Conservation Issues

The Historical Occurrence of Fire in the Central Hardwoods, with Emphasis on Southcentral Indiana

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ABSTRACT: Answers to questions concerning the occurrence of fire in the Central Hardwoods Region of the United States before European settlement can be found in the writings of early visitors to the region, and in the structure and composition of the forest today. There are numerous accounts by the European travelers of smoke and fire throughout the eastern United States. Most of the fires were set by Native Americans. The dominance of oaks in the uplands of the Central Hardwoods Region is another indication of the importance of fire in this ecosystem. The frequent occurrence of fire is necessary to maintain the presettlement biological diversity of the oak-dominated forests of the Midwest.

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INTRODUCTION

What did the forests of the midwestern United States look like at the time of European settlement? Braun (1950) suggested that in the eastern United States, the forests formed a closed canopy, which was interrupted only by cliffs, swamps, and barrens. Butler (1907) stated that most of Indiana had a dense, unbroken canopy except for the "poorer hillsides covered with underbrush" and "the smaller growth of less productive uplands." The General Land Office (GLO) surveyors in the early 1800s frequently encountered dry, brushy forest in southcentral Indiana. Assuming these interpretations and observations are true, much of southcentral Indiana and other similar areas in the Midwest must have been "less productive uplands."

Discussing primarily New England, Day (1953) cast doubt on "the dense, unbroken canopy" as a condition over most of North America, because of "The Indian as an ecological factor." There has been human occupation of the continent for over 15,000 years, and there is ample evidence of large areas being manipulated for hunting and agriculture by Native Americans (Noss 1985). Thus, it is more appropriate to ask, what was the pre-European-settlement forest actually like? Heinselman (1973) de-fined presettlement forests in northern Minnesota as, "those areas or forests never directly altered by man through logging, land clearing, tree planting, farming, mining, road building or similar activities. ... To do otherwise would require setting a totally arbitrary stand age."

Both Day (1953) and Heinselman (1973), working in regions generally not considered to be fire dependent, showed that fire was,. in fact, a regular if not common occurrence. Since it has been shown that many fires were set and areas were kept clear for villages and agriculture by Native Americans (Noss 1985), it is necessary to change "man" to "Europeans" in Heinselman's definition. The majority of temper-ate North America was influenced by Native Americans, but the land was not altered on a grand scale or **permanently** until European settlement. Thus, the pre-Europeansettlement forests are "those areas never directly altered by Europeans."

How, then, do we determine what these forests were like, and what ecological processes were working on the landscape before European settlement? How important was fire? How much of the land burned and how often? Unfortunately, there are few collections of information to draw from to answer such questions.

Because ecological processes do not follow political boundaries, but rather natural features such as geologic formations and watersheds, southern Indiana has similarities to adjacent portions of adjacent states. The Shawnee Hills Natural Region ex-tends from southcentral Indiana, arcs through western Kentucky, and crosses extreme southern Illinois (McNab and Avers 1994); all of these areas are ecologically similar. Likewise, the Highland Rim Natural Region extends from southern Indiana across Kentucky and Tennessee and into northern Alabama (McNab and Avers 1994). Southern parts of the Highland Rim resemble southern Indiana. Oak-dominated central hardwood forests extend from the Appalachian Mountains to the Ozark Plateau and the midwestern prairies (Braun 1950). Including these similar areas in an inquiry into the historical occurrence of fire in the Central Hardwoods increases the available information about the character and ecological processes of the region.

Information about ecological processes in Indiana at the time of European settlement is difficult to find because settlement of the Indiana Territory north of the Ohio River

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could only advance as the "danger of Indian hostilities lessened" (Buley 1950). An-other reason that southcentral Indiana was slow to be settled was the lack of consistent sources of water (Wilson 1910); with-out permanent water, there was little reason to keep settlers in the area. Flint (1822) noted: "It is not uncommon now to see mill streams entirely dried up."

The notes from the GLO surveys offer the most comprehensive set of data over most of the United States. These surveys were conducted primarily before settlement, and they cover practically all lands north of the Ohio River and west of the Mississippi River. Some areas south of the Ohio River (Delcourt and Delcourt 1974) and in New England (Marks et al. 1992) also were surveyed. The surveyors' notes typically include whether the land was in timber, barrens, or prairie; the dominant species of trees; the character of the land; the quality of the soil; and the presence of streams (Hutchison 1988).

