Abstract on the Oak Association of Northern Michigan

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For:
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Forest, Minerals, and Fire Management Division
Wildlife Division

September 30, 2006

Report Number 2006-21

Cover photograph: Young white oak forest occurring on sandy outwash plain in northern Lower Michigan (Photograph by Joshua Cohen).

OVERVIEW

Oak associations are found in every county in Michigan, but the largest areas are in northern Lower Michigan, where they comprise a range of managed forest ecosystems dominated by four oak species: northern pin oak (*Quercus ellipsoidalis*); black oak (*Quercus velutina*); white oak (*Quercus alba*); and red oak (*Quercus rubra*). These oak species were a component of several natural community types in northern Lower Michigan forests in the early 1800s, including dry northern forest, dry-mesic northern forest, mesic northern forest, oak-pine barrens, and jack pine barrens (MNFI 2003). However, oaks were not a dominant species in northern Michigan forests, as they were in southern oak-hickory and dry mixed-oak forests. Oaks were a co-dominant species in approximately 135,000 hectares (333,452 acres) of white pine-white oak and red pine-oak stands (Comer et al. 1995), and red oak dominated some small localized stands associated with Native American activities (Albert and Minc 1987, Whitney 1987). Rather, oak associations have generally been formed through conversion of other natural communities by a combination of logging, repeated slash fires followed by fire suppression, and other management activities. Oak associations typically occupy acidic, sandy, well-drained to droughty soils, although some areas with loamier and more mesic soils—formerly mesic northern forest—have also been converted to oak.

Oaks are a diverse and highly valued natural resource. They comprise a major source of commercial timber, accounting for roughly 12% of the timber acreage sold from State Forests in 2005 to 2006 (Pedersen 2006), for an estimated total sales price of $3.2 million (MDNR 2006).[1] Oak associations offer food and habitat for many wildlife species, and are sometimes managed specifically for this resource. In addition, they host considerable biodiversity, potentially harboring up to 58 rare plant species (State Endangered, Threatened, or Special Concern) and 48 rare animal species (15 rare bird species; 24 insect species, including 10 species of butterflies; 3 rare mammal species; and 6 rare reptile species). It is likely, however, that most current oak forests do not host the full range of species that inhabited the natural communities from which they were converted (Johnson 1992b), and some Michigan stake-holders would prefer that they be managed for ecological values and restored, when possible, to their circa 1800 condition (Pedersen 2006). Oak associations may also be valued for aesthetic and recreational opportunities and for watershed management to maintain water quality.

Oak management is particularly challenging because oak regeneration is poor in many parts of Michigan (and throughout eastern North America), with implications for ecosystem structure and function (Barnes et al. 1998). It is important to recognize, however, that oak associations now present are an anomaly (Pedersen 2006); compared to historic oak ecosystems, current oak forests are much different in terms of their species composition and structure. For greater regional- or landscape-level biodiversity, managers could allow or encourage succession of these oak ecosystems to their derivational natural community types by allowing oaks to serve as nurse trees for later-successional species, replanting formerly dominant tree species, such as pines, where natural regeneration is inadequate, and if necessary, removing mesophytic species, such as red maple (*Acer rubrum*) and black cherry (*Prunus serotina*), that have invaded many of these systems. Conversion to mixed oak-pine systems, which include both forest and barrens communities can meet all goals. Where oak associations now occupy former oak-pine barrens and pine barrens communities, prescribed fire and removal of shade-tolerant species can be used to restore open conditions and stimulate growth of barrens vegetation. Research indicates that oaks growing in low densities incur fewer incidences of tree diseases and insect defoliation and that fire inhibits both acorn predators and certain tree pathogens and pests (McManus et al. 1989, O'Brien 2000, Johnson et al. 2002). Promoting oak-pine forest and barrens in place of oak-dominated forests and implementing prescription burning regimes may help reduce oak density and the incidence of oak decline. In addition, oak regeneration benefits from lower tree densities, fire, and reduction of overabundant deer populations (Marquis et al. 1976, Rooney and Waller 2003, Johnson et al. 2002).

OAK DISTRIBUTION

The genus *Quercus*, to which oaks belong, is one of the most diverse genera of flowering plants. Oaks form a varied group of 500 to 600 tree and shrub species worldwide and are most abundantly distributed in temperate regions north of the equator, where they are often prominent in dry sites on every continent except Australia and Antarctica. Depending on how species and varieties are classified, there are around 43 species in the United States (Miller and Lamb 1985). Of these, at least 12 species of oaks are found in Michigan, with at least one natively-occurring oak species in every county of the state (Voss 1985, Barnes and Wagner 2004). Prominent among Michigan oaks are northern pin oak (*Quercus ellipsoidalis*); black oak (*Quercus velutina*); white oak (*Quercus alba*); and red oak

[1] Calculated by volume sold X average sales price for mixed oak, red oak, and white oak sawwood and pulpwood (MDNR 2006).

(*Quercus rubra*). All four of these species are found in southern and northern Lower Michigan (Ecoregions VI and VII, Albert 1995). Black oak does not occur in the Upper Peninsula, while northern pin oak and white oak occur in the southern portion of the Upper Peninsula (Ecoregions VIII and IX). Red oak, which occurs in all four Michigan Ecoregions, is both the northernmost and most widely distributed of these major oaks.

Various other oak species have a more limited distribution in the state. Bur oak (*Quercus macrocarpa*), with its spreading canopy, was formerly scattered across the bur oak plains and oak openings of southern Lower Michigan. Other oak tree species found primarily or exclusively in the southern Lower Peninsula include swamp white oak (*Quercus bicolor*), scarlet oak (*Quercus coccinea*), shingle oak (*Quercus imbricaria*), chinquapin oak (*Quercus muehlenbergii*), pin oak (*Quercus palustris*), chestnut oak (*Quercus prinus*), and Shumard oak (*Quercus shumardii*), along with the shrub species, dwarf chestnut or dwarf chinquapin oak (*Quercus prinoides*). However, these species are not typically a dominant component of any Michigan forest community type, so they are not described in detail here. Additional information on these species can be found in Miller and Lamb 1985, Barnes et al. 1998, Burns and Honkala 1990, Johnson et al. 2002, and Barnes and Wagner 2004.

Even within species, oaks vary considerably and hybridize readily, complicating species identification (Miller and Lamb 1985, Voss 1985). For example, some Michigan scientists consider scarlet and northern pin oaks to be separate species: Barnes and Wagner (2004) distinguish between *Q. coccinea* and *Q. ellipsoidalis*. Other botanists lump the two as geographic variants of the same species—Voss (1985) considers them part of the same species continuum, which some botanists extend to include black and red oaks. Researchers who have reconstructed forest species composition based on General Land Office (GLO) survey records often lump together northern pin oak, black oak, and occasionally red oak because many surveyors did not differentiate between them reliably or at all (Whitney 1986, Leahy and Pregitzer 2003). Voss (1985) suggests that many oaks identified as *Q. velutina* in Michigan, especially in the northern Lower Peninsula, may be hybrids in the *velutina—rubra—coccinea* complex, if not actually *Q. coccinea* or *Q. rubra* instead. Among the named hybrids that may be found in Michigan are *Q.* X *hawkinsiae* (*Q. rubra* X *Q. velutina*), and *Q.* X *palaeolithicola* (narrowly used to refer to *Q. ellipsoidalis* X *Q. velutina*, but also used more broadly for *Q. coccinea* X *Q. velutina*).

Despite the considerable taxonomic debate, most foresters and forest ecologists recognize northern pin oak as characterized by a particular growth form in which low-lying branches persist on the boles, rather than self-pruning, and cause pins or stubs that reduce the timber value. In ecological terms, the northern pin oak (and/or its hybrids with black or red oak) is considered to inhabit the driest and most acidic conditions, and often serves as an indicator that the site may have once been an open-canopied barrens until fire suppression facilitated an increase in tree density. Because these forestry and ecological distinctions are widely used, northern pin oak is treated as a separate species throughout this abstract.

BACKGROUND

In the early 1800s, Michigan's oak forests primarily occurred in the southern Lower Peninsula at the boundary between open grasslands and forests. Where soils were driest and fires frequent, oaks would occur in barrens and savannas, which had canopy cover of less than 50% (Curtis 1959). Where fires were less frequent or kettlehole ponds, rivers, or streams served as natural firebreaks to prevent fire from spreading across landforms, or on moisture-retaining northern slopes, oaks and associated tree species (including hickory, black cherry, and sassafras, and on more mesic sites, maple and ash) would grow densely enough to form closed-canopy dry southern forest and dry-mesic southern forest (MNFI 2003). These forests were dominated by oak species ranging from black to white to red oak along the soil continuum from dry sands to dry-mesic loamy sands and occasionally to mesic sandy loams or sandy clay loams (Curtis 1959). Other oak species, including bur oak, northern pin oak, and scarlet oak also occurred in some southern forests. Bur oak, along with white and black oaks, was important in large stretches of more open-canopied southern Michigan savanna communities, including bur oak plains and oak openings.

The closed-canopy oak forests, or oak associations, in northern Michigan, like southern oak forests, have arisen partly as a result of fire suppression. Unlike southern oak forests, however, oak forests were not a widespread natural forest community type in northern Michigan at the time of European settlement. Instead, they have mostly developed from several different natural communities in response to land use and anthropogenic disturbance patterns, especially logging and fire suppression. The major natural community types (MNFI 2003) that have converted to oak associations are pine barrens, oak-pine barrens, dry northern forest, dry-mesic northern forest, and mesic northern forest. Dry sand prairies, which occurred in pockets in some barrens communities, have also converted to closed-canopy oak ecosystems or, in some cases, barrens with oak as a prominent species (Comer et al. 1995). In addition, small areas of various other natural communities, including the inland dune ridges of wooded dune and swale complex, have also been converted to oak associations.

