

A Field Survey of the Yellowwood, *Cladrastis Lutea*, in Brown County, Indiana

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Introduction

From a biogeographical viewpoint Indiana is blessed with a rich and varied flora. Within the state is situated the maximum extent of three glacial ice sheets, the eastern edge of the prairie peninsula, the northern extent of lowlands representing the Mississippi embayment, and remnant uplands of the original Highland Rim Peneplain. Thus it is no surprise that the state has been described as a "critical botanical area" (7). Indeed, a number of plant species native to Indiana are represented by disjunct populations lying on the periphery of the species' natural range.

Uncommon or rare native trees of Indiana with disjunct populations include eastern hemlock, white pine, yellow birch, and bald cypress, among others. Such populations may be relicts of a contracting, formerly more extensive distribution in the area, or colonizers within a species' newly expanding range. In either case, disjunct or relict populations are often important as indicators of rare or unique habitats and significant natural communities. Perhaps the most prominent disjunct population of a tree species in Indiana is that of the yellowwood, *Cladrastis lutea* (Michx. F.) K. Koch.

The yellowwood, which is a small to medium sized tree with smooth gray bark, is distinguished by pinnately compound leaves of alternating leaflets and a prolific number of showy blossoms when in bloom. The tree's drooping panicles of white pea-like flowers which occur in late spring identify it as a member of the bean family, Leguminosae, which also includes the better known redbud, black locust, and honey locust trees. Taxonomists include four more species in the genus *Cladrastis*, all restricted to China and Japan (14).

The yellowwood, the sole member of its genus in North America, is endemic to unglaciated portions of the central and eastern United States. Its occurrence is sporadic and rare throughout its range due to its rather limited habitat. It is most commonly found in three areas; the Great Smoky Mountains, the Ozark Mountains, and along the Kentucky River and its tributaries in the Bluegrass region of Kentucky. Altogether the yellowwood is found in eleven states; Kentucky, Tennessee, North Carolina, South Carolina, Georgia, Alabama, Arkansas, Oklahoma, Missouri, Illinois, and Indiana (12). Its distribution by county is illustrated in Figure 1.

Yellowwood populations are restricted to two main types of habitat within its range; moist coves of mixed mesophytic forests as in the Great Smoky Mountains, and steep, exposed river bluffs as in the Ozarks and along the Kentucky River. Due to its rare occurrence and the destruction of thousands of these trees by inundation from man-made reservoirs in Arkansas and Missouri, it has been suggested that the yellowwood tree be placed on the federal list of endangered plant species (14).

The northernmost natural population of yellowwoods occurs in Brown County, Indiana. A stand was initially discovered there in 1933 by two employees of the Civilian Conservation Corps while working in the former Brown County State Game Preserve (now Brown County State Park). This site, a steep ravine near the head of Ogle Hollow, was promptly visited by the botanist Charles C. Deam, who collected specimens (Deam's specimen # 54,279; Indiana University Herbarium # 77,769 and 77,770) and reported the find in the Proceedings of the Indiana Academy of Science (4).

