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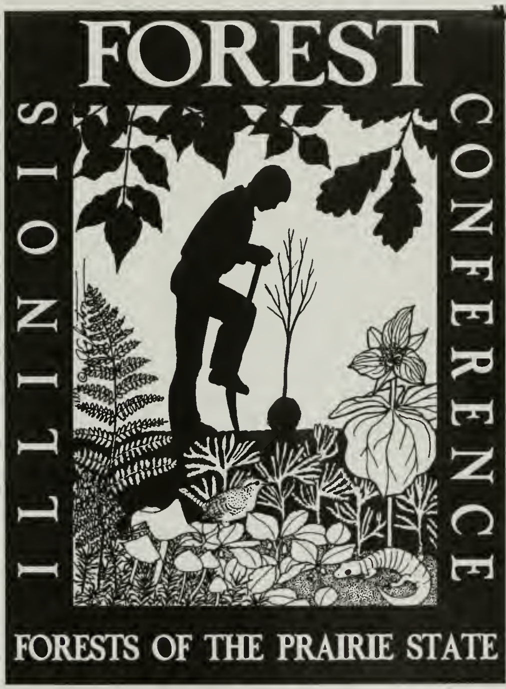

Journal of the
Illinois Native Plant Society

Conference Proceedings
26-27 September 1992
Eastern Illinois University
Charleston

Erigenia

Number 13, June 1994

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The Illinois Native Plant Society is dedicated to the preservation, conservation and study of the native plants and vegetation of Illinois.

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This issue is a tribute to Ken and Lorna Konsis for their outstanding contributions to the Illinois Native Plant Society. Without their tirele efforts, the Society would not be as dynamic as it is today. Ken and Lorna, we thank you.

Proceedings of the Illinois Forest Conference: Forests of the Prairie State

26-27 September 1992
Eastern Illinois University, Charleston

Illinois is often known as "The Prairie State," reflecting the prairie heritage of much of the landscape of the state. There have been numerous conferences held in recent years about prairies in Illinois. The Executive Board of the Illinois Native Plant Society, with Jon Duerr (Kane County Forest Preserve District) as president, conceived the idea of a conference devoted to our forests. After all, it is estimated that in 1820, before European settlement, forests covered approximately 38.2% of Illinois, some 13.8 million acres (see the article by Iverson in this issue).

An organizing committee was established with Jeffrey O. Dawson (University of Illinois) as Chair. Other members included John E. Ebinger (Eastern Illinois University), Mary Hruska (Eastern Illinois University), Fran Harty (Illinois Department of Conservation), Louis R. Iverson (then of the Illinois Natural History Survey, now with the U.S.D.A. Forest Service), Ken Konsis (Vermilion County Conservation District), and Kenneth R. Robertson (Illinois Natural History Survey).

The conference, entitled "Illinois Forest Conference: Forests in the Prairie State," was held at Eastern Illinois University on September 26, 1992, with over 300 persons attending. This issue of *Erigenia* contains papers and abstracts presented at the conference. A Conference Program is included at the beginning of this issue.

The Illinois Native Plant Society wishes to thank the following organizations for their sponsorship of the Conference:

Botany Department
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Champaign County Audubon Society
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Urbana, IL 61801

Champaign County Design and Conservation Foundation
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Illinois Native Plant Society Chapters

Illinois Natural History Survey
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U.S.D.A. Forest Service
Shawnee National Forest
901 S. Commercial St.
Harrisburg, IL 62901

Conference Schedule
Saturday, 26 September 1992

9:00 Opening Remarks and Welcome
John E. Ebinger, Eastern Illinois University
Kenneth R. Robertson, President, Illinois Native Plant Society

9:15 Opening Address
An Overview of Illinois Forest Resources, Louis R. Iverson, Illinois Natural History Survey

10:00 Session A
Woody Plants of Illinois Forests, Kenneth R. Robertson, Illinois Natural History Survey
The Forest Stewardship Program in Illinois, Gary Rolfe and Stephanie Brown, University of Illinois
Diseases of Illinois Forests, H. Walker Kirby, University of Illinois
Higher Fungi of Illinois Forests, Andrew Methven, Eastern Illinois University and Walter Sundberg, Southern Illinois University, Carbondale

10:35 Session B
Wild Flowers of Illinois Forests, Floyd Swink, The Morton Arboretum
Production of Plant Materials for Reforestation and Savanna Restoration, Stewart Pequignot, Illinois Department of Conservation
What is Causing the Death of Pine Trees in Illinois? James Appleby, University of Illinois
Stewardship of Forested Nature Preserves, Gretchen Bonfert, Illinois Nature Preserves Commission

11:10 Session C
Vegetation Dynamics of the Prairie/Forest Interface at Coles Creek Hill Prairie, William Werner, Jr., Carlinville, Illinois
State and Federal Programs to Assist Forest Management and Stewardship, R. Daniel Schmoker, Illinois Department of Conservation
Exotic Species in Illinois: Impacts and What Can We Do to Deal With Them, John Schwegman, Illinois Department of Conservation
Forest Root Structure: Root Symbionts and Their Function, Jeffrey Dawson, University of Illinois

11:45 Lunch

12:30 *Cowboy Poetry*, Philip Robertson, Southern Illinois University

1:15 Luncheon Address
Fighting for Survival: A Plan for Endangered Plants, Robert H. Mohlenbrock, Southern Illinois University

2:00 Session D
Diversity and Management of Forest Communities in the Shawnee National Forest, Lawrence Stritch, U. S. D. A. Forest Service
Structure and Function of Illinois Forested Wetlands under Disturbed Hydrologic Regimes, Sandra Brown, University of Illinois
The Occurrence of Prairie Fires in Illinois and Adjacent Midwestern States During the Period 1673-1873, William E. McClain, Illinois Department of Conservation
The Challenge: Biography of Illinois, Jon Duerr, Kane County Forest Preserve District

2:35 Session E
Cultivating a Land Ethic: Who are the Stewards of Illinois Forests? Timothy Marty, University of Illinois
The Bottomland Forests of the Southern Illinois Area, Philip Robertson, Southern Illinois University
Deer in Illinois Forests, Todd Strole, Illinois Department of Conservation
A Sampling of Arthropod Diversity from a Central Illinois Woodland, Michael Jeffords and Susan Post, Illinois Natural History Survey

3:10 Session F
Dynamics of Bird Populations within Fragmented Forest/Agricultural Landscapes, Jeffrey D. Brawn and Scott K. Robinson, Illinois Natural History Survey
Upland Forests of Central Illinois: Past and Present, Dr. Roger Anderson, Illinois State University
Effects of Riparian Buffers in Reducing Agricultural Pollution, David Kovacic, University of Illinois
The Presettlement, Present, and Future Forest of the Shawnee and Ozark Hills Regions of Illinois: Management Implications, James Fralish, Southern Illinois University

3:45 Session G
Threatened and Endangered Animals of the Illinois Forests and Savannas, James Herkert, Illinois Nature Preserves Commission
Illinois Savannas: Past and Present, Victoria Nuzzo, Native Landscapes, Rockford, Illinois
Native Trees for Urban Use: Urbanization of Illinois Forests, George Ware, The Morton Arboretum
The Impact of Climate Change on Forest Ecosystems, Evan DeLucia, University of Illinois

4:30 Closing Address
Floristic Changes after Five Growing Seasons in Burned and Unburned Woodland, Gerould Wilhelm and Linda Masters, The Morton Arboretum

5:15 Closing Remarks, Jeffrey Dawson, Chair, Organizing Committee

Forest Resource Trends in Illinois

Louis R. Iverson[1]

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INTRODUCTION

Even though forests occupy only 12% of the land area of Illinois, they play a valuable role in the health of the state's environment and that of its citizens. Many of these benefits have been reviewed in *Forest Resources of Illinois: An Atlas and Analysis of Spatial and Temporal Trends* (Iverson *et al.* 1989), and summarized in the *Forests of Illinois* (Iverson *et al.* 1991). Readers are encouraged to obtain copies of these documents from the Illinois Natural History Survey. The purpose of this paper is to focus on current trends in Illinois forests and to report information obtained following these earlier publications, specifically, changes in forest cover from 1820 to 1985, current (1990) trends and patterns of forest land for a portion of south-central Illinois, and trends in forest composition and diversity, timber growth and harvest, value for wildlife habitat, and value for carbon sequestration.

Trends in Forest Area from 1820 to 1985

Illinois forests have undergone drastic changes since European settlement. In 1820 there were 13.8 million acres (5.6 m ha) of forest in the state (Fig. 1a, see also the large wall map by Iverson and Joselyn 1990, available at no charge from the author). Only 31% (4.26 million acres or 1.72 m ha) of the forest area present in 1820 remained in 1985 (Fig. 1b shows forest distribution as of 1980); essentially all (except for about 11,600 acres or 4700 ha) of the present forests are secondary or cutover timberland. Illinois also ranks 49th (Iowa is 50th) in the percentage of land remaining in the vegetation types (Kuchler 1964) on the land when the European settlers arrived (11 percent). The pattern and rate of deforestation in the latter part of the last century, estimated at 1.13% per year (Iverson 1991), rivals and even surpasses that of any tropical deforestation occurring today.

However, forest area has recently been increasing in Illinois. The lowest estimate of forest area in the state was made by Telford (1926), who estimated forest area to be only 3.02 million acres (1.22 m ha) compared to estimates of 4.0 million acres (1.62 m ha) in 1948 (USDA Forest Service 1949), 3.87 million acres (1.57 m ha) in 1962 (Essex and Gansner 1965), and 4.26 million acres (1.72 m ha) in 1985 (Hahn 1987). Forest area increased by 10% from 1962 through 1985 due primarily to reduced cattle production in the state during that period with subsequent conversion of hayland and pastures to secondary forest. Recent farm programs such as the Conservation Reserve Program have provided incentive to convert additional marginal acres to forest land.

When the state is evaluated according to five ecologically based regions (Fig. 2), changes in forest area since 1820 show similar patterns: major declines in forest area are dramatic between 1820 and 1924, with slow increases in area since 1924 (Fig. 3). The only region to lose forest area between 1962 and 1985 was the South-Central Region, a group of 31 counties south of the Shelbyville moraine and north of the Shawnee Hills. Figure 4 is a county map showing trends of forest area between 1962 and 1985. Counties that lost more than 5,000 acres (2,000 ha) of forest land between 1962 and 1985 were Bond, Clark, Clinton, Fayette, Franklin, Gallatin, Hamilton, Jasper, Lawrence, Marion, Montgomery, Perry, Richland, Shelby, St. Clair, Wabash, and Wayne. Counties from other regions that lost more than 5,000 acres were

[1]The majority of this work was conducted while the author was employed by the Illinois Natural History Survey, Champaign, IL.

Alexander and Massac from the Southern Unglaciated Region, Greene from the Western Region, and Lake from the Northern Region. However, an additional 38 counties gained more than 5,000 acres of forest land during this interim, mostly from the northern two-thirds of the state (9 of 12 counties in the Northern Region, 11 of 31 in the Grand Prairie Region, 14 of 21 in the Western Region, 1 of 31 in the South-Central Region, and 3 of 7 in the Southern Unglaciated Region. Clearly, the northern counties generally have increased in forest area (especially those along the major river systems) while the southern portion of the state (except for the Shawnee National Forest counties) suffered significant forest losses during the same period.

Forest Pattern and Trends in South-Central Region

To better understand the temporal and spatial patterns of forest patches in the South- Central Region, a detailed analysis of one 1990 Landsat TM scene, that covered 13 counties was performed. This region was selected for intensive study since it was the only one with forest loss during 1962-85. The satellite data were at a resolution of 98 x 98 ft (30 m x 30 m), so that forest patches as small as approximately 0.25 acre (0.1 ha) could be identified. The distribution of the forest is highly fragmented and primarily distributed adjacent to streams. Given the constraints of a completely different methodology, direct comparisons of trends between the Forest Service's 1985 estimate (a sampling procedure) and the 1990 assessment (satellite image classification) are not reliable. Still, it is useful to estimate forest area and the amount of fragmentation in this portion of the state.

According to the satellite data, the forest area for the 13 counties was substantially lower in the 1990 estimate compared to the 1985 or 1962 estimates of the Forest Service (Fig. 5). However, it is likely that many of the changes can be attributed to variation in the methodology -- the classification of the satellite data did not include some areas interpreted by the Forest Service as forest in 1985. Still, the region of satellite analysis was the one portion of the state that showed a decline in forest area between 1962 and 1985 (Figs. 3-4), and this trend might have continued since 1985.

The satellite data also show the extraordinarily fragmented nature of the forests. Fragmentation of forest habitat generally has negative implications for wildlife, especially for neotropical migrant birds that need large blocks of uninterrupted forest for successful nesting. As large tracts of forest are broken into small isolated woodlots, more forest edge is created and there are more opportunities for edge-adapted species, most commonly the cowbird, to invade the area and prevent adequate nesting for many forest songbirds. Most of the forest parcels in this region are less than 1 acre (0.4 ha) in size (Fig. 6). In these forest patches, as small as about 65 by 65 ft (20 by 20 m), trees dominate the area, even in backyards, so that the 98 by 98 ft (30 by 30-m) pixel would classify as forest in the satellite imagery. Parcels larger than 40 acres (16 ha) are much less frequent (range: 95 parcels in St. Clair County to 269 parcels in Fayette County). When one considers the larger forest-patch sizes (e.g., 600 acres or 243 ha) approaching that needed to support forest interior birds, the range is 3 in Montgomery County to 17 in Fayette County for a total of 131 patches in the entire 13-county area (Fig. 6).