In northern Michigan, oaks were a component, but rarely a dominant, of several forest and barrens communities that typically occurred on well- to excessively-drained, acidic soils associated with glacial landforms such as sandy outwash plains, coarse-textured moraines, and glacial lake plains. Oak associations also occur on aeolian features such as inland and coastal dune ridges. Dry northern forest and dry-mesic northern forest, which were dominated by pines, included northern pin oak, black oak, and white oak as associates (Kittredge and Chittenden 1929, Curtis 1959, Whitney 1986, 1987, Cohen 2002a, 2002b, Copenheaver and Abrams 2002, Leahy and Pregitzer 2003). In areas where GLO survey data has been comprehensively examined, oaks were often noted in the understory of these forest types, but typically comprised less than 10% of total overstory canopy cover (Whitney 1986, 1987, Copenheaver and Abrams 2002, Leahy and Pregitzer 2003). Similarly, red oak and occasionally white oak were found in the mesic northern forests dominated by hemlock, sugar maple, and beech that occurred on loamier soils of glacially-shaped landforms, including glacial lake beach ridges and coarse-textured end moraines (Curtis 1959, Cohen 2000a). Oaks were a minor component of mesic northern forests (Whitney 1987, Abrams 1992, Copenheaver and Abrams 2002, Leahy and Pregitzer 2003, Cleland et al. 2004) except in localized stands, generally near lakeshores and water-ways, where red oak dominance appears to have been promoted by Native American activities (Albert and Minc 1987).

The particular processes that led to the development of oak associations depend on the original community type, land use and disturbance, and physiographic context. These factors, in turn, shape the biodiversity values that managed oak systems now hold.

HISTORIC AND PRESENT RANGE

The current extent of oak associations in northern Michigan is greater than that of the 1800s in both absolute and relative terms. Expansion of oaks has occurred despite a decrease in the overall area of upland forests. Although several northern forest and barrens communities included oaks as a component or even co-dominant, and oaks occasionally dominated localized stands, oaks were a dominant species only in the white pine-white oak forest and mixed pine-oak forest types. According to GLO survey records for Ecoregion VII,[2] these two forest types occupied about 135,000 hectares (333,452 acres). In addition, there were approximately 36,320 ha (89,711 ac) of oak savanna types and oak-pine barrens with a prominent component of northern pin oak and black oak (Comer et al. 1995). Oak species were a lesser component in approximately 3.0 million ha (7.3 million ac) of barrens and forest ecosystems in Ecoregion VII, which included the following systems and oak species: pine barrens (northern pin oak); jack pine forest (northern pin oak), jack pine-red pine forest (northern pin oak); red pine forest (northern pin oak or black oak), red pine-white pine forest (northern pin oak, black oak, and/or white oak), white pine forest (black oak and/or white oak), white pine-beech-maple forest (white oak and red oak); and northern hardwoods forest (white oak and/or red oak). In proportional terms, natural communities in which oaks were a dominant component accounted for about 5.0% of upland forest and savanna systems in the region or close to 4.0% of the 4.3 million ha (10.5 million ac) of land in Ecoregion VII (Comer et al. 1995).

Photograph 1. Oak-pine barrens have been dramatically diminished from northern Lower Michigan due to logging and fire suppression (Photograph by Michael Kost).

Late 19th century logging and subsequent slash fires resulted in the clearing of millions of acres of these forests and the natural oak-pine and pine barrens communities, followed by forest recolonization on lands that turned out not to be suitable for farming. After cutting and repeated burning in the late 1800s and early 1900s, oak forests occupied about 526,316 ha (1.3 million ac) in northern Lower Michigan in the 1920s (Kittredge and Chittenden 1929). Many of these

[2] Ecoregion VII includes northern Lower Michigan except for counties in the Saginaw Bay region (Albert 1995).

lands were subjected to repeated fires, as noted by (Whitney 1987): "The slash left after the logging provided the fine fuel while the fires set by vandals, berry pickers, farm-clearing operations and sparks from railways supplied the ignition." The resulting "scrub oak" forests or barrens were formed of short and often multi-stemmed, stump-resprouted oaks of little value for timber (Kittredge and Chittenden 1929). Some scrub oak lands were replanted with pine (mostly red pine), resulting in an increase of approximately 7% in pine from 1927 to 1979 in some northern Michigan counties (Whitney 1987). Oaks have, however, remained dominant in large areas. Oak associations now occupy approximately 427,926 ha (1,056,976 ac) of upland forested land in Ecoregion VII (MDNR 2000, 2001)—that is, about 20% of upland forests, or 10% of the total land area.[3]

Present and historic estimations are not directly comparable, due to differences in how cover types are defined, derived, and assessed. Furthermore, these figures must be interpreted within the perspective of an overall reduction in regional forests following the logging era. Forested land was reduced by roughly 40% overall in the Great Lakes states of Michigan, Minnesota, and Wisconsin from 1840 GLO data compared to 1980s U.S. Forest Service Forest Inventory and Analysis data (Frelich 1995). The reduction in upland forest in northern Lower Michigan has followed a similar pattern: approximately 3.4 million ha (8.4 million ac) of upland forest circa 1800 in Ecoregion VII was reduced to about 2.1 million ha (5.2 million ac) by 2001. What is clear regardless of these caveats, however, is that oak-dominated forests have expanded considerably, both in total acreage covered (despite a large reduction in forested acres), and in the proportion of upland forests they dominate, particularly in northern Lower Michigan.

At the same time that the area of oak associations was increasing, most of the natural communities from which they were derived declined. For example, GLO records circa 1840 suggest that there were approximately 1.2 million ha (2.9 million ac) of pine and mixed pine forest cover types in Ecoregion VII, including jack pine, red pine-jack pine, red pine, red pine-white pine, white pine, white pine-white oak, and white pine-sugar maple-beech forests, all of which included oak as a component (Comer et al. 1995). However, by 2001, pine and mixed pine cover types occupied about 344,322 ha (850,475 ac), a figure that includes pine plantations, some of which have gone through several rotations (MDNR 2001; see also Cohen 2002a, 2002b). Pine and oak-pine barrens have also been considerably diminished, so that they now occupy less than 2,025 ha (5,000 ac) for the entire state. MNFI has estimated a 60-fold reduction in high-quality oak-pine barrens (Cohen 2000b), and an even more drastic reduction of pine barrens (Comer 1996).

Despite the absence of directly comparable data, these figures suggest the extent to which oak forest associations resulting from fires, resource use, and management now occupy more land than was previously occupied by the natural forest community types in which oak species were prominent. Indeed, although the total amount of forested upland decreased, oak associations now occupy a greater amount of land than was occupied in the mid-1800s by their derivational ecosystems. Thus, both the absolute and relative cover of oaks in northern Michigan forests has increased dramatically as some areas naturally dominated by other species, especially red pine, white pine, and hemlock, have been converted to oak associations. Oaks, which were formerly a frequent but minor component of northern Michigan ecosystems, now dominate approximately 20% of upland forests in the region. Proportions of former pine and mixed oak-pine forest cover types converted to oak range from 10 to 34%.

PHYSIOGRAPHIC CONTEXT

Oak associations are found on various landforms including sandy glacial outwash, sandy glacial lake plains, coarse-textured end moraines, on aeolian deposits including inland and coastal dunes and beach ridges on glacial lake plains, and occasionally on sand ridges within peatlands on glacial outwash or glacial lake plains. Oak associations may occur on level to undulating to hilly sites, with the oak species varying according to aspect and position on slope. Northern pin oak tends to occur on the higher and drier

[3] Due to the way land cover is classified, it is difficult to gauge the amount of land remaining in barrens communities, so this estimate includes only forested lands. Savanna and barrens areas have been reported to convert to closed-canopy forest within 20 to 30 years of fire suppression (Curtis 1959, White 1983), so some areas that were formerly barrens are included in estimates of total land in upland forests (Comer et al. 1995). In any event, the eight natural savanna, barrens, and prairie communities associated with oaks (bur oak openings, dry sand prairie, lakeplain oak openings, oak barrens, oak openings, oak-pine barrens, pine barrens, and woodland prairie, MNFI 2003), which were documented by GLO surveyors to have occupied roughly 3.4% of the land area in the Lower Peninsula during the early 1800s, have been reduced to a fraction of their former distribution, and together occupy <0.007% of that area (Comer 1996, Cohen 2000a, 2000b, 2001, 2002a, 2002b, 2004a, 2004b, MNFI 2003, Kost 2004a, Kost 2004b)

ridgetops and south to southwest exposures, red oak on the more mesic lower and north-facing slopes, and black oak and white oak on intermediate and level topography; northern pin oak is also prevalent on flat to rolling, droughty, outwash plains (Livingston 1905, Host et al. 1987, Barnes et al. 1998, Barnes and Wagner 2004, Cleland et al. 2004).

Oak associations typically occur on well-drained to excessively well-drained sand to loamy sand. These soils often lack fine-textured particles and are quite drought-prone, but in some areas, a fine-textured illuvial horizon may aid soil water retention. These soils are acidic, ranging from strongly acid (pH of 5.0) in loamier sites to extremely acid (pH of 4.0) in the sandiest sites (Albert 1995).

NATURAL PROCESSES

Oaks have a long history in the Great Lakes region. They were a relatively minor component of eastern North American forests until 18,000 years ago, and by 10,000 years ago, they expanded to occupy and even dominate forests and savannas in many of the eastern states. This period coincided with a generally warmer and drier continental climate. Pollen studies have indicated that the presence of oaks is often associated with deposits of charcoal, indicating that periods of oak expansion were often correlated with recurring fire (Abrams 1992).

Over the past 10,000 years, oaks have continued to play an important role in regional forests, especially in fire-prone areas with sandy, droughty soils (Kittredge and Chittenden 1929, Barnes et al. 1998). Frelich (1995) has characterized oak-pine forests in the Lake States as a fire-dependent ecosystem, in which catastrophic, stand-initiating fires occurred every 150 to 200 years, with lighter surface fires occurring every one to several decades. These forests typically endured for a single generation of trees in relatively even-aged stands. Most trees killed by severe fire had been initiated during the last major fire episode. Oak and oak-pine forests rarely progressed to gap-phase dynamics driven systems, which are characterized by uneven-aged tree structure, in which individual trees periodically die and their gaps are filled by younger trees recruited from the understory.

