

# CHARACTERIZATION OF MIDWESTERN OAK SAVANNAS

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## **ABSTRACT**

Oak savannas occur along the prairie border from south-central Texas to Manitoba (Fig. 1). In the upper Midwest, oak dominated savannas develop on both xeric and mesic sites; six distinct communities can be identified. These communities are distributed along geographic and physiographic gradients, and each also varies along a fire gradient. This paper provides an interpretation of these communities types and their successional derivatives which develop in the absence of fire.

## **INTRODUCTION**

In previous papers, we discussed Midwest oak savanna structure and dynamics (Haney and Apfelbaum 1990, Apfelbaum and Haney 1991). Nuzzo (1986) pointed out that high quality examples of this once prominent biome were extremely rare. Specifically, nearly all savannas on mesic sites have been destroyed by land-use changes or so altered by successional change and invasion of exotic species, that most are no longer recognizable as savannas (Haney and Apfelbaum 1990). Trees and shrubs also have increased several fold in savannas on dry and mesic sites where fires have been long excluded, but dry savannas are more easily restored by fire (White 1986) and have fewer exotic invasives (Apfelbaum and Haney 1991).

Lack of understanding of the post fire successional gradient has lead to much confusion regarding definition of savannas (Henderson and Long 1984, EPA 1993). Community classification systems have largely ignored the fire gradient, suggesting that oak communities are either barrens, savannas, or forests (Curtis 1959). In the upper Midwest, these are variations of similar communities along the fire gradient. For example, barrens, or brush prairies, were once wide-spread in the Midwest. Most are now oak forests, as a result of fire exclusion. Curtis (1959) labeled barrens with jack pine (*Pinus banksiana*), pine barrens, although virtually all have some oak and, in the absence of fire, most develop into oak-dominated

forests. Consequently, most barrens in Wisconsin are now closed oak forests with varying amounts of jack pine (Haney and Apfelbaum, in press). These barrens that had as few as four trees per acre when the region was first surveyed in the mid-19<sup>th</sup> Century, were forested 100 years later (Brown and Curtis 1952).

## **METHODS**

Remnants of over 100 oak savannas were studied, located from northern Indiana through eastern Iowa and the upper peninsula of Michigan. Permanent transects were placed systematically in communities representing the full range of oak savanna types and conditions found in the region. In most cases, initial data were collected prior to any restoration effort. Many of the savannas had not been burned for 70 or more years. A few, in contrast, had been burned shortly before sampling, and some had been subjected to both grazing and fire disturbance. Restoration efforts including a combination of brush removal and fire had been initiated in savannas. Where possible, transects were placed in restored areas as well as in control areas to determine community responses to fire or other restoration treatments. Many of the oak savannas were resurveyed following restoration treatments. Where transects were resurveyed, data were treated as a separate community from the initial data. This information gave us an opportunity to determine the response of different community types along the fire gradient, providing further insight into the dynamics of oak savannas.

Transects were laid out in 50 m. segments along compass lines with each end point marked with a metal pipe. In larger communities, as many as 25 or more 50 m. segments were established along, a range from one to as many as 10 different transect lines. Tree cover was estimated along each 50 m. segment by line intercept. Trees were defined as stems > 5 cm. (2 inches) dbh. Intercept of each species was recorded separately and summed to determine the percent cover for each sample unit. Small tree and shrub species cover was estimated along the same 50 m. intercept. Small trees and shrubs were defined as living stems <5 cm. dbh, but more than 1 m. tall. Cover of all species, both herbaceous and woody plants less than 1 m. tall, were estimated in 1 m<sup>2</sup> circular quadrants centered at each 10 m. point beginning at the zero point of each 50 m. segment. In many savannas, herb layer oak regeneration was plotted in each circular 1 m<sup>2</sup>. Young oaks were defined according to whether they were seedlings (Plants originating directly from seed without resprouting), or grubs. Grubs were identified as young grubs, having a root crown diameter < 2 cm., or old grubs, those having a root crown > 2 cm. in diameter.