When evaluated on a per-unit-area basis (density of forest patches per township-size area of 36 mi^2 or 93.2 km^2), one can better understand the "population dynamics" of the forest patches. A range of 211 to 770 forest patches less than 1 acre can be found in St. Clair and Jefferson Counties, respectively (Fig. 7). The data also show the paucity of large forest patches in the region. Of all patches larger than 40 acres, only 5.2 patches of this size can be found on average in each township of St. Clair County, ranging up to 14.1 patches per township in Jefferson County. Jefferson originally (ca. 1820) had 73% forest cover, at least 20% higher than any other county in the study area (Iverson *et al.* 1989); so it would be expected to have the highest density of forest patches remaining. For the entire 13-county area, an average of 10.1 forest patches per township can be expected--about one patch for each 4 mi^2 (10 km^2). A cautious comparison of these data can be made to data from a study by Iverson *et al.* (1989). Using U.S. Geological Survey land-use data for 1974-79, Iverson *et al.* (1989) calculated a density of forest patches larger than 40 acres of 7.1 to 9.7 per township in this region. If the comparison is reliable, these data represent a slight increase in patch density over the past 11 to 16 years. This trend could be achieved in at least two ways: (1) additional patches of at least 40 acres have been added to the pool due to regrowth or aggregation of smaller patches, or (2) some large patches have been split into two or more medium-size (but still larger than 40 acres) patches due to continued fragmentation. On the basis of these data and a reevaluation of the data in Iverson *et al.* (1989), the latter is most likely the case.

By overlaying the forest classification from satellite data with the streams from the area (1:100,000 digital line graph files), we can estimate the proportions of the Illinois forests within certain distances of the streams. For this area, no less than 78% of the forests is within 984 ft (300 m) of the streams (Fig. 8); a full 22% of the forests is within 98 ft (30 m) of the streams. An evaluation of the distribution of forests circa 1820 (Fig. 1) shows that the proximity of streams and forest in this region has historically been the case; the streams were efficient fire barriers which reduced the frequency of fire near them. As evidence continues to mount on the value of riparian forests in maintaining stream health (the reverse is also true), it can be seen that the majority of forests in Illinois are well situated on the landscape.

Changes in Forest Composition

The composition of Illinois forests has changed dramatically over the past three decades. Today, about one-half of the commercial forest acreage (2.03 million acres or 0.82 m ha) is oak-hickory, one-fourth is maple-beech (1.05 million acres or 0.42 m ha, almost exclusively sugar maple), and one-sixth is elm-ash-soft maple (0.72 million acres or 0.29 m ha) (Fig. 9). The remaining forest types (white-red-jack pine, loblolly-shortleaf pine, oak-pine, and oak-gum-cypress) account for an additional 217,000 acres (87,850 ha) of commercial forest land. However, in 1962, there was much more acreage of oak-hickory and elm-ash-cottonwood and little area dominated by the maple-beech type; the maples (especially sugar maple) have increased by a factor of 41 since that time, whereas the oaks have been reduced by 14% and the elms have been cut in half (Fig. 9). The loss of oak-hickory forest is largely explained by the maple "takeover," that is mature oak-hickory forests are unable to regenerate because tree seedlings are intolerant of excessive shade, whereas maple seedlings thrive in the shady environment and are positioned for rapid growth and dominance once the overstory is removed or dies (Ebinger 1986). This takeover by maple is common throughout the northeastern quarter of the country, with red maple dominant in many of the more states (Powell *et al.* 1993). The reduction of elm-ash-soft maple is largely due to the effects of Dutch elm disease and the conversion to agriculture of bottomland forests that once supported these trees (especially in the South-Central Region). These trends also are evident by the age-class distribution of the major forest types (Fig. 10). The oak-hickory type dominates in the older age classes, while the maple-beech type dominates in the younger age classes; as time passes, maples will continue to increase in dominance. The changing composition of the forests will continue to have wide-ranging implications with respect to plant and animal habitat as well as timber resources.

Botanical Diversity

The Illinois Plant Information Network (ILPIN) was queried regarding the county distribution of forest-associated taxa within the state (Iverson and Ketzner 1988). The wide range in latitude from north to south accounts for a considerable range in climate and geomorphic conditions, and, subsequently, a remarkable diversity of habitats. For example, 261 species of trees (native and introduced) have been recorded in Illinois. Southern counties have the greatest variety: Jackson has 145 species, Pope 129, and Union 128; several northeastern counties also have high diversity due to varied landscapes and escaped cultivars from the Chicago Region (Fig. 11). Also, there are 284 taxa of shrubs (some of which can be called trees) and 47 taxa of lianas reported for the state. Overall, 508 taxa of woody plants have been recorded; 370 are native and 138 are introduced.

Besides the woody flora, Illinois forests are exceptionally rich in nonwoody taxa. Including woody species, there are 1,581 forest-associated plant taxa in the state, 1,414 (89%) of which are native. Jackson County, a botanicially rich southern county that includes Southern Illinois University, from which numerous botanical forays have been conducted, has 954 forest-associated native taxa on record, while Warren County in the northwest (not near a botanical center) has had only 262 taxa recorded (Fig. 12). Again one can see the higher botanical diversity levels in the southern counties, with species richness in Appalachian flora, and in the northern counties, with richness in northern temperate flora. Relatively lower diversities of forest-associated species are found naturally in the counties formerly dominated by prairie.

The forests of Illinois harbor nearly half of the state's threatened and endangered species even though forests occupy only 12% of the land area. The importance of maintaining high-quality forests as refuges for these taxa cannot be overemphasized, especially in the face of extreme pressures from human activity.

The major problem related to biodiversity in Illinois no longer is from land-use change and habitat conversion, a major concern until 20 to 30 years ago. Rather, it is now the invasion of exotic species, many of which compete aggressively with the native species, eventually replacing them. The proportion of the Illinois flora that is exotic has reached 28%, according to the ILPIN data base. Published vascular plant floras of the state dating back to 1846 show a continued rise in the percentage of exotics (Henry and Scott 1980). To date, about 130 exotic species from Illinois forests have been recorded, according to ILPIN. More than 50 exotic species have been recorded in each of several counties, especially in the northeastern and southwestern part of the state. The numbers of taxa per county probably are even higher because routine collection of exotics is not a high priority of most field botanists. Some of the major pests include *Alliaria petiolata* (garlic mustard), *Lonicera maackii* (amur honeysuckle), *Lonicera tatarica* (tartarian honeysuckle), *Rhamnus cathartica* (common buckthorn), *Rosa multiflora* (multiflora rose), *Lonicera japonica* (Japanese honeysuckle), and *Pueraria lobata* (kudzu-vine). The problem of exotics is increasing in severity and scope in the forests of Illinois.

Timber volume and growth

The total volume of growing stock in 1985 was 4.8 billion feet^3 (135 million m^3), 40 percent greater than the 3.4 billion feet^3 (96.3 million m^3) reported for 1962 (Hahn 1987). Estimates of net volume for 1985 showed the prominence of oak and hickory in commercial forests, with considerable amounts of ash, black walnut, cottonwood, elm, maple, and sycamore. The 1985 volumes averaged 1,200 feet^3/acre (83.9 m^3/ha) of commercial forest land in Illinois.

The trends in volume since 1948 for several major species groups are shown in Figure 13. For all groups except elm, there has been a dramatic increase in volume since 1962. The elms have declined since 1948 due to bottomland conversion to agriculture and Dutch elm disease. White and red oaks and black walnut had decreased in volume from 1948 to 1962, but showed increases from 1962 to 1985. The hickories, maples, and ashes have increased in volume since 1948.

Estimated net annual growth in 1985 (Hahn 1987), totaled 96 million feet^3 (2.72 million m^3) in growing stock (437 million board feet of sawtimber growth). More than 42% of net annual sawtimber growth was accounted for by oaks, with another 10% by soft maple, 6.3% by ashes, 3.7% by black cherry, 3.3% by hard maple, and 3.2% by black walnut. Only elm and black ash had negative growth rates between 1962 and 1985, attributable to Dutch elm disease and the clearing of bottomlands during this period.

In contrast to the 1985 data, the 1962 inventory showed annual growth of 125 million cubic ft^3 (3.5 million m^3) in growing stock, an increase of 30 percent. The lower annual growth and higher volumes in 1985 compared to 1962 indicate that growth has outstripped removals in the past several decades but that growth rates may be declining due to maturing forests. When evaluated by county, trends in volume during 1962-85 show large percentage increases for all northern and central counties (except Whiteside), but generally lower or even negative volume changes for south-central counties (Fig. 14). This trend can be linked primarily to area changes for the region discussed earlier (see Fig. 3).

Timber harvest

Illinois ranks fifth in the nation in demand for wood but 32nd in the production of wood; as a result, the state imports much of this wood from other states. Therefore, it is surprising to discover that 14 % of the wood harvested in Illinois is processed in neighboring states and then imported back into Illinois (Blyth *et al.* 1987). Currently, the annual growth of timber (96 million cubic ft^3 or 2.72 million m^3) exceeds timber removals (68.6 million cubic ft^3 or 1.94 million m^3), so a higher proportion of Illinois' demand for wood could be met within the boundaries of the state if it had processing facilities. With judicious management of an increased harvest, negative effects on the environment could be minimized and multiple benefits achieved. Local markets for Illinois hardwoods could be an incentive for reforestation with native trees and as provide needed local employment, especially if value-added industry located in the resource-rich regions.

An enormous quantity of firewood is harvested from Illinois forests -- nearly 2 million cords a year (Blyth et al 1985). In fact, about 43% of all trees removed in a given year in the state are used for firewood! However, the demand for firewood does not present a major threat to the state's forests, because 75% of the firewood cut is from dead trees, mostly from forests in the heavily populated northeastern counties (Fig. 15). Trees cut for sawlogs are primarily from the southern half of the state (Fig. 16); the major counties cutting sawlogs in 1983 were Franklin, Fulton, Jackson, and White (more than 6 million board feet per county).

Sequestration of Carbon

Because of the massive changes in total forest volume in Illinois over the past several decades, the amount of carbon being sequestered into forest biomass in the state also has changed considerably during that time. From 1948-62 there was a slight loss (0.15 million metric ton) of total forest volume due to conversion of forestland to other uses (Fig. 17). This loss was offset by an increase in the volume contained within extant forests (0.06 million metric ton) and the harvesting of wood products which put 0.29 million metric ton of carbon into long-term storage. The result was that forestlands were a net sink of 0.20 million metric ton of carbon per year during 1948-62. After 1962 there was a gain in forest land and particularly a gain in forest volume per unit of forest land, with a resulting sequestration of about 1.37 million metric tons (1.51 million tons) of carbon per year (Fig. 17). Carbon sequestration into long-term storage of wood products also increased between the two time periods, though not as significantly as the change in land use or volume. This net sink from Illinois forest lands helps balance the carbon cycle in the state, but still represents only about 2.7% of the total emissions of carbon that the people of Illinois contribute to the atmosphere each year --51.55 million metric tons (56.82 million tons) in 1988.

Trends in Wildlife Habitat

The forests of Illinois provide the major habitat for numerous wildlife species. Losses in the quality and quantity of that habitat severely affect wildlife populations (Illinois Wildlife Habitat Commission 1985). One method of summarizing the value of wildlife habitat in Illinois is based on land use. One method for calculating an index of wildlife habitat is presented in Graber and Graber (1976); revised calculations based on current data are given in Iverson *et al.* (1989). The index devised by Graber and Graber is based on the proportion of a particular habitat type within a given area, the availability of that habitat type within the state or region, the trends associated with that habitat over the previous decade, and the "cost" of a given habitat measured in years required to replace the ecosystem. A summary of habitat factors for Illinois as of 1985 is presented in Table 1. By this calculation, more than three-quarters of the wildlife habitat (88 of 115.7 habitat factor points) is derived from forests. Elm-ash-cottonwood rates highest because this forest type has been disappearing so quickly over the past two decades (Fig. 9). Values for oak-hickory would be higher except that numbers in older age classes are increasing as secondary forests mature, even though numbers in younger age classes are decreasing (Fig. 10). A minor rating was earned by maple-beech because this forest type has increased so dramatically in recent years (Fig. 9). Scores for habitat factor generally were much more favorable for wildlife habitat in the southern half of the state, which is more heavily forested. In fact, total habitat-factor scores for the South Region were twice those of the Central Region, with the North Region in between (Iverson *et al.* 1989).