These natural processes predominated in Michigan into the early 1800s and were augmented in some areas by Native Americans, who spread fire both intentionally (for agriculture, hunting, and defense) as well as accidentally (Day 1953, Russell 1983, Albert and Minc 1987). At that time, Michigan's oak forests primarily occurred in the southern Lower Peninsula. Oaks occurred in barrens and savannas, which had canopy cover of less than 50% in areas where fires were frequent and/or soils were dry (Curtis 1959). Where fires were less frequent (e.g., where natural firebreaks prevented fire from spreading across landforms or on moisture-retaining northern slopes), oaks and associated tree species formed closed-canopy forests, which were dominated by oak species ranging from black to white to red oak along the soil continuum from dry sands to dry-mesic loamy sands and occasionally to mesic sandy loams or sandy clay loams (Curtis 1959). In northern Michigan, the closed-canopy oak forests, or oak associations, have arisen partly as a result of fire suppression. Unlike southern oak forests, however, oak forests were not a ubiquitous natural forest community type in northern Michigan circa 1800. These oak associations have mostly developed from several different natural communities in response to land use and anthropogenic disturbance patterns, especially logging and fire suppression. Pine barrens, oak-pine barrens, dry northern forest, dry-mesic northern forest, and mesic northern forest are the major natural community types (MNFI 2003) that have converted to oak associations. The particular processes that led to the development of oak associations are dependent upon the original community type, physiographic context, and land use and disturbance.

As oak associations in northern Lower Michigan have arisen from the combination of logging, slash fires, fire suppression, and other anthropogenic disturbances, two major features characterize the process by which distinctive natural communities ranging from forests to barrens to prairies have converged to form this broad grouping: a shift in species composition and an increase in tree density. The shift in species composition occurred as pines and other conifers were initially selectively logged from forests and barrens in the late 1800s, effectively removing seed trees from large tracts, while subsequent slash fires further destroyed seed sources. The increase in tree density in both forests and barrens was associated with fire suppression. Areas of barrens and prairie were typically maintained on dry sites by relatively frequent fires, so fire suppression allowed for denser and taller growth of woody plants. In formerly forested areas, slash fires initially promoted oak resprouting, then fire suppression allowed the "scrub oaks" to mature into stands of oak forest. An examination of oak reproduction and regeneration serves to elucidate how the shift in species composition toward oaks and the increased density occurred.

Table 1. Summary of site characteristics, communities and associated species, reproduction and regeneration, and commercial uses for northern pin oak, black oak, white oak, and red oak.

Oak Species Profiles	Northern pin oak *Quercus ellipsoidalis*	Black oak *Quercus velutina*	White oak *Quercus alba*	Northern red oak *Quercus rubra*
<u>**Typical Site Characteristics in MI**</u>				
Landform	Outwash plains (level to gently rolling)	Outwash plains (level to gently rolling); ice-contact terrain (hilly)	Outwash plains (level to gently rolling); ice-contact terrain (hilly)	Ice-contact terrain (hilly); moraine
Soils	Sands to loamy medium sands	Sands to medium loamy sands	Sands to loamy sands with clay loam subsurface bands	Loamy fine sands to sandy clay loams
Moisture Regime	Xeric to dry-mesic	Dry-mesic to xeric	Dry-mesic, but ranges from xeric to mesic	Mesic
Michigan Distribution (Native Range)	Statewide	Lower Michigan	Statewide	Statewide
<u>**Communities & Associated Species**</u>				
MNFI Natural communities	Oak-pine barrens (associated with dry sand prairie), pine barrens, dry northern forest, dry southern forest	Dry northern forest, dry-mesic northern forest, dry southern forest, dry-mesic southern forest, oak barrens	Dry northern forest, dry-mesic northern forest, dry southern forest, dry-mesic southern forest, oak openings, oak-pine barrens	Mesic northern forest, mesic southern forest, and on moist topographic locales (north-facing and toe slopes) within dry-mesic northern forest and dry-mesic southern forest
MNFI GLO land cover types	Mixed pine-oak forest, oak-pine barrens, pine barrens, black oak barrens, jack pine-red pine forest	Oak-hickory forest, mixed pine-oak forest, mixed oak forest, black oak barren, oak-pine barrens, mixed oak savanna	White pine-white oak forest, white pine-mixed hardwood forest, mixed pine-oak forest, oak-hickory forest, mixed oak forest, mixed oak savanna, black oak barren, beech-sugar maple forest	Mixed pine-oak forest, white pine-mixed hardwood forest, beech-sugar maple-hemlock forest, beech-sugar maple forest, oak-hickory forest
Common tree species associates	Jack pine, red pine, black oak, white oak, black cherry, pin cherry	White oak, red oak, white pine, red pine, pignut hickory, black cherry	Black oak, red oak, white pine, pignut hickory, shagbark hickory, black cherry, sassafras	White oak, white pine, hemlock, sugar maple, beech
Burger and Kotar Habitat Types (for northern Lower Michigan, 2003)	PVCd	PArVHa	PArVHa	PArVHa, PArVVb, PArVCo; also associated with AFO, AFOCa
<u>**Reproduction and Regeneration**</u>				
Acorn Production				
Maturation Time (pollination to ripe	up to 2 yrs	up to 2 yrs	6–8 months	up to 2 yrs
Average Age to Acorn Production	20 (best at 40–75)	20 (best at 40–70)	20 (but typically 50–200)	25 (but abundant by 50)
Max. Number/Tree in Good (Mast) Year	NA	9,640	23,788	to 14,000
Average Duration Between Masts		2–3 yrs	4–10	3–5 yrs
Germination	Spring	Spring	Autumn	Spring
Understory Tolerance (Adaptation number ranging from 1-10, intolerant to tolerant, from Curtis 1959)	Intolerant (1.0-2.0)	Intermediate between northern pin oak and white oak (2.5)	Intermediate when young, less tolerant with age (3.5-4.0)	Intermediate (5.5-6.0)
Proportion of sprouts compared to seedlings in overall regeneration	NA	65%	50%	40%
Resprouting ability	NA	NA	Declines by 80 yrs	NA
Longevity	70-90 (may start declining at 50)	Mature at 100; 150–200+	200+	125+
<u>**Commercial Uses**</u>	Pallets, firewood, pulpwood	Firewood, posts, pulpwood, pallets	Barrels, furniture, veneer, pulpwood	Cabinetry, flooring, veneer, firewood, posts and pilings

NA = not available

Sources: Curtis 1959, Miller & Lamb 1985, Voss 1985, Burns & Honkala 1992, Host et al. 1987, Barnes et al. 1998, Keator 1998, Johnson et al. 2002, Burger & Kotar 2003, Barnes & Wagner 2004.

Oak Reproduction and Regeneration

Oak stands regenerate after catastrophic fires through three processes: 1) resprouting by existing but damaged trees; 2) reproduction from seed (acorns); and 3) rapid growth to the canopy of saplings and small trees that survive the fire. First, a majority of the stand regeneration may come from resprouting. Oaks from seedlings to mature trees resprout vigorously following damage (although resprouting ability declines somewhat with age: white oaks do not resprout readily after age 80, Table 1). Second, oaks may reproduce from acorns that remain in unburned patches or, if the fire occurs before a good acorn crop, acorns may germinate well in a recently-burned area. Reproduction from acorns differs somewhat for white oaks versus species in the red oak group (i.e., northern pin oak, black oak, and red oak). White oak acorns require six to eight months to develop, while acorn maturation requires up to two years for species in the red oak group (Table 1). Germination time also differs: white oak acorns typically germinate in the autumn, immediately after they mature and fall, while acorns in the red oak group typically overwinter and germinate in the spring (Table 1). Thus, it is possible that the timing of a fire may interact with these reproductive characteristics to affect which species has the highest rate of acorns that germinate and establish. Third, some stand replacement may come from established but shade-suppressed understory saplings and pole-sized trees (variously termed "advance" or "advanced" regeneration) that are poised to capture the canopy (Barnes et al. 1998). However, most upland oak species have low to intermediate shade tolerance, and small trees will persist in the understory for a limited amount of time (although occasionally as long as several decades, Johnson et al. 2002) without a light gap before they die (Table 1). Northern pin oak is the most intolerant of Michigan's major oak species, and the mid-tolerant red oak is the most tolerant (Table 1).

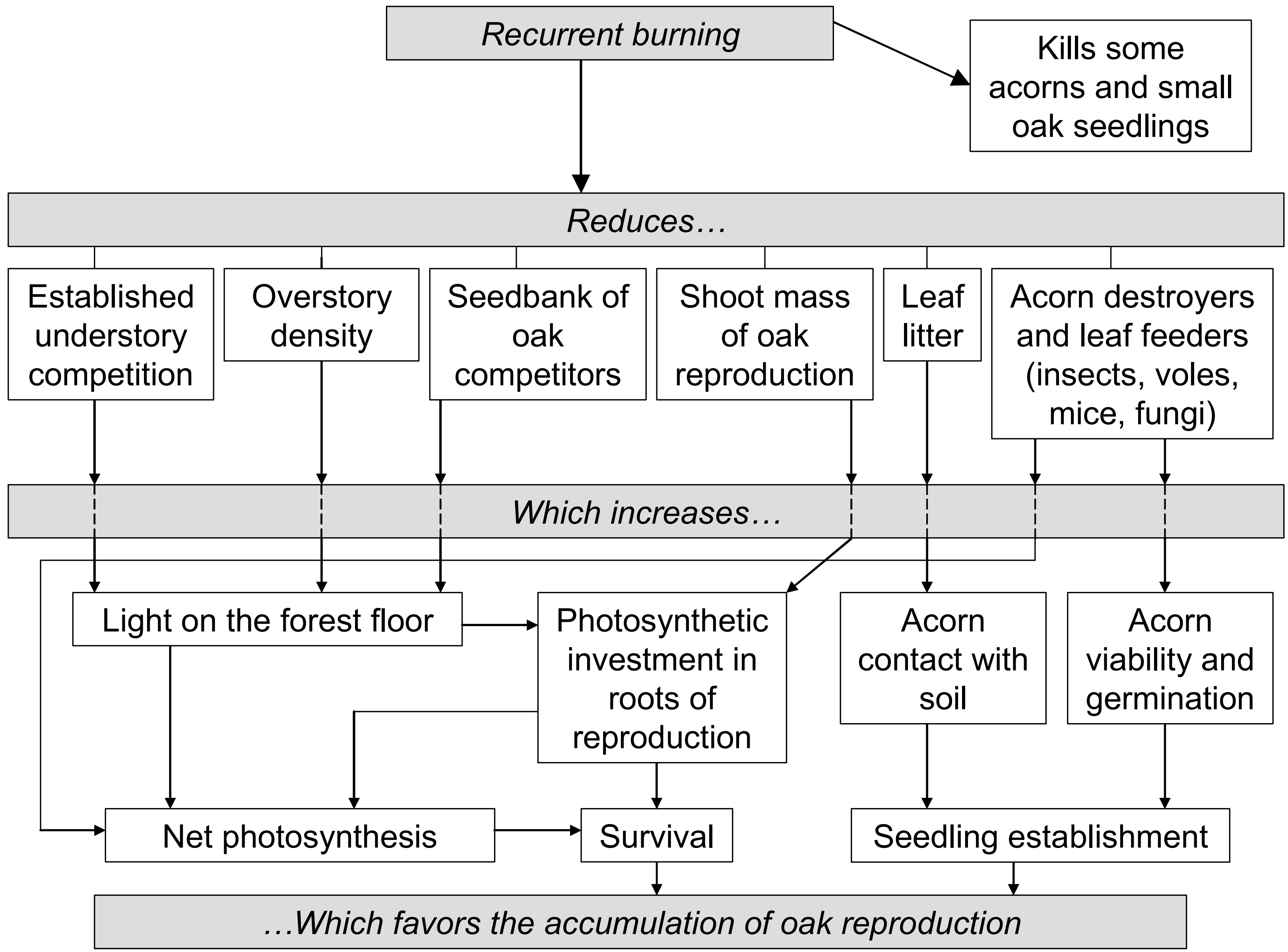
In the absence of major disturbance, oak stands may start to shift to gap-phase dynamics, with the advanced regeneration being recruited into the overstory in gaps left by the death of individual trees. As the stand ages, however, competition from shade-tolerant or mesophytic species intensifies (Barnes et al. 1998). Mesophytic species like red maple typically casts denser shade than oaks, which causes greater suppression to advanced oak regeneration (Abrams 1998). Furthermore, due to their low shade tolerance, advanced oak regeneration will often die off relatively quickly, while understory trees of more shade-tolerant invaders such as red maple may persist longer, and thus succeed in capturing canopy gaps. In time, the stand may convert to more mesic species.