All trees within 1 m. of each 50 m. line were tallied by diameter and noted as to whether they were alive or dead. Ages of selected trees were determined from increment cores. In selecting trees to be cored, we attempted to sample the full range of diameters and species. Shrub and small tree stems 1 m. to the right

side of each 50 m. line were tallied; alive and dead stems were tallied separately. Basal area of alive and dead woody stems was determined at each 25 and 50 m. point along each transect segment using a 10 factor prism. Following completion of transects, a thorough search was made for species not sampled along the transects. These were recorded as present. Species cover data were summarized by mean and standard deviation, and ordinated by detrended correspondence analysis (DCA) and cluster analysis (Hill and Gauch, 1980; Gauch and Whittaker, 1981) to determine overall community similarities and relationships along environmental and disturbance gradients.

## **RESULTS AND DISCUSSION**

Oak savannas of the Midwest tend to separate into two types, those on dry sites, and those on mesic sites (Fig. 2). The former are characterized by black oak (*Quercus velutina*), Pennsylvania sedge (*Carex pensylvanica*), Hill's oak (*Q. ellipsoidalis*), post oak (*Q. stellata*), or blackjack oak (*Q. marilandica*). Mesic savannas are characterized by bur oak (*Q. macrocarpa*), white oak (*Q. alba*), northern red oak (*Q. rubra*), and swamp white oak (*Q. bicolor*). Both savanna types generally have a great diversity of forb and grass species and both are dominated by Pennsylvania sedge. The six major oak savanna associations in the Midwest are summarized in Table 1. This classification is based on ordination of 150 communities with 830 species found in 100 savannas. Our data provide a basis for interpreting savanna formations along successional gradients as well as along geographic and physiographic gradients.

**Eastern Sand Savanna** This formation occurs on sandy lacustrine and outwash plains, moraines, and dunes in northwestern Indiana, northeastern Illinois, and southwest Michigan (Henderson and Long 1984, Anon. 1983, Nuzzo 1986). Soils typically are excessively drained with very low cation exchange capacities (CEC). Organic matter in the surface soil is usually less than 2%. Litter accumulates in the absence of fire and may immobilize nutrients reducing plant productivity ((Ovington 1963). Black oak is the clear dominant but integrates with pin oak (*Q. palustris*) along steep hydrologic gradients, giving way to pin oak flats that have standing water part of the year. On soils with greater CEC in this region, white oak or bur oak are present. Black prairie soils occur in places; we describe the bur oak savanna that develops on these soils as the clay-loam savanna (see below). At Indiana Dunes, jack pine reaches its southern-most range extension where it is mixed with black oak (Bacone, et al., 1979). Hill's oak occurs on intermediate sites between black and pin oak in extreme northwestern Indiana.

Historically, intense fire in the eastern sand savanna produced a barrens formation with virtually all trees reduced to stumps in a prairie-like matrix of grass and forbs (Table 2). In experiments with fire we have used a single hot fire to convert some blocks of dry oak forests at the northwestern Indiana Jasper-Pulaski

Fish and Wildlife Area to barrens communities. In contrast, moderate to light fires reduced tree and shrub cover only 10 to 30 percent. In the eastern sand savannas, tree cover varies from virtually zero, after intense fire, to nearly 100 percent in the absence of fire for 50 or more years. In the long-term absence of fire, black cherry increases as does black oak. Under the heavier tree canopy, shrubs also increase and litter accumulates, resulting in further loss of the ground cover forbs and grasses. Light or intermediate fire, however, removes the smaller tree and shrub stems, and opens the canopy with a corresponding increase in forb and grass cover, and in species. Often as much as 30% increase in plant diversity develops the first year following moderate to hot fire. Nearly all shrubs and small diameter trees are top-killed. Species that vigorously resprout, such as sassafras (*Sassafras albidum*) or blackberry (*Rubus* sp.), sometimes increase after one fire, but are reduced by reoccurring fire. Because black oak is tolerant of fire, higher fire frequency and intensity favors black oak in the eastern sand savanna.