A second stand of yellowwood trees was subsequently discovered approximately

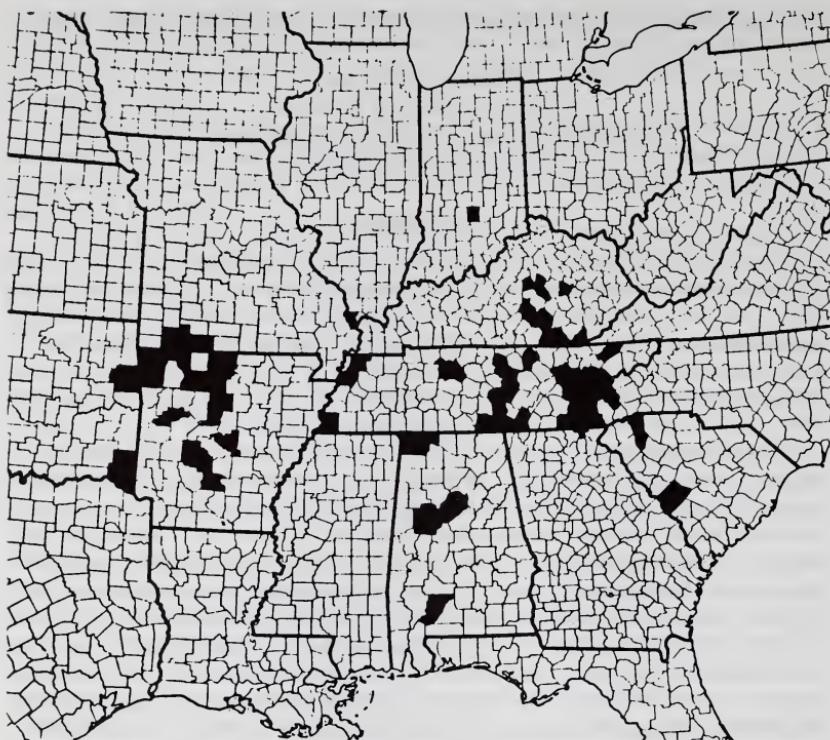


FIGURE 1. Distribution of *Cladrastis lutea* by county.

eight kilometers (five miles) southwest of the Ogle Hollow site, for which Yellowwood State Forest was named. It was thought that this stand of trees was inadvertently cut down in 1963. Supposedly few, if any, yellowwoods remained at this second site, evidently leaving the trees at the first location as the only extant stand (11). This stand of trees at Ogle Hollow was dedicated as a state nature preserve in 1970 and was believed at that time to contain 63 of the 74 yellowwood trees known in Indiana (2). Subsequently the yellowwood was recognized as a state endangered species by the Indiana Department of Natural Resources (1).

While employed as a seasonal naturalist at Brown County State Park during the summer of 1980, I became aware of the presence of several hundred additional yellowwood trees in the vicinity of Ogle Hollow Nature Preserve. It appeared that the population was much more extensive than previously thought. I therefore undertook the present study to determine the actual extent and size of the Brown County yellowwood population, and to investigate the structural characteristics of the population.

Methods

A systematic search for yellowwood trees was conducted in areas with likely habitat, beginning with the previously known locations within the state park. All stands of yellowwoods found were located and marked on standard 1:24,000 scale topographic maps.

All yellowwood trees that were found were measured with a standard tree diameter tape at 4.5 feet from the ground in order to obtain d.b.h. measurements (diameter

at breast height). A number of trees consisted of two or more major trunks or branches arising from a common base. This results from the yellowwood's branching growth habit. In these cases each branch was counted as a separate stem if it was one inch or greater in diameter at the 4.5 foot height. Uprooted trees in horizontal positions were counted and measured at about 4.5 feet from the former ground level, provided they were still alive. Many live trees and dead trunks were found with abundant basal shoots (in some instances 20 to 30 shoots each). These shoots were found to be too numerous to count individually, thus I merely recorded the number of trees and stumps possessing them.