Another source of firsthand descriptions of pre-European America can be found in the writings of the early visitors and settlers. Because these writings were neither systematic nor reproducible, they are rarely used in reconstructing the pre-European landscape (Ladd 1991). They are, however, the most valuable source for determining common events and uncommon plants and animals, things usually not mentioned in the GLO notes. Ladd (1991) correctly noted: "Despite the authors lack of formal education in ecology and putatively 'unscientific' outlook, early accounts are extremely valuable sources. These individuals had the unsurpassable advantage of actually having seen presettlement landscapes and aboriginal land management practices."

Letters and diaries of early travellers make generalizations about what areas were like and what was going on, such as activities of Native Americans (Bartram 1791), fires (Faux 1823), storms (Bartram 1791), and great migrations (Audubon 1831). A few postulated why areas looked as they did (Bourne 1820). Other writers were very specific about given locations, especially unusual inclusions within the landscape, and included lists of plants and animals (Bartram 1791, Michaux 1796, Michaux 1802, Schoolcraft 1820, Audubon 1831). Descriptions of the forests are summarized in county and state histories (Chamberlain 1850, Stout 1885, Butler 1907,Wilson 1910).

Fire is an important tool for managing the landscape. As Heinselman (1973) said, "lb understand the dynamics of fire-dependent ecosystems fire must be studied as an integral part of the system. The search for stable communities that might develop without fire is futile and avoids the real challenge of understanding nature on her own terms." To be able to use fire effectively, Mutch (1991) added, "Fire history and fire regime information [is] not just `nice to know' reference data, but rather [is] absolutely essential background data for the appropriate design and implementation of resource management projects at the ecosystem and landscape level of organization".

DID THE CENTRAL HARDWOODS REGION BURN?

There is widespread evidence of the occurrence of fire throughout eastern North America. Direct evidence comes from first-hand observations of smoke, fire, and descriptions of fire-killed timber. Indirect evidence is found in the character of existing forests and the forests as described by early visitors.

Some parts of the Midwest were known for their smokiness at certain times of the year. An early surveyor of the Ohio River, A. Ellicot, in 1796 noted day-long fog and smoke near Gallipolis, Ohio, because of "the effect of fires extending over the vast forests of our country" (Gordon 1969). Ladd (1991) cited numerous authors who discussed the occurrence of fire in the early European settlement period in Missouri. Seasonal fires were also seen in Indiana. Faux (1823) mentioned in his travels near Princeton, Indiana, the day-long smoke of "Indian Summer." "Indian Summer" was typically a time from mid-October through early November after the first killing frost throughout the Ohio and Mississippi valleys (McClain and Elzinga 1994). It was a period of dense smoke, gray skies, and a red sun. Faux (1823) said that the fires of "Indian Summer" crossed both prairie and forest.

There are many accounts by early travellers describing large stands of trees that had died because of fires Williams 1994). However, Day (1953) noted "that there is no evidence in the early authorities for the wholesale conflagration of southern New **England . . .** but only **burning** 'in those **places where *Indians* inhabit,' and outside** the swamps." Likewise, in the Midwest, there is no evidence of widespread, all-consuming fires.

Among the features noted by the GLO surveyors were disturbances, including fire kills. References to fire-killed trees are relatively rare in the notes, but evidence of fire-killed trees has been found through-out the eastern United States. About 0.10% of the lines surveyed in western New York in 1790 had timber killed by fire (Marks et al. 1992). Fire kills are also rare in the GLO notes from Illinois but did occur in at least the Wabash River valley and in the hills of western Illinois (Hutchison 1988). "Timber this mile chiefly destroyed by fire" was a comment made during the GLO survey in Spencer County, Indiana, along the south line of the property settled by the Lincoln family (Bearss 1967).

The GLO notes from within the area now encompassed by Hoosier National Forest in Indiana describe three areas where fire had killed timber. One section line about 5 miles east of Tell City **had "poor brushy** hills; timber dead by fire." At the opposite end of the national forest area, about 2 miles west of Waymansville, the comment was "hilly and poor; w & b oak; mostly killed by fire." An adjacent line outside the national forest area also had fire-killed timber. The largest burned area mentioned in the GLO notes was about 5 miles east of Shoals. Three contiguous lines inside the national forest and three more outside mention that timber was "all" or "mostly killed by fire."

It is likely that the effects of surface fires, which were quite common, based on the writings of early travellers, went unreport-

ed by the GLO surveyors owing to the fires' widespread nature. They also may have gone unreported because they were covered by the regrowth of woody vegetation (Marks et al. 1992). It appears that catastrophic fire was quite rare, but low, creeping fires were so common as to go unrecorded by the surveyors.

