, 2004).

Beginning at the time of European settlement in the early 1800s, the general level of disturbance was higher because land was cleared for agricultural crops. Fire was used to clear the land and it sometimes escaped to the woods, so that the level of fire disturbance remained similar to the conditions before the settlement of Europeans (Fralish, 2004).

In southeast Ohio, timber harvesting on the uplands was limited until the mid-1800s when the charcoal iron industry became prominent in the region. The charcoal industry (ca 1830 – 1890) was the primary cause of the clearcutting of many forest stands in southeast Ohio. In 1875 there were 69 iron furnaces in the Hanging Rock region of southeast Ohio and northeast Kentucky. To supply charcoal for a typical furnace 200 to 600 acres of forest were harvested annually, and the forest was harvested again at 20 to 30 year intervals. These cuts were essentially coppice harvests, whereby regeneration was of sprout-origin. This cutting regime ultimately fostered oak regeneration and reinforced its dominance (Abrams and Nowacki, 1992).

In southern Ohio the fire-return intervals during the period of the mid-1800s to 1925 was in the range of 3 to 7 years (Abrams and Nowacki, 1992). Fire scar data analyzed in Vinton County, Ohio show that the fire return interval averaged 3.6 years for low-intensity fires, and 7.5 years for major fires. The fires were probably ignited by people and occurred mostly in the dormant season or early spring, and only a few (6%) occurred during the summer. There is little indication that climate patterns caused the fire events since they were human-caused. The fires appeared to have burned until either weather extinguished them or they encountered barriers. (Sutherland, 1997) As shown in Figure D - 1, the acreage of land that experienced fire dropped dramatically after the late 1920s and early 1930s when fire control laws were passed and the general protection of the forest ecosystem began (Sutherland and Hutchinson, 2003).

Seemingly, fire reduction was a widespread phenomenon throughout the region; the same trend was documented in neighboring Pennsylvania (Abrams and Nowacki, 1992).

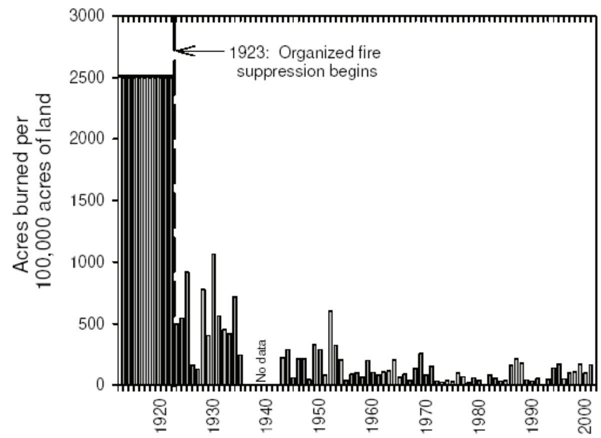

Figure D - 1. Annual acreage burned per 100,000 of land for 10 counties in southeastern Ohio. (Source: Sutherland and Hutchinson, 2003)

Since the early 1930s, previously established oak and hickory trees have continued to grow, but few seedlings reach sapling size before dying. Forested areas have remained relatively undisturbed for the past 70 years, and so scattered stems of fire-intolerant but shade tolerant species such as red and sugar maple and American beech have grown to tree size and become a major seed source. Now forest communities are converting from mid-successional oak and hickory species to shade tolerant climax mesophytes. The near absence of fire has permitted the development of this classical secondary successional process, particularly on mesic sites. (Fralish, 2004).

Table D - 1 shows the relative abundance of trees existing when the Ohio Company Purchase was surveyed in the late 1700s and early 1800s (based on witness tree documentation) versus the representation of the same species in 1991 when the Forest Inventory was reported. In southeast Ohio, the oak and hickory components have declined roughly 26 percent when comparing presettlement to current vegetation (Dyer, 2001).

Table D - 1. The relative abundance of trees when the Ohio Company Purchase was surveyed in late 1700s and early 1800s compared to representation of the same species in 1991.

Species Group	Percentage of Witness Trees 1796 – 1802	Percentage of Trees documented by FIA (as reported in 1991)	Change
White Oaks	40.0	14.5	- 25.5
Hickory	13.6	8.0	- 5.6
Black Oaks	12.2	13.6	+ 1.4
Beech	8.4	3.6	- 4.8
Sugar Maple	3.6	7.6	+ 4.0
Red maple	3.2	5.4	+ 2.2
Yellow Oak	3.2	7.2	+ 4.0
Yellow Poplar	2.9	10.8	+ 7.9
Ash	2.4	4.8	+ 2.4
Other	10.6	24.5	+ 13.9

In addition to a decrease in the dominant oaks and hickories with an increase of more shade tolerant species such as sugar maple, a second evident trend is a dramatic increase in early successional species such as yellow poplar, ash, pine, aspen, and black cherry. Past land practices have clearly favored those trees with greater seed dispersal ability (Dyer, 2001).

Reliability of Public Land Survey Data

Studies concerning the use of Public Land Surveys (PLS) to determine vegetation characteristics find some degree of variability among surveyors. These records do not constitute an unbiased sample of presettlement vegetation. Instead, one must understand the PLS data in their historical context. The data were created for legal, not ecological, purposes. These purposes affected the manner in which the surveyors collected the data. The surveyors also independently interpreted how best and easiest to meet these purposes. Sometimes these interpretations result in significant differences among surveyors as to the species they chose as witness trees, the diameters of those trees, and the distances traveled to record them.

The important question is how these levels of variability affect the biological significance of the PLS data, especially when representing large areas (>24,700 acres); the counties studied by Dyer (2001) and presented in the Table D - 1 included 1,235,550 acres. At such scales the effect of surveyor variability may not be strong enough to greatly influence results. For example, surveyors were constrained by which species were present at each point. These forests are usually dominated by only a few species. Thus, great deviations from which species would occur at a site were not

likely. Differences due to environmental variability may also exceed the effect of surveyor differences when examining the PLS data over areas of great extent. Over large areas, such as Dyer's (2001) study area, PLS data are appropriate for reconstructing the vegetation before European settlement (Manies et al., 2001).
To assess changes in forest composition and structure over the last 200 years in southeast Ohio, USDA Forest Service Forest Inventory and Analysis (FIA) data were summarized for the eight counties that encompass the original Ohio Company Purchase. Although the instructions established by Congress did not comment on witness tree selection, it is intuitive that surveyors were unlikely to select very small individuals; this is born out by an examination of the size-class distributions of witness trees. To facilitate comparison with the witness trees, FIA data for this analysis included trees ≥9 inches in diameter, in stands of natural origin (n = 364 plots). Data on slope, aspect, physiographic class, and location also were obtained for each plot. Latitude and longitude coordinates for each plot are reported to the nearest 100 feet, so that the exact location of the site may be within 1.8 miles of what is reported. Although the nature of the witness tree data (point samples) and FIA data (area samples) preclude direct comparison, the limited conclusion can be drawn that the dominant forest taxa are occupying similar environmental sites today as they did in the presettlement forest, although relative abundances have changed significantly (Dyer, 2001).

Understory Plants

Early accounts from Ohio indicate that presettlement forests were clear of underbrush and that one could travel through the woods on horse-drawn sleds (Goebel and Hix, 1996). The surveyors did make brief reference to oak and hickory underbrush (presumably saplings and seedlings) blocking their line of sight. Dogwood was also noted frequently, and spicebush (*Lindera benzoin*) was recorded in several valleys. Sapling species, which are presently abundant, such as red maple, sugar maple, and black gum were not recorded in the underbrush descriptions by the surveyors (Sutherland and Hutchinson, 2003).