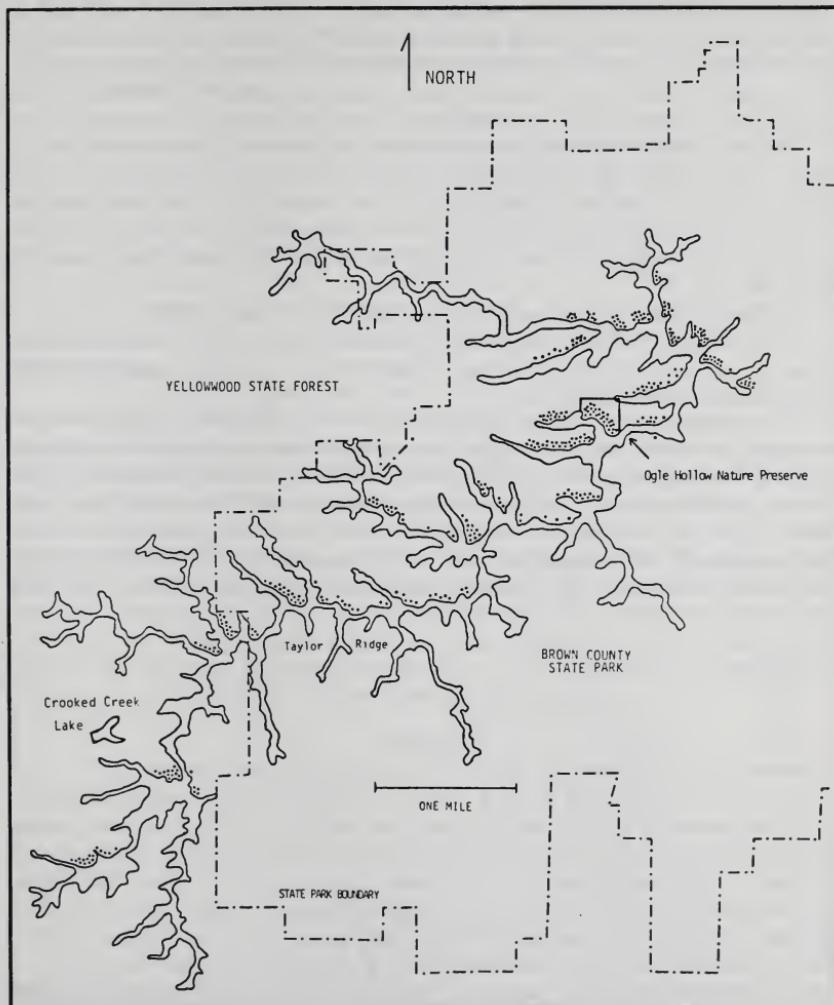


FIGURE 2. Local distribution of yellowwood trees in Brown County, Indiana. Primary ridge top is indicated by irregular outline. General extent and density of each yellowwood stand is shown; each dot represents approximately five individuals of one inch or greater d.b.h.

Results

The Brown County yellowwood population was found to be comprised of some 20 to 30 more-or-less discrete stands containing anywhere from a few to over 150 trees. The population extends in a band for ten kilometers (six miles) in a general southwest to northeast direction from the eastern half of section 21 in Johnson Township to the middle of section 32 in Washington Township. As illustrated by the local distribution map (Figure 2), the individual stands are strictly limited to steep north and northeast facing slopes and ravines found along the highly dissected primary ridge system that runs through the center of Brown County State Park. Apparently the unique physiography of this area offers the appropriate habitat for the yellowwood at this edge of its natural range. Yellowwoods are rarely, if ever, found on ridge tops or non-northfacing slopes separating individual stands. This distribution pattern suggests that the yellowwood is very exacting in its requirements. The distribution map in Figure 2 is intended to show only the approximate extent and density of each stand; each dot represents approximately five individual yellowwoods of one inch or greater d.b.h.

The field survey revealed a total of 2009 individual living yellowwoods. Of this figure, 93 individuals are represented by dead trunks with live basal shoots, and 105 more are seedlings and small saplings less than one inch in d.b.h. The remaining 1811 trees are represented by a total of 2003 stems with measurements of 1.0 inch or greater in d.b.h. Of this figure, 449 were 1.0 to 3.9 inches, and 1554 stems were at least 4.0 inches in d.b.h.

Although these figures result from a careful count, undoubtedly a number of yellowwood trees, and perhaps even an individual stand or two, were overlooked. However, this census should be thorough enough to derive conclusions regarding population structure and management.

Figure 3 shows the overall abundance for the entire yellowwood population in one inch size classes. Size classes of approximately 5.0 inches and greater in diameter comprise what appears to be a stable population structure. However an apparent decline in size classes less than 5.0 inches in diameter is noticeable. This would seem to indicate a decrease in recruitment among the smaller (and thus younger) size classes. The majority of the individual stands reflected this general trend. Typically there are several large sized trees, many medium sized trees, and then fewer small to seedling

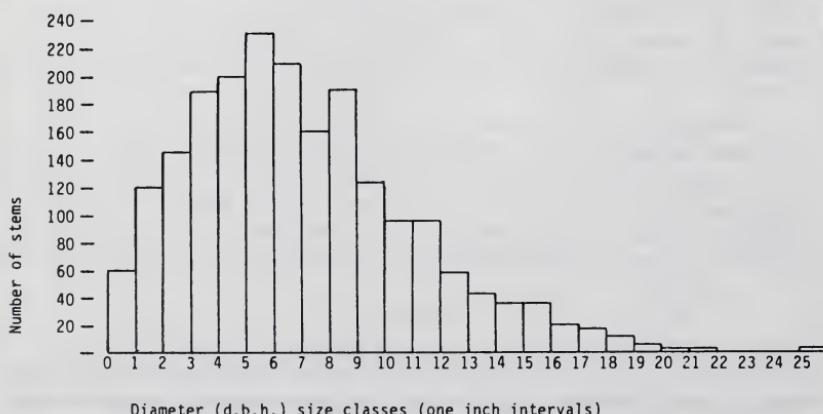


FIGURE 3. Size class abundance of all yellowwood stems in one inch intervals of diameter at breast height.

sized trees. Seedlings were scarce or absent in the majority of the individual stands. Lindsey (11) also mentions the absence of yellowwoods less than 4.0 inches d.b.h. in his survey of Ogle Hollow.