Among the more common line comments in the GLO notes from the area now within Hoosier National Forest are descriptions of "brush" of oak or beech, or other species more typically associated with the forest canopy. This may be attributed to the interruption of short-return-interval fires. Timber kills reported by the GLO surveyors may also have resulted from this. Where there is several years' accumulation of greenbriers, fuel loads may be heavy enough to kill timber (S. Olson, pers. obs.).

Fire may explain the frequent observations made by European travellers of a lack of undergrowth in many forests of the eastern United States. In his review of the literature concerning the Native American influence on the landscape of the North-east, Day (1953) cited authors as far back as 1670 who attributed the open character of the forest to annual burning. In discussing the presettlement character of Missouri, Ladd (1991) cited about 20 accounts of early residents from the prairies, wood-lands, and river bottoms throughout the state. A common thread running through these statements is the openness of the understory and the occurrence of fire. Frequent fires tend to resemble low-intensity prescription burns (Day 1953). Such fires modify species composition and create parklike stands without destroying the herbaceous layer and animal life (Day 1953).

Early travellers through eastern North America frequently noted fire and the open character of the forest. Many accounts remarked about the lack of understory to impede travel. Vogl (1972), for example, found that most uplands in the Coastal Plain and Piedmont in the Southeast were "occupied by a pine savanna rather than a forest." The barrens of Pennsylvania grew into forest by 1800, after the annual fires stopped when the region was settled in the 1730s (Tyndall 1992). Croghan (1765) wrote of the Big Bone Lick area of Boone County, Kentucky, in May 1765: "In our way we passed through a fine timbered clear wood." Low-intensity surface fires kept woodlands open in the Ozarks (Guyette and Cutter 1991). The GLO notes in southcentral Indiana frequently mention clear understories, but there are also many notes of brushy undergrowth as well.

The brushy character of many areas also can be attributed to frequent fire (Marks et al. 1992). If short-return-interval fires are interrupted for several years, allowing undergrowth to advance, when fire re-enters the ecosystem, a brushy forest understory can result and persist for many years. The writings of early travellers in the Midwest support this pattern (Ladd 1991). There is a flush of woody growth, frequently dominated by the "grub"- forming oaks, which form dense thickets. Oak "grubs" have root systems equivalent to those of mature trees (Peet and Loucks 1977).

Fire suppression began several hundred years ago in New England and about 100 years ago in the Ozarks (Johnson 1993). Annual burning continued until very recently in some areas of Illinois (Anderson and Schwegman 1991). Areas within the Hoosier National Forest boundary are known to have burned regularly as recently as the 1970s, until they were acquired by the federal government (R. Roark, Recreation Technician, Hoosier National Forest, Tell City, Indiana, pers. corn.). Tree stern analysis from sites in Hoosier National Forest show that fires intense enough to scar trees occurred at 5- to 7-year intervals but ceased when the land was acquired by the federal government.

In the Great Lakes region, canopy oaks are declining and regeneration is poor in the dense shade of beech *(Fagus grandifolia* Ehrh.) and maples *(Ater* spp.) (Apfelbaum and Haney 1991). The situation is much the same in Hoosier National Forest (Hoosier National Forest 1990). Since the onset of fire suppression, the open oak forests and woodlands have become closed forest stands, but without a concurrent change in the herbaceous flora toward shade-tolerant species (Packard 1991). When such areas are burned and the mesic understory trees are killed, the prairie and woodland plants display better growth and flower profusely (S. Olson, pers. obs.). Such behavior indicates that it is reasonable to assume that these forests were formerly subjected to frequent fire.

Many existing oak-dominated upland forests in the Midwest have large old trees with wide-spreading branches that appear to have been **open** grown (Stritch 1990; S. Olson, pers. obs.). Coming in beneath these forests now are much smaller and younger trees, with narrow crowns, that are typical of mesic situations. On the forest floor are many herbs that prefer open woodland or prairie conditions. Mead's 1846 list of plants of western Illinois has many species that do as well in full sunlight as in partial shade, but which decline under a closed canopy (Packard 1991). The dry slopes and ridges of southern Indiana dominated by oak contain many of the same species. Most of these are present as weak flowering individuals or rosettes.

WHY DID THE LANDSCAPE BURN?

Without question, fire was a significant part of the pre-European-settlement for-est. There were two sources of ignition of fires prior to European settlement—Native Americans and lightning. Human-caused fires generally do not coincide with the timing of natural fires (Martin 1991). Lightning fires are most likely to occur in late summer in the Midwest, whereas anthropogenic fires occur most often in the spring and fall of the year. Michaux (1802) recorded fires in the barrens of Kentucky in March and April.