In terms of forest succession, then, upland oaks are generally considered an early- to mid-successional, or transitional, species. Kittredge and Chittenden (1928) suggest that oaks form a self-replacing community only on the driest sites. Barnes et al. (1998), reviewing more recent trends, also conclude that oaks may be self-replacing on only extremely dry sites, and that oak regeneration failure on other sites could lead to major changes in ecosystem structure and function, accompanied by major shifts in plant and animal populations and species composition. Hartman et al. (2005) highlight recent research that suggests that oak-dominated ecosystems may not follow the classical model of forest succession, with predictable patterns of species replacement over time, but that oak and pine may exhibit a cyclic or alternating relationship, in which oak regenerates best under pine, and pine regenerates best under oak.

Problems with oak regeneration have been reported over the past several decades for oak forests in all but the driest sites (e.g., Fralish et al. 1991, Johnson 1992a, Johnson 1992b). An analysis of 1992 Forest Inventory and Analysis data found that in much of eastern North America few mature oak forests have a generation of younger, smaller-diameter oak trees ready to succeed them (McWilliams et al. 2002). Abrams (1992) describes the poor recruitment of oaks in many second-growth oak and oak-pine forests, suggesting that these forests may be "transitional . . . . a one-generation phenomenon." Barnes et al. (1998) suggest that altered fire regimes, along with deer herbivory, have placed "oaks at risk." In a review of 26 studies of forest composition and regeneration, Abrams (2005) notes that although oaks expanded in importance in Appalachian and Alleghenian forests following dramatic downfall of American chestnut (*Castanea dentata*) due to chestnut blight, oak forests have generally been reduced in area, and oak species have declined in importance, in the forests of most regions of eastern North America—the exception being the Lake States, where their importance has increased due to the decline of pine. Fire exclusion is likely a major cause of poor oak regeneration, as oak species and ecosystems are uniquely adapted to wildfire.

While fire suppression is linked to poor oak regeneration in forest stands, it was also fire suppression that allowed oaks to increase in density to form closed-canopy forests in the xeric and/or fire prone environments formerly occupied by barrens or prairie communities. In these areas, the natural fire return interval was frequent enough to limit oak regeneration and maintain open-canopy conditions (50% or under) with low tree densities. Savanna and

Figure 1. Potential effects of fire on the accumulation of oak reproduction. Adapted from Johnson et al. 2002.



barrens areas have been reported to convert to closed-canopy forest within 20 to 30 years of fire suppression (Curtis 1959, White 1983, See Photograph 2). Thus, the role of fire in promoting oak regeneration interacts with site conditions and environmental factors. On dry-mesic to mesic sites, fire is necessary to facilitate oak regeneration and limit mesophytic competitors, while on xeric sites, oaks will regenerate successfully enough to form a closed-canopy forest unless fire occurs frequently enough to limit tree density. To understand this apparent paradox, it is useful to consider how oaks are adapted to xeric conditions and to fire.

Photograph 2. Barrens and savannas can convert to closed-canopy forest within 20 to 30 years of fire suppression (Photograph by Gary Reese).

Fire and Drought Adaptations of Oaks

Oaks are well-adapted to hot and dry conditions and, especially, to fire. The upland oak species (including northern pin oak, black oak, white oak, red oak, and bur oak) all have deep tap roots, which allow them to reach water reserves even when the water table is quite low or drawn down by drought. Deeply lobed leaves dissipate heat, and thick glaucous or scruffy leaves minimize moisture loss (Raven et al. 1992).

In addition to these drought adaptations, oaks also exhibit many adaptations to fire. Barnes et al. (1998) describe four categories of traits that are important in fire adaptation: 1) traits that help trees avoid damage from fire; 2) traits that allow trees to recover after fire; 3) traits that promote colonization of or expansion into recently burned sites; and 4) traits that may serve to promote fire. Upland oaks possess all four types of traits (Barnes et al. 1998, Johnson et al. 2002). Thick bark helps insulate the bole from damage, and the deep tap roots minimize the loss of total biomass from fire, as tap roots store a considerable proportion of biomass below ground—80% or more for young seedlings (Courteau 2005). Dormant buds at the base of the stem (i.e., within the root collar zone), allow for recovery from fire by prolific resprouting. Some oak species depend on resprouting rather than acorn germination for more than half of their total reproduction (Table 1). The rapid growth of resprouts, fueled by ample reserves in the tap roots, allows oaks to quickly reclaim space on burned sites. Following a fire, acorn germination benefits from direct contact with mineral soil (after fires have consumed leaf litter). Finally, although oak leaf litter is not as flammable as that of pines, it is more likely to spread fire than the recalcitrant and rapidly decaying leaves of mesic species such as red maple. In addition, some oak species, such as northern pin oak, retain their lower branches, which can serve as a “fuel ladder” to allow fire to climb to the trees’ crowns.

Photograph 3. Ground fires in closed-canopy oak forests can promote oak reproduction by reducing mesophytic competition and providing favorable conditions for seedling establishment (Photograph by Alan Tepley).

Fire benefits oak regeneration in numerous ways (Johnson et al. 2002, See Figure 1). Fire spurs oak sprouting, allowing for oak recovery. Fire reduces competition for seedlings as well as understory trees, particularly from shade-tolerant species such as red maple. By killing understory shade-tolerant trees and seedlings, fire increases light on the forest floor, promoting growth of relatively intolerant oaks. Fire reduces leaf litter, allowing acorns to come into direct contact with mineral soil, which promotes increased germination and seedling establishment. Fire also reduces, at least temporarily, various “acorn destroyers”: gypsy moth larvae, weevils, and small mammals. Mice and voles are most likely to be directly affected by fire, but the reduction of litter and ground cover may also reduce cover for, and thus foraging time by, many other wildlife species that consume acorns, including turkeys and potentially even deer. Acorn weevils (*Curculio* sp.) can destroy 20% or more of an acorn crop, or even an entire acorn crop in low productivity years or after prolonged fire suppression, and even in good years, the combination of weevils and wildlife can consume an entire acorn crop (Marquis et al. 1976, Sander 1977). Millipedes in the forest litter may also consume the germinating radicles of acorns that overwinter (Galford et al. 1992). While resprouting remains the major source of oak regeneration in many stands, reproduction from seed benefits from a reduction of acorn predators (Sander 1977).

Insects, Disease, Deer Herbivory, and Global Change

Oaks are attacked by numerous insects and fungal diseases. As noted by Sander (1977), oak wood may be attacked by the carpenterworm (*Prionoxystus robiniae*, which prefers red oaks but also attacks other oak species and tree genera), the Columbian timber beetle (*Corthylus columbianus*, which attacks white oaks, and, to a lesser extent, red oaks), the twolined chestnut borer (*Agrilus bilineatus*, which often infests oaks already weakened by disease or insect defoliation), the oak borer (*Agrilus angustulus*), the white oak borer (*Goes tigrinis*), and the red oak borer (*Enaphalodes rufulus*). While borers rarely kill forest-grown oaks outright, they can deform the boles and reduce sawtimber value by an estimated 15% (Solomon 1995, Johnson et al. 2002). In addition, young trees with trunks that have been damaged by several generations of boring insects may be more vulnerable to wind damage and may be prone to snap off (Sander 1977).

Numerous insect herbivores feed on oak leaves from early-season leaf emergence to mid-summer to early autumn: the variable oak leaf caterpillar (*Heterocampa manteo*); oak leaf tier (*Archips semiferanus*) and the oak leaf roller (*Archips semiferanus*), both of which prefer white oak but will feed on most Michigan oak species; the orange-striped oakworm (*Anasota senatoria*); the forest tent caterpillar (*Malacosoma disstria*), a generalist that will feed on many hardwoods but prefers aspens and oaks in the Lake States; and the notorious gypsy moth (*Lymantria dispar*), which prefers oaks but will feed on almost any tree species during dense outbreaks (Sander 1977, Batzer and Morris 1978, Wilson and Surgeoner 1979, McManus et al. 1989, See Photographs 4 and 5). All of these leaf-feeders may, on occasion, totally defoliate trees, although outbreaks by forest tent caterpillars and gypsy moths tend to be the most severe. A single defoliation typically will not cause tree mortality, but weakens trees, and defoliations of more than 50% may decrease tree growth by up to 90% (Batzer and Morris 1978, McManus et al. 1989). However, defoliation in two or three successive years can cause widespread mortality, particularly if trees are already stressed from drought (Sander 1977, Johnson et al. 2002). Forest tent caterpillar outbreaks typically last three years in the Lake States, with regional outbreaks occurring every six to sixteen years (Batzer and Morris 1978). Gypsy moth outbreaks last from two to four years, with several intervening years of low infestations (McManus et al. 1989). Northern pin oak and other oaks growing on poor sites appear particularly susceptible to infestation, but faster-growing trees on better sites may incur more damage (Kidd 1992, Johnson et al. 2002).