Definite size class (or age class) peaks were evident in most of the individual stands. These peaks may correspond to past disturbances, either man-made or natural, and subsequent regeneration resulting in increased recruitment at these times. An overall lack of correspondence between size class peaks among the different stands would seem to indicate that the influences responsible are acting on each stand separately.

In contrast to the general lack of saplings and seedlings was an obvious abundance of vegetative shoots arising from the bases of healthy and dead or dying trees. A total of 272 living trees and 93 dead trunks and stumps possessed vegetative growth in the form of basal shoots for a total of 365 or 18.2% of the 2009 individual trees. This compares to a total of 105 seedlings and small saplings which comprised only 5.2% of the population.

An interesting and perhaps more important observation was that 98 or 26.8% of the 365 yellowwoods with basal shoots showed varying degrees of damage evidently due to browsing, likely by white-tailed deer. Small shoots were often eaten to within inches of the trunk and foliage up to four feet high was missing from larger stems. Browsing appeared to become much more obvious in late summer and fall, thus the figure of 26.8% may be considered a minimum since many of the observations were made earlier in the year. Indeed, in some locations nearly all the basal growth of the yellowwoods showed signs of damage late in the year, and the surrounding vegetation appeared to be almost "neatly trimmed" from browsing, even on nearly inaccessible steep slopes.

The isolated southwesternmost stand in Yellowwood State Forest apparently represents the "lost" yellowwood stand mentioned earlier. On an upper portion of the slope in this stand, an unusually large concentration of young yellowwoods averaging 1.9 inches in d.b.h was found. Medium and large sized yellowwoods were absent from this part of the stand. It seems plausible that these trees may correspond to a recruitment resulting from the known disturbance of some twenty years ago. In this same stand thirty-three seedlings were found. This was the greatest number of seedlings found in any of the stands. Intensive searching would undoubtedly turn up more. Ironically, this very interesting yellowwood stand, which was previously lamented as having been destroyed, was rediscovered in the midst of a current state forest timber sale in 1982. Fortunately, this now presents an opportunity to monitor the effects of a documented disturbance upon a stand's structure over subsequent years.

Discussion

At the very least, this study allows us a new view of the status of the yellowwood in Indiana. The native yellowwood population, formerly thought of as being perhaps several hundred trees in two separate locations in Brown County, is now seen as several thousand individuals in a nearly continuous band that represents a significant component in the mosaic of the local forest community. The distribution pattern is directly related to the occurrence of suitable habitat—steep, sheltered, north-facing slopes of a loose, well drained soil—that results from the dissected topography of the area.

The steep slopes occupied by the yellowwoods are covered by Muskingum stony silt loam, which is the predominant soil of the county. The soil erodes easily when exposed, and large amounts of siltstone, sandstone, and shale comprise the surface and subsurface (15). Throughout the yellowwood's local range are severely eroded ravines too steep and unstable to support large trees for any length of time. The local relief varies from about 300 meters (1000 feet) above sea level on the ridge tops to 200 meters (650 feet) in the ravine bottoms.

The area receives on the average over 44 inches of precipitation annually. The mean annual temperature is approximately 55° F., although the average temperature is below freezing a number of days each winter. The average number of frost free days is around 160. All three of these average figures are among the lowest extremes encountered by the yellowwood within its natural range (12).

The yellowwoods seem to favor a slightly east-of-north facing slope which receives far less direct sunlight at ground level. These northern and northeastern exposures, although well drained, are continuously moist due to their being sheltered from the midday sun. Fog is frequent in the early morning and evening among the ravines throughout the growing season. The increased soil moisture and higher humidity may significantly reduce transpirational stress in the yellowwood. This may be particularly important during periods of summer drought. The decrease in insolation minimizes daily temperature fluctuations and the resultant freezing-thawing cycles of the soil in winter months. Snow typically covers the north-facing slopes and ravines long after it has melted elsewhere.

The complex topography of the area allows an interdigitation of habitat types, permitting a rich mixture of vegetation to occur on the upper north-facing slopes. Typical co-dominants associated with the yellowwoods include sugar maple, red oak, white oak, black gum, white ash, basswood, beech, shagbark hickory, bitternut hickory, tulip tree, and green ash, with black oak and chestnut oak on the upper slopes. Red elm, flowering dogwood, and sassafras are prominent in the understory. Dense stands of pawpaw are often encountered.