Fire was no doubt used as a management tool in southeast Ohio as Hildreath in 1788 describes for Washington County "Yearly autumnal fires of the Indians, during a long period of time, had destroyed all the shrubs and undergrowth of woody plants, affording the finest hunting grounds" (Dyer, 2001).

Blueberry and other ericads were commonly found on the forest floor of a dry oak stand. The frequent fires of the past would have benefited the plants by top pruning and thinning the plants to encourage young growth, and the semi-open canopy would have allowed the plants to bear more fruit.

The present high density of seedlings, saplings, and small trees of mesophytic species within the central states oak-hickory forest is having a major deleterious effect on the herbaceous layer. Data collected from Trail of Tears State Forest in the Illinois Ozark Hills region indicates that as photosynthetically active radiation decreases and the amount of ground litter increases, there is a major decrease in the number of herbaceous species. Species richness increased 200 percent from an average of 10 species/108 square feet in a forest composed of black and white oak and hickory with a closed canopy of smaller sugar maple trees (dbh of 4-8 inches) to an average of 31.5 species/108 square feet in open stands dominated by black oak, white oak, and hickory without maple. In dense sugar maple dominated forest of the Ozark Hills region, few seedlings or herbs can be observed (Fralish, 2004).

A decrease has also been reported in the number of summer and fall flowering species between 1980 and 1988 and related this decrease to the increase in sugar maple importance in the tree canopy. At Land Between The Lakes (LBL) in Kentucky and Tennessee, about twice the number and double the cover of herbaceous cover species were found in shelterwood cut stands as compared to uncut post oak, black oak, and white oak dominated stands, suggesting that even in oak dominated stands, the light resource prevents full development of understory herbs. Therefore, it should be of no surprise that the added layers of branches and leaves, due to a midcanopy of mesophytic species, impoverishes the herbaceous stratum (Fralish, 2004).

Restoring the characteristics of an oak forest that is maintaining itself, and all the other forest types on the Wayne National Forest, will take several decades. Over time the treatments prescribed will slowly change the conditions that have developed over several decades. For example, since many of the current oak stands have many other species in the understory and mid-story, just one or two silvicultural practices will not change the ecosystem to what it was several hundred years ago.

Ecosystem Descriptions

The previous discussion describes the general characteristics of a predominantly oak ecosystem on the Wayne National Forest in the past and possibly in the future.

Below are the characteristics of other ecosystems found on the Wayne National Forest. These describe, in general terms, common ecosystems that exist on the Wayne National Forest. Many sections of the forest will differ slightly from these descriptions, but the general concepts should be evident. Also, some areas will demonstrate traits common to one or more different ecosystem depending on the physical conditions, and past land management. These descriptions are intended to describe the most common associations, but not to describe every ecosystem that may exist on the Forest.

The Wayne National Forest is within the Appalachian Unglaciated Plateau and within the central hardwood region; this region can be defined as the area south of the beech-maple forests, east of the Great Plains, and north and west of the southern pine forests. Within this central hardwood region are other subdivisions including Oak-Hickory and Mixed Mesophytic. (Hicks, 1998)

The **Mixed-Mesophytic Forest** is a high-diversity and predominately deciduous forests occurring on deep and enriched soils, usually in somewhat protected landscape positions such as coves or lower slopes. Dominant species include sugar maple (*Acer saccharum), American beech (Fagus grandifolia),* Yellow Poplar *(Liriodendron tulipifera), and* Red Oak (*Quercus rubra).* Trees may grow very large in undisturbed areas. The herb layer is very rich, often with abundant spring ephemerals. Many examples may be bisected by small streams. Shrub strata are open to sparse and can include spicebush *(Lindera benzoin)*. Herbaceous strata are typically lush and diverse. A partial list of typical species includes Trillium *(Trillium erectum),* May-apple (Podophyllum peltatum)*,* Tall White Violet *(Viola Canadensis),* water-leaf (*Hydrophyllum canadense),* and Sedge *(Carex austrocaroliniana). (Natureserve, 2005)*

The **Beech-Maple Forest** is found primarily on flat to rolling uplands to steep slopes with rich loam soils. This system is characterized by a dense tree canopy that forms a thick layer of humus and leaf litter leading to a dense and rich herbaceous layer. Sugar Maple (*Acer saccharum)* and American Beech (*Fagus grandifolia)* comprise up to 80% of the canopy. Other associates can include red oak (*Quercus rubra),* Basswood *(Tilia americana),* ironwood *(Carpinus caroliniana)*, and hophornbeam (*Ostrya virginiana)*. The relative dominance of sugar maple compared to other tree species varies across the range of this system based on regional climate and microclimate. The herbaceous layer is very diverse and typically includes spring ephemerals. Some common species include jack-in-the-pulpit *(Arisaema triphyllum),* bedstraw *(Galium aparine),* Woolly sweet-cicely *(Osmorhiza claytonia),* Smooth Solomon's Seal *(Polygonatum biflorum)*, and trillium (*Trillium grandiflorum)*. *(Natureserve, 2005)*

The **Mixed Oak – Hickory Forest** occurs on gentle to moderately steep slopes of dissected hills and plains. Soils are well-drained, shallow to deep, often over sandstone, cherts, or cherty limestone. Stands are dominated by a closed-canopy deciduous tree layer. The dominants are white oaks and red oaks. Typical associates include hickories (*Carya sp),* red and sugar maples (*Acer sp*)*,* and Black Gum (*Nyssa sylvatica)*. The shrub and small-tree layer contains dogwood *Cornus florida*), virginia creeper (*Parthenocissus quinquefolia)* is a typical vine. The low-shrub layer may be dominated by blueberry (*Vaccinium pallidum).* The herbaceous layer contains Black cohosh *(Actaea racemosa),* tick trefoil (*Desmodium glutinosum),*bedstraw (*Galium pilosum)*, and christmas fern (*Polystichum acrostichoides)*. *(Natureserve, 2005)*

The **Virginia Pine- Shortleaf Pine Forest** includes Virginia Pine (*Pinus virginiana) and* shortleaf pine (*Pinus echinata)* dominated forests of ridges and steep upper slopes. This community occurs on narrow ridges, steep slopes, and other exposed topographic positions, over shallow, infertile soils. This mainly evergreen forest is often of low stature, with a somewhat open to closed canopy, sparse to very dense shrub cover dominated by ericaceous species, and a sparse herb stratum. Virginia pine and / or Shortleaf pine dominate the canopy, with various oaks also occurring. Deciduous species may form a subcanopy or sapling stratum, particularly in areas where fire has been excluded. Blueberries are a common shrub. Herbs are typical of infertile, xeric habitats such as lowbush blueberry (Vaccinium pallidum) and striped wintergreen (Chimaphilla maculate). *(Natureserve, 2005)*

The **Bottom Land Forest** is dominated by silver and red maple occurring in moist, deep, hydric soils associated with wetland depressions on level plains and floodplain backswamps. Soils are saturated for a few months of the growing season, but often are dry by late summer. Canopy cover is complete and dominated by Red maple (*Acer rubrum),* Silver Maple *(Acer saccharinum)*, Sycamore (Platanus occidentalis), River Birch (*Betula nigra),* Ash (*Fraxinus pennsylvanica)*, and Elm (*Ulmus Americana)*. The subcanopy consists primarily of Red Maple (*Acer rubrum)* and Elm (*Ulmus americana)* underlain by a shrub layer which may contain a mixture of ironwood (*Carpinus caroliniana),* winterberry *(Ilex verticillata),*spicebush *(Lindera benzoin),*elderberry *(Sambucus Canadensis),*poison ivy *(Toxicodendron radicans), and* arrowwood *(Viburnum recognitum)*.. The depth and duration of flooding and light penetrating the forest canopy regulate density and diversity found in the herbaceous layer. Jewelweed (*Impatiens capensis),* jack-in-the-pulpit (*Arisaema triphyllum),* Fowl mannagrass *(Glyceria striata)*, and a variety sedges (*Carex* spp.) are among the most common species encountered. *(Natureserve, 2005)*

Role of Mychorizae

Mycorrhizae are symbiotic associations of tree fine roots and certain soil fungi. Oak species are classified as ectomycorrhizal (possessing an external fungal mantle and Hartig net hyphae between cortical cells) while maples are classified as endomycorrhizal (with vesicles, arbuscules, and/or hyphal coils in cortical cells). Both types of mycorrhizae generally benefit seedling establishment or growth through increased nutrient uptake and improved water relations in the roots.