*Aronia* spp. often forms a dense shrub layer, especially on the mesic end of the hydrologic gradient. Staghorn sumac (*Rhus typhina*) and hazel (*Corylus americana*) occasionally form a subcanopy above the herb layer. Bracken fern (*Pteridium aquilinum*) is common, but less abundant than in the northern sand savanna (see below).

**Northern Sand Savanna** The northern sand savanna occurs from south central Wisconsin north into the Upper Peninsula of Michigan, and west into Minnesota (Grimm 1984, Matthiae and Stearns 1978). Examples are also present in north and central lower Michigan, but these were studied only casually during this project. The transition between the eastern and the northern sand savanna occurs in southern Wisconsin where many of the species which characterize these two associations occur. A distinction between the two is the dominance of black oak in the eastern sand savanna and Hill's oak in the northern sand savanna. Where ranges overlap, these species hybridize, resulting in difficulty interpreting these formations (Curtis 1959). In addition to jack pine, white pine (*Pinus strobus*) and red pine (*P. resinosa*) occur throughout the northern sand savanna (Whitney 1986). Bur oak, particularly in Minnesota, is often associated with Hill's oak. Black cherry (*Prunus serotina*), and serviceberry (*Amelanchier* spp.) are frequent in these savannas, while choke cherry (*P. virginiana*), blueberry (*Vaccinium angustifolium*), huckleberry (*Gaylussacia baccata*), and hazel (*Corylus americana*), are common. The latter species often form dense clones that may range from several square meters to several hectares. Bracken fern is more abundant in the northern sand savanna than in the eastern sand savannas. Rice grass (*Oryzopsis* spp.) is common in the northern sand savanna, but not in the eastern sand savanna.

The northern sand savannas historically became barrens when subjected to intense or frequent fire (Curtis 1959, Haney and Apfelbaum, in press). In many areas, from northern Illinois throughout the range of the northern sand savanna, hazel or blueberry formed shrub-dominated communities with an herbaceous component similar to the oak and pine dominated communities. These shrub dominated communities were fire maintained (Bowles, in press). Oaks in these barrens were reduced by fire to shrub-layer grubs. Fire suppression in Northern barrens during the past 70 years has resulted in their developing into closed forests with a canopy of black oak, or northern pin oak, and jack pine, with a scattered understory of serviceberry and hazelnut. In openings, black cherry and aspen also occur, particularly on more mesic sites. These closed forests have lost most of the associated forb and grass cover that were typical of the open barrens. Tree productivity is limited, probably by nitrogen (Tilman 1984). As a result of the nutrient limitation in the coarse, acid soils, accumulation of litter and standing crop biomass quickly curtails productivity, often resulting in high populations of small, stunted trees. Fire releases nutrients and stimulates productivity (Vogl 1965, 1964 and 1970), and leads to a remarkable increase in herbaceous species.

**Southern Oak Savanna** Extending from southern Indiana across central and southern Illinois through Missouri to Oklahoma and Texas, the southern oak savanna is dominated primarily by post oak and blackjack oak (Vestal 1936, Howell and Kucerk 1956, Stritch 1990, and Anderson and Schwegman 1991).

On deeper soils, white oak occurs while chinkapin oak (*Q. muehlenbergii*) is present on alkaline sites. In the absence of fire, these savannas are invaded by winged elm (*Ulmus alata*), Eastern red cedar (*Juniperus virginiana*), black maple (*Acer nigrum*), and sugar maple (*A. saccharum*), hickory (*Carya* spp.), and other species, with the corresponding demise of the herbaceous layer. This savanna formation is associated with older leached clay-loam soils, usually with pans or impermeable layers as well as on thin soils on steep slopes. Some of the southern oak savanna occurs on sandy soils where post and blackjack oak are scattered in sand prairies. Overall, the southern savannas are confined to sites with limited water-holding ability.