Photographs 4 and 5. Gypsy moth caterpillars can totally defoliate oaks; successive years of defoliation can cause widespread tree mortality (Photographs by David Kenyon, MDNR).

In addition to borers and defoliators, oaks are also susceptible to various diseases, particularly if they are already weakened by one or more season of defoliation (McManus et al. 1989). *Anthracnose* fungi attack oak leaves. *Armillaria* fungi often cause root rot, and dead branch stubs may leave openings for entry of fungal rot species, including *Poria andersonii, Stereum gaustapatum, Stereum frustulatum, Hericium* spp., *Polyporus compactus, Poris cocos, Irpex molli,* and *Polyporus sulphureus* (Sander 1977). Trees that have been first defoliated then attacked by fungal rots may die within two to three years (McManus et al. 1989). Oak wilt (*Ceratocystis fagacearum*) was found in twelve counties in southern Lower Michigan and has begun to move north as well, with documented occurrences in four counties in the northern Lower Peninsula as of 1998 (O'Brien et al. 2000) and in Menominee County in the Upper Peninsula. Oak wilt is transmitted locally by root grafts in forest stands where oaks are growing densely enough that their roots touch (root grafting occurs at distances up to 100 feet) and at longer distances by nitidulid beetles. Trees infected by oak wilt rarely recover. All the major oak species in Michigan are affected by oak wilt, which can cause mortality in one to four years (O'Brien et al. 2000).

Photograph 6. Defoliation from oak wilt tends to be more severe in denser stands, since oak wilt is transmitted locally by root grafts (Photograph by Jacqueline Courteau).

Throughout the eastern U.S., local and even regional oak die-offs occur periodically due to a general "decline" syndrome, which Wargo et al. (1983) define as "a disease caused by the interaction of several injurious agents working simultaneously." This may include several factors operating in various combinations, including drought, frost damage, defoliation by insects or wilt, various rot fungi, and wood-boring insects. Finally, sudden oak death, caused by the canker-inducing pathogen *Phytophthora ramorum,* has killed tens of thousands of oaks in California. It has not yet been reported as naturally occurring in the forests of eastern North America, but inoculation tests have demonstrated that eastern oak species are susceptible (O'Brien et al. 2002).

Although some of these insects and diseases are exotic invaders that have become major problems relatively recently, many are native to the U.S. and have a long-documented history (i.e., since the early 1900s) (Sander 1977, Batzer and Morris 1978, Wilson and Surgeoner 1979, McManus et al. 1989). What appears to be new is the extent to which these agents are affecting oak forests, and the increased effects of deer and, in some areas, invasive species. Stressed trees are more likely to be affected than healthy ones (Sander 1977). While drought stress has always been a factor, logging activity and construction associated with the expansion of residential development into oak associations in northern Michigan may damage more trees, opening up wounds where disease agents can enter (O'Brien et al. 2000). Changing climate, due to global warming, may further stress trees, particularly if it leads to more frequent or severe episodes of drought or a longer growing season that can support an extra generation of insects (OTA 1993, EPA 1997, National Assessment Synthesis Team 2001). Finally, the various sources of oak deterioration and mortality are of heightened concern in the context of the widespread declines in oak regeneration.

While insects and disease pose a threat primarily to mature trees, oak seedlings and resprouts are increasingly threatened by heavy browsing from large deer populations in much of the northeastern U.S. (McShea et al. 1997, Abrams 1998, Cote 2004), including parts of Michigan (MSAF 2005, Sargent and Carter 1999). Numerous studies have shown that overabundant deer may contribute to oak regeneration problems (Marquis et al. 1976, Barnes et al. 1998, Rooney and Waller 2003, See Photograph 7). In addition, deer may disperse seeds of exotic and invasive shrub species (Myers et al. 2004), which may further inhibit oak regeneration (Woods 1993, Fagan and Peart 2004, Courteau 2005).

Photograph 7. Oak seedling defoliated by deer browsing. High deer densities can lead to oak regeneration problems (Photograph by Jacqueline Courteau).

VEGETATION DESCRIPTION[4]

Oaks are part of many different forested systems in Michigan. Because of the diverse array of physiographic contexts and natural communities from which oak associations are derived, vegetation within oak associations varies widely. Many oak associations likely contain some remnant natural vegetation that has persisted, with altered species abundances, since logging, slash fires, and fire suppression, as well as disturbance-associated native (and possibly invasive) species that have subsequently colonized. Even within each derivational natural community, species composition changes with differences in geography, topography, soil texture, soil drainage, and disturbance regime.

In broad terms, oaks on dry sites in northern Michigan are generally associated with pines: jack pine (*Pinus banksiana*); red pine (*Pinus resinosa*); and white pine (*Pinus strobus*). Black cherry (*Prunus serotina*) and bigtooth aspen (*Populus grandidentata*) are common canopy associates on dry to dry-mesic sites. With increasing moisture, forest tree species associates can include white pine, sugar maple (*Acer saccharum*), beech (*Fagus grandifolia*), basswood (*Tilia americana*), hemlock (*Tsuga canadensis*), white ash (*Fraxinus americana*), paper birch (*Betula papyrifera*) and trembling aspen (*Populus tremuloides*). In southern Michigan, oaks on dry sites are generally associated with pignut hickory (*Carya glabra*) and black cherry, while with increasing moisture, tree associates include sassafras (*Sassafras albidum*), shagbark hickory (*Carya ovata*), and black walnut (*Juglans nigra*). Prevalent subcanopy tree species associated with fire-suppressed oak forests include black cherry, red maple (*Acer rubrum*), and balsam fir (*Abies balsamea*).

Photograph 8. Fire suppression in oak forests has allowed for the mesophytic invasion by red maple (Photograph by Jacqueline Courteau).

Prevalent shrubs on xeric to dry sites can include serviceberries (*Amelanchier* spp.), bearberry or kinnikinick (*Arctostaphylos uva-ursi*), New Jersey tea (*Ceanothus americanus*), sweetfern (*Comptonia peregrina*), dogwood species (*Cornus* spp.), American hazelnut (*Corylus americana*), beaked hazelnut (*Corylus cornuta*), hawthorn species (*Crataegus* spp.), bush-honeysuckle (*Diervilla lonicera*), huckleberry (*Gaylussacia baccata*), witch hazel (*Hamamelis virginiana*), wild plum (*Prunus americana*), choke cherry (*Prunus virginiana*), sand cherry (*Prunus pumila*), dwarf chestnut or dwarf chinquapin oak (*Quercus prinoides*), pasture rose (*Rosa carolina*), northern dewberry (*Rubus flagellaris*), prairie or upland willow (*Salix humilis*), low sweet blueberry (*Vaccinium angustifolium*), and velvetleaf blueberry (*Vaccinium myrtiloides*).

The ground layer of dry sites is dominated by graminoids and forbs. Common graminoid species include little bluestem (*Schizachyrium scoparium*), big bluestem (*Andropogon gerardii*), and Pennsylvania sedge (*Carex pensylvanica*); these species are especially present in former oak-pine barrens and pine barrens or within openings of oak forest. Additional common grasses include poverty oats (*Danthonia spicata*), hair grass (*Deschampsia flexuosa*), June grass (*Koeleria macrantha*), rice grass (*Oryzopsis* spp.), and needle grass (*Stipa avenacea*).

Prevalent dry site herbs include: spreading dogbane (*Apocynum androsaemifolium*), wild sarsaparilla (*Aralia nudicaulis*), big-leaved aster (*Aster macrophyllus*), harebell (*Campanula rotundifolia*), striped wintergreen (*Chimaphila maculata*), trailing arbutus (*Epigaea repens*), wild strawberry (*Fragaria virginiana*), wintergreen (*Gaultheria procumbens*), white pea (*Lathyrus ochroleucus*), hairy lespedeza (*Lespedeza hirta*), dwarf blazing star (*Liatris cylindrica*), wild lupine (*Lupinus perennis*), whorled loosestrife (*Lysimachia quadrifolia*), Canada mayflower (*Maianthemum canadense*), cow-wheat (*Melampyrum linneare*), wild bergamot (*Monarda fistulosa*), and wood betony (*Pedicularis canadensis*).

Typical shrubs of dry-mesic to mesic sites include striped maple (*Acer pennsylvanicum*), mountain maple or moosewood (*Acer spicatum*), serviceberries, grey dogwood (*Cornus foemina*), American hazelnut (*Corylus americana*), beaked hazelnut (*Corylus cornuta*), bush-honeysuckle, witch hazel, fly honeysuckle (*Lonicera canadensis*), choke cherry, wild

[4]Species lists throughout this section compiled from MNFI database and from Livingston 1905, Stearns 1950, Brown and Curtis 1952, Zimmerman 1956, Curtis 1959, Byer 1960, Gleason and Cronquist 1964, Brubaker 1975, Abrams and Dickman 1982, Palmgren 1999, Walker 1999, Faber-Langendoen 2001, Burger and Kotar 2003, and NatureServe 2006.

gooseberry (*Ribes cynosbati*), red elderberry (*Sambucus pubens*), and maple-leaf viburnum (*Viburnum acerifolium*). Prevalent herbs of the dry-mesic to mesic oak forests include: baneberries (*Actaea* spp.), wild leek (*Allium tricoccum*), wild columbine (*Aquilegia canadensis*), wild sarsaparilla, jack-in-the-pulpit (*Arisaema triphyllum*), big-leaved aster, long-awned wood grass (*Brachyelytrum erectum*), blue cohosh (*Caulophyllum thalictroides*), blue-bead lily (*Clintonia borealis*), bunchberry (*Cornus canadensis*), bedstraw (*Galium triflorum*), sharp-lobed hepatica (*Hepatica acutiloba*), Indian cucumber root (*Medeola virginiana*), Canada mayflower, partridge berry (*Mitchella repens*), rice grass (*Oryzopsis asperifolia*), hairy sweet cicely (*Osmorhiza claytonii*), fringed polygala (*Polygala paucifolia*), Solomon's seal (*Polygonatum pubescens*), false spikenard (*Smilacina racemosa*), twisted stalk (*Streptopus roseus*), star flower (*Trientalis borealis*), and common trillium (*Trillium grandiflorum*).