By comparing habitat-factor scores of Iverson *et al.* (1989) for 1985 to those of Graber and Graber (1976) for 1973, one can evaluate temporal trends in habitat, and the role of forest land in those changes. This evaluation was possible for the North, Central, and South regions. Caution is advised in this comparison, however, because these regions are not an exact match geographically. It was not possible to directly compare habitat scores between dates because of slight variations in the methodology. However, by calculating the percentage of the habitat factor occupied by each land type for the two dates, relative contributions to habitat by each land type can be calculated over time (Fig. 18), as can total contributions of forest land to habitat. For example, in the north, the cumulative percentage from forest was 53.4 in 1973 and 65.3 in 1985 -- an increase of 22% in relative habitat factors from forests in that region (Fig. 18a). This increase is due mostly to large increases in relative habitat factors for the elm-ash-cottonwood and pine types and a decrease in marsh habitat. In the Central Region, relative habitat increased from 71.6 to 76.1% (Fig. 18b), while in the south, relative habitat decreased from 88 to 84% (Fig. 18c). In all regions there were increases in relative habitat factors for elm-ash-cottonwood because that type decreased in area by nearly 50% between 1973 and 1985 (Fig. 9). All regions showed a decrease in relative habitat value for the oak-hickory and maple-beech types, though for different reasons. The oak-hickory type decreased because large increases in availability were apparent in the older (> 60 yr) age classes even though the younger age classes had decreasing acreages. The maple-beech type decreased in relative habitat value because of the extremely large increases in area for all age classes. This resulted in low changing availability scores which, in turn, lowered the habitat-factor scores.

Another way to evaluate the trends in relative habitat factor scores for forest types between 1973 and 1985 is to plot the percentage changes during the period (Fig. 19). Here we see increases in relative habitat factors in all three regions for elm-ash-cottonwood, an increase in pine for the North Region, and an increase in oak-hickory in the South Region. Scores for pine increased in the north because its availability increased, especially in the older (> 40 yr) age class. Similarly, oak-hickory increased in the south primarily because of a negative changing availability in the younger age classes. All other forest types showed decreases between 1973 and 1985. Especially apparent is the decrease in all regions of the score for maple-beech. Pine decreased in the south because of increasing availability in that region. Overall, the data show the extremely high value, and an increasing value of forest habitat relative to other habitat, for wildlife habitat across the state.

CONCLUSIONS

A review of some of the trends apparent in Illinois forests over the past several decades lead to several conclusions:

1. The state's forests are now increasing in area when evaluated statewide, probably due to several incentive and educational programs as well as to an overall reduction in pastureland during this period. The exception may be in the South Central region where fragmentation apparently is continuing.

2. Most of the forests historically and currently are associated with the state's stream network. In the south-central portion of Illinois, 78% of the forest land is within 300 m of the streams.

3. Although forest area is increasing overall, the composition of the forests is changing dramatically, as it is in many states in the northern and northeastern United States. Maple species are replacing much of the oak-hickory in forests and dominating new forest land succeeding from abandoned pastures. The oak-hickory forests are not being regenerated and will continue to decrease in area and importance.

4. The botanical diversity of the state is being carried, in large part, by its forests. More than half of the native flora and more than half of the threatened or endangered flora are found in Illinois forests. Invasion by exotic species, one of the most serious problems facing these forests, continues to increase both in severity and scope.

5. Timber volume increased by 40% between 1962 and 1985. Volumes of most forest types have increased substantially except for elm-ash-cottonwood, which has decreased because of Dutch elm disease and conversion of bottomland forests. However, net annual growth over all forests in the state was 30% higher in 1962 than in 1985, showing the aging nature (with concomitant slowing of growth rates) of our secondary forests.

6. Because of the dramatic increases in volumes, Illinois forests served as a large carbon sink during 1962-85. The estimated annual sequestration of carbon into the state's forests is 1.37 million metric tons, enough to counteract about 2.7% of the total emissions of carbon into the atmosphere by the people of Illinois.

7. According to one index, more than 75% of the wildlife habitat in the state is within its forests. Further, in the northern two-thirds of Illinois, the relative contributions of forest land to wildlife habitat has been increasing over the past two decades.

LITERATURE CITED

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ACKNOWLEDGEMENTS

The author thanks Elizabeth Cook for her work with the classification of the satellite data, Eric Lambert and Sandra Brown for efforts with the carbon budget data, and Gary Rolfe, Jeff Dawson, John Ebinger, and Ken Robertson for their technical reviews of this paper, and Marty Jones for his editorial review. Special thanks are given to the people of the Illinois Natural History Survey for the support they gave the author in the 10 years he was employed there, and to the Illinois Council on Forestry Development for its encouragement and support.

Table 1. Habitat factors for Illinois, 1985, calculated according to Graber and Graber (1976).

Land type	Habitat factor	% of wildlife habitat
Forest		
Pine	5.70	4.9
Oak-hickory	30.07	26.0
Oak-gum-cypress	11.97	10.3
Elm-ash-cottonwood	40.19	34.7
Maple-beech	0.14	0.1
Subtotal		76.0
Nonforest		
Cropland	0.29	0.3
Pasture/hayland	10.01	8.7
Prairie	1.46	1.3
Marsh	15.28	13.2
Water	0.38	0.3
Urban, residential	0.03	0.0
Fallow	0.19	0.2
Subtotal		24.0
Total	115.73	100.0

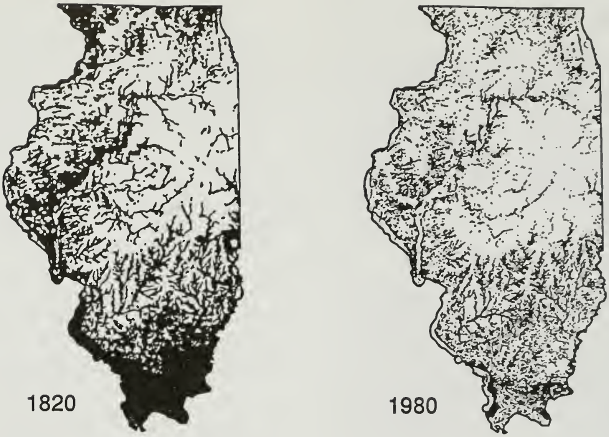


Figure 1. Forest coverage in Illinois in (a) 1820 and (b) 1980. Sources: Anderson 1970 and U.S. Geological Survey land-use data, 1973-1981.

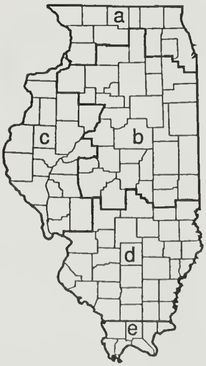


Figure 2. Illinois regions: (a) Northern, (b) Grand Prairie, (c) Western, (d) South Central, and (e) Southern Unglaciated.

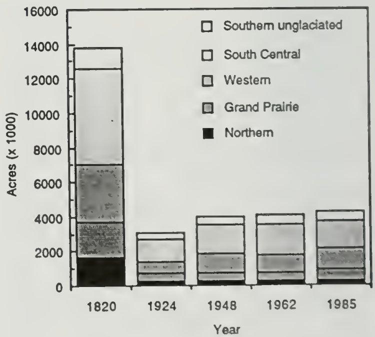


Figure 3. Trends in forest area in Illinois by region, 1820-1985.

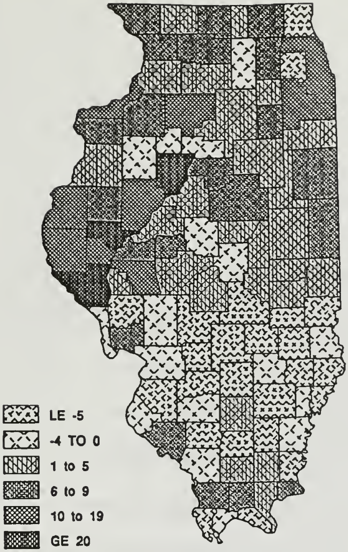


Figure 4. Distribution of forest-area trends (acres x 1000) in Illinois by county, 1962-1985.

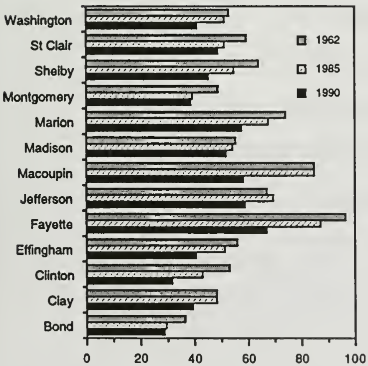


Figure 5. Forest-area trends (1962-1990) for 13 counties in south-central Illinois.

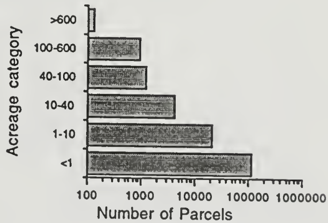


Figure 6. Number of forested parcels, by acreage class, for each of 13 counties in south-central Illinois, as detected by satellite in 1990.

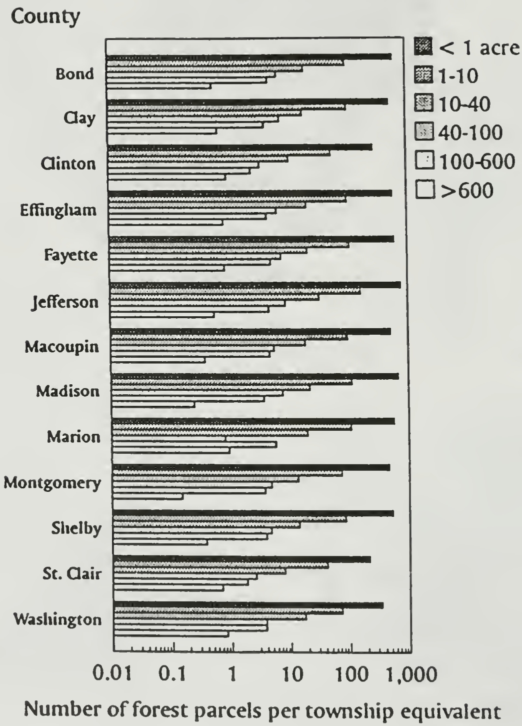


Figure 7. Number of forested parcels, by acreage class, per township equivalent (36 miles^2 or 93.2 km^2) for each of 13 counties in south-central Illinois, as detected by satellite in 1990.

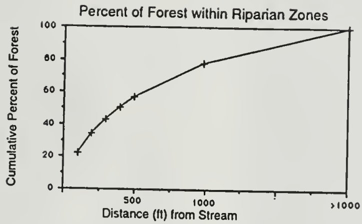


Figure 8. Distribution of forests at various distances from streams in the 13 counties in south-central Illinois.

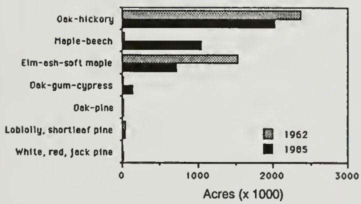


Figure 9. Composition of Illinois commercial forests, 1962 and 1985.

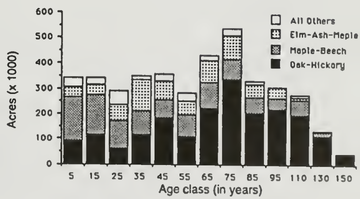


Figure 10. Acreage by age class of the major forest types in Illinois, 1985.

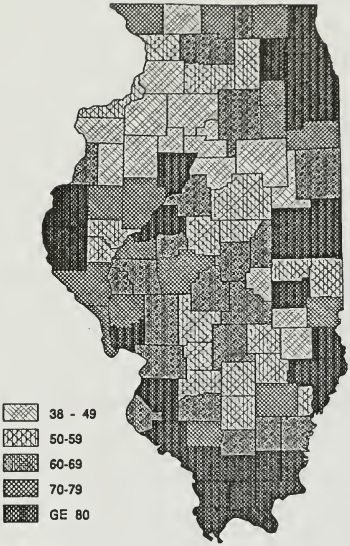


Figure 11. Number of tree taxa in Illinois by county (includes native and introduced species).

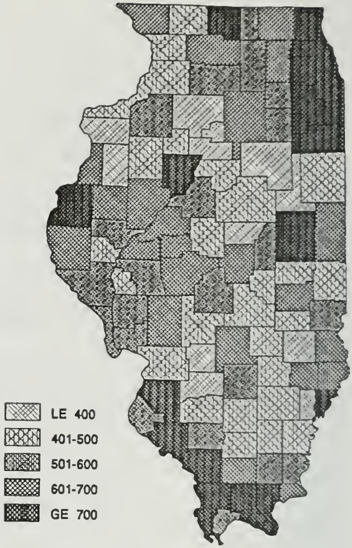


Figure 12. Number of forest-associated native taxa in Illinois, by county.

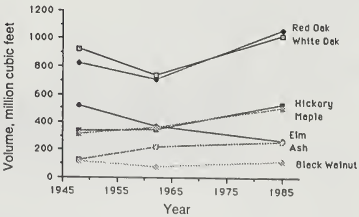


Figure 13. Trends in forest volume in Illinois by type, 1948-1985.

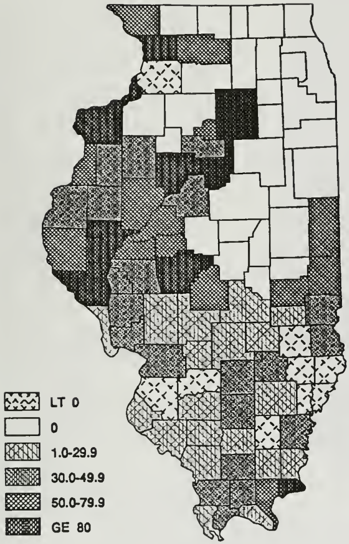


Figure 14. Trends in forest volume in Illinois by county, 1962-1985 (millions of cubic feet of sawtimber). [Note: for 28 counties with no coded change, no specific data were available for 1962 volumes; over all these prairie counties, however, there was a 269% increase in volume between 1962 and 1985.]