In a study on Ohio's Zaleski State Forest, after thinning and burning, the extensive endomycorrhizal colonization of red maple in the study (59 to 76 percent) was high. Much of the herbaceous vegetation in the understory was classified as endomycorrhizal; therefore, a high level of soil inoculum may account for the high colonization levels in the study. A lack of effect due to thinning on endomycorrhizal colonization was observed: selective cutting had no negative effect on mycorrhizal community structure because of the rapid regeneration of mycorrhizal hosts and minor levels of soil disruption.

Oak species generally are considered as ectomycorrhizal; however, the study on the Zaleski State Forest observed both ectomycorrhizal and endomycorrhizal associations on black oak roots. Endomycorrhizal infection of predominantly ectomycorrhizal host plants might be increased in the presence of abundant endomycorrhizal hosts, as occurred in the understory at Zaleski State Forest. (McQuattie, Carolyn J.; Rebbeck, Joanne; Yaussy, Daniel A., 2004)

Sudden Oak Death (SOD)

Sudden Oak Death (SOD) is a new disease that has spread rapidly since 1995 in California. It is caused by a newly discovered pathogen (Phytophtora ramorum. The disease has been found in nursery stock in the eastern United States, so infection of natural stands is possible. Fire suppression has been effective where SOD has emerged in the west. Analysis by Moritz and Odion demonstrates a strong and consistent negative relationship between locations of confirmed SODS and areas that have been burned since 1950. The potential for fire to influence the growth of spores and mycelia of fungal pathogens through direct effects of heat and/or smoke has long been known. (Moritz and Odion, 2005)

Oak Decline

Periodic occurrences of decline and death of oaks over widespread areas have been recorded since 1900. The condition is often caused by a complex interaction of stresses and pests. Generally trees are weakened by environmental stresses such as droughts, frosts, of pests such as defoliating or sucking insects. Weakened trees are then invaded by other insects or diseases and the trees subsequently die. Healthy trees could withstand the secondary pests, but in a weakened condition, there is a not sufficient energy reserve to survive. Usually, the progression of decline is slow, occurring over several years. Control of oak decline is generally considered to involve keeping the trees healthy, and thus able to withstand pests and diseases. Certain causal factors such as drought and frost cannot be controlled, but management actions such as thinning can reduce competition for moisture and nutrients and thus promote a better physiological condition of the remaining trees. (Wargo, Houston, LaMadeleine, 1983)

Old Growth

Old Growth Forest Characteristics

As described above, frequent fires were a common occurrence and the fires had significant effects on the species and structure of the forests before fire suppression became common. Since fire did have a long and significant effect on the forests of southeast Ohio, the following descriptions of old-growth forests will be made with the recognition that frequent fires had significant influences in developing the forests that existed at the time of European settlement.

Because of ecological micro-climates, a fire has different effects depending on factors including temperature, fuel moistures, aspect, and humidity. For example, in a deep cove the intensity of a fire would likely be very different than on a south facing ridge top. A cove will be cooler in temperature, the fuels on the ground will be moister, and the humidity may be higher; therefore a fire will be smaller and cooler and so affect the vegetation differently than on the ridge top. A fire could go around the cove, or not burn at all, if the fuels are moist enough in the cove. Conversely, a fire is likely to burn hot on south slopes and ridge tops because the fuels are drier and air temperature is warmer. This same principal applies to some stream and river bottoms; these are often moister and more protected and thus do not burn as hot or as frequently as the uplands.

This concept would result in the plant species being different on more mesic sites. The size of these different microclimates can vary from less than an acre, for example, in a small cove and up to several hundred acres along some river corridors.

Definitions of old growth include several physical attributes combined with local plant species and their particular niches considering other events such as fire and weather.

Following are the physical characteristics of Old Growth that will be used on the WNF for all possible designations:

Downed Logs – Coarse woody debris (stems greater than 4 inches in diameter) are a common component of the forest floor. The downed logs are from a variety of size classes, and in various stages of decay, suggesting the logs are from a long-term process, not a single event such as a storm.

Standing Snags – Standing dead trees greater than 4 inches in diameter are prominent, indicating that trees have reached their natural mortality in place, and not selectively removed.

Treefall Gaps – There are many small blowdowns of one to several trees in each group. The gaps created by the blowdowns create a change in the understory microenvironment. As a greater solar radiation reaches the forest floor, advanced regeneration results in a forest with multiple layers (3 to 5) instead of the 1 to 2 typically found in a younger forest.

Pit and Mound Topography – The soil surfaces in old-growth is often dominated by a rolling topography produced by windthrown trees. When the trees are thrown, their root mat and associated soil is ripped up from the forest floor, creating a pit or depression. As the root ball decays, the soil is loosened and falls into a mound adjacent to the pit. These pits and mounds are important in forest nutrient cycling and understory diversity, but are generally absent from human-disturbed forests.

Undisturbed Soils – Old-growth forests typically have a soil which is high in organic matter, with a thick organic layer and considerable numbers of ferns, mosses, and fungi. Not having experienced recent heavy logging equipment, horses, dragged logs, or grazing livestock, the soils will not be compacted. Soil macropores (2 to 4 inches in diameter), formed by the dead decaying roots of old trees, are often present in the upper soil profile.

Uneven-Aged Canopy Structure – Eastern old-growth forests are generally characterized by trees of all ages and diameters. They typically exhibit a reverse-J age distribution, whereby younger stems are at a much higher density than older stems. The shape of the age distribution often (but not always) parallels that of the diameter distribution. The age/diameter structure is driven largely by small-scale natural disturbances and differential shade tolerance among species. To be considered an old growth stand, the number of large/old trees must be fairly well distributed across the area, and fit the reverse-J curve as described above.

Figure D - 2 shows the physical structure of a mature second growth stand compared to an old growth forest. The mature second growth forest has a closed canopy, very few small trees on the forest floor, and very little dead woody materials. In the old growth sketch, notice the many different sized trees, gaps in the tree canopy created by the fallen trees, and the standing dead snags (McCarthy, 1995).