It appears that Native Americans set most of the fires. Native Americans would use fire to clear bottomlands for agriculture and villages. Bourne (1820) observed that Native Americans set fires to make travel easier, to aid in hunting, and to encourage the growth of grasses. Day (1953) cited several reasons for burning the forests, including improving visibility, reducing populations of insect pests, and offensive and defensive warfare. Native Americans also used fire to improve berry crops (Vora

1993). Williams (1994) listed several additional reasons why Native Americans burned the landscape: to prevent uncontrolled fire, to collect insects as food, to control access to resources, and to help in felling trees. Native Americans burned to promote diversity of habitats, whereas European settlers **burned** to create uniformity for safety and because of their "need" to be self-sufficient on their property (Williams 1994).

Lightning also is a significant cause of fires in the **humid** East. **Although** rain **usu**ally accompanies lightning, the open character of ridgetop forests with large, often hollow trees is ideal "habitat" for smoldering embers,which can later spread to dry leaf litter (Martin 1991). The typical behavior of lightning suggests that most lightning-ignited fires begin on ridges, where dry-site oaks typically dominate.

Fire history of a given site varied with its **physiographic** characters (Kline and Cot-tam 1979). Exposed ridges and dry south-to west-facing slopes would have burned more frequently than protected slopes and mesic sites. Swamps and deep ravines protected by high cliffs, for example, would have burned only rarely. Fire in creek bottoms can maintain oak openings in wet prairies (McClain et al. 1993). Historically, the extent of fires varied with drought cycles, in that more land burned during dry periods. Many fires continued to burn until the next rain or until factors con-trolled by local **physiography** put them out. Once an area was settled by Europeans, fire frequency declined, closing the understory of the open woodlands and al-lowing forests to grow in what had been barrens. The barrens of Pennsylvania and Maryland were burned annually at least through 1731 (Tyndall 1992).

WHAT IS A FIRE-DEPENDENT ECOSYSTEM?

To fully understand how and why the central hardwoods ecosystem is fire dependent, it is necessary to know what makes an ecosystem fire dependent and how the species in the ecosystem are adapted to such conditions. Mutch (1991) offered this definition of fire-dependent ecosystems:

> An ecosystem can be called fire de-pendent if periodic changes in the system due to fire are essential to functioning of the natural system. In such systems fire is a significant environmental factor that initiates and terminates key vegetational successions, regulates the age structure and species composition of vegetation, produces the vegetation mosaic on the landscape, affects insects and plant diseases, influences nutrient cycles and energy flows, regulates the productivity, diversity, and stability of ecosystems, and determines the habitats of wildlife.

Fire suppression favors oaks over grasses because the growing point of grasses is below the surface of the ground while that of oaks is exposed to flames. This in turn reduces both the loading of fine fuels and fire intensity by removing large amounts of heavy combustible material (Guyette and Cutter 1991). Suppression also favors sugar maple *(Acer saccharum* Marshall) **and beech over the upland oaks (Packard** 1991). **Beech and** sugar **maple lack** the **adaptations** of **oaks that** make them more susceptible to damage from fire. In addition, the shade produced by the canopy of oaks moderates temperature and moisture conditions at a site. Without fire, the mesophytic sugar maple and beech may gain a foothold on such sites.

The absence of redcedar *(Juniperus virginiana* L.) and winged elm *(Ulmus alata* Michx.) on dry sites is an indication of recurring fire (Fralish et al. 1991). Neither of these species was mentioned by the GLO surveyors in southcentral Indiana. Red maple *(Acer **rubrum** L.)* and ragweed *(Ambrosia* spp.), species adapted to soil disturbance but not well-adapted to fire, became abundant with European settlement of the Highland Rim, according to sediment analysis (Delcourt 1979).

Fire regimes vary over short distances with soil, geologic, and topographic factors. Fire does not travel as well over steep terrain (Anderson 1991). Fire moves up slopes more readily than down slopes because of convection and radition. During daylight hours, winds move heat and fire upslope **through convection and surface heating.** Fire moving downslope works against these forces and thus moves more slowly. Savannas and open forest historically formed in areas where fire frequency was reduced by dissected **topography** and/or low fuel loads (Anderson 1991). Being more ex-posed to the drying effects of sun and wind, south- to west-facing slopes tend to burn hotter and more frequently than other slopes. Anderson (1991) tied the presence of prairie vegetation to **topography** be-cause of the frequency of fire. Where beech and sugar maple occur, fire has been re-moved from the system as a result of either suppression or **physiographic** position. The beech–sugar maple condition tends to reinforce itself because this forest type itself is less flammable. Fire tends to create a more open forest and causes oaks and hickories to "grub" when top-killed (Peet and Loucks 1977). Upland oak forests depend on occasional fires to maintain open conditions (Anderson 1991). Packard (1991) noted "regular burning is necessary to pre-vent rapid loss of the shade intolerant herb component to increasing shade from shrubs and trees."