Figure 15. Fuelwood production in Illinois by county (standard cords x 1000), 1983.

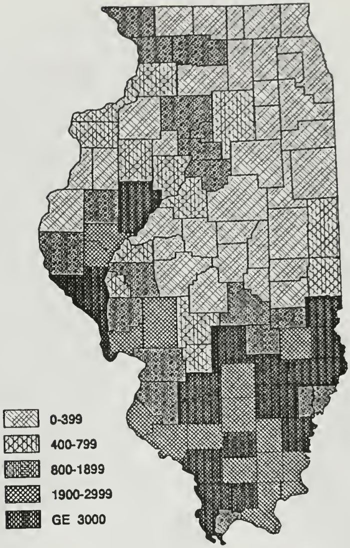


Figure 16. Sawlog production in Illinois by county, 1985 (thousands of cubic feet).

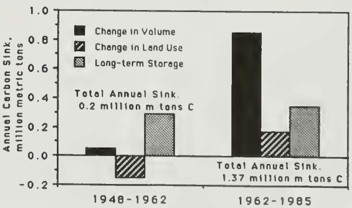
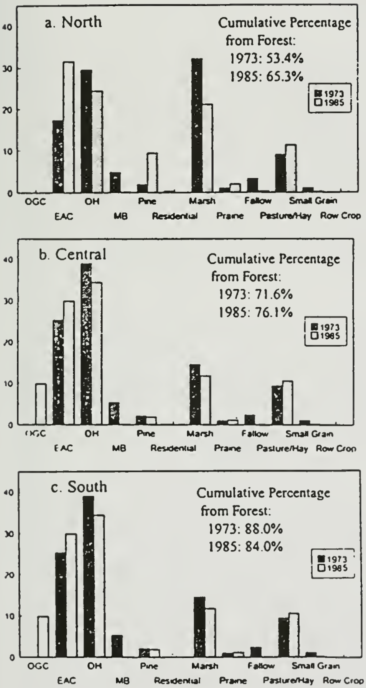


Figure 17. Carbon sinks and sources for Illinois forest lands, 1948-1985. Volume represents changes in carbon due to changes in volume per unit area of forest. Land indicates carbon changes because of land use changes, and storage represents long-term storage of carbon from harvesting of timber products.



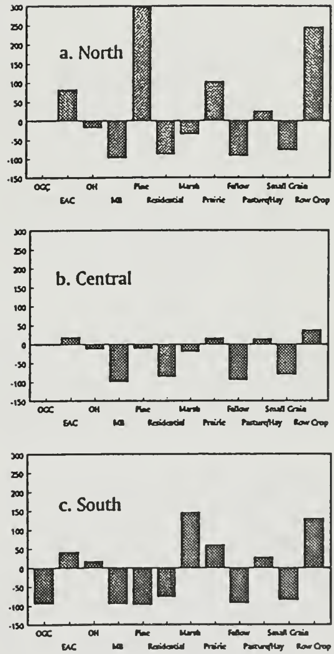


Figure 18a, b, c. Relative habitat factors for three regions of Illinois, 1973-85, according to the index of Graber and Graber (1976). OGC = oak-gum-cypress, EAC = elm-ash-cottonwood, OH = oak-hickory, MB = maple-beech.

Figure 19a, b, c. Percent change of relative habitat factors in Illinois between 1973 and 1985. OGC = oak-gum-cypress, EAC = elm-ash-cottonwood, OH = oak-hickory, MB = maple-beech.

Woody Plants of Illinois

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ABSTRACT

This paper contains a list of the native and naturalized woody plants of Illinois, along with summary information derived from this list. A total of 315 species of woody plants are native to Illinois, representing 56 families and 113 genera. There are 167 native species of trees, 166 shrubs, and 31 lianas (some species belong to more than one habit category). By far the largest woody plant family is the Rosaceae (rose family), with 74 native species in 11 genera. The Fagaceae and Salicaceae are the next most numerous woody families, each with 22 species native to the state. Conifers are poorly represented in Illinois, constituting only 6.6% of our native trees and 2.4% of native shrubs. Approximately 25% of the native tree species that occur in the continental United States occur naturally in Illinois. A total of 125 species of woody plants have been introduced and become naturalized in Illinois, including 57 trees, 76 shrubs, and 10 lianas (some species can be either trees or shrubs).

INTRODUCTION

As related elsewhere in these Proceedings, there is a wide diversity of forest types in Illinois. Concomitantly, the state also has many kinds of trees, shrubs, and woody vines. Of the approximately 2,300 taxa of vascular plants native to Illinois, 375 taxa, or approximately 16%, are woody.

There have been several publications on woody plants of Illinois. Perhaps the most familiar is *Forest Trees of Illinois*, published by the Illinois Department of Conservation. The first edition by Mattoon and Miller was published in 1927; G. D. Fuller and others revised the publication in 1946 and 1955; R. H. Mohlenbrock has written several editions, the first in published in 1970 and the most recent in 1990. All editions of Forest Trees of Illinois have line drawings showing the characteristic features of the species listed, along with short descriptions. More recent editions show distributions by county. Ebinger and Thut (1970) is an important regional treatment of the woody plants of east-central Illinois.

Two publications from the Illinois Natural History Survey are long out-of-print, but they contain information still useful today. Miller and Tehon's *The Native and Naturalized Trees of Illinois* (1929) has photographs of herbarium specimens, and the text has useful information on the habitats, uses, and historical records for large tree specimens. The *Fieldbook of Native Illinois Shrubs* (Tehon 1942) includes woody vines as well as shrubs and has line drawings, short descriptions, and brief accounts of distributions and habitats.

METHODS

The most recent listing of the woody plants of Illinois is in Appendix iii of Iverson *et al.* (1989). A modified version of this list with selected information is included as Table 2 in this present paper; summary information derived from this list is presented in Table 1. In preparing Tables 1 and 2, certain information from Iverson *et al.* (1989) was entered into FileMaker Pro data base on a Macintosh computer. Information was added on endangered or threatened status in Illinois (Illinois Endangered Species Protection Board (1994), Herkert and Kruse (1992), and Herkert (personal communication). Habit was considered only as plants occur in Illinois; for example, native populations of *Juniperus communis* are always shrubs in Illinois, and this is the way the species is listed in Table 2, even though the species can become a tree in New England. Four species of *Smilax* (Liliaceae) are included in this tabulation. Technically, monocots do not produce wood, but superficially these species of *Smilax* are lianas.

Numerous interspecific hybrids that have been given binomial names were added, largely following Mohlenbrock (1986). Common names come from a variety of sources: Iverson *et al.* (1989), Mohlenbrock (1986), Swink and Wilhelm (1979), Little (1979), and Hightshoe (1987). Species included here not in Iverson *et al.* (1989) are: *Rubus pubescens* and *Vaccinium oxycoccus*. Species included in Iverson *et al.* (1989) but excluded here are: *Gossypium hirsutum* (not woody when adventive in Illinois), *Hypericum densiflorum* (occurrence in Illinois doubtful, see Bowles *et al.* 1991), and *Rubus avipes* (placed in synonymy with *R. pensilvanicus* following Gleason and Cronquist, 1991)). Nomenclature follows Mohlenbrock (1986), except when an endangered or threatened species is listed under a different name (Illinois Endangered Species Protection Board, 1994; Herkert and Kruse, 1992).

RESULTS AND DISCUSSION

Some interesting observations can be made based on this list; only species--not varieties and hybrids--were used in compiling the summary information given below and in Table 1. There are a total of 314 species of woody plants native to Illinois, representing 56 families and 113 genera (Table 1). There are 167 species of trees, 166 species of shrubs, and 31 species of lianas or woody vines (some species belong to more than one habit category). Classified as a shrub in these tabulations, *Phoradendron serotinum* is a photosynthetic parasite that grows epiphytically on a number of different host tree species. By far the largest plant family represented by woody plants is the Rosaceae (rose family), with 74 species in 11 genera. Even among trees, the Rosaceae is twice as large with 44 native tree species, compared with the second largest family of trees, the Fagaceae with 22 species. Of the 44 species of tree Rosaceae, 28 belong to *Crataegus*; Mohlenbrock's treatment of this genus (1986), followed here, is very conservative, considering the number of apomictic variants. The same is also true of *Rubus*, with 16 native species recognized. The Rosaceae is also the largest family of trees in the continental United States (Little, 1979), with 77 species in 12 genera (Table 1).

In Illinois, two families have 22 species of woody plants, Fagaceae and Salicaceae; the former all trees, while the latter is about evenly divided between trees and shrubs. The forth largest woody family in the state, Caprifoliaceae, is largely composed of shrubs, with only three species becoming small trees and two species of *Lonicera* being vines. Somewhat surprisingly, the Ericaceae, a family largely restricted to acid habitats, is the fifth (second in numbers of genera) largest woody family in Illinois, with 16 species of shrubs in eight genera. The variety of sandstone habitats in Illinois, along with the few remaining acidic bogs in the northeastern part of the state, provide habitat for the members of the Ericaceae.

There are 47 endangered and 9 threatened species of woody plants in Illinois (Illinois Species Protection Board, 1994; Herkert and Kruse, 1992; Herkert, personal communication). Several species are thought to perhaps be extirpated from Illinois. These include: *Castanea dentata, Linnaea borealis, Andromeda polifolia,* and *Vaccinium stramineum.* The first has been decimated by chestnut blight, a fungal disease introduced from Europe. Habitat destruction is the probable cause for the demise of *Linnaea borealis* and *Andromeda polifolia*. *Vaccinium stramineum* has been recorded from only one site, in Pope County, and recent attempts to relocate the species have been unsuccessful, even though the original habitat is extant (Bowles *et al.*, 1991).

The total number of non-native woody species that have been introduced from other geographic regions and naturalized in Illinois is 126. There are 70 species of adventive shrubs, 10 adventive lianas, and 57 adventive trees. In addition, seven hybrids are reported to be naturalized, five of which are bush honeysuckles (*Lonicera*). Some of these introduced species are local and probably ephemeral, while others have invaded natural communities, displacing native species (see Schwegman, this issue). Some examples include *Lonicera japonica, Pueraria lobata,* the different species and hybrids of bush honeysuckles (*Lonicera*), *Rhamnus cathartica, R. frangula, Viburnum opulus, Berberis thunbergii, Morus alba, Rosa multiflora*, and *Elaeagnus umbellata*. Other species readily spread into disturbed habitats; examples include: *Ailanthus altissima, Albizia julibrissin* (in southern Illinois), and *Ulmus pumila. Robinia pseudoacacia*, native to southern Illinois, has spread widely beyond its original range.

A number of interspecific hybrids are known to occur naturally in Illinois. Some 25 of these hybrids have been given specific ephitets, and these are listed in Table 2. These include: *Aesculus* x *mississippiensis* (*A. pavia* x *A. glabra*), *Betula* x *purpusii* and *B.*x *sandbergii* (both reputed to be *B. alleghaniensis* x *B. pumila* var. *glandulifera*), *Carya* x *lecontei* (*C. aquatica* x *C. illinoensis*), *Carya nussbaumeri* (*C. illinoensis* x *C. laciniosa*), *Carya* x *schneckii* (*C. tomentosa* x *C. illinoensis*), *Populus* x *smithii* (*P. grandidentata* x *P. tremuloides*), *Salix* x *myricoides* (*S. rigida* x *S. sericea*), *Salix* x *subsericea* (*S. petiolaris* x *S. sericea*), and 18 different interspecific hybrids of *Quercus*.

In the most recent compendium of the trees of the United States (Little, 1979), a total of 679 species of trees are reported to be native to the continental United States. Since slightly different specific, generic, and familiar concepts were used by Little and in Table 2 of the present paper (*Crataegus* is, however, treated conservatively in both), only general comparisons should be made. About 25% (167 of 679) tree species native to the continental United States occur naturally in Illinois. As noted above, the Rosaceae has the most number of tree species in both Illinois and the continental United States. The Fagaceae, tied for second with the Salicaceae in Illinois, is clearly the second largest family nationally. One striking difference with the national list is the dearth of gymnosperms in Illinois, with only 11 native species, of which seven are listed as state endangered or threatened. Tree conifers make up only 6% of the trees in Illinois, while they constitute 14% of the tree species in the continental United States.

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Table 1. Summary data by plant family for the native woody plants of Illinois and comparisons with the native trees of the continental United States. Illinois data based on Appendix iii of Iverson et al. (1989); only species — not subspecies, varieties, or hybrids — were used in this tabulation. Species that can be either a tree/shrub or a shrub/liana are counted in both columns. The information on U. S. trees is from Little (1979); only general comparisons should be made between U. S. and Illinois trees since the two sources have slightly different familial, generic, and specific concepts. The first number in the columns is the number of native species while the number after the slash is the number of genera.