Nearly the entire area of Brown County State Park and adjacent parts of Yellowwood State Forest have been heavily disturbed by agriculture and timbering in the past, and thus bears second or third growth forests. Nonetheless several small areas within the yellowwood's range appear to be in a fairly undisturbed state with a number of old growth trees. Ogle Hollow Nature Preserve, the site of the yellowwoods' initial discovery in Brown County, is thought to be in a relatively undisturbed state. Examination of aerial photographs taken in 1939 and 1949 indicate that all yellowwood sites had fairly closed canopies with large to medium size tree crowns. Sites of suitable habitat that conspicuously lacked yellowwoods were easily recognized as disturbed areas on the same photos. Ogle Hollow and the adjacent hollow along Limekiln Ridge appear in the aerial photos as having the largest tree crown sizes and most uneven canopies—both sites have the greatest number and most dense yellowwood stands within the population.

Yellowwoods receiving greater amounts of sunlight, either canopy trees or trees adjacent to openings, bloomed in Brown County during the late spring of 1981 and 1984. No trees were observed in bloom in either of the intervening years. Several yellowwoods which are located on the campus of Indiana University in adjacent Monroe County likewise bloomed these same years. It should be noted that a number of seedlings and saplings have been found near one of these planted trees on campus.

The yellowwood stand in southern Illinois's Alexander County is similar in many aspects to the Indiana population. The Illinois stand is isolated to the north of the yellowwood's major areas of concentration, and is situated on steep north-facing slopes of a well drained soil. However the Illinois yellowwood population, which consists of less than one hundred mature individuals, has a higher frequency of seedlings and sapling sized trees. This indicates a more stable population structure than that of the Indiana population. Yellowwood seedlings and saplings have a density of 1235 and 145 individuals per hectare, respectively, at the southern Illinois site (13).

Yellowwood populations along the Kentucky River in Mercer County, Kentucky, which is the nearest natural population to that in Brown County, also have been observed to contain an abundance of yellowwood seedlings (12).

The abundance of seedlings found in other locations makes their scarcity even more apparent in the Brown County population. It appears that vegetative growth, in the form of basal shoots from tree trunks and stumps, is currently the primary means of reproduction within this population. Basal shoots were also found to be common in the southern Illinois population (13). Although other tree species displayed basal shoots, they lacked the vigor and abundance of the yellowwood's. This mode of reproduction, coupled with the yellowwood's penetrating deep root system, perhaps gives the yellowwood an advantage on the steep and often unstable slopes where it occurs.

From the unstable population structure it appears that if present trends continue, the Brown County yellowwood population will eventually diminish. The decline in recruitment may be due to a decrease in flowering and seed formation. This might be related to subtle changes in the climate or competitive interactions. Likewise a decline in disturbances, particularly man-made, may have resulted in a decrease in canopy openings conducive to flowering or seedling survival. However, it is tempting to hypothesize that the yellowwood's population structure has been influenced by increasing predation from deer browsing. Damage to basal shoots due to browsing has already been noted. White-tailed deer, which were extirpated from the state by the turn of the century, were reintroduced in the Brown County area from 1934 through 1942. The deer population increased steadily and limited hunting was allowed in the park in 1951 and 1952. Hunting was subsequently forbidden in the state park and the deer population reached a maximum in the years 1976 through 1978 (personal communication with John Olson, Indiana Department of Natural Resources deer biologist). This increase in the deer population of the area may very well be correlated to the steady decline in the recruitment of size classes presently less than 5.0 inches in d.b.h., which may likely correspond to ages of approximately 50 years and younger.

Brown County lies within the physical region of the state known as the Norman Upland. The vegetation of both the Norman Upland and the nearby Crawford Upland has been variously defined by a number of individuals. The area appears as part of the Chestnut Oak Upland in Deam's (5) map of floral areas, as Western Mesophytic Forest in Braun (3), and as Oak-Hickory Forest in Kuchler's (10) map of natural vegetation. Most recently the area has been denoted as part of the Brown County Hills Section of the Highland Rim Natural Region (8). This unglaciated and diverse natural region contains a complex mixture of vegetative communities including upland oak hickory, mixed mesophytic, and bottomland forests. Glades and barrens, stands of eastern hemlock, and disjunct communities principally appalachian in nature occur in suitable habitats scattered throughout the region.