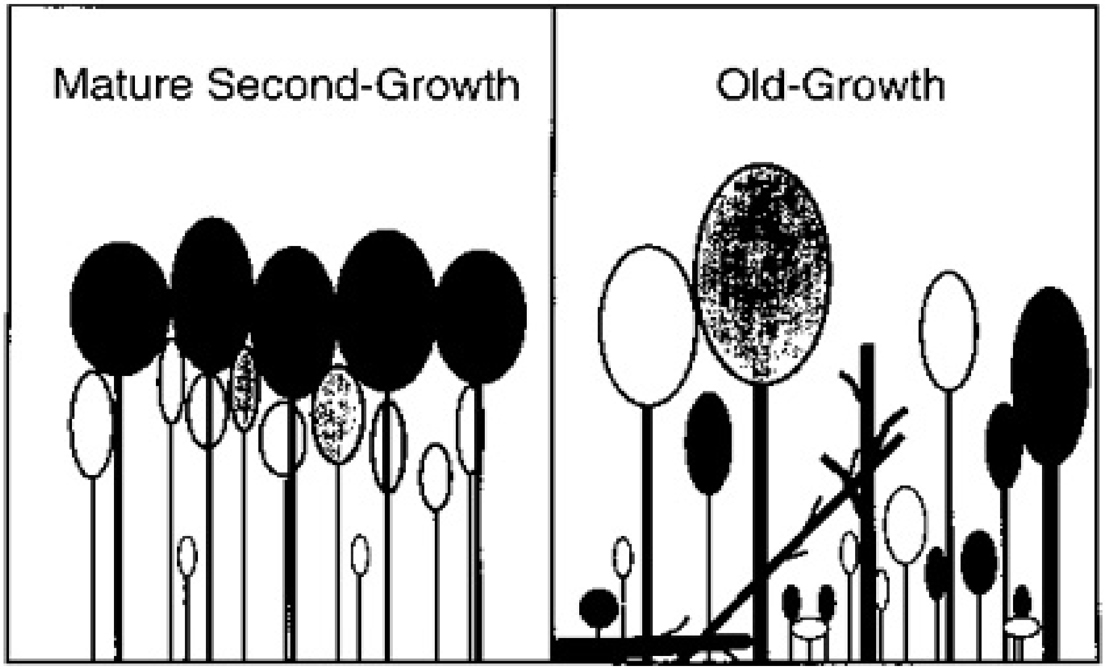

Figure D - 2. Physical structure of a mature second growth stand compared to an old growth forest. (Source: McCarthy, 1995)

Overtime, old growth characteristics will likely be present in forest stands on the WNF in each of the alternatives. These old growth stands would occur in the three forest systems found on the WNF: Central Appalachian Cove Forest System, Allegheny-Cumberland Dry Oak Forest and Woodland System, and Cumberland Dry Circumneutral Forest and Woodland System (TNC 2003; also refer to Draft EIS, Appendix E for more information about these forest systems).

Each of these forest systems are characterized by an association of various tree species. In addition to the old growth characteristics described previously, the stands would contain some trees of great age. Following are brief descriptions of these forest systems, along with examples of species and ages of older trees likely to be associated with future old growth stands. Tree ages were determined by adding 50 percent to the biological lifespan as listed in the *Silvics of North America* (Burns and Honkala, 1965), a method proposed by Dr. Brian McCarthy, Forest Ecologist, Ohio University(McCarthy, 1995). Old Growth in a pine type was not formulated because pine in southeast Ohio is generally a pioneer species that is replaced by hardwoods.

Forest stands with old growth characteristics would occur on a contiguous block of land at least 4 acres in size. When mapping forest stands, the Wayne National Forest's October 2002 *Guidelines for Delineating Stands* calls for stands to be greater than or equal to 10 acres, unless something significant is present, then the minimum mapping unit is to be 4 acres.

Allegheny – Cumberland Dry Oak Forest Old Growth:

These stands would likely be located on the dry to moderate sites on the forest. Typical locations would be ridgetops, the upper one-third of the hills, southwest to southeast slopes, and some west slopes. This type was perpetuated in the past because of the frequent fires. Eventually, without fire, this type will evolve into a mixed-mesophytic type except for on the driest sites.

Typical tree species and ages of the older individual trees within the stand are:

White oak – 300 years old

Northern red oak – 180 years old

Chestnut oak – 180 years old

Hickory – 300 years old

Central Appalachian Cove Forest Old Growth:

These stands would likely be located on northerly and easterly slopes, on some lower slopes, and in coves. The sites where this type developed in the past were in locations where frequent and hot fires were rare. This allowed the fire-sensitive and shade tolerant trees to develop and mature.

Typical tree species and ages of the older individual trees within the stand are:

Sugar maple – 375 years old

American beech – 375 years old

Red maple – 120 years old

Yellow poplar – 300 years old

Hemlock – 600 years old

Bottomland Hardwood Old Growth:

These stands would likely be located adjacent to major streams and rivers. The sites where this type developed were on soils that frequently flooded and stayed moist most of the year. Frequent and hot fires were rare.

Typical tree species and ages of the older individual trees within the stand are:

Silver maple – 200 years old

American elm – 250 years old

Red maple – 120 years old

Sycamore – 300 years old

Silvicultural Systems

Even-aged Management

Even-aged forests occur naturally after a major disturbance initiates the processes involved in stand regeneration. Even-aged stands generally have one age class, although two age classes can be found in some two-layered natural or managed stands. These stands generally have a well-developed canopy with a regular top at a uniform height.

Pure even-aged stands generally have a nearly bell-shaped diameter distribution. This means that most trees are in the average diameter class. However, diameter distributions should be viewed cautiously because diameter can be a poor criterion for age. The smallest trees in natural even-aged stands are generally spindly, with vigor suppressed by the overstory.

Clearcutting

In a clearcut system the stand overstory is generally removed in one harvest. The following silvicultural considerations are provided by Sanders and Graney (1992).

If there are adequate numbers of advanced oak seedlings that are vigorous and have well-developed root systems, clearcutting is the most effective method to regenerate the stand to species dominated by oak and hickory. Although understory species may appear to dominate the stand for about 10 years following clearcutting, the oaks and other overstory species begin to assert dominance, and by age 10-15 the understory species are generally in a subdominant position.

Stands should be a minimum of 2 acres in size. If the advanced oak reproduction potential is not adequate and the stand is clearcut, the new stand will be dominated by a varying mixture of species, but likely oaks and hickories will not dominate the site. With the exception of yellow-poplar, the species that dominate the advance reproduction will be predominant in the new stand. Yellow-poplar will also be abundant if it is present in the overstory, and some oaks will probably be present.

If the clearcut stand is on southeast or northwest middle and upper slopes, we can expect to have a stand at about age 20 that can be molded into an essentially pure oak stand by thinning. On north and east aspects and lower slopes, the stand composition may be highly variable. Yellow-poplar will likely be abundant. Other species such as white ash, black cherry, and red and sugar maples will also be present. However, if the oak advance regeneration is adequate, expect to have a predominantly oak stand 20 years after clearcutting.

In practice, the WNF will not normally prescribe true clearcuts, in which ALL merchantable trees would be cut from an area. The Wayne is likely to prescribe *Clearcutting with Reserves*, which is a clearcutting method in which varying numbers of reserve trees are left standing to attain goals other than regeneration. The overstory trees that would be retained, called reserve trees, may be small or large trees, or combinations of small and large trees, retained for:

- Future growth
- Certain species components
- Current or future den trees; future sources of snags or coarse woody debris
- Visual quality

Shelterwood

In general, a shelterwood treatment is the cutting of most of the trees, but leaving those needed to produce seedlings in a moderated microclimate (SAF, 1998)**.** In particular on the WNF and in the central hardwoods, when the regeneration potential of the existing oak advance reproduction is not adequate to replace the stand, the shelterwood method can be used to develop the required advanced reproduction. The minimum number of advanced reproduction is determined by inventorying the area to discover the amount and size of oak seedlings and estimating the number of stump sprouts after cutting. The procedure is outlined in (Sander et al. (1976). The following silvicultural considerations are taken from Sander and Graney (1992).