	Illinois Woody Plants	Illinois Shrubs	Illinois Lianas	Illinois Trees	Unites States Trees
Families	56	35	13	31	73
Genera	113	62	18	54	216
Species	314	166	31	167	679
Endangered	47	28	3	18	not available
Threatened	8	4	0	4	not available
Extirpated	4	3	0	1	not available
Rosaceae	74/ 11	52 / 8	0	44 / 5	77 / 12
Fagaceae	22 / 3	0	0	22 / 3	65 / 5
Salicaceae	22 / 2	12 / 1	0	13 / 2	35 / 2
Caprifoliaceae	19 / 6	17 / 6	2 / 1	3 / 1	11 / 2
Ericaceae	16 / 8	16 / 8	0	0	14 / 8
Juglandaceae	12 / 2	0	0	12 / 2	17 / 2
Betulaceae	11 / 5	5 / 3	0	7 / 4	20 / 5
Fabaceae	10 / 7	4 / 2	1 / 1	6 / 5	44 / 19
Vitaceae	10 / 3	0	10 / 3	0	0
Cornaceae	9 / 1	7 / 1	0	3 / 1	11 / 1
Ulmaceae	8 / 3	1 / 1	0	8 / 3	14 / 4
Aceraceae	6 / 1	0	0	6 / 1	13 / 1
Anacardiaceae	6 / 2	6 / 2	1 / 1	3 / 1	15 / 5
Oleaceae	6 / 2	1 / 1	0	6 / 2	22 / 4
Rhamnaceae	6 / 3	5 / 2	1 / 1	1 / 1	15 / 7
Hypericaceae	5 / 2	5 / 2	0	0	1 / 1
Pinaceae	5 / 2	0	0	5 / 2	61 / 6
Celastraceae	4 / 2	3 / 1	1 / 1	0	7 / 6
Cupressaceae	4 / 2	3 / 1	0	3 / 2	26 / 5
Grossulariaceae	4 / 1	4 / 1	0	0	0
Liliaceae	4 / 1	0	4 / 1	0	12 / 2
Aquifoliaceae	3 / 2	3 / 2	0	2 / 1	14 / 2
Bignoniaceae	3 / 3	0	2 / 2	1 / 1	5 / 4
Hippocastanaceae	3 / 1	2 / 1	0	2 / 1	6 / 1
Menispermaceae	3 / 1	0	3 / 1	0	0
Stryacaceae	3 / 2	2 / 1	0	1 / 1	6 / 2
Hamamelidaceae	2 / 2	1 / 1	0	2 / 2	2 / 2
Lauraceae	2 / 2	1 / 1	0	1 / 1	5 / 5
Magnoliaceae	2 / 2	0	0	2 / 2	11 / 3
Nyssaceae	2 / 1	0	0	2 / 1	3 / 1
Ranunculaceae	2 / 1	0	2 / 1	0	0

(Table 1 continued)

	Illinois Woody Plants	Illinois Shrubs	Illinois Lianas	Illinois Trees	Unites States Trees
Rutaceae	2 / 1	2 / 1	0	1 / 1	12 / 5
Sapotaceae	2 / 1	2 / 1	0	2 / 1	8 / 5
Tiliaceae	2 / 1	0	0	2 / 1	3 / 1
Anonaceae	1 / 1	0	0	1 / 1	4 / 2
Apocynaceae	1 / 1	0	1 / 1	0	0
Araliaceae	1 / 1	1 / 1	0	1 / 1	1 / 1
Aristolochiaceae	1 / 1	0	1 / 1	0	0
Berberidaceae	1 / 1	1 / 1	0	0	0
Cistaceae	1 / 1	1 / 1	0	0	0
Ebenaceae	1 / 1	0	0	1 / 1	2 / 1
Elaeagnaceae	1 / 1	1 / 1	0	0	1 / 1
Escalloniaceae	1 / 1	1 / 1	0	0	0
Hydrangeaceae	1 / 1	1 / 1	0	0	0
Moraceae	1 / 1	0	0	1 / 1	5 / 3
Myricaceae	1 / 1	1 / 1	0	0	5 / 1
Philadelphaceae	1 / 1	1 / 1	0	0	0
Platanaceae	1 / 1	0	0	1 / 1	3 / 1
Polygonaceae	1 / 1	0	1 / 1	0	2 / 1
Rubiaceae	1 / 1	1 / 1	0	0	7 / 6
Staphyleaceae	1 / 1	1 / 1	0	1 / 1	2 / 1
Taxaceae	1 / 1	1 / 1	0	0	4 / 2
Taxodiaceae	1 / 1	0	0	1 / 1	4 / 3
Thymelaeaceae	1 / 1	1 / 1	0	0	0
Viscaceae	1 / 1	1 / 1	0	0	0

Table 2. List of trees, shrubs, and woody vines native or naturalized in Illinois. Arranged alphabetically by genus and species. Based primarily on Iverson et al. (1989, Appendix iii) with some modifications and additions, especially with regards to interspecific hybrids and subspecific taxa. Nomenclature, including family names, follows Mohlenbrock (1986) except when the official list of endangered and threatened species uses a different name (Illinois Endangered Species Protection Board, 1994; Herkert & Kruse, 1992; Herkert, personal communication). Habit applies only to Illinois, i.e., some species that are always shrubs in Illinois may become trees elsewhere. Only one common name is given for each species; these come from various sources: Iverson et al. (1989), Little (1979), Mohlenbrock (1986), and Hightshoe (1987). Botanical forms are not included. The following abbreviations are used below. Column 3: T = tree, S = shrub, L = liana. Column 4: N = native, I = introduced. Column 5: E = endangered in Illinois, T = threatened in Illinois, X = presumed extirpated from the wild in Illinois.

Scientific name	Family	Habit	Native	E/T	Common name
Acer floridanum	Aceraceae	T	N		Southern sugar maple
Acer ginnala	Aceraceae	T/S	I		Amur maple
Acer negundo	Aceraceae	T	N		Boxelder
Acer nigrum	Aceraceae	T	N		Black maple
Acer platanoides	Aceraceae	T	I		Norway maple
Acer pseudoplatanus	Aceraceae	T	I		Sycamore maple
Acer rubrum var. *drummondii*	Aceraceae	T	N		Drummond's red maple
Acer rubrum var. *rubrum*	Aceraceae	T	N		Red maple
Acer rubrum var. *trilobum*	Aceraceae	T	N		Red maple
Acer saccharinum	Aceraceae	T	N		Silver maple
Acer saccharum var. *saccharum*	Aceraceae	T	N		Sugar maple
Acer saccharum var. *schneckii*	Aceraceae	T	N		Schneck's sugar maple
Aesculus flava	Hippocastanaceae	T/S	N		Yellow buckeye
Aesculus glabra var. *glabra*	Hippocastanaceae	T	N		Ohio buckeye
Aesculus glabra var. *leucodermis*	Hippocastanaceae	T	N		Ohio buckeye
Aesculus hippocastanum	Hippocastanaceae	T	I		Horse chestnut
Aesculus pavia	Hippocastanaceae	T/S	N		Red buckeye
Aesculus × *mississippiensis*	Hippocastanaceae	T/S	N		Hybrid buckeye
Ailanthus altissima	Simaroubaceae	T	I		Tree-of-heaven
Albizia julibrissin	Fabaceae	T	I		Mimosa-tree
Alnus glutinosa	Betulaceae	T	I		Black alder
Alnus rugosa	Betulaceae	S	N	E	Speckled alder
Alnus serrulata	Betulaceae	T/S	N		Common alder
Amelanchier arborea	Rosaceae	T/S	N		Downy serviceberry
Amelanchier humilis	Rosaceae	S	N		Low shadbush
Amelanchier interior	Rosaceae	T	N	E	Inland serviceberry
Amelanchier laevis	Rosaceae	S	N		Allegheny serviceberry
Amelanchier sanguinea	Rosaceae	T/S	N	E	Round-leaved serviceberry
Amorpha canescens	Fabaceae	S	N		Lead plant
Amorpha fruticosa var. *angustifolia*	Fabaceae	S	N		False indigo
Amorpha fruticosa var. *croceolanata*	Fabaceae	S	N		False indigo
Amorpha fruticosa var. *fruticosa*	Fabaceae	S	N		False indigo
Amorpha nitens	Fabaceae	S	N	E	Smooth false indigo
Ampelopsis arborea	Vitaceae	L	N		Pepper vine
Ampelopsis cordata	Vitaceae	L	N		Raccoon grape

(Table 2 continued)

Scientific name	Family	Habit	Native	E/T	Common name
Andromeda polifolia var. *glaucophylla*	Ericaceae	S	N	X	Bog rosemary
Aralia elata	Araliaceae	T/S	I		Japanese angelica tree
Aralia spinosa	Araliaceae	T/S	N		Devil's walking stick
Arctostaphylos uva-ursi subsp. *coactilis*	Ericaceae	S	N	E	Bearberry
Aristolochia tomentosa	Aristolochiaceae	L	N		Dutchman's pipe
Aronia melanocarpa	Rosaceae	S	N		Black chokeberry
Aronia prunifolia	Rosaceae	S	N		Purple chokeberry
Artemisia abrotanum	Asteraceae	S	I		Garden sagebrush
Artemisia absinthium	Asteraceae	S	I		Absinthe
Artemisia frigida	Asteraceae	S	I		Fringed sagebrush
Artemisia pontica	Asteraceae	S	I		Roman wormwood
Asimina triloba	Annonaceae	T	N		Pawpaw
Berberis canadensis	Berberidaceae	S	N	E	Allegheny barberry
Berberis thunbergii	Berberidaceae	S	I		Japanese barberry
Berberis vulgaris	Berberidaceae	S	I		Common barberry
Berchemia scandens	Rhamnaceae	L	N	E	Supple-jack
Betula alleghaniensis	Betulaceae	T	N	E	Yellow birch
Betula nigra	Betulaceae	T	N		River birch
Betula papyrifera	Betulaceae	T	N		Paper birch
Betula populifolia	Betulaceae	T	N	E	Gray birch
Betula pumila var. *glabra*	Betulaceae	S	N		Dwarf birch
Betula pumila var. *glandulifera*	Betulaceae	S	N		Dwarf birch
Betula pumila var. *pumila*	Betulaceae	S	N		Dwarf birch
Betula × *purpusii*	Betulaceae	T/S	N		Purpus' birch
Betula × *sandbergii*	Betulaceae	T/S	N		Sandberg's birch
Bignonia capreolata	Bignoniaceae	L	N		Cross vine
Broussonetia papyrifera	Moraceae	T	I		Paper mulberry
Brunnichia ovata	Polygonaceae	L	N		Buckwheat vine
Bumelia lanuginosa var. *oblongifolia*	Sapotaceae	T/S	N	E	Chittam wood
Bumelia lycioides	Sapotaceae	T/S	N		Southern buckthorn
Calycanthus floridus	Calycanthaceae	S	I		Strawberry shrub
Calycocarpum lyonii	Menispermaceae	L	N		Cupseed
Campsis radicans	Bignoniaceae	L	N		Trumpet creeper
Caragana arborescens	Fabaceae	T/S	I		Siberian pea-tree
Carpinus caroliniana	Betulaceae	T	N		American hornbeam
Carya aquatica	Juglandaceae	T	N		Water hickory
Carya cordiformis	Juglandaceae	T	N		Bitternut hickory
Carya glabra var. *megacarpa*	Juglandaceae	T	N		Pignut hickort
Carya illinoensis	Juglandaceae	T	N		Pecan
Carya laciniosa	Juglandaceae	T	N		Shellbark hickory
Carya ovalis var. *obovalis*	Juglandaceae	T	N		Sweet pignut hickory
Carya ovalis var. *odorata*	Juglandaceae	T	N		Sweet pignut hickory
Carya ovalis var. *ovalis*	Juglandaceae	T	N		Sweet pignut hickory
Carya ovata var. *fraxinifolia*	Juglandaceae	T	N		Ash-leaved shagbark hickory

(Table 2 continued)

Scientific name	Family	Habit	Native	E/T	Common name
Carya ovata var. *nuttallii*	Juglandaceae	T	N		Small shagbark hickory
Carya ovata var. *ovata*	Juglandaceae	T	N		Shagbark hickory
Carya pallida	Juglandaceae	T	N	E	Pale hickory
Carya texana	Juglandaceae	T	N		Black hickory
Carya tomentosa	Juglandaceae	T	N		Mockernut hickory
Carya × lecontei	Juglandaceae	T	N		Hickory
Carya × nussbaumeri	Juglandaceae	T	N		Hickory
Carya × schneckii	Juglandaceae	T	N		Hickory
Castanea dentata	Fagaceae	T	N	X	American chestnut
Castanea mollissima	Fagaceae	T	I		Chinese chestnut
Catalpa bignonioides	Bignoniaceae	T	I		Common catalpa
Catalpa speciosa	Bignoniaceae	T	N		Western catalpa
Ceanothus americanus var. *americanus*	Rhamnaceae	S	N		New Jersey tea
Ceanothus americanus var. *pitcheri*	Rhamnaceae	S	N		New Jersey tea
Ceanothus ovatus	Rhamnaceae	S	N	E	Redroot
Celastrus orbicularis	Celastraceae	L	I		Round-leaved bittersweet
Celastrus scandens	Celastraceae	L	N		American bittersweet
Celtis laevigata var. *laevigata*	Ulmaceae	T	N		Sugarberry
Celtis laevigata var. *smallii*	Ulmaceae	T	N		Toothed sugarberry
Celtis laevigata var. *texana*	Ulmaceae	T	N		Cliff sugarberry
Celtis occidentalis var. *canina*	Ulmaceae	T	N		Hackberry
Celtis occidentalis var. *occidentalis*	Ulmaceae	T	N		Hackberry
Celtis occidentalis var. *pumila*	Ulmaceae	T	N		Small hackberry
Celtis tenuifolia var. *georgiana*	Ulmaceae	T/S	N		Dwarf hackberry
Celtis tenuifolia var. *tenuifolia*	Ulmaceae	T/S	N		Dwarf hackberry
Cephalanthus occidentalis var. *occidentalis*	Rubiaceae	S	N		Buttonbush
Cephalanthus occidentalis var. *pubescens*	Rubiaceae	S	N		Buttonbush
Cercis canadensis	Fabaceae	T/S	N		Redbud
Chaenomeles japonica	Rosaceae	S	I		Japanese quince
Chamaedaphne calyculata var. *angustifolia*	Ericaceae	S	N	T	Leatherleaf
Cladrastis lutea	Fabaceae	T	N	E	Yellowwood
Clematis occidentalis	Ranunculaceae	L	N	E	Purple clematis
Clematis virginiana	Ranunculaceae	L	N		Virgin's bower
Cocculus carolinus	Menispermaceae	L	N		Snailseed
Comptonia peregrina	Myricaceae	S	N	E	Sweetfern
Cornus alternifolia	Cornaceae	T	N		Pogoda dogwood
Cornus amomum	Cornaceae	S	N		Silky dogwood
Cornus drummondii	Cornaceae	T/S	N		Rough-leaved dogwood
Cornus florida	Cornaceae	T	N		flowering dogwood
Cornus foemina	Cornaceae	S	N		Stiff dogwood
Cornus obliqua	Cornaceae	S	N		Pale dogwood