Certain types of vegetation are **thought** to perpetuate themselves based on the fire regime within which they developed (Kline and Cottam 1979). It is difficult for forest to invade established grasslands because of intense competition for moisture and light. It is difficult for grassland vegetation to invade forests for the same reasons (Barnes 1948). Fire selects for fire-resistant species (Peet and Loucks 1977). Few trees of bottomlands are adapted to fire, while nearly half of those on dry ridges are fire dependent (Martin 1991). Species of mesic upland sites have wider ecological amplitudes and are more difficult to predict in their reaction to fire. Among understory trees and shrubs, very few do not have the ability to resprout after fire (Martin 1991).

Upland oaks have several physiologic adaptations to frequent fire, including: thick bark, resistance to rotting, sprouting ability, fire-created seed beds, deep roots, xe-**romorphic leaves, and high photosynthetic** rates during drought (Abrams 1992). These characteristics give them greater resistance to *fire* than "late-successional" species.

Oak forests on bottomlands, particularly pin oak *(Quercus palustris* Muenchh.) stands, have trees with thin bark and seldom encounter fire.

The occurrence of fire in uplands appears "to be the common denominator for the development of oak forests" (Abrams 1992). Most upland oaks require occasional disturbance to reduce competition (Johnson 1993). The predominance of shrubby oaks in western New York forests may be attributed to frequent fires set by Native Americans (Marks et al. 1992). Natural communities in the Shawnee Hills were influenced by large herbivores, storms, disease, drought, and fire, which kept ridgetop forests open and "savanna-like" (McNab and Avers 1994). Fire appears to have been a dominant feature of the landscape, and many species of the Midwest thrive with fire. Many forest trees other than oaks are also fire tolerant or at least require exposed soil, such as results from fire, for germination of seeds (Martin 1991). Even some mesic forest species may require fire for their existence. Eastern hemlock *(Tsuga canadensis [L.]* Carriere), for example, is well suited to the invasion of burned ground as well as blowdown areas (Henry and Swan 1974).

"Not al[l oak dominated ecosystems re-quire fire or disturbance for their sustainment. Many xeric forests appear to be relatively stable communities that show little evidence of succession to shade tolerant or mesophytic species" (Johnson 1993). Examples of this situation in Hoosier Nation-al Forest are some of the dry sandstone ridges dominated by chestnut oak *(Quercus prinus L.),* and the most open parts of the barrens dominated by post oak (Q. *stellata* Wangenh.) and Indian grass *(Sorghastrum nutans [L.]* Nash).

Many prairie and forest species overlap in their habitats; this overlap varies with drought cycles, fire, and other disturbances (Bronny 1989). In 1846, Mead listed plants that occurred in both forest and prairie (Packard 1991); many of these plants of western Illinois are common in the oak forests elsewhere in the Midwest. Many herbs usually associated with mesic forest have wide ecological amplitudes and can be found in a wide variety of forest conditions. Shade-tolerant species are found in ravines and near streams where stand density is greater than on uplands.

Fire enhances habitat for ground- and brush-foraging birds (Martin 1991). Wood-peckers, especially common flicker, are well adapted to open forests. Many other birds, including Bewick's wren, eastern bluebird and eastern screech-owl, take advantage of cavities woodpeckers make for nesting. Several species of migratory birds that have declining populations may be fire dependent, including prairie warbler and Bachman's sparrow. Raptors will use snags killed by fire.

Fire may affect the phenological development of an ecosystem (White et al. 1991). Nutrient release, elevated soil temperature, and increased available light can lengthen the growing season of plants. On the other hand, if fire occurs during the growing season, plants may be stressed, thereby reducing their productivity.

While many authors have emphasized forest succession, relatively few have discussed the importance of catastrophic disturbance and the changes in vegetation it brings (Henry and Swan 1974). Removal of fire from fire-dependent ecosystems can be considered a catastrophic disturbance (Packard 1993). Vogl (1972) noted that, "Without repeated disturbance the grass-land species become decadent, deteriorating until they can no longer compete with the advancing woody plants and trees." This so-called "artificial succession" is what happens when fire is removed from fire-adapted ecosystems (Packard 1993). Artificial succession leads to a reduction in the diversity of the ecosystem (Packard 1993). Beech and sugar maple enter the understory of the oak forests creating dense shade, which prevents the successful re-generation of the oaks. Curtis (1959) saw this occurring in the forests of Wisconsin, where he observed that white oaks did not regenerate in stands where canopy closure was greater than 85%. At the same time, maples are replacing oaks in the forests of the Midwest, and other plants and animals of the oak woods, in turn, are being lost (Packard 1993).