When oak advance reproduction is small, scarce, or absent, the regeneration method most likely to produce the best results is the shelterwood method. However, the method must be tailored to produce the micro-environments required by oaks for successful seedling establishment and early seedling growth.

Without any specific treatment, oak advance reproduction is most likely to be inadequate on the middle and lower north- and east-facing slopes; south-facing slopes and ridge tops may develop advanced oak regeneration without specific treatments because of the dry and open microclimate.

When applying the shelterwood method to develop oak regeneration, following are some general practices (Sander and Graney, 1992). Depending on site-specific conditions some or all of these treatments are probable.

Control the understory that will compete with the small oaks by cutting or preferably killing the non-oak species by prescribed burning or applying herbicides.

Reduce the overstory to 40-80 percent stocking. Leave the best dominant and codominant oaks as uniformly spaced as possible.

If possible, apply the understory and overstory treatments before seedfall in a good seed year.

Monitor seedling establishment and growth and make additional light cuts to keep the overstory from restricting growth.

Apply additional understory control if the understory redevelops to a point where it restricts the oak reproduction growth. This control may be desirable 5-10 years after the original treatment; treatment could be by prescribed burning or applying herbicides.

When the regeneration potential of the oak reproduction is adequate to replace the stand, remove the remaining overstory sufficiently to allow the oaks to fully develop. The length of time required to establish oaks and grow them to adequate size under a shelterwood will probably be 10 to 20 years or more.

When using prescribed fire to develop oak seedling development, more than one burn may be needed if oak regeneration is not adequate after one burn. In many situations within the Central Hardwood Region and beyond, decades of fire exclusion have allowed oak competitors to become so firmly established that oak regeneration may not be as plentiful as desired. Oak dominance of the advance regeneration can be increased with repetitive burning (Van Lear, 2004).

In one study, Brose and Van Lear conducted a shelterwood harvest, followed by a variety of prescribed burns. Oak regeneration density was not reduced by any fire prescription, but yellow poplar density was reduced and resprouting poplar stems exhibited accelerated growth for only one year. Red maple density was significantly reduced after moderate to high intensity prescribed burning. Results indicated that prescribe burning after a shelterwood is a promising approach to regenerating oaks on productive sites. (Brose, P , Van Lear, D. 2004)

Another silvicultural treatment that has proved effective on more mesic sites is to remove midcanopy and some lower canopy trees and leaving a main canopy with no large gaps, the survival and growth of small oak advance reproduction increases. This treatment allows the population of small oak advance reproduction to develop after a few years into a population of larger advance reproduction, making oaks more competitive after release. Plus, this process also reduces competition from other species. Potential sprouts from midcanopy and lower canopy trees are treated with herbicides or prescribed fire, thereby directly reducing competition from these trees both before and after overwood removal. The reduction in competition from yellow-poplar is more subtle. First, while the residual canopy with no canopy gaps is sufficient to allow oak seedlings to develop, it is not sufficient to allow the establishment and development of yellow poplar. Secondly, new yellow-poplar seedlings that become established after overwood removal will be in an inferior competitive position, at least on a patch-wise basis, because of the development of large advance reproduction of oaks and other species (Loftis, 2004).

Two- Aged Management

The two-aged system regenerates a timber stand and maintain two age classes (SAF, 1998). Various other publications refer to this type of management scenario as deferment cutting, irregular shelterwood, or a shelterwood with reserves. As applied on the Wayne, the objectives of the harvest would include the need to develop early-successional wildlife habitat, while at the same time retaining an important overstory component. The Forest would retain 15 to 20 square feet of basal area per acre of the original overstory; the selection of the "leave trees" would be based on plant and animal habitat needs. For example, if the average diameter of the retained trees was 18 inches, this would be approximately 9 to 12 trees per acre. To regenerate the two-aged areas to an oak-hickory forest type, the same adequate numbers of healthy and well distributed oak seedlings must exist as was discussed for clearcut harvests prior to applying the two-aged harvest.

Perkey et al. (1999) reported the following observations regarding the development of two-aged stands after a regeneration cut in the central Appalachians.

Leaving 12 to 15 residual overstory trees per acre and cutting all other trees 1-inch dbh and larger resulted in hardwood reproduction similar to that expected after clearcutting.

In the Fish Trough treatment area, a sample of 10 yellow-poplar overstory crop trees was remeasured at about age 94 to determine if they were still growing well; they were. During the first 16 years of the study they grew at a rate of 2.9 inches/decade. During the last 3 years they grew at a rate of 3.2 inches/decade.

Residual overstory trees (the older age class) were still free to grow, with an average of 20 feet of growing space between adjacent crowns; these trees were scattered over the area, not left in clumps or corridors.

At 10 years, 70 to 85 percent of codominant reproduction had the potential to become timber crop trees. Three of the four treatment areas can be regarded as successfully regenerated with acceptable quality stems.

The canopy of the younger age class was nearly closed after 10 years.

Frequently, grapevine control work is needed in the younger age class of two-aged stands, just as it is needed in young stands regenerating after a clearcut

Tree regeneration in the two-age harvest areas would be adequate if implemented as described. Experimental harvests on the Monongahela National Forest applied from 1979 to 1983 indicated that reproduction developed included a wide variety of species, similar to that observed after clearcutting. Also, the experiments found that 89 percent of the larger trees left uncut had survived, 76 – 100 percent of the survivors maintained their initial grade, and diameter growth increased for most species (Miller et al., 1997).

Uneven-aged Management

Uneven-aged management treatments work towards the goal of creating and maintaining an area in an uneven-aged condition. An uneven-aged stand has trees of three or more distinct age classes, either intimately mixed or in small groups (SAF, 1998). Also, uneven-aged stands have an uneven and highly broken or irregular canopy (often with many gaps). This broken canopy allows for greater light penetration and encourages deeper crowns and greater vertical structure in a stand. Most stems occur in the smallest age/size class, as regeneration quickly fills the canopy gaps. The number of small trees declines through normal species competition as age/size classes increase, to the point where the large trees are low in number and scattered (although distribution may be highly regular). In its ideal form, where diameters approximate age, distribution of diameters in uneven-aged management will approach the classic inverted-J form. As you progress through the diameter classes, the number of stems per acre drops in an inverted geometric fashion, giving a dipping curves relationship which looks like the mirror image of a "J" without the top. Figure D - 3 shows the distribution of trees in an uneven-aged condition. Note that there are a large number of very small trees and very few large trees per acre.

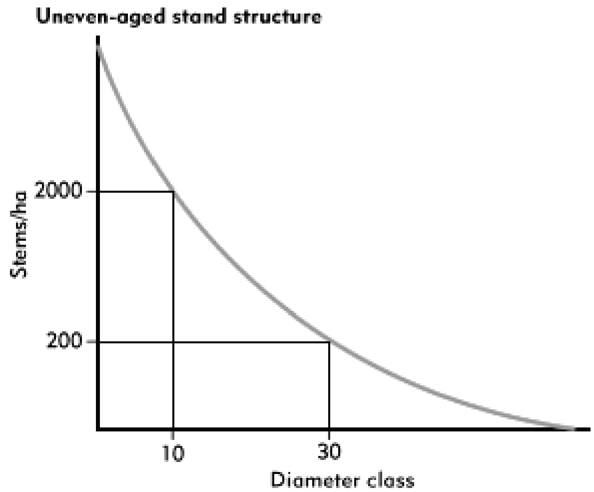

Figure D - 3. Distribution of trees in an uneven-aged condition

Initially, to convert an even-aged stand to an uneven-age stand, the objective is to develop new age classes, but not to immediately create a structure as pictured in the graph above. Eventually, a more formalized uneven-aged regulation method can be implemented to supplement and guide the retention of given levels of stocking in the different age classes. Although a q-factor based approach is essential for maintaining an established uneven-aged structure in an oak-dominated system, using q-factor ratios is not applicable when beginning to convert stands from an even-aged to an uneven-aged structure.