Photograph 8. Bracken fern is a prevalent dominant in the ground cover of oak forests of northern Michigan (Photograph by Michael Kost).

Common ferns and clubmosses found in oak forests include bracken fern (*Pteridium aquilinum*, which is frequently the dominant plant in the ground layer), rattlesnake fern (*Botrychium virginianum*), evergreen woodfern (*Dryopteris intermedia*), spinulose woodfern (*Dryopteris carthusiana*), stiff clubmoss (*Lycopodium annotinum*), shining clubmoss (*Lycopodium lucidulum*), and groundpine (*Lycopodium obscurum*). Lichens are prevalent on xeric to dry sites and include grey reindeer lichen (*Cladina rangifera*) and green reindeer lichen (*Cladina mitis*).

Numerous invasive plants are dominant components in the ground layer of oak forests, especially in disturbed openings and where fire has been excluded. Prevalent invasive plants include spotted knapweed (*Centaurea maculosa*), hawkweeds (*Hieracium* spp.), Canada bluegrass (*Poa compressa*), Kentucky bluegrass (*Poa pratensis*), timothy (*Phleum pratense*), sheep sorrel (*Rumex acetosella*), and common mullein (*Verbascum thapsus*).

Other Noteworthy Species (Rare Plants and Animals)

Little research has been conducted on the biodiversity of oak associations and the extent to which any rare species are presently found in them. Activities such as logging, hot fires associated with burning of slash, and soil disturbances associated with logging and subsequent planting, thinning, and other management have very likely affected the presence and abundance of rare species that relied on the derivational communities for habitat. However, some rare species likely persist, at least in isolated pockets. For example, small remnant populations of plant species associated with natural barrens communities have been found in the forests to which they succeeded, even up to 100 years after canopy closure (Will-Wolf and Stearns 1999). Fifty-eight rare plant species (State Endangered, Threatened, or Special Concern) are associated with dry northern forest, dry-mesic northern forest, mesic northern forest, dry sand prairie, oak-pine barrens, and oak barrens that might be harbored in areas now occupied by oak associations (Table 2). Locating any of these species within an oak association would suggest that the area is a good target for protection and potential restoration toward the derivational community.

Oak barrens and forests in northern Lower Michigan may also provide habitat for up to 48 rare animal species that are known to be associated with natural communities from which oak associations were derived (Tables 3 and 4). This list includes 15 bird species; 24 insect species (including 10 species of butterflies); 3 mammal species; and 6 reptile species. In addition, some songbirds that are forest interior obligates may be associated with oak associations derived from dry northern forest, dry-mesic northern forest, and mesic northern forest, while barrens areas hosted various neotropical migrants.

WILDLIFE HABITAT VALUE

In addition to potentially harboring rare plant and animal species, oak associations offer food and habitat for many wildlife species, including wild turkey (*Meleagris gallopavo*), white-tailed deer (*Odocoileus virginianus*), ruffed grouse (*Bonasa umbellus*), black bear (*Ursus americanus*), squirrels (*Sciurus* spp.), chipmunks (*Tamias* spp), porcupine (*Erethizon dorsatum*), mice (*Peromyscus* spp.), blue jay (*Cyanocitta cristata*), woodpeckers (*Melanerpes* spp.), northern bobwhite (*Colinus virginianus*), rabbit (*Sylvilagus floridanus*), fox (*Vulpes vulpes*), raccoon (*Procyon lotor*), and various

Table 2. Rare plant species associated with natural communities from which oak associations were derived.

Scientific name	Common name	Status[1]	Derivational Natural Community[2]
Adlumia fungosa	climbing fumitory	SC	MNF
Agalinus gattingerii	Gattinger's gerardia	E	OP
Agoseris glauca	prairie or pale agoseris	T	PB
Amorpha canescens	leadplant	SC	DSP
Arabis missouriensis var. *deamii*	Missouri rock-cress	SC	OP
Arnica cordifolia	heart-leaved arnica	E	DNF, DMNF
Asclepias ovalifolia	dwarf milkweed	E	OP
Asplenium rhizophyllum	walking fern	T	MNF
Asplenium scolopendrium	Hart's-tongue fern	E	MNF
Asplenium trichomanes-ramosum	green spleenwort	ST	MNF
Aster sericeus	western silvery aster	T	DSP
Astralagus canadensis	Canadian milk-vetch	T	OP
Astralagus neglectus	Cooper's milk-vetch	SC	OP
Botrychium mormo	goblin moonwort	ST	MNF
Botrychium pallidum	pale moonwort	SC	OP
Bouteloua curtipendula	side-oats grama grass	T	OP
Carex assiniboinensis	Assiniboia sedge	ST	MNF
Carex tincta	sedge	SC	DNF, DMNF
Cirsium hillii	Hill's thistle	SC	OP, PB
Clematis occidentalis	purple clematis	SC	DNF, DMNF
Cuscuta indecora	dodder	SC	OP
Cuscuta pentagona	dodder	SC	OP
Cystopteris laurentiana	Laurentian fragile-fern	SC	MNF
Dalibarda repens	false violet	T	DNF, DMNF
Danthonia spicata	flattened oatgrass	SC	DNF, DMNF
Dentaria maxima	large toothwort	ST	MNF
Diosporum hookeri	fairy bells	ST	MNF
Dryopteris filix-mas	male fern	ST	MNF
Festuca scabrella	rough fescue	T	PB
Galearis spectabilis	showy orchis	ST	MNF
Galium kamtschaticum	boreal bedstraw	ST	MNF
Gentiana flavida	white gentian	E	OP
Gentiana puberulenta	downy gentian	E	OP
Geum triflorum	prairie-smoke	T	DSP
Helianthus hirstutus	whiskered sunflower	SC	OP
Helianthus mollis	downy sunflower	T	OP
Hieracium paniculatum	panicled hawkweed	SC	OP
Kuhnia eupatoroides	false boneset	SC	OP
Lechea stricta	erect pinweed	SC	OP
Linum sulcatum	furrowed flax	SC	DSP, PB
Linum virginianum	Virginianan flax	T	PB
Oryzopsis canadensis	Canada rice-grass	T	PB
Panax quinquefolius	ginseng	ST	MNF
Penstemon calycosus	smooth beard-tongue	T	OP
Penstemon pallidus	pale beard-tongue	SC	OP
Phlox bifida	cleft or sand phlox	T	OP
Prunus alleghaniensis	Alleghany plum	SC	PB
Pterospora andomedea	pine-drops	T	DNF, DMNF
Solidago missouriensis	Missouri goldenrod	T	DSP
Sporobolus ceandestinus	dropseed	SC	OP
Tipularia discolor	cranefly orchid	ST	MNF
Tradescantia virginiana	Virginiana spiderwort	SC	OP
Trichostema brachiatum	false pennyroyal	T	DSP
Triphora trianthophora	three-birds orchid	ST	MNF
Triplasis purpurea	purple sand grass	SC	DSP
Vaccinium cespitosum	dwarf bilberry	T	DSP
Viola novae-angliae	New England violet	ST	MNF

1. T=State Threatened; E=State Endangered; SC=State Special Concern

2. DMNF=Dry-mesic northern forest; DNF=Dry northern Forest; DSP=Dry Sand Prairie; MNF=Mesic Northern Forest; OP=Oak Barrens, Oak-Pine Barrens; PB=Pine Barrens

Table 3. Rare animal species and neotropical migrant birds associated with natural communities from which oak associations were derived.

Scientific name	Common name	Status[1]	Derivational Natural Community/Habitat[2]
Birds			
Accipiter gentilis	northern goshawk	SC	DMNF, DNF, MNF
Ammodramus henslowii	Henslow's sparrow	SC	DSP
Ammodramus savannarum	grasshopper sparrow	SC	DSP, OP
Asio flammeus	short-eared owl	E	DSP
Asio otus	long-eared owl	T	DSP
Buteo linatus	red-shouldered hawk	T	MNF
Dendroica discolor	prairie warbler	E	DMNF, DNF, OP
Dendroica kirtlandii	Kirtland's warbler	FE, E	DMNF, DNF (in dense young jack pine stands), PB
Falco columbarius	merlin	T	DMNF, DNF (near Great Lakes shorelines)
Haliaeetus leucocephalus	bald eagle	T	DMNF, DNF
Lanus ludovicianus migrans	migrant loggerhead shrike	E	DSP
Pandion haliaetus	osprey	T	DMNF, DNF
Spiza americana	dickcissel	SC	DSP
Sturnella neglecta	western meadowlark	SC	DSP
Tyto alba	barn owl	E	DSP
Neotropical migrant bird species			
Dendroica caerulescens	black-throated blue warbler		DMNF, DNF, MNF
Dendroica cerulea	cerulean warbler		MNF
Dendroica virens	black-throated green warbler		DMNF, DNF, MNF
Melospiza lincolnii	Lincoln's sparrow		OP
Passerina cyanea	indigo bunting		OP
Picoides arcticus	black-backed woodpecker		DMNF, DNF
Piranga olivacea	scarlet tanager		DMNF, DNF, MNF
Pooecetes gramineus	vesper sparrow		OP
Seiurus aurocappilus	ovenbird		DMNF, DNF, MNF
Sial sialis	eastern bluebird		OP
Spizella passerina	chipping sparrow		OP
Toxostoma rufum	brown thrasher		OP
Tympanuchus cupido	prairie chicken		PB
Tympanuchus phaisanellus	sharptail grouse		PB
Vermivora pinus	blue-winged warbler		OP
Vermivora ruficapilla	nashville warbler		OP
Mammals			
Cryptotis parva	least shrew	T	OP
Microtus ochrogaster	prairie vole	E	DSP, OP
Microtus pinetorum	woodland vole	SC	MNF
Reptiles			
Clemmys guttata	spotted turtle	SC	DSP, OP
Elaphe o. obsoleta	black rat snake	SC	DSP, OP
Emydoidea blandingii	Blanding's turtle	SC	DSP (when adjacent to wetlands)
Glyptemys insculpta	wood turtle	SC	DMNF, DMF, DSP, OP, PB (when adjacent to drainages)
Sistrurus catenatus catenatus	eastern massasauga rattlesnake	FC, SC	DMNF, DNF, DSP, OP
Terrapene carolina carolina	eastern box turtle	SC	DMNF, DNF, DSP

1. T=State Threatened; E=State Endangered; SC=State Special Concern; FE=Federally Endangered; FC=Federally Special Concern

2. DMNF=Dry-mesic northern forest; DNF=Dry northern Forest; DSP=Dry Sand Prairie; MNF=Mesic Northern Forest; OP=Oak Barrens, Oak-Pine Barrens; PB=Pine Barrens

Table 4. Rare insect species associated with natural communities from which oak associations were derived.