Interruption of fire is only one disturbance to the **oak-dominated** ecosystem. Other disturbances include the local extinction of elk and bison, and the activities of settlers in open areas (Stitch 1990).

A brief discussion of barrens is necessary because of the proximity of the barrens regions of Indiana and **Kentucky** to the Central Hardwoods Region, and the importance of their management to Hoosier National Forest and other midwestem land management agencies. In its classic sense, "'barrens'... is used in the west to designate a species of land which partakes, as it were, at once of the character of the forest and prairie" (Ellsworth 1838). Boume (1820) attributed the existence of barrens to fire. Flint (1822) attributed the barrens to frequent fire. Butler (1907) believed that meadows, probably referring to barrens and prairies in the southern part of Indiana, were "the result of the destruction of the forest by Indian fires." He noted that the soil of many barrens was rich, capable of producing good timber, especially after settlement by Europeans, who seldom set fires. Ellsworth (1838) seems to concur with Bourne (1820): "When the fires are stopped, these barrens produce timber, at a rate of which no northern emigrant can have any just conception." Another suggested explanation for why some barrens may have grown in so rapidly following settlement is that birds and mammals may have cached acorns in them (Mclnteer 1946).

While the rich soil of barrens rapidly produced timber in many areas, especially large barrens regions of Illinois, Indiana, Kentucky, and Tennessee, the existence of outlying barrens appears to be more strongly influenced by edaphic conditions. The "barren" noted by the GLO **surveyors** near the present site of Derby, Indiana, is one example. The extensive barrens region of Indiana is about 20 km away from the Derby barrens, which is situated on a thin band of limestone and calcareous shale on a high ridge and extends onto a south-facing slope. Soils are thin and droughty. This site retained its open character well into the 1950s, in large part because of its exposure to extreme conditions. Also influencing the openness of the site were occa-

sional fires set by the **landowner.** Barnes (1948) noted that many tree species appear to be less tolerant of calcium carbon-ate than grasses, which may partly explain the distribution and appearance of this barrens.

WHAT OTHER PROCESSES MAY HAVE CAUSED THE OPEN CHARACTER OF THE CENTRAL HARDWOODS?

It is possible that other factors may have caused or contributed to the open forests mentioned in early writings. The factors most often suggested are herds of grazing animals, passenger **pigeons,** and storms.

Ungulates, such as elk and bison, could have influenced herbaceous species composition of forests, favoring grassland over forest species (Vora 1993). Furthermore, grazing and browsing of woody stems can create **brushy** appearing plants resembling those resulting from burning. Trampling of the vegetation would also be a factor. While disturbances from grazing animals certainly did occur, it seems unlikely that they constitute the primary cause of the open character of the central hardwood forests. Croghan (1765) noted in Boone County, Kentucky: "We came into a large road which Buffaloes have beaten, spacious enough for two waggons to go abreast." In the late 1700s both Boone and Filson saw herds of hundreds of bison in central Kentucky (Martin 1991). There is no evidence, however, of herds comparable to those of the prairies and plains. Bison, elk, and deer were found in the Ohio River valley, but herds were not of sufficient size to maintain the character of the entire region.

Herds of grazers would have had more of an effect on the distribution of fire. Herds of ungulates reduce fuel loads, locally creating fire breaks. In **subsequent** years, the unburned areas would be grazed so that they would not burn, allowing the other portions to burn (Pyne 1986).

Passenger pigeons may have had a more widespread effect on the forests because of their feeding behavior. A flock of pigeons would cover several acres scouring the forest floor for food (Bradbury 1819). As the flock progressed, birds from the rear would fly and land at the front. From their roosts, pigeons travelled up to 400 miles a day in search of beechnuts. Roosts, up to 6 miles in circumference, covered the woodlands and barrens (Faux 1823). One roost near Huntingburg, Indiana, killed several square miles of timber, according to the GLO surveyors (Hutchison 1988). It is likely that the timber was killed by many years' accumulation of pigeon droppings.

Disturbance features were noted by the GLO **surveyors.** Storm damage, most of-ten large windfalls and "hurricanes," was rarely mentioned. Storms that blow down large areas of forest create conditions in which fire may occur because of large quantities of drying fuel. Burned areas related to large windfalls are typically larger than the windfalls themselves (Marks et al. 1992). One area of windfall was observed by the GLO surveyors within the Hoosier National Forest boundary, and a handful of other lines were noted adjacent to the Forest. Windfalls, however, were not large enough or widespread enough to maintain the open character of the forests.