Conversion of a stand to an uneven-aged structure cannot be accomplished in the same manner as the maintenance of stand structure in an existing uneven-aged stand. Generally with the objective of changing the stand's structure to uneven-aged, the first harvest in the stand would be a reduction across the stand of one-third but no more than 60 percent stocking. Depending on the stand's age or species mix, the cutting could target different trees. Considerations would include such concerns as whether the stand has a component of short-lived trees which could not survive through the time that would be required to develop the uneven-aged structure. Therefore, the exact prescription must be tailored to each stand (Loewenstein and Guldin, 2004).

The larger trees that are retained in an uneven-aged harvest will add to the visual character of the area, provide important wildlife habitat, and will provide large quantities of seed from individuals that have been successful on that site.

Single-tree selection system

Single-tree selection methods are most appropriate for stands in which the desired species composition is to be composed of primarily shade-tolerant species such as beech and maple. Therefore, the single tree selection method generally is considered inappropriate for regenerating oak forests (Hicks, 1998).

The establishment and development of oak regeneration is not as likely or consistent using the single-tree selection system. Harvesting single trees to achieve and maintain a specific diameter distribution does not provide the microclimate needed for oak regeneration, but does provide the conditions needed for the establishment and growth of shade-tolerant species (Sander, Graney, 1992). Over time, single-tree selection in a mature oak stand will convert the area to predominantly shade-tolerant species such as beech and maple.

However, empirical and experimental data suggest that under certain specific conditions, oak stands can be managed using uneven-aged methods (Loewenstein and Guldin, 2004). By applying oak advanced regeneration techniques, such as controlling the mesic seedlings, the oak component of the resulting uneven-aged stand can be increased, but it is unlikely that oak and hickory will be majority components of the stands in the long term. If the more shade tolerant and mesic species are controlled, the more xeric parts of the stand, such as south-facing slopes and ridgetops, may have significant oak and hickory components, but the mesic parts of a stand, such as the lower elevations, coves and north slopes, will likely be occupied by more mesic species such as yellow poplar, maple, and beech.

Oak seedlings have been found to show greatest response and successful establishments in the centers of forest clearings and a retardation of growth on the edges of openings. High levels of sun light are required for the survival and growth of advanced oak regeneration and that these light conditions cannot be achieved by the single tree selection method (Fischer, 1979).

Group Selection Systems

Group Selection is a system of tree regeneration in which the objective is to create an uneven-aged stand by regenerating parts of the stand by cutting small "groups". The stand is managed as a whole, including the groups cut and the uncut portions in between the groups. Individual groups are not managed as individual stands. As applied on the WNF, to regenerate oak-hickory types, each group can be up to 2 acres in size. When regenerating shade tolerant species, such as maple and beech, the groups are up to the height of two mature trees (0.4 to 0.7 acres).

Group selection can be used to reproduce oaks satisfactorily, assuming (Sander and Graney, 1992):

The oak advance reproduction is adequate

Culls and small trees within the groups are cut or killed, unless specifically retained for wildlife or other.

The growth and development of the reproduction will be similar to the responses after clearcutting, except that reproduction growth will be retarded in a large part of the opening area because of the influence of the surrounding stand (Sander and Graney, 1992).

If the oak advance reproduction is not adequate, cutting the trees to create the opening will not result in oak reproduction, and the opening will be filled by whatever species are present in the understory and by species that have seeds on the site, such as yellow poplar. If there is not adequate advanced oak regeneration, the procedures for developing it as described above for the shelterwood, would be implemented first (Sander and Graney, 1992).

Frequently at the same time as the groups are being cut to create a young age-class, the other parts of the stand will be thinned to enhance oak reproduction establishment and growth throughout the stand.

Intermediate Silvicultural Treatments

Effects of Cleaning Treatments and Precommercial Thinning

Cleanings are release treatments performed during the sapling stage to free selected trees from competition of overtopping trees of comparable age (or woody vines and shrubs) and to favor the trees that are needed top meet wildlife habitat or other management objectives.

It is better to wait until the stand is well into the sapling stage and has a closed canopy in order to make better decisions regarding future crop trees and to assure that stump sprouts will not overtake the desirable trees. Simply cutting most broadleaved trees and shrubs will normally stimulate sprouting, and often with increased vigor. To prevent this, workers might apply an herbicide (Nyland, 1996).

Benefits of release from cleaning vary with species, age, degree of suppression, and completeness of a treatment. Generally, cleaning works best in young stands while the preferred trees still have sufficient vigor to respond to release.

Timber crop tree management can provide high-quality timber products from individual trees growing at a rapid rate. The limiting factors in managing for crop trees are:

The existing number of good-quality trees

Increasing their growth while retaining their valuable characteristics.

Crop tree selection criteria include:

Select dominant/codominant trees at least 20 feet tall with large healthy crowns. On the WNF, this height would be attained when the regeneration is from 10 to 20 years old.

Select low-origin stump sprouts with U-shaped connections. Stump sprouts that originate close to the ground are suitable crop tree candidates if they are stable and have good form.

Select trees with no epicormic branches. For most species, dominant/codominant trees with large crowns and good vigor are not likely to epicormic branch to a significant degree.

Select trees without leans or forks

Grape Vine Control

When wild grapevines grow into the tree crowns, especially in young trees, they can damage trees by breaking the tops and limbs, twisting and bending the tree boles, and uprooting trees. Wild grapevines grow best on moist soils and in full sun; prolonged shade reduces growth and will kill the vines. The vines sprout prolifically when cut.

Since grapevines are intolerant of shade, the vines will generally die or not be a problem if they are cut near ground level, and the crown of the surrounding stand has closed so that the ground is well shaded.

If grapevines are present in the stand before harvest, and an even-aged harvest is planned, it can be assumed that grapevines will be a problem in the regenerating stand because of the combination of sprouting vines and multiple seedlings after harvest plus the increase in available sunlight. Grape seed stays viable for many years.

Solutions to a grapevine problem are most commonly (Smith, 1984):

After an even aged or group selection harvest, in the first 10 years after the ground is shaded, sever the grapevines at ground level; the vines will resprout, but will die.

At least 4 to 5 years before an even aged or group selection harvest, sever the grapevines at ground level; the vines will resprout, but will die before the harvest.

If a harvest is planned within 4 years, treat the vines with an herbicide treatment.

(Note: If the area is treated before the harvest, it is likely that a post treatment may be necessary, particularly on better than average sites, also because of the seedlings that will start from the seed already on the forest floor. However, the growth rate of the vines from the seedlings would be much less that from established roots, so the damage will be less.)

All of the grape vines will not be eliminated from an area. Any sensitive or rare species of grape will be retained. Grape arbors (large concentrations of vines in a small localized area) will be left untreated. The wildlife habitat impacts will be considered before any control is begun.