Southern oak savannas support many species that do not extend into the eastern or northern savannas (Table 2). Post and blackjack oak are virtually unknown from eastern sand savannas whereas they are dominant in the southern savanna. Many southern oak savannas look much like the eastern and northern sand savannas, and likewise were sometimes converted by fire to barrens. Fire is clearly essential to maintain southern oak savannas against the invasion of juniper, maple, and other species. Grazing

undoubtedly was important as well. Southern oak savannas frequently are interspersed with prairie openings, particularly on south facing slopes where exposure, fire frequency and intensity was somewhat greater.

**Mesic Loam Savanna** The mesic loam savanna occupies moderate to well drained loam and clay-loam soils from Ohio through southern Michigan to northern Illinois and through southern Wisconsin into eastern Iowa and southeastern Minnesota. Many of the mesic loam savannas are on bluffs and ridges or morainal deposits in soils developed in loess. They occasionally occur on thin soils over bed rock. Those on level to gently rolling topography, are more mesic and less stable. All mesic loam savannas are successionaly unstable and were historically maintained by periodic fire perhaps coupled with grazing by large ungulates. Dominant species are white oak, bur oak, northern red oak, and black oak. In the absence of fire or grazing, sugar and black maple, black cherry, shagbark hickory (*Carya ovata*), basswood (*Tilia americana*), and ironwood (*Carpinus caroliniana*), increase in the understory along with red elm (*Ulmus rubra*). A simultaneous increase in shrubs occurs until canopy closure after which these shrubs and herbaceous species decline. Although the more xeric bluff savannas are more stable, all the mesic loam savannas are more quickly invaded by shade tolerant species than are the sand savannas. Prickly ash (*Xanthoxylum americanum*), European buckthorn (*Rhamnus* spp.) and honeysuckle (*Lonicera tartarica*), are local problems where fire has been excluded for many years. The exotic garlic mustard (*Alliaria officinalis*) invades degraded mesic savannas. Good mesic loam savannas have a rich herbaceous diversity with low dominance of grasses and high cover by sedges. As these sites are opened by intense fire, prairie grasses may replace sedges as the dominants. This same trend occurs in northern and eastern sand savannas. Native shrub cover is somewhat heavier in mesic loam savannas, particularly from gooseberry (*Ribes* spp.), and viburnums (*Viburnum* spp.).

With fire exclusion, most mesic loam savannas soon develop nearly 100 percent tree cover. Dominant oaks, particularly white and red oak, and on occasion, bur oak, have wide crowns that indicate the once open to semi-open nature of these savannas prior to invasion by more shade tolerant species. Maples, hickory, ironwood, boxelder (*Aces negundo*), green ash (*Fraxinus pensylvanica*) red elm, honeysuckle, buckthorn) can form such dense shade that fire may be difficult to reintroduce, especially in the spring. Fall fires can often be used to begin to open the understory. In time, fires will again serve to continue to restore the rich diversity of the herb layer.

**Floodplain Savanna.** Floodplain savannas occupy alluvial soils in primary floodplains and upland swales throughout the upper Midwest. The dominant tree species are bur oak and swamp white oak

(*Quercus bicolor*). Cottonwood often produces structurally similar communities on larger flood plains. These savannas are maintained by fire and periodic flooding. With drainage and fire control, successional change leads to a rapid loss of the savanna characteristics with an invasion of many species including green ash, boxelder, red elm, buckthorn, bitternut hickory (*Carya condiformis*), red maple, river birch (*Betula nigra*), and others. Swamp white oak increases as well, resulting in closed canopies. These systems have become the extensive river bottom hardwood forests along Midwestern rivers. The best examples occur in coarser alluvial soils without heavy sediment deposition. Many of the species associated with the floodplain savannas are not commonly found in the other savannas of the region (see Table 2). Dominant ground cover species vary from dense stands of Virginia wild rye (*Elymus virginicus*) and wood reed (*Cinna arundinacea*) to many sedges (e.g. *Carex typhina*), and many forbs. Relatively little is known about these rare communities.