(Table 2 continued)

Scientific name	Family	Habit	Native	E/T	Common name
Cornus racemosa	Cornaceae	S	N		Gray dogwood
Cornus rugosa	Cornaceae	S	N		Round-leaved dogwood
Cornus stolonifera var. *baileyi*	Cornaceae	S	N		Bailey's dogwood
Cornus stolonifera var. *stolonifera*	Cornaceae	S	N		Red osier dogwood
Corylus americana	Betulaceae	S	N		Hazelnut
Corylus cornuta	Betulaceae	S	N	E	Beaked hazelnut
Crataegus acutifolia	Rosaceae	T	N		Hawthorn
Crataegus calpodendron	Rosaceae	T/S	N		Urn-shaped hawthorn
Crataegus coccinioides	Rosaceae	T/S	N		Hawthorn
Crataegus collina	Rosaceae	T	N		Hawthorn
Crataegus corusca	Rosaceae	T	N		Hawthorn
Crataegus crus-galli var. *barrettiana*	Rosaceae	T/S	N		Barrett's hawthorn
Crataegus crus-galli var. *crus-galli*	Rosaceae	T/S	N		Cock-spur hawthorn
Crataegus cuneiformis	Rosaceae	T	N		Hawthorn
Crataegus engelmanii	Rosaceae	T/S	N		Barberry-leaved hawthorn
Crataegus faxonii	Rosaceae	T/S	N		Hawthorn
Crataegus fecunda	Rosaceae	T	N		Fruitful hawthorn
Crataegus hannibalensis	Rosaceae	T/S	N		Hawthorn
Crataegus holmesiana	Rosaceae	T/S	N		Hawthorn
Crataegus lucorum	Rosaceae	T/S	N		Hawthorn
Crataegus macrosperma	Rosaceae	T/S	N		Hawthorn
Crataegus margaretta	Rosaceae	T/S	N		Hawthorn
Crataegus marshalii	Rosaceae	T/S	N		Parsley hawthorn
Crataegus mollis	Rosaceae	T	N		Red haw
Crataegus monogyna	Rosaceae	T/S	I		English hawthorn
Crataegus neobushii	Rosaceae	T	N		Hawthorn
Crataegus nitida	Rosaceae	T	N		Glossy hawthorn
Crataegus pedicellata	Rosaceae	T/S	N		Hawthorn
Crataegus permixta	Rosaceae	T	N		Hawthorn
Crataegus phaenopyrum	Rosaceae	T	N		Washington hawthorn
Crataegus pringlei	Rosaceae	T	N		Hawthorn
Crataegus pruinosa	Rosaceae	T/S	N		Frosted hawthorn
Crataegus punctata	Rosaceae	T/S	N		Dotted hawthorn
Crataegus succulenta	Rosaceae	T/S	N		fleshy hawthorn
Crataegus tortilis	Rosaceae	T/S	N		Hawthorn
Crataegus viridis	Rosaceae	T	N		Green hawthorn
Cydonia oblonga	Rosaceae	T/S	I		Quince
Deutzia scabra	Philadelphaceae	S	I		Pride-of-Rochester
Diervilla lonicera	Caprifoliaceae	S	N		Bush honeysuckle
Diospyros virginiana	Ebenaceae	T	N		Permisson
Dirca palustris	Thymelaeaceae	S	N		Leatherwood
Elaeagnus angustifolia	Elaeagnaceae	T/S	I		Russian olive
Elaeagnus multiflora	Elaeagnaceae	S	I		Oleastern
Elaeagnus umbellata	Elaeagnaceae	S	I		Autumn olive

(Table 2 continued)

Scientific name	Family	Habit	Native	E/T	Common name
Epigaea repens	Ericaceae	S	N		Trailing arbutus
Euonymus alatus	Celastraceae	S	I		Burning bush
Euonymus americanus	Celastraceae	S	N	E	Strawberry bush
Euonymus atropurpureus	Celastraceae	S	N		Eastern wahoo
Euonymus euopaeus	Celastraceae	S	I		European spindle-tree
Euonymus fortunei	Celastraceae	S	I		Wintercreeper
Euonymus kiautschovicus	Celastraceae	S	I		Spreading euonyumus
Euonymus obovatus	Celastraceae	S	N		Running strawberry bush
Fagus grandifolia var. *caroliniana*	Fagaceae	T	N		American beech
Forestiera acuminata	Oleaceae	T/S	N		Swamp privet
Fraxinus americana	Oleaceae	T	N		White ash
Fraxinus nigra	Oleaceae	T	N		Black ash
Fraxinus pennsylvanica	Oleaceae	T	N		Green ash
Fraxinus profunda	Oleaceae	T	N		Pumpkin ash
Fraxinus quadrangulata	Oleaceae	T	N		Blue ash
Gaultheria procumbens	Ericaceae	S	N	E	Wintergreen
Gaylussacia baccata	Ericaceae	S	N		Black huckleberry
Gleditsia aquatica	Fabaceae	T	N		Water locust
Gleditsia triacanthos	Fabaceae	T	N		Honeylocust
Gymnocladus dioica	Fabaceae	T	N		Kentucky coffee tree
Halesia carolina	Styracaceae	T	N	E	Carolina silverbell
Hamamelis virginiana	Hamamelidaceae	T/S	N		Common witch-hazel
Hedera helix	Araliaceae	L	I		English ivy
Hibiscus syriacus	Malvaceae	S	I		Rose-of-Sharon
Hudsonia tomentosa var. *intermedia*	Cistaceae	S	N	E	Beach heather
Hudsonia tomentosa var. *tomentosa*	Cistaceae	S	N	E	Beach heather
Hydrangea arborescens	Hydrangeaceae	S	N		Smooth hydrangea
Hypericum hypericoides	Hypericaceae	S	N		St. Andrew's cross
Hypericum kalmianum	Hypericaceae	S	N	E	Kalm St. John's-wort
Hypericum lobocarpum	Hypericaceae	S	N		St. John's-wort
Hypericum prolificum	Hypericaceae	S	N		Shrubby St. John's-wort
Hypericum stragulum	Hypericaceae	S	N		St. Andrew's cross
Ilex decidua	Aquifoliaceae	T/S	N		Possom haw
Ilex verticillata	Aquifoliaceae	T/S	N		American holly
Itea virginica	Escalloniaceae	S	N		Virginia sweetspire
Juglans cinerea	Juglandaceae	T	N		Butternut
Juglans nigra	Juglandaceae	T	N		Black walnut
Juniperus communis var. *comnunis*	Cupressaceae	S	N	T	Common juniper
Juniperus communis var. *depress*	Cupressaceae	S	N	T	Ground juniper
Juniperus horizontalis	Cupressaceae	S	N	E	Trailing juniper
Juniperus virginiana	Cupressaceae	T	N		Eastern redcedar
Kerria japonica	Rosaceae	S	I		Japanese kerria
Koelreuteria paniculata	Sapindaceae	T	I		Goldenrain tree
Larix decidua	Pinaceae	T	I		European larch

(Table 2 continued)

Scientific name	Family	Habit	Native	E/T	Common name
Larix laricina	Pinaceae	T	N	T	Tamarack
Ligustrum obtusifolium	Oleaceae	S	I		Border privet
Ligustrum vulgare	Oleaceae	S	I		Common privet
Lindera benzoin var. *benzoin*	Lauraceae	S	N		Spicebush
Lindera benzoin var. *pubescens*	Lauraceae	S	N		Hairy spicebush
Linnaea borealis subsp. *americana*	Caprifoliaceae	S	N	X	Twinflower
Liquidambar styraciflua	Hamamelidaceae	T	N		Sweetgum
Liriodendron tulipifera	Magnoliaceae	T	N		Tulip tree
Lonicera dioica var. *dioica*	Caprifoliaceae	S/L	N		Red honeysuckle
Lonicera dioica var. *glaucescens*	Caprifoliaceae	S/L	N	E	Red honeysuckle
Lonicera flava	Caprifoliaceae	L	N	E	Yellow honeysuckle
Lonicera japonica var. *chinensis*	Caprifoliaceae	L	I		Japanese honeysuckle
Lonicera japonica var. *japonica*	Caprifoliaceae	L	I		Japanese honeysuckle
Lonicera maackii	Caprifoliaceae	S	I		Amur honeysuckle
Lonicera morrowii	Caprifoliaceae	S	I		Morrow honeysuckle
Lonicera prolifera	Caprifoliaceae	L	N		Grape honeysuckle
Lonicera ruprechtiana	Caprifoliaceae	S	I		Manchurian honeysuckle
Lonicera sempervirens	Caprifoliaceae	L	I		Trumpet honeysuckle
Lonicera standishii	Caprifoliaceae	S	I		Honeysuckle
Lonicera tatartica	Caprifoliaceae	S	I		Tatarian honeysuckle
Lonicera × *bella*	Caprifoliaceae	S	I		Belle honeysuckle
Lonicera × *minutiflora*	Caprifoliaceae	S	I		Bush Honeysuckle
Lonicera × *muendeniensis*	Caprifoliaceae	S	I		Bush honeysuckle
Lonicera × *muscaviensis*	Caprifoliaceae	S	I		Bush honeysuckle
Lonicera × *xylosteoides*	Caprifoliaceae	S	I		Bush honeysuckle
Lonicera xylosteum	Caprifoliaceae	S	I		European fly honeysuckle
Lycium barbarum	Solanaceae	S	I		Common matrimony vine
Lycium chinense	Solanaceae	S	I		Chinese matrimony vine
Maclura pomifera	Moraceae	T	I		Osage orange
Magnolia acuminata	Magnoliaceae	T	N		Cucumber magnolia
Malus angustifolia	Rosaceae	T	N	E	Southern crab apple
Malus coronaria var. *coronaria*	Rosaceae	T	N		Sweet crab apple
Malus coronaria var. *dasycalyx*	Rosaceae	T	N		Sweet crab apple
Malus ioensis	Rosaceae	T	N		Prairie crab apple
Malus pumila	Rosaceae	T	I		Apple
Malus × *soulardii*	Rosaceae	T	I		Soulard crab apple
Menispermum canadensis	Menispermaceae	L	N		Moonseed
Morus alba var. *alba*	Moraceae	T/S	I		White mulberry
Morus alba var. *tatarica*	Moraceae	T/S	I		Russian mulberry
Morus rubra	Moraceae	T	N		Red mulberry
Nemopanthus mucronatus	Aquifoliaceae	S	N		Mountain holly
Nyssa aquatica	Nyssaceae	T	N		Water tupelo
Nyssa sylvatica var. *caroliniana*	Nyssaceae	T	N		Black tupelo
Nyssa sylvatica var. *sylvatica*	Nyssaceae	T	N		Black tupelo

(Table 2 continued)