DISCUSSION

The following discussion was adapted from Ladd (1991).

The vegetation of the Midwest, including all of the organisms comprising its wood-land systems, has evolved under a regime of frequent, low-intensity fires since the glacial period. Recurring fires perpetuate the oak-dominated forest by preventing the establishment of species that are sensitive to fire. Thus, recent attempts at wood-land preservation, which include fire suppression, have created what may be the first prolonged fire-free interval in the history of the central hardwoods ecosystem. Many oak woodlands throughout the Mid-west have an increasingly large component of mesophytic species, particularly beech and sugar maple, in their unburned understories. Such an abrupt change is bound to bring major structural and compositional alterations.

It is often argued that even if frequent fires were part of the region's presettlement landscape, such fires must have been anthropogenic in their origins and hence "unnatural." Proponents of this viewpoint assert that by interrupting the fire cycle, "natural succession" will reassert itself. Regardless of perceptions of the "naturalness" of various factors and beliefs that diverse mesophytic systems may have existed in the region prior to Native American **occupation,** the **vegetational** assemblage present immediately prior to settlement is all that remains. A rich association of mesophytic organisms from the eastern cove forests is not likely to migrate into the midwestem oak **woodlands** across **today's fragmented landscape.** To **allow midwestern woodlands to degrade and become depauperate** in the name **of** "natural succession" would result in continuing loss of **biodiversity** without any possibility of corresponding gains. Wilhelm (1991) has questioned the entire concept of succession and climax vegetation as applied to midwestem woodlands.

In the postsettlement environment, normal migration patterns and processes for dispersion and recolonization by conservative organisms have been completely disrupted (Wilhelm 1991). Because abrupt changes in the abiotic factors influencing natural systems appear to result in a loss of native species, and because there are no longer adequate mechanisms for recolonization by conservative species adapted to the new environmental parameters, the overall effect of such actions will be one of decline and loss. This decline will be compounded by the presence of an expanding group of Old World plants well adapted to invading fire-free woodlands, such as garlic mustard *(Alliaria petiolata* [Bieb.] Cavara & Grande) and Amur **honeysuckle** *(Lonicera maackii* [Rupr.] Maxim.).

A totally different vision emerges when current concepts of woodlands are reconciled with information from early descriptions. Many woodlands, even in closed-canopy situations, may have been largely devoid of **understory** over large areas, or with only low, frequently top-killed shrubs. There was often a **well-developed** ground layer of vegetation interspersed with the rich and diverse assemblage of flowering plants mentioned in some early accounts.

Presence of a well-developed ground layer does, not automatically imply a dense stand of warm-season prairie grasses. Woodlands on less productive soils may have been dominated by sedges and smaller grasses, including James's sedge *(Car-ex jamesii* Schwein), few-fruited sedge (C. *oligocarpa* Schk.), rose sedge (C. *rosea* Schk.), false brome ***(Brachyelytrum*** *erectum* [Schreber] P. Beauv.), woodland **brome *(Bromus pubescens* Muhl.), wood** reed *(Cinna* ***arundinacea L.),*** twingrass ***(Diarrhena americana*** P. **Beauv.),** Virginia wild rye ***(Elymus virginicus L.),*** wood-land fescue *(Festuca subverticillata* [Pers.] E. Alex.eev.), and woodland bluegrass *(Poa sylvestris A.* Gray). Fires in these fuels would have been far less intense than fires in tallgrass prairies. With frequent bum cycles, these fires would have occurred under low fuel loads with relatively fast rates of spread, short contact periods, and **patchy burn coverage.**

Not all of the forests of the Central Hard-woods Region were of uniform composition and character. The geology and, there-fore, the topography, soils, and vegetation of this large part of the Midwest varied considerably. **Physiography** and waterways prevented some areas from being burned regularly, allowing them to become more mesic in character and, thus, provide refuge to species requiring such conditions. Curtis (1959) showed that fluctuations in climate could cause substantial movements of major vegetation types in an area over a relatively short period of time. The degree of human habitation would vary with local conditions as well, but there is no evidence to suggest changes in the way Native Americans managed the landscape during their occupation.

The available information suggests that the presettlement central hardwood forests were very different in character and appearance than present-day forests, and that these woodlands were influenced by frequent fires for a long period prior to European settlement. Pre-European-settlement woodlands are often portrayed as being more open, with widely spaced trees, little or no brushy understory, and well-developed groundcover vegetation.