Commercial Thinning

As the trees in a stand of timber grow, they compete with each other for nutrients, water, space, and sunlight. Each tree attempts to grow as fast and large as possible so that it can maintain a good position to compete for food, water and sunlight. As time passes however, there is always a limiting factor that prevents all of the trees from their full potential. Sometimes the species of tree or genetic make-up of individual trees pre-dispose individuals to be less effective competitors. Trees that do not grow as fast as the others become weakened and increasingly less competitive for sunlight, water, nutrients, and/or space. These trees are those with small live crowns that cannot reach direct sunlight because they are shorter than the best competitors. These trees are more vulnerable to damage from insects and diseases, and will likely die before their normal life spans would predict.

Also, even trees that have succeeded in becoming dominant or codominant trees often have different natural life spans. For example on the WNF, individual white oak trees can live to be a maximum of 200 to 600 years old, whereas the oldest scarlet oak trees normally can live only 100 to 150 years. These ages are for individual trees; like people, some die young while others live beyond the averages. However, as can be seen when comparing scarlet and white oak longevity, some species are more likely to live longer than others.

As the stand of trees is growing, the lower the density of trees on the site, the healthier and larger the individual trees will be since the available nutrients, water, space, and sunlight is shared among fewer individuals.

Thinning the forest by reducing the density of trees is normally done to accomplish one or more of the following objectives:

- Improve growth of the remaining trees
- Enhance the overall health of the forest's trees so they can withstand insects and diseases
- Recover potential mortality
- Favor the species of trees that will best meet the objectives of the area.

The relative stand density is determined using one of several stocking guides or charts developed for eastern hardwoods. The relative density of the stand is then compared to management stocking levels. Acceptable growing stock (AGS) is defined as trees of acceptable species, form, and quality that could be selected as crop trees. One common method of quantifying and comparing relative stocking is by using the graphs in Figure D - 4 that was developed by Gingrich in 1967 (Gottschalk, 1993). A stocking level of 80 percent defines the upper management zone (sufficient mortality increase, growth decline, and volume present to thin). The lower management zone is 60 percent or B-level stocking (minimum residual level to thin to). Stands between 60 and 80 percent stocked usually do not need to be thinned (Gottschalk, 1993).

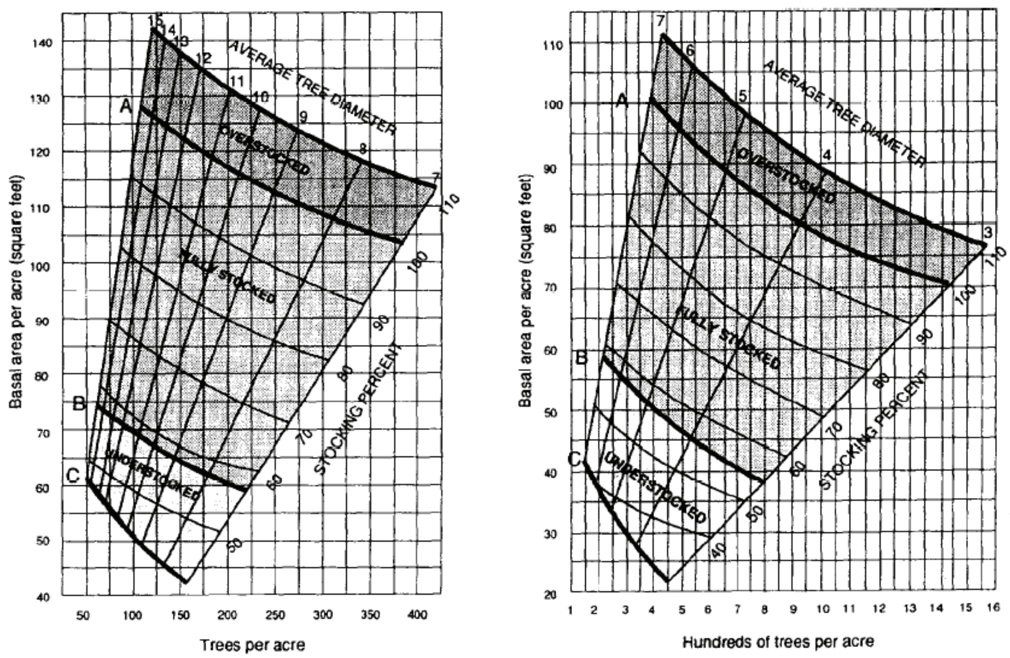

Figure D - 4. Relative stand density for upland hardwood stands, including oak. (Source: Gottschalk, 1993)

Oak, and other, stands could be thinned when they have greater than B-level density of acceptable growing stock that are more than 15 years from maturity and have more than 80 percent relative density. Under normal management, they would receive a commercial thinning from below. The commercial thinning would reduce relative stand density to 60 percent, but not remove more than 35 percent in any one cut. It should remove unacceptable growing stock, harvest anticipated mortality, increase the growing space for residual trees, and possibly decrease the rotation length depending on the overall objectives for the area. The result is an increase in average stand diameter, a reduction in rotation length, and an improvement in stand quality and value. (Gottschalk, 1993)

Gypsy Moth

The Gypsy Moth (a non-native) is advancing across the northeastern United States. The population has reached the northeastern edge of the Forest, and will likely spread across the remainder of the WNF in the next 10 to 15 years.

To preserve the health and future composition of the Forest, several treatments, such as the “Slow-the-Spread” campaign will likely be instituted by different agencies such as the USDA Forest Service)State and Private Forestry) and the Ohio Department of Natural Resources. In addition to these tactics, thinning the forest in advance and after the Gypsy Moth infestations can help to minimize damage and guard against significant impacts to the Oak component of the Forest. Presalvage thinning is designed to reduce damage by removing highly vulnerable (high hazard) trees before they are defoliated and die; the major objective is to reduce stand vulnerability. Secondary objectives of the treatment are to increase stand and tree vigor (and crown condition), to remove structural features or refuges for gypsy moth larvae and pupae, and to promote predator and parasite habitat. (Gottschalk, 1993)

The chances of oak trees dying after Gypsy Moth infestation is tied to the health and position of the tree’s crown. The charts in Figure D - 5 show the rate of tree mortality based on these two factors; as can be seen, the trees with crown in the understory that have poor conditions (small and sparse) most commonly die after an infestation.

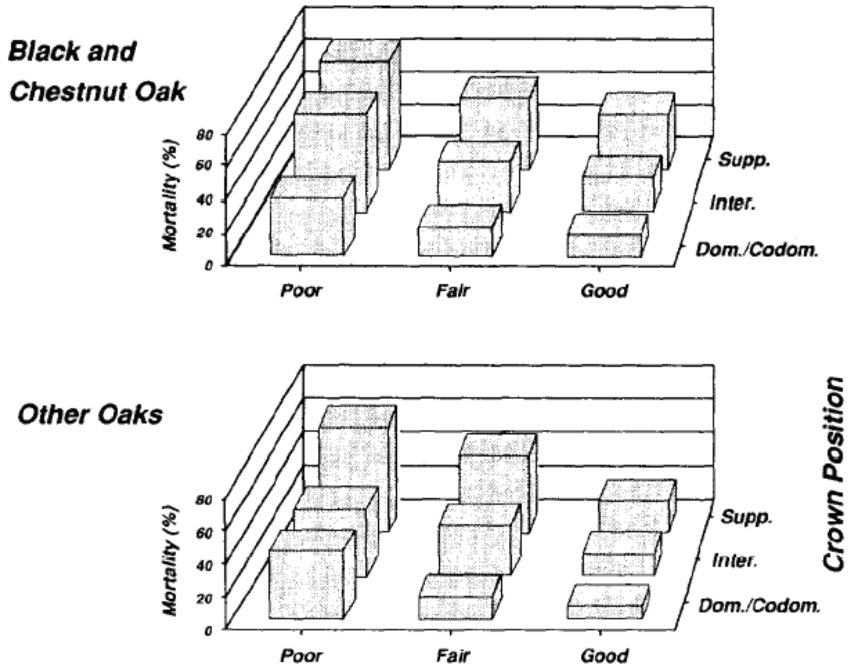

Figure D - 5. Rate of tree mortality based on health and position of the tree's crown. [Supp. = Suppressed; Inter. = Intermediate; Dom./Codom. = Dominant and Codominant] (Source: Gottschalk, 1993)