Scientific name	Family	Habit	Native	E/T	Common name
Onosis spinosa	Fabaceae	S	I		Rest-harrow
Ostrya virginiana	Betulaceae	T	N		Hop hornbeam
Oxydendrum arboreum	Ericaceae	T	I		Sourwood
Parthenocissus inserta	Vitaceae	L	N		Virginia creeper
Parthenocissus quinquefolia	Vitaceae	L	N		Virginia creeper
Parthenocissus tricuspidata	Vitaceae	L	I		Boston ivy
Paulownia tomentosa	Scrophulariaceae	T	I		Royal paulownia
Philadelphus coronarius	Philadelphaceae	S	I		Sweet mock-orange
Philadelphus inodorus	Philadelphaceae	S	I		Scentless mock-orange
Philadelphus pubescens	Philadelphaceae	S	N		Mock-orange
Phoradendron serotinum	Viscaceae	S	N		Mistletoe
Physocarpus opulifolius	Rosaceae	S	N		Common ninebark
Picea abies	Pinaceae	T	I		Norway spruce
Picea mariana	Pinaceae	T	I		Black spruce
Pinus banksiana	Pinaceae	T	N	E	Jack pine
Pinus echinata	Pinaceae	T	N	E	Shortleaf pine
Pinus nigra	Pinaceae	T	I		Austrian pine
Pinus pungens	Pinaceae	T	I		Prickly pine
Pinus resinosa	Pinaceae	T	N	E	Red pine
Pinus rigida	Pinaceae	T	I		Pitch pine
Pinus strobus	Pinaceae	T	N		White pine
Pinus sylvestris	Pinaceae	T	I		Scotch pine
Pinus taeda	Pinaceae	T	I		Loblolly pine
Pinus wallichiana	Pinaceae	T	I		Himalayan pine
Planera aquatica	Ulmaceae	T	N	E	Water elm
Platanus occidentalis	Platanaceae	T	N		Sycamore
Populus alba	Salicaceae	T	I		White poplar
Populus balsamifera	Salicaceae	T	N	E	Balsam poplar
Populus deltoides	Salicaceae	T	N		Eastern cottonwood
Populus grandidentata	Salicaceae	T	N		Big-toothed aspen
Populus heterophylla	Salicaceae	T	N		Swamp cottonwood
Populus nigra var. *italica*	Salicaceae	T	I		Lombardy poplar
Populus tremuloides	Salicaceae	T	N		Quaking aspen
Populus × *canescens*	Salicaceae	T	I		Gray poplar
Populus × *gileadensis*	Salicaceae	T	I		Balm-of-Gilead
Populus × *smithii*	Salicaceae	T	N		Barnes' aspen
Potentilla fruticosa subsp. *floribunda*	Rosaceae	S	N		Bush cinquefoil
Prunus americana var. *americana*	Rosaceae	T/S	N		American plum
Prunus americana var. *lanata*	Rosaceae	T/S	N		American plum
Prunus angustifolia	Rosaceae	T/S	N		Chickasaw plum
Prunus armeniaca	Rosaceae	T	I		Apricot
Prunus avium	Rosaceae	T	I		Sweet cherry
Prunus cerasus	Rosaceae	T	I		Sour cherry
Prunus hortulana	Rosaceae	T	N		Wild goose plum

(Table 2 continued)

Scientific name	Family	Habit	Native	E/T	Common name
Prunus mahaleb	Rosaceae	T/S	I		Mahaleb cherry
Prunus mexicana	Rosaceae	T	N		Mexican plum
Prunus munsoniana	Rosaceae	T	N		Wild goose plum
Prunus nigra	Rosaceae	T	N		Canadian plum
Prunus padus	Rosaceae	T/S	I		European bird cherry
Prunus pensylvanica	Rosaceae	T/S	N		Pin cherry
Prunus persica	Rosaceae	T	I		Peach
Prunus serotina	Rosaceae	T	N		Black cherry
Prunus susquehanae	Rosaceae	S	N		Sand cherry
Prunus triloba	Rosaceae	T/S	I		flowering almond
Prunus virginiana	Rosaceae	T/S	N		Choke cherry
Ptelea trifoliata	Rutaceae	T/S	N		Wafer ash
Pueraria lobata	Fabaceae	L	I		Kudzu-vine
Pyrus calleryana	Rosaceae	T	I		Callery pear
Pyrus communis	Rosaceae	T	I		Common pear
Pyrus pyrifolia	Rosaceae	T	I		Chinese pear
Quercus alba	Fagaceae	T	N		White oak
Quercus bicolor	Fagaceae	T	N		Swamp white oak
Quercus coccinea	Fagaceae	T	N		Scarlet oak
Quercus ellipsoidalis	Fagaceae	T	N		Hill's oak
Quercus falcata	Fagaceae	T	N		Southern red oak
Quercus imbricaria	Fagaceae	T	N		Laurel oak
Quercus lyrata	Fagaceae	T	N		Overcup oak
Quercus macrocarpa	Fagaceae	T	N		Bur oak
Quercus marilandica	Fagaceae	T	N		Blackjack oak
Quercus michauxii	Fagaceae	T	N		Swamp chestnut oak
Quercus nuttallii	Fagaceae	T	N	E	Nuttall's oak
Quercus pagoda	Fagaceae	T	N		Cherrybark oak
Quercus palustris	Fagaceae	T	N		Pin oak
Quercus phellos	Fagaceae	T	N	T	Willow oak
Quercus prinoides var. *acuminata*	Fagaceae	T	N		Chinkapin oak
Quercus prinus	Fagaceae	T	N	T	Chestnut oak
Quercus rubra	Fagaceae	T	N		Northern red oak
Quercus shumardii	Fagaceae	T	N		Shumard's oak
Quercus stellata	Fagaceae	T	N		Post oak
Quercus velutina	Fagaceae	T	N		Black oak
Quercus × *anceps*	Fagaceae	T	N		Hybrid oak
Quercus × *bebbiana*	Fagaceae	T	N		Hybrid oak
Quercus × *bushii*	Fagaceae	T	N		Hybrid oak
Quercus × *deamii*	Fagaceae	T	N		Hybrid oak
Quercus × *exacta*	Fagaceae	T	N		Hybrid oak
Quercus × *fallax*	Fagaceae	T	N		Hybrid oak
Quercus × *fernowii*	Fagaceae	T	N		Hybrid oak
Quercus × *filialis*	Fagaceae	T	N		Hybrid oak

(Table 2 continued)

Scientific name	Family	Habit	Native	E/T	Common name
Quercus × *hillii*	Fagaceae	T	N		Hybrid oak
Quercus × *humidicola*	Fagaceae	T	N		Hybrid oak
Quercus × *jackiana*	Fagaceae	T	N		Hybrid oak
Quercus × *ludoviciana*	Fagaceae	T	N		Hybrid oak
Quercus × *palmeriana*	Fagaceae	T	N		Hybrid oak
Quercus × *runcinata*	Fagaceae	T	N		Hybrid oak
Quercus × *saulii*	Fagaceae	T	N		Hybrid oak
Quercus × *schochiana*	Fagaceae	T	N		Hybrid oak
Quercus × *schuettei*	Fagaceae	T	N		Hybrid oak
Quercus × *tridentata*	Fagaceae	T	N		Hybrid oak
Rehsonia floribunda	Fabaceae	L	I		Japanese wisteria
Rehsonia sinensis	Fabaceae	L	I		Chinese wisteria
Rhamnus alnifolia	Rhamnaceae	S	N	E	Alder buckthorn
Rhamnus caroliniana	Rhamnaceae	T/S	N		Carolina buckthorn
Rhamnus cathartica	Rhamnaceae	T/S	I		Common buckthorn
Rhamnus davurica	Rhamnaceae	T	I		Dahurian buckthorn
Rhamnus frangula var. *angustifolia*	Rhamnaceae	T/S	I		Narrow-leaved glossy buckthorn
Rhamnus frangula var. *frangula*	Rhamnaceae	T/S	I		Glossy buckthorn
Rhamnus lanceolata	Rhamnaceae	S	N		Lance-leaved buckthorn
Rhododendron periclymenoides	Ericaceae	S	N		Pinxter flower
Rhododendron prinophyllum	Ericaceae	S	N		Early azalea
Rhodotypos scandens	Rosaceae	S	I		Jetbead
Rhus aromatica var. *arenaria*	Anacardiaceae	S	N		Beach sumac
Rhus aromatica var. *aromatica*	Anacardiaceae	S	N		Fragrant sumac
Rhus aromatica var. *serotina*	Anacardiaceae	S	N		Fragrant sumac
Rhus copallina	Anacardiaceae	T/S	N		Winged sumac
Rhus glabra	Anacardiaceae	T/S	N		Smooth sumac
Rhus typhina	Anacardiaceae	T/S	N		Staghorn sumac
Ribes americanum	Grossulariaceae	S	N		Wild black current
Ribes cynosbati	Grossulariaceae	S	N		Prickly gooseberry
Ribes hirtellum	Grossulariaceae	S	N	E	Northern gooseberry
Ribes missouriense	Grossulariaceae	S	N		Missouri gooseberry
Ribes nigrum	Grossulariaceae	S	I		Black current
Ribes odoratum	Grossulariaceae	S	I		Buffalo current
Ribes rubrum	Grossulariaceae	S	I		Red current
Robinia hispida	Fabaceae	S	I		Bristly locust
Robinia pseudoacacia	Fabaceae	T	N		Black locust
Robinia viscosa	Fabaceae	T/S	I		Clammy locust
Rosa acicularis	Rosaceae	S	N	E	Prickly rose
Rosa arkansana	Rosaceae	S	I		Lunell's rose
Rosa blanda	Rosaceae	S	N		Meadow rose
Rosa canina	Rosaceae	S	I		Dog rose
Rosa carolina var. *carolina*	Rosaceae	S	N		Pasture rose

(Table 2 continued)

Scientific name	Family	Habit	Native	E/T	Common name
Rosa carolina var. *villosa*	Rosaceae	S	N		Pasture rose
Rosa eglanteria	Rosaceae	S	I		Sweet-brier
Rosa gallica	Rosaceae	S	I		French rose
Rosa micrantha	Rosaceae	S	I		Small sweet-brier
Rosa moschata	Rosaceae	S	I		Musk rose
Rosa multiflora	Rosaceae	S	I		Multiflora rose
Rosa palustris	Rosaceae	S	N		Swamp rose
Rosa rubrifolia	Rosaceae	S	I		Red-leaved rose
Rosa rugosa	Rosaceae	S	I		Rugose rose
Rosa setigera var. *setigera*	Rosaceae	S	N		Prairie rose
Rosa setigera var. *tomentosa*	Rosaceae	S	N		Prairie rose
Rosa spinosissima	Rosaceae	S	I		Scotch rose
Rosa suffulta	Rosaceae	S	N		Sunshine rose
Rosa wichuriana	Rosaceae	S	I		Memorial rose
Rubus allegheniensis	Rosaceae	S	N		Common blackberry
Rubus alumnus	Rosaceae	S	N		Blackberry
Rubus argutus	Rosaceae	S	N		Highbush blackberry
Rubus discolor	Rosaceae	S	I		Himalaya-berry
Rubus enslenii	Rosaceae	S	N		Arching dewberry
Rubus flagellaris	Rosaceae	S	N		Dewberry
Rubus frondosus	Rosaceae	S	N		Blackberry
Rubus hispidus	Rosaceae	S	N		Swamp dewberry
Rubus idaeus	Rosaceae	S	I		European raspberry
Rubus laciniatus	Rosaceae	S	I		Cut-leaved blackberry
Rubus occidentalis	Rosaceae	S	N		Black raspberry
Rubus odoratus	Rosaceae	S	N	E	flowering raspberry
Rubus pensylvanicus	Rosaceae	S	N		Blackberry
Rubus phoenicolasius	Rosaceae	S	I		Wineberry
Rubus pubescens	Rosaceae	S	N	T	Dwarf raspberry
Rubus roribaccus	Rosaceae	S	N		Velvet-leaved dewberry
Rubus setosus	Rosaceae	S	N	E	Bristly blackberry
Rubus strigosus	Rosaceae	S	N		Red raspberry
Rubus trivalis	Rosaceae	S	N		Southern dewberry
Salix alba var. *alba*	Salicaceae	T	I		White willow
Salix alba var. *calva*	Salicaceae	T	I		White willow
Salix alba var. *vitellina*	Salicaceae	T	I		White willow
Salix amygdaloides	Salicaceae	T	N		Peach-leaved willow
Salix babylonica	Salicaceae	T	I		Weeping willow
Salix bebbiana	Salicaceae	T/S	N		Beaked willow
Salix candida	Salicaceae	S	N		Hoary willow
Salix caprea	Salicaceae	T/S	I		Goat willow
Salix caroliniana	Salicaceae	T	N		Carolina willow
Salix discolor	Salicaceae	T	N		Pussy willow
Salix eriocephala	Salicaceae	T	N		Willow

(Table 2 continued)

Scientific name	Family	Habit	Native	E/T	Common name
Salix exigua	Salicaceae	S	N		Sandbar willow
Salix fragilis	Salicaceae	T	I		Crack willow
Salix glaucophylloides var. *glaucophylla*	Salicaceae	S	N		Blue-leaf willow
Salix humilis var. *humilis*	Salicaceae	S	N		Prairie willow
Salix humilis var. *hyporhysa*	Salicaceae	S	N		Prairie willow
Salix humilis var. *microphylla*	Salicaceae	S	N		Sage willow
Salix lucida	Salicaceae	T/S	N		Shinning willow
Salix nigra	Salicaceae	T	N		Black willow
Salix pedicellaris var. *hypoglauca*	Salicaceae	S	N		Bog willow
Salix pentandra	Salicaceae	T/S	I		Laurel willow
Salix petiolaris	Salicaceae	S	N		Meadow willow
Salix purpurea	Salicaceae	S	I		Purple osier
Salix rigida	Salicaceae	S	N		Heart-leaved willow
Salix sericea	Salicaceae	T/S	N		Silky willow
Salix serissima	Salicaceae	S	N	E	Autumn willow
Salix syrticola	Salicaceae	S	N	E	Dune willow
Salix × nyricoides	Salicaceae	S	N		Willow
Salix × subsericea	Salicaceae	S	N		Willow
Sambucus canadensis	Caprifoliaceae	S	N		Elderberry
Sambucus pubens	Caprifoliaceae	S	N	T	Red-berried elder
Sassafras albidum var. *albidum*	Lauraceae	T	N		Sassafras
Sassafras albidum var. *molle*	Lauraceae	T	N		Red sassafras
Shepherdia canadensis	Elaeagnaceae	S	N	E	Buffalo-berry
Smilax bona-nox var. *bona-nox*	Liliaceae	L	N		Catbrier
Smilax bona-nox var. *hederaefolia*	Liliaceae	L	N		Catbrier
Smilax glauca var. *glauca*	Liliaceae	L	N		Catbrier
Smilax glauca var. *leurophylla*	Liliaceae	L	N		Catbrier
Smilax hispida	Liliaceae	L	N		Bristly greenbrier
Smilax rotundifolia	Liliaceae	L	N		Catbrier
Sorbus americana	Rosaceae	T	N	E	American mountain-ash
Sorbus aucuparia	Rosaceae	T	I		European mountain-ash
Spiraea alba	Rosaceae	S	N		Meadowsweet
Spiraea japonica	Rosaceae	S	I		Japanese spirea
Spiraea latifolia	Rosaceae	S	I		Meadowsweet
Spiraea prunifolia	Rosaceae	S	I		Bridalwreath
Spiraea tomentosa	Rosaceae	S	N		Hardhack
Staphylea trifolia	Staphyleaceae	S/T	N		Bladdernut
Styrax americana	Styracaceae	S	N	T	Storax
Styrax grandifolia	Styracaceae	S	N	E	Bigleaf snowbell bush
Symphoricarpos albus var. *albus*	Caprifoliaceae	S	N	E	Common snowberry
Symphoricarpos albus var. *laevigatus*	Caprifoliaceae	S	I		Common snowberry
Symphoricarpos occidentalis	Caprifoliaceae	S	N		Western snowberry
Symphoricarpos orbiculatus	Caprifoliaceae	S	N		Coralberry
Syringa vulgaris	Oleaceae	S	I		Common lilac