Scientific name	Common name	Status[1]	Derivational Natural Community/Habitat[2]
Insects			
Appalachia arcana	secretive locust	SC	DSP, PB (when adjacent to wetlands)
Atrytonopsis hianna	dusted skipper	T	DMNF, DNF, DSP, OP
Brachionyncha borealis	boreal brachionyncha moth	ST	DMNF, DNF
Catocala amestris	three-staff underwing	E	OP
Erynnis persius persius	Persius duskywing	T	DMNF, DNF, DSP, OP
Gomphus quadricolor	rapids clubtail dragonfly	SC	MNF (streams and pools within forest)
Hesperia ottoe	Ottoe skipper	T	DMNF, DNF, DSP, OP
Incisalia henrici	Henry's elfin	SC	DMNF, DNF, OP
Incisalia irus	frosted elfin	T	DMNF, DMF, DSP, OP, PB
Lepyronia gibbosa	Great Plains spittlebug	T	DMNF, DNF, DSP, OP
Lycaeides melissa samuelis	Karner blue	T,FE	DSP, OP, PB
Merolonche dolli	Doll's merolonche moth	SC	DMNF, DNF
Oecanthus pini	pine-tree cricket	SC	DMNF, DNF, OP
Orphulella p. pelidna	barrens locust	SC	OP
Papaipema beeriana	blazing star borer	SC	DMNF, DNF, DSP
Papaipema sciata	Culver's root borer	SC	OP
Prosapia ignipectus	red-legged spittlebug	SC	DMNF, DNF, DSP, OP
Pygarctia spraguei	Sprague's pygarctica	SC	DSP, OP
Pyrgus wyandot	grizzled skipper	SC	DMNF, DNF, DSP, OP
Schinia indiana	phlox moth	E	DSP, OP
Schinia lucens	leadplant flower moth	E	OP
Scudderia fasciata	pine katydid	SC	OP
Spartiniphaga inops	Spartina moth	SC	OP
Speyeria idalia	regal fritillary	E	DSP, OP

1. T=State Threatened; E=State Endangered; SC=State Special Concern; FE=Federally Endangered; FC=Federally Special Concern
2. DMNF=Dry-mesic northern forest; DNF=Dry northern Forest; DSP=Dry Sand Prairie; MNF=Mesic Northern Forest; OP=Oak Barrens, Oak-Pine Barrens; PB=Pine Barrens

Table 5. Wildlife species that rely heavily on acorn masting by oaks (Rodewald 2003).

Wildlife species that rely heavily on acorns for fall or winter diets

Common name	*Scientific name*	*Studies*
red-bellied woodpecker	*Melanerpes carolinus*	Smith 1986, Smith and Scarlett 1987, McShea
tufted titmouse	*Baeolophus bicolor*	and Schwede 1993, McShea and Healy 2002
blue jay	*Cyanocitta cristata*	
wild turkey	*Meleagris gallopavo*	
white-tailed deer	*Odocoileus virginianus*	
mice	*Peromyscus* spp.	
chipmunks	*Tamias* spp.	
squirrels	*Sciurus* spp.	
black bear	*Ursus americanus*	

Wildlife species with population dynamics correlated to acorn yield

Common name	*Scientific name*	*Studies*
white-footed mouse	*Peromyscus leucopus*	McShea 2000, McShea and Healy 2002,
deer mouse	*Peromyscus maniculatus*	Schnurr et al. 2002
eastern chipmunk	*Tamias striatus*	
gray squirrel	*Sciurus caroliniensis*	
acorn woodpecker	*Melanerpes formicivorus*	Hannon et al. 1987, Koenig and Mumme 1987
red-headed woodpecker	*Melanerpes erythrocephalus*	Smith and Scarlett 1987
blue jay	*Cyanocitta cristata*	Smith and Scarlett 1987
white-tailed deer	*Odocoileus virginianus*	McShea and Healy 2002
black bear	*Ursus americanus*	McShea and Healy 2002

species of waterfowl (Johnson 1992b). In all, more than 90 species of wildlife feed on acorns (Kirkpatrick and Pekins 2002). At least a dozen of these species rely heavily on acorns for their winter diet (Smith 1986, Smith and Scarlett 1987, McShea and Schwede 1993, McShea and Healy 2002), and studies have found correlations between acorn crops and populations of nine animal species (Hannon et al. 1987, Koenig and Mumme 1987, Smith and Scarlett 1987, McShea 2000, McShea and Healy 2002, Schnurr et al. 2002, Rodewald 2003; See Table 5).

Oaks appear to offer greater benefits to wildlife than red maple, which is succeeding oaks in many areas (Rodewald and Abrams 2002, Rodewald 2003). Acorns provide a better food source, with a large amount of highly digestible energy inside a durable hard shell, whereas the softer tissues of smaller maple samaras tend to decompose more rapidly (Rodewald 2003). Foliage-gleaning passerine birds appear better able to locate and recover arthropods from shorter-petioled oak leaves than from longer-petioled red maple leaves (Rodewald 2003). Red maple leaf litter decomposes faster than that of oaks; lower litter levels harbor fewer arthropods that are a primary food source for ground-foraging birds, such as chickadees (*Poecile* spp.), as well as for salamanders (Rodewald 2003). The rough and deeply fissured bark of oaks offers greater surface area for arthropods to nest and feed, and thus greater foraging opportunities for birds, such as chickadees, tufted titmouse (*Baeolophus bicolor*), and white-breasted nuthatch (*Sitta carolinensis*), than on red maples, which tend to have relatively smooth bark. Mixed oak-pine systems provide important habitat for numerous breeding birds (DeGraaf et al.1991). Finally, butterfly and moth larvae, which comprise an important food source for insectivorous birds, appear to be less likely to be found on red maple leaves than on leaves of oak and other hardwood species (Rodewald 2003).

BIODIVERSITY CONSERVATION VALUE

Despite their clear value for wildlife, current managed oak associations—particularly those derived from oak-pine and pine barrens, dry sand prairie, and dry northern forest—likely do not host the full range of species that inhabited the natural communities from which they were converted. The transition from open-canopy systems, with their diverse patchwork of light and shade, and the associated gradients in moisture, to the more uniform conditions of a closed-canopy forest has been associated with species declines, particularly among plants. A recent study of an oak savanna in northern Illinois showed a dramatic decline in flora and fauna as the savanna succeeded to closed-canopy forest: the number of plants species dropped from more than 300 to less than 25, while bird species dwindled from 28 to 4 (Haney and Apfelbaum 1990, Johnson 1992b). Biodiversity declines probably happened as well in northern Michigan's oak-pine and pine barrens communities as they converted to closed-canopy oak forests.

CONSERVATION AND BIODIVERSITY MANAGEMENT

The management of oak associations, with their diverse values for commercial timber production, wildlife habitat, and biodiversity conservation, presents numerous challenges. Oak associations throughout northern Michigan are maturing. Two-thirds of State Forest oak stands are 70 to 100 years old, with one third of them in the 80- to 90-year age class (Pedersen 2006). As existing oak forests age, they are being harvested at a rate of 5,000 to 7,000 acres per year (Pedersen 2006). At the same time, insect and disease outbreaks are a potentially increasing source of oak die-back, which could be further exacerbated by climate change. Lastly, as in many other areas in eastern North America (Abrams 1992, 2005), oak regeneration is a significant issue in Michigan (Pedersen 2006).

While the decline in oak trees and oak forest regeneration is a concern, it must be considered in the context of increased prominence of oaks in Michigan's forests following historic logging and intensive slash fires, and the concurrent decrease in mixed oak-pine and pine-dominated forests and barrens. This situation may actually present an opportunity to manage oak systems in a way that could increase forest health and productivity, while at the same time conserving biodiversity and helping to restore natural communities. Doing so will involve identifying the natural community type from which an oak stand likely converted, and using prescribed fire to help reduce canopy density and promote oak and possibly pine regeneration. Timing of prescribed fire should be carefully considered since acorn germination varies between the white oak group (fall germination) and the red oak group (spring germination). In areas that were formerly pine-dominated or barrens systems, it may be necessary to use repeated prescribed fires to reduce canopy density. In oak stands where white pine is already regenerating well, little additional management may be necessary other than prescription burning and allowing time for succession to occur. If existing seed trees of formerly dominant species, especially red pine and white pines, are adequate, prescribed fire may promote pine regeneration. However, if seed sources are not present, it may be necessary to do limited replanting of pines.

Allowing oak associations to convert to mixed oak-pine systems may benefit the oaks themselves, and potentially allow for high-value harvests even with a lower oak tree density. Gypsy moth attacks cause higher mortality in oak-dominated stands than in oak-pine or other mixed hardwood stands (McManus et al. 1989). Forest stands with a diversity of overstory species tend to experience slower spread and less damage from oak wilt (O'Brien 2000). Sander (1977) suggested that "the best management for oak stands on the poorest sites may be no management," and suggests that poor oak sites be allowed to convert to pine or pine-oak stands where feasible. Pine that is allowed to grow to sawlog size is comparable to oak in timber value (MDNR 2006).

Photograph 9. Oak stands can function as nurse crops for pine regeneration. Managing for mixed oak-pine forests may help reduce the incidence of oak decline (Photograph by Joshua Cohen).

At the same time, where pines are dominant, especially on intermediate quality sites that have been planted to pine, it may be useful to consider allowing or promoting oak regeneration (Hartman et al. 2005). At least one study has found that, even if understory competitors (such as red maple) are controlled, oaks may not progress as well to the canopy after shelterwood cuts in oak stands as in pine stands (Hartman et al. 2005). Recent work suggests that oaks and pines may have a cyclical rather than unidirectional successional relationship (Crow 1988, Sarnecki 1990, Johnson 1992b), and this perspective could be used to inform management.