When presalvage thinning before the Gypsy Moth has arrived, the normal thinning prescription must be altered slightly. In stands with more than 50 percent of their basal area in gypsy moth-preferred food species, as is the case for most of the WNF, the normal thinning prescriptions will not reduce the preferred food species enough to significantly change the stand's susceptibility. Presalvage thinning concentrates on reducing vulnerability. It is necessary to implement presalvage thinning 1 to 3 years before defoliation because the stand needs time to recover from the stress and disturbance caused by the thinning. As part of the stress induced by thinning, stands may be temporarily disposed to attack by certain damaging agents. However, these harmful effects gradually reduced by the increased tree growth and vigor that occur eventually (Gottschalk, 1993).

As a supplement to normal thinning guidelines (such as removing unacceptable growing stock and targeting a specific density), priorities for marking trees to be removed are (highest to lowest): 1) oaks with poor crowns, 2) non-oak species with poor crowns, 3) oaks with fair crowns, and 4) non-oak species with fair crowns.

The upper drawing in Figure D - 6 depicts marking priorities for presalvage thinning in an older stand (-) (WO = white oak, RO = red oak, HI = hickory, RM = red maple). The lower drawing shows the result of thinning.

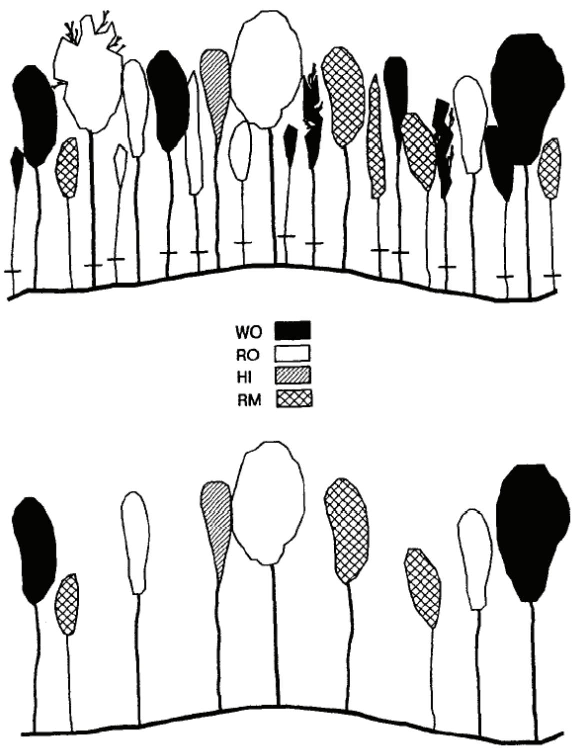

Figure D - 6. Marking priorities for presalvage thinning in an older stand (upper) and the result of thinning (lower).

Oak Management in the Historic Forest Management Area

As described in the desired future conditions for the HF and HFO management areas (see proposed Revised Forest Plan), one of the main visions is that the land in these management areas will eventually mimic the conditions of several hundred years ago when oak dominated the landscape. The treatments that are likely include intensive thinning (to maintain a 50 percent to 60 percent stocking), frequent prescribed burns to control the more mesic species and promote oak regeneration, and herbicide treatment.

The herbicide treatment will likely be necessary initially when the forest community is being transformed into the desired conditions because the mesic species, such as maple and poplars, will be too large to be effectively controlled by prescribed burns. Once the structure and composition of the forest community has reached the desired condition and the number of maples and poplars are minimal and small, the periodic fires will likely control these species.

For the first 2 or 3 decades, thinning may be needed as the crowns of the trees expand to levels outside the desired condition. After the historic forest system is in place and functioning (in 30 to 50 years), some periodic timber removal may be necessary to release seedlings to grow.

Effects to Understory Vegetation

Between 1993 and 1995 a ground-layer vegetation study was done in Indiana on 150 on mesic slope and dry-mesic slope forests plots to determine how the understory of these forests responded to forest management (Jenkins and Parker, 1998). Since the ecology of this study area and the Wayne National Forest are similar, the effects would likely be reasonably close. Four different stand types, clear-cuts (5-30 acres), group-selection openings (0.25-4 acres), single-tree selection openings (0.25-4 acres) and uncut 80–100 y-old reference stands were sampled. There was little relationship between the percent cover of most ecological species groups and opening age or size on either mesic or dry-mesic slopes. While clear-cuts and group-selection openings had significantly greater cover of several ecological species groups (used to classify mesic and dry-mesic slopes) than reference stands, single-tree selection openings did not differ significantly from reference stands in the cover of any ecological species group. More ground-layer species were significantly correlated with opening size than opening age, suggesting that the size of the initial opening has more influence on species composition than opening age. Overall, forest management has not constituted a severe enough disturbance to shift ground-layer species composition away from that associated with the sampled ecological landtype phases (mesic and dry-mesic slopes). Aspect was the dominant factor determining species distribution of ground-layer vegetation in both openings and reference stands.

In openings, the cover of species dependent on disturbance decreased with opening age and will eventually return to that of reference stands. Other studies have shown that this flush of disturbance species dominance is relatively short-lived (and may be important in retaining the nutrient capital of a site after disturbance) (Jenkins and Parker, 1998).

Forest management does favor some ecological species groups. The cover of Canadian wild ginger (*Asarum spp.*) within group-selection openings on mesic slopes was three times that in reference stands. Conversely, the cover of blueberry (*Vaccinium spp.*) in clear-cuts on dry-mesic slopes was five times that of reference stands. The increased light reaching the forest floor on dry-mesic slopes may combine with low water availability to allow blueberry (*Vaccinium spp.*), a species group more typical of dry slopes and ridges, to increase in cover. On mesic slopes, the reduced competition for light and water may have allowed the increased importance of the wet-mesic Canadian wild ginger (*Asarum spp.*) (Jenkins and Parker, 1998).

Opening size may be more important than opening age in determining the species composition of silvicultural openings. While a given area may follow a distinctive sequence of post-harvest recovery, the size of the initial opening determines the rate of recovery. The forest floor of large openings has higher light intensities for a longer time, thus allowing early successional and shade-intolerant species to persist longer. Species composition has been shown to change little after the creation of smaller openings (Jenkins and Parker, 1998).

Openings on mesic slopes have greater species richness than reference stands. This increased richness was mostly due to an influx of disturbance and Canadian wild ginger (*Asarum spp.*). However, the cover of early successional species should continue to decrease with increasing stand age, thereby returning species to reference stand level (Jenkins and Parker, 1998).

Overall, after Central Hardwood forests have passed through the stand initiation phase of development, ground-layer species composition returns to a state similar to that of uncut 80 to 100 year old stands (Jenkins and Parker, 1998).