(Table 2 continued)

Scientific name	Family	Habit	Native	E/T	Common name
Tamarix gallica	Tamaricaceae	T/S	I		French tamarisk
Taxodium distichum	Taxodiaceae	T	N		Bald cypress
Taxus canadensis	Taxaceae	S	N		Canada yew
Thuja occidentalis	Cupressaceae	T	N	T	Eastern arborvitae
Thymus praecox	Lamiaceae	S	I		Creeping thyme
Tilia americana var. *americana*	Tiliaceae	T	N		American basswood
Tilia americana var. *neglecta*	Tiliaceae	T	N		American basswood
Tilia heterophylla	Tiliaceae	T	N	E	White basswood
Toxicodendron radicans	Anacardiaceae	S/L	N		Poison ivy
Toxicodendron toxicarum	Anacardiaceae	L	I		Poison oak
Toxicodendron vernix	Anacardiaceae	S	N		Poison sumac
Trachelospermum difforme	Apocynaceae	L	N		Climbing dogbane
Ulmus alata	Ulmaceae	T	N		Winged elm
Ulmus americana	Ulmaceae	T	N		American elm
Ulmus pumila	Ulmaceae	T/S	I		Siberian elm
Ulmus rubra	Ulmaceae	T	N		Slippery elm
Ulmus thomasii	Ulmaceae	T	N	E	Rock elm
Ulmus procera	Ulmaceae	T	I		English elm
Vaccinium angustifolium	Ericaceae	S	N		Low-bush blueberry
Vaccinium arboreum var. *arboreum*	Ericaceae	S	N		Farkleberry
Vaccinium arboreum var. *glaucescens*	Ericaceae	S	N		Farkleberry
Vaccinium corymbosum	Ericaceae	S	N	E	Highbush blueberry
Vaccinium macrocarpon	Ericaceae	S	N	E	American cranberry
Vaccinium myrtilloides	Ericaceae	S	N		Canada blueberry
Vaccinium oxycoccus	Ericaceae	S	N	E	Small cranberry
Vaccinium pallidum	Ericaceae	S	N		Low-bush blueberry
Vaccinium stramineum	Ericaceae	S	N	X	Deerberry
Viburnum acerifolium	Caprifoliaceae	S	N		Maple-leaved arrowwood
Viburnum dentatum var. *deamii*	Caprifoliaceae	S	N		Southern arrowwood
Viburnum lantana	Caprifoliaceae	T/S	I		Wayfaring tree
Viburnum lentago	Caprifoliaceae	T/S	N		Nannyberry
Viburnum molle	Caprifoliaceae	S	N	E	Arrowwood
Viburnum opulus	Caprifoliaceae	S	I		European Cranberry-bush
Viburnum prunifolium	Caprifoliaceae	T/S	N		Black haw
Viburnum rafinesquianum	Caprifoliaceae	S	N		Downy arrowwood
Viburnum recognitum	Caprifoliaceae	S	N		Smooth arrowwood
Viburnum rufidulum	Caprifoliaceae	T/S	N		Rusty nannyberry
Viburnum trilobum	Caprifoliaceae	S	N		American cranberry-bush
Vitis aestivalis var. *aestivalis*	Vitaceae	L	N		Summer grape
Vitis aestivalis var. *argentifolia*	Vitaceae	L	N		Silver-leaved grape
Vitis cinerea	Vitaceae	L	N		Winter grape
Vitis labrusca	Vitaceae	L	I		Fox grape
Vitis palmata	Vitaceae	L	N		Catbird grape
Vitis riparia var. *praecox*	Vitaceae	L	N		Riverbank grape

(Table 2 continued)

Scientific name	Family	Habit	Native	E/T	Common name
Vitis riparia var. *riparia*	Vitaceae	L	N		Riverbank grape
Vitis riparia var. *styricola*	Vitaceae	L	N		Riverbank grape
Vitis rupestris	Vitaceae	L	N		Sand grape
Vitis vulpina	Vitaceae	L	N		Frost grape
Wisteria frutescens	Fabaceae	L	N		American wisteria
Zanthoxylum americanum	Rutaceae	S	N		Prickly-ash

Higher Fungi of Illinois Forests

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Although a number of systematics treatments have been completed for fungi in the Great Lakes region, the northeastern United States and Canada, the southern Appalachian Mountains, and the Pacific Northwest, knowledge of the fleshy higher fungi of many Midwestern states, including Illinois, lags far behind. Although Illinois was once dominated by prairies and is now covered by vast expanses of corn and soybeans, the paucity of information regarding Illinois fleshy higher fungi is not the result of a lack of fungi. Indeed, the unique vascular plant flora found in oak-hickory forests, northern hardwood forests, mesic bottomland forests, and forests of the Ozark Ridge is reflected in a diverse assemblage of fleshy higher fungi (Sundberg 1984). Instead, the absence of data on Illinois higher fungi is a reflection of the small number of mycologists who have resided in Illinois and studied these unique organisms. The lack of mycological studies on fleshy higher fungi in Illinois is obvious when one considers that, as of the mid-1980's, only 46 reports documenting 750 taxa could be found in mycological literature dating back to the late 1870's (Sundberg 1984). The paucity of information available is amplified when one realizes that the fungi included in these reports were collected in only 30 of Illinois' 102 counties. Thus, prior to the early 1970's, 71% of the counties in Illinois were essentially unexplored for fleshy higher fungi. Scarcity of data on Illinois higher fungi is further emphasized by the fact that the majority of the fungi included in these reports were collected in six counties: Cook, DuPage, Henry, Champaign, Jackson, and Union.

Fortunately this situation began to change following the arrival of Walter Sundberg at SIU-Carbondale in 1972 and several additional mycologists interested in fleshy higher fungi in the ensuing years. This paper is intended as an overview of fleshy higher fungi in Illinois, the data which has begun to accumulate on their occurrence and distribution, and the ecological role of these fungi in the maintenance and preservation of the Illinois' forests.

The life cycle of most higher fungi begins with the dispersal of spores from a sporocarp to a suitable substrate where they germinate and produce filamentous threads called hyphae (Alexopoulos and Mims 1979). The vegetative phase is thus composed of a massive network of rapidly elongating hyphal threads collectively termed a mycelium. The hyphae release enzymes into the substrate on which they grow to break down organic compounds into simpler, soluble forms. The resulting nutrient suspension is absorbed by the hyphae and used for growth. The life span of the mycelium is determined in part by the amount of organic material available, how rapidly it is used, and a variety of poorly understood components including climatic conditions, edaphic factors, and interactions among soil microorganisms. Not all of the nutritive material absorbed is used in producing new hyphae. A substantial amount is stored as glycogen, lipids or fats and used when environmental conditions are favorable for the formation of sporocarps. The sporocarps produce spores which are dispersed, and if they settle in a suitable habitat with proper environmental conditions, germinate and begin the cycle anew.

Although the morphology of the vegetative stages of higher fungi are often monotonously similar, there is significant variation in the type of sporocarps fungi produce (Alexopoulos and Mims, 1979). As a result, the classification of fungi, like that of most organisms, is based primarily upon characteristics of the reproductive structures. When considered in this fashion, two very large and distinctive groups of fleshy higher fungi can be delimited, the Divisions Ascomycota and Basidiomycota.

The Division Ascomycota includes fungi that produce sac-like structures during the reproductive phase of the life cycle called asci which contain 4 or 8 ascospores (Alexopoulos and Mims 1979). The asci and ascospores are produced on or in sporocarps called ascocarps. Although many ascocarps are cup-shaped or disc-shaped (*e.g., Bisporella citrina* (Batsch: Fr.) Korf and Carpenter and *Galiella rufa* (Schw.) Nannf. and Korf), a wide range of forms are likely to be encountered in the forests of Illinois. For example, the cup or disc may be elevated on a distinct stalk (*e.g., Sarcoscypha occidentalis* (Schw.) Sacc. and *Urnula craterium* (Schw.) Fr.). Alternatively, the ascocarp may bear no resemblance to a cup but be shaped like a club (*e.g., Microglossum olivaceum* (Pers.: Fr.) Gill.), a fan (*e.g., Spathularia flavida* Pers.: Fr.) or a malformed head attached to the apex of a stalk (*e.g., Leotia lubrica* Pers.: Fr.). Finally, the apex of the ascocarp may be saddle-shaped with a fluted stalk (*e.g., Helvella crispa* Scop.: Fr.), cone-shaped and marked by various degrees of pitting (*e.g., Morchella elata* Fr.), or brain-like with irregular convolutions (*e.g., Gyromitra caroliniana* (Bosc: Fr.) Fr.).

The remaining fleshy higher fungi likely to be collected in Illinois are included in the Division Basidiomycota. These fungi produce basidiospores at the ends of projections called sterigmata which arise from the apex of club-shaped cells called basidia (Alexopoulos and Mims 1979). Many of the fungi included in the Division Basidiomycota produce fleshy basidiocarps on which the basidia line the surface of gills or lamellae which form on the undersurface of a cap or pileus which in turn is supported by a stalk or stipe. These basidiocarps are the "mushrooms" with which most of us are familiar (*e.g., Amanita rubescens* (Pers.: Fr.) S. F. Gray and *Laccaria ochropurpurea* (Berk.) Peck).

Not all members of the Basidiomycota form gill-bearing, mushroom-like basidiocarps and a variety of basidiocarp morphologies may be encountered in the forests of Illinois. In coral and club fungi, the basidia cover the surface of upright, branched or unbranched basidiocarps (*e.g., Clavaria aurantio-cinnabarina* Schw. and *Ramaria stricta* (Pers.: Fr.) Quel.) while the chanterelles form basidia in a smooth, wrinkled or gill-like layer on a mushroom-like basidiocarp (*e.g., Cantharellus lateritius* (Berk.) A. H. Smith and *Cantharellus cinnabarinus* Schw.). The boletes form fleshy basidiocarps in which the basidia line the inner surface of pendant tubes which open to the environment as pores (*e.g., Boletus pallidus* Frost and *Strobilomyces floccopus* (Vahl.: Fr.) Karsten). Hedgehog or spine fungi produce basidiocarps in which the basidia cover the surface of pendant spines or teeth (*e.g., Hericium erinaceus* (Bull.: Fr.) Pers. and *Hydnum repandum* L.: Fr.). The polypores produce leathery to woody basidiocarps that often form shelving masses on trees and fallen logs and also produce basidia which line the inner surface of pendant tubes (*e.g., Polyporus alveolaris* (DC: Fr.) Bond. and *Trametes versicolor* (L.: Fr.) Pilat). The jelly fungi are also found primarily on fallen logs but produce gelatinous, amorphous basidiocarps which bear four-celled basidia (*e.g., Tremella foliacea* Pers.: Fr. and *Exidia glandulosa* Bull.: Fr.).

Particularly odd among the Division Basidiomycota are those fungi included in the Class Gasteromycetes. The Gasteromycetes include fungi in which the basidiospores are not forcibly discharged and are enclosed within the basidiocarps even at maturity. Puffballs (*e.g., Lycoperdon perlatum* Pers.), earth stars (*e.g., Geastrum saccatum* Fr.), bird's nest fungi (*e.g., Cyathus striatus* (Huds.) Willd. per Pers.), and stinkhorns (*e.g., Phallus impudicus* L. per Pers.) are examples.

The inability of fungi to manufacture their own organic matter through photosynthesis is the key to their role in nature's scheme (Hudson 1972). Fungi are directly or indirectly dependent on the organic materials provided by plants and animals. Thus, plants and other groups of organisms build up organic matter and fungi break it down. As a result, fungi have become adapted to a variety of natural and synthetic substrates and have evolved fascinating relationships with other forms of life.

Fungi which survive solely on, and at the metabolic expense of, other living organisms are called obligate parasites (Wheeler 1968). Plant rusts such as *Puccinia podophylli