It is difficult to overstate the immediate importance of prescribing fire for maintaining oak regeneration, decreasing density-dependent insect and disease infestations, and potentially restoring some areas to oak-pine or even pine-dominated forest and barrens systems (Photograph 10). The combination of invasion by red maples and concentrated browsing by abundant deer may have far-reaching and long-standing consequences for oak regeneration, and could lead to alternative successional states (McCune and Cottam 1985, Host et al. 1987, Ellison et al. 2005). Red maple's rapidly decaying leaves reduce buildup of leaf litter and the dense shade cast by its canopy slows growth of ground cover species. Thereby, red maple can reduce the forest floor flammability of invaded stands by reducing available fuel (Abrams 2005). Deer browsing may amplify this effect by eliminating more ground cover, and may exert heavy pressure on resprouting oaks if a fire does succeed in carrying through a forest. If red maple has already altered the flammability characteristics of oak stands, it may also be necessary to remove red maple in order to restore a more natural fire regime. In addition, it may be helpful to control deer populations before prescribed fires to allow pine seedlings and oak sprouts to get a head start prior to burning.

Photograph 10. Prescribed fire has been utilized by the Traverse City Forest Management Unit as a management tool for the restoration of oak-pine barrens (Photograph by Stephen Griffith, MDNR).

Photographs 11 and 12. Prescribed fire can be employed to control red maple invasion (Photograph by Joshua Cohen). The presence of lupine often indicates former open-canopy ecosystems that would benefit from reintroduction of fire (Photo by Jacqueline Courteau).

RESEARCH NEEDS

Further research is needed on the biodiversity values of existing oak associations. Studies showing the extensive use of oaks and oak forests as wildlife food and habitat have generally been done on historically oak forest rather than forests that have converted to oak. Generalist herbivores and seed predators—including many small mammals (chipmunks, squirrels, and some vole, shrew, and mouse species), deer, bear, turkeys, blue jays, and various other forest bird species—may have adapted to changing conditions, but less is known about effects on specialist species. Have oak specialist species effectively moved into managed oak stands, thereby increasing their range? What has become of species that were typically found in oak-pine or pine-dominated systems and barrens and savanna communities? To what extent have oak associations maintained the species assemblages that characterized the natural communities from which they were derived? Have oak associations developed new species assemblages comprised of distinctive groupings of species, rather than simply subsets of the species that characterized their derivational communities? Or has the simplification of ecosystem structure at the landscape level, from a mosaic of pine and mixed oak-pine forests and barrens with varying amounts of oaks, led to a change of regional biodiversity?

In addition to assessing biodiversity values, additional research is needed on how to maintain and regenerate oaks in Michigan. Oaks show a general pattern of declining regeneration, but the extent to which regeneration differs across ecosystems and management regimes is not clear. MNFI is in the midst of a three-year study of oak regeneration throughout the Lower Peninsula that will examine the following questions: 1) What is the present status of oak regeneration in Michigan? 2) How do regeneration patterns vary across landscape ecosystem types and with varying management regimes? 3) Where and to what extent is deer overbrowsing correlated with reduced regeneration? Data was collected from 56 sites in southern Lower Michigan in 2006, with additional data collection planned for northern Lower Michigan for 2007. Preliminary results will likely become available starting in late 2007.

Maintaining oak ecosystems will also benefit from greater understanding of the factors that lead to oak decline (insect and disease outbreaks), and the extent to which those factors are density-dependent. For example, many insect and disease outbreaks seem more severe in denser tree stands; oak wilt spreads by root grafts (which are common where trees of the same species occur at intervals of 100 feet or less); and gypsy moths appear to kill more trees in oak-dominated than in mixed oak stands. However, further research is needed to elucidate these patterns. Does reducing the density of oaks, in and of itself, lead to lower incidence of various insect and disease outbreaks? If fire is used to reduce tree density, how much improvement in oak health is due to the decreased tree density vs. the direct effects of fire (destruction of insect pupae, larvae, and fungal spores)? Do these density-dependent effects differ for oak forests with a low tree density vs. for mixed oak-pine stands with higher overall canopy density but an equivalent density of oaks? Answering these questions will help resource practitioners set ecosystem management priorities for the oak association.

OTHER CLASSIFICATIONS

Michigan Natural Features Inventory (MNFI): Dry-mesic northern forest; dry-mesic southern forest; dry northern forest; dry southern forest; mesic northern forest. In addition, the following savanna, barrens, and prairie types may have been converted to oak associations: Bur oak plains; dry sand prairie; lakeplain oak openings; oak barrens; oak openings; oak-pine barrens; pine barrens; woodland prairie.

Michigan Natural Features Circa 1800 Vegetation (MNFI): Land-cover types with oak species dominant or co-dominant: black oak barrens; oak-pine barrens; mixed oak savanna; mixed pine-oak forest; white pine-white oak forest; oak-hickory forest; mixed oak forest. Other cover types with an important component of oak: Pine barrens; jack pine-red pine forest; red pine-white pine forest; white pine-mixed hardwood forest; beech-sugar maple-hemlock forest; beech-sugar maple forest.

Michigan Department of Natural Resources (MDNR): O-Oak

Michigan Resource Information Systems (MIRIS): 33 (Pine or Oak Opening), 412 (Central Hardwood), 41207 (Undifferentiated Oak/Hickory), 41214 (Red Oak), 41227 (White Oak), 41235 (Black Oak), 42 (Coniferous Forest), 43 (Mixed Conifer-Broadleaved Forest), 431 (Upland Hardwoods and Pine), 4342 (Upland Hardwoods and Red Pine), and 4343 (Upland Hardwoods and Jack Pine)

The Nature Conservancy National Classification:

CODE; ALLIANCE; ASSOCIATION; COMMON NAME

I.A.8.N.b; *Pinus banksiana* Forest Alliance; *Pinus banksiana / (Quercus rubra, Quercus ellipsoidalis)* Forest; Jack Pine / Scrub Oak Forest

The Nature Conservancy National Classification:
I.B.2.N.a; *Quercus alba - (Quercus rubra, Carya* spp.) Forest Alliance; *Quercus alba - Quercus rubra - Carya ovata* Glaciated Forest; Midwestern White Oak - Red Oak Forest

I.B.2.N.a; *Quercus rubra - (Acer saccharum)* Forest Alliance; *Quercus rubra - Acer saccharum* Forest; Northern Red Oak - Sugar Maple Forest

I.B.2.N.a; *Quercus rubra - (Acer saccharum)* Forest Alliance; *Quercus rubra - Quercus alba - (Quercus velutina, Acer rubrum) / Viburnum acerifolium* Forest; Northern Red Oak - White Oak - (Maple) Forest

I.B.2.N.a; *Quercus velutina - Quercus alba - (Quercus coccinea)* Forest Alliance; *Quercus velutina - Quercus alba - Carya (glabra, ovata)* Forest; Black Oak - White Oak - Hickory Forest

I.B.2.N.a; *Quercus velutina - Quercus alba - (Quercus coccinea)* Forest Alliance; *Quercus velutina - Quercus alba / Vaccinium (angustifolium, pallidum) / Carex pensylvanica* Forest; Black Oak - White Oak / Blueberry Forest

I.C.3.N.a; *Pinus banksiana - Quercus (ellipsoidalis, velutina)* Forest Alliance; *Pinus banksiana - (Pinus resinosa) - Quercus ellipsoidalis / Carex pensylvanica* Forest; Jack Pine - Northern Pin Oak Forest

I.C.3.N.a; *Pinus strobus - Quercus (alba, rubra, velutina)* Forest Alliance; *Pinus strobus - (Pinus resinosa) - Quercus rubra* Forest; White Pine - Red Oak Forest

I.C.3.N.a; *Pinus strobus - Quercus (alba, rubra, velutina)* Forest Alliance; *Pinus strobus - Quercus alba / (Corylus americana, Gaylussacia baccata)* Forest; White Pine – White Oak Sand Forest

II.A.4.N.a; *Pinus (banksiana, resinosa)* Woodland Alliance; *Pinus banksiana - Pinus resinosa / Quercus ellipsoidalis* Woodland; Jack Pine - Red Pine / Scrub Oak Woodland

II.B.2.N.a; *Quercus alba - (Quercus velutina)* Woodland Alliance; *Quercus velutina - (Quercus ellipsoidalis) - Quercus alba / Deschampsia flexuosa* Woodland; Black Oak - Northern Pin Oak Common Hairgrass Woodland

V.A.6.N.f; *Pinus banksiana - (Pinus resinosa)* Wooded Herbaceous Alliance; *Pinus banksiana - Pinus resinosa - (Quercus ellipsoidalis) / Carex pensylvanica* Wooded Herbaceous Vegetation; Jack Pine - Red Pine Barrens

V.A.6.N.f; *Pinus banksiana - (Pinus resinosa)* Wooded Herbaceous Alliance; *Pinus banksiana - (Quercus ellipsoidalis) / Schizachyrium scoparium* - Prairie Forbs Wooded Herbaceous Vegetation; Jack Pine / Prairie Forbs Barrens

V.A.6.N.c; *Pinus strobus - Quercus (alba, rubra)* Wooded Herbaceous Alliance; *Pinus strobus - Quercus alba - (Quercus velutina) / Andropogon gerardii* Wooded Herbaceous Vegetation; White Pine - White Oak Barrens

V.A.6.N.c; *Quercus velutina - (Quercus ellipsoidalis)* Wooded Herbaceous Alliance; *Quercus velutina - (Quercus alba) - Quercus ellipsoidalis / Schizachyrium scoparium - Lupinus perennis* Wooded Herbaceous Vegetation; Black Oak / Lupine Barrens

ACKNOWLEDGEMENTS

Funding for this abstract was provided by the Michigan Department of Natural Resources' Forest, Mineral, and Fire Management Division and Wildlife Division. Numerous MNFI staff assisted with the creation of this paper. Kraig Korroch assisted with final report formatting. Helen Enander and Christopher Weber provided GIS support and data interpretation. Lyn Scrimger served as the grant administrator and Sue Ridge, Connie Brinson, and Patrick Brown provided administrative support. In addition, Paul Graham, Patrick Brown, and Jeffrey Lee contributed editorial assistance. Special thanks to Richard and Julia Graham for perpetual inspiration.

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