**Clay-loam Savanna.** Clay-loam savannas, otherwise referred to as oak openings or tallgrass savannas (Packard 1988), occupy poorly drained clay-loam soils derived from lake or glacial deposits throughout northern Illinois, southern Wisconsin, Iowa, parts of Michigan, and Minnesota (Stout 1944, Bray 1960, Curtis 1959). Clay-loam savannas are among the rarest and most diverse of all savannas. Clay loam savannas on level to rolling topography and include poorly drained upland swales. They may vary in species composition from domination by sedges or Canada blue joint grass in depressions that hold water to species such as Virginia wild rye and wood reed. These are similar to some floodplain savannas that quickly drain after floods. Unlike other savannas, clay loam savannas also have an herbaceous component, dominated by bottle brush grass, sunflowers and many sedge species. In a high quality site in northeastern Illinois, over 300 species of vascular plants occurred in a 4 hectare savanna. Most clay-loam savannas have been modified or lost to agriculture or development, or have been altered by regional surface drainage. Soils associated with clay-loam savannas are typically near neutral, and high in organic matter, indicating a high productivity of herbaceous species. Those that were not cleared for tillage were often used for pasture. The clay-loam savanna is quickly invaded in the absence of fire and grazing. European buckthorn is particularly aggressive in mesic soils and partial shade, and soon leads to a dense understory with a virtual total loss of herbaceous diversity and a concurrent decline in avian richness (Apfelbaum and Haney 1991). Restoration of clay-loam savannas often requires a combination of annual or mechanical reduction of woody vegetation and repeated prescribed fires. Restoration potential is high where seed banks have not been lost.

## **DISCUSSION AND CONCLUSIONS**

Oak savannas of the Upper Midwest can be broadly divided into two types, those associated with

either dry sites or with mesic sites. The former were often subjected to frequent intense fire and reduced to barrens. Barrens, primarily of fire-stunted Hill's oak and young jack pine, were once common in the upper Midwest, although shrub or grass dominated communities further south also were called barrens. Barrens represent one extreme of the fire gradient in the oak savanna complex. The three types of dry site oak savannas in the Midwest are separated primarily along a geographic gradient with corresponding difference in species. The **southern oak savanna** is characterized by blackjack and post oak. This savanna occurs on shallow soils, or soils with impermeable layers, or sands. The **eastern sand savanna** is characterized by black oak. The **northern sand savannas** are characterized by jack pine and Hill's oak. Jack pine is frequently more common than oak, although oak grubs, in the absence of fire, result in oak forests with varying amounts of jack pine.

Three types of mesic site savannas occur primarily on different soils and, therefore, are distributed along edaphic/hydrologic gradients. The **clay-loam savanna**, also referred to as the tall-grass savanna (Packard 1988), occurs on moderate to poorly drained, rich black soils characterized primarily by bur oak and a high diversity of herbaceous plants. **Flood plain savannas** occur on floodplains or along swales with other mesic or dry savannas and are characterized by bur oak or swamp white oak. They have a high vascular plant diversity. **Mesic loam savannas** vary from mesic to moderately dry sites, but occur consistently in silt loam soils often of loess origin. The mesic loam savanna is characterized by high diversity of herbaceous species and by dominant oaks including white oak, northern red oak, burr oak, black oak, Hill's oak, and occasionally chinkapin and swamp white oak.

All mesic savannas are subject to rapid invasion by shade tolerant species and exotics in the absence of fire. European buckthorn and garlic mustard present particular problems because of their rapid growth and invasions in deteriorated savannas. Native tree and shrub species such as sugar and black maple, red elm black cherry, ironwood, basswood, boxelder, green ash, and prickly ash, also are prone to invade or increase in mesic savannas in the absence of fire. As a consequence mesic savannas are typically more degraded and require more effort to restore than dry site savannas which usually can be restored with fire, often with a few successive burns. The most degraded mesic savannas have lost many of their associated native species, their soil seed-banks, and even topsoil, and require long-term restoration efforts to recover. Those with altered hydrology or that experienced severe erosion are the most difficult to restore.

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## **References**

Research for this paper is based on more than 40 references of technical materials. Contact AES for the complete bibliography.