Reintroduction of fire to the central hard-woods forests is not a panacea for full ecosystem recovery. Many other equally important factors are vital to the ecological health of a woodland system, including hydrology, soils, plant/soil reactions, erosion, minimum area considerations, and other often poorly understood criteria.

Much of the failure to understand the true nature of midwestern forests derives from an overly simplistic, two-sided concept of presettlement vegetation. Because the two major vegetation types mapped in the original land survey were timber (including barrens) and prairie, the two have been considered mutually exclusive systems—one of trees and one of grass. This view has been reinforced by studies conducted in modern woodlands, which reveal a composition, structure, and light level totally incompatible with a well-developed graminoid or groundcover vegetation. It seems more reasonable to propose that present-day woodlands may not resemble the pre-settlement woodland systems, and that the latter may have been adapted to and even dependent on fire for their continued existence.

Woodland management and assessment are too often predicated on trees. Unfortunately, this view often ignores non-tree components of woodland systems, of which there are orders of magnitude more than there are trees. Many of these organisms are far more conservative and restricted in niche than characteristic trees. The notion that a healthy forest is always characterized by an abundance of large, old, straight trees sounds plausible but is ultimately counterproductive. Just as prairies are not assessed by the age and form of grass clumps to the exclusion of other biota, woodlands should not be evaluated exclusively by the age and form of their trees.

A subtle but potentially devastating bias has influenced perceptions of woodland management to date: when in doubt about the role of fire, it is safer not to burn. There are frequent calls for studies to be con-ducted on an area before considering fire management, but no accompanying call for similar studies and justification on unburned woodland areas. There is a fundamental flaw in this approach: the decision not to burn is a management action with at least as many ramifications and potential pitfalls as the decision to burn. In light of available evidence about the pervasiveness of fires in the pre-European-settlement woodland systems, it seems that **stronger justification should be required** for the exclusion of fire from a site.

For areas subject to fire management, a widespread and prevailing belief is the desirability of using relatively infrequent fires to allow areas to "recover." This could prove to be a more harmful action than regular fires at frequent intervals. Frequent fires generally would occur under lower fuel loads, producing a more patchy burn coverage, rather than the more complete and uniform coverage produced by burns at higher fuel accumulations. The patchier burn coverage of frequent fires creates more diversity of habitat, allowing more species to inhabit the forest.

The presettlement woodlands of the Central Hardwoods Region encompassed a diverse array of landscapes capable of **evoking thoughtful** comment from many early travellers. To maintain these wood-lands as sustainable and functional systems, we must ensure that we are maintaining the complex of biotic and abiotic factors to which these systems have be-come acclimated. Such factors are required to sustain the full spectrum of biotic diversity in these systems.

If preservation of presettlement ecosystems and their inherent biodiversity is a worthwhile goal, as acknowledged in the mission statements of various public and private environmental conservation agencies, then steps should be taken to ensure that representative examples of midwestern woodlands are managed in a manner that sustains their presettlement character. Attempts must be made to retain those components of presettlement biological systems that are still present. Protocols for woodland natural area management should include provisions for assessing effects of reintroduction of fire under a regime approximating aboriginal fire cycles.

CONCLUSION

Humans have occupied the Central Hard-woods Region since the last glaciation, and there is abundant evidence *of* their effects on the landscape before the arrival *of* Europeans. The early European visitors observed Native American management *of* the landscape, which included intentional use *of* fire. There was at least one other source *of* fire: lightning fires occurred regularly.

The historical occurrence *of* fire can ex-plain both the lack *of* a woody understory in some oak forests and the brushiness *of* other oak forests. Herds *of* grazers may have influenced the structure *of* the forest but probably were not the primary determinant *of* the character *of* the woodlands.

The trees coming up in the understory *of* today's oak woodlands are mostly species that are shade tolerant. Oak regeneration is generally poor. The herbaceous flora remains typical *of* oak forests, but individuals appear weak from lack *of* sufficient light.

It seems that the central hardwoods is a fire-dependent ecosystem because the herbs recover their vigor, oaks resume re-generating, and shade-tolerant trees de-cline when fire occurs. The absence *of* fire-sensitive species in descriptions *of* the pre-European settlement forest also leads to this conclusion.

Fire suppression since European settlement has created the longest period with-out fire in the history *of* the Central Hard-woods Region. This sudden change in fire regime has resulted in the *loss of* diversity in the region. To regain the former diversity of the central hardwoods, fire should be reintroduced to the ecosystem in a con-trolled mariner.

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