Habitats similar to that of the yellowwood's, in nearby Lilly-Dickey Woods, have been termed western mesophytic (11). However all such community-type designations have their shortcomings. The slopes containing yellowwoods can perhaps be best thought of as a local faciation of a mixed mesophytic forest. The vegetation differs from Braun's (3) Mixed Mesophytic Forest of the Cumberland Mountains by the replacement of certain characteristic species, such as american basswood, *Tilia americana*, for white basswood, *T. heterophylla*, and the absence of many others.

The yellowwood has been identified as a component of the Mixed Mesophytic Forest, which has been thought to have descended from, and to be similar to, a more extensive circumboreal plant assemblage of Tertiary times. Braun (3) interprets the disjunct occurrence of members of the Mixed Mesophytic Forest near the southern limit of glaciation as evidence of their persistence in these northern locations from pre-Pleistocene times to the present. Indeed the yellowwood's range is, for the most part, limited to ancient land masses that have escaped glaciation and inundation, and thus have been continuously available for habitation by plants since the close of the Paleozoic Era. This widely held interpretation implies that the Brown County yellowwood

population persisted through the climatic changes of the Pleistocene in their sheltered location as a relict of a formerly more widespread distribution.

This concept of "refugia" near the limit of glacial advance is in conflict with modern palynological studies. From the work of Whitehead (18, 19), Delcourt (6), Watts (16), and others, it now appears that a major displacement of biota took place during times of glacial advance with a resulting reshuffling of components, or species, within assemblages. A belt of tundra and forest tundra evidently existed south of the ice margin during the glacial maximum. The pollen spectra from these communities and the boreal-like forest to their south lack modern analogs. Delcourt (6) believes that full glacial refuges for deciduous forest taxa may have existed in favorable locations in the Cumberland Plateau and the Appalachians as well as bluff habitats along major north-south trending rivers in the Southeast. Refugia more likely existed along the Gulf Coast and latitudes farther south. Locally abundant peri-glacial features in the form of asymmetrical valleys, which result from far more severe climatic conditions than presently occur, suggests that locations near the ice margin, as in Brown County, would have proven unsuitable to present day vegetation (17). Thus it seems unlikely that the yellowwoods and their associated vegetation could have persisted intact during the Pleistocene within sheltered locations in Brown County, Indiana. The yellowwood therefore should be considered a relatively more recent member of a contemporary assemblage in this state, currently restricted to its present local range by its exacting habitat requirements.

Management Recommendations

The fact that the entire Indiana population of yellowwood trees already is found on public land (Brown County State Park and Yellowwood State Forest) provides the state with a unique opportunity for the preservation of an entire population of a significant disjunct tree species. The mere inclusion of most of the population within the state park does not adequately guarantee its protection considering the current level of development and resource management. Although the close proximity of recreational and maintenance facilities has not greatly influenced the yellowwood stands (with the exception of cleared powerline corridors), all known yellowwood stands should nonetheless be recognized as natural areas to prevent or minimize any future disturbances. In addition, the yellowwood stands in the relatively undeveloped and primitive portion of the state park and adjoining state forest should be left as undisturbed as possible to protect the integrity of their rich and diverse ecosystems. This would necessarily preclude any subsequent timbering and alterations within, or in close proximity to, the yellowwood stands on state forest property. These recommendations concur with those made for the Alexander County, Illinois yellowwood site, by the Illinois Nature Preserve Commission (9).

Currently two yellowwood stands are dedicated as state nature preserves, 41 acres in Ogle Hollow within the state park, and 35 acres near Crooked Creek within the state forest. It is strongly recommended that an additional preserve be dedicated to protect the presently least disturbed yellowwood stands and their diverse communities located along the north side of Taylor Ridge. Similar designation should be given to include in the Ogle Hollow Nature Preserve the very dense yellowwood stands to its west and southwest.

The most serious unresolved question concerning the yellowwood population is the current imbalance of its age-class structure which has apparently resulted from a decline in the recruitment of new individuals over the past 40 to 50 years. If this trend continues unabated the population will subsequently diminish in size. In light

of the observed damage to vegetation from browsing, management steps may have to be taken to control the level of the local deer population.

The subsequent protection of the yellowwood tree and its environment will insure its potential as a subject for long term ecological study. It is suggested that further research be conducted, including a more detailed vegetation analysis, an analysis of potential size-class spatial distribution correlations, establishment of a photo point reference system, a continuing assessment of damage from deer browsing, and long term monitoring of structural changes in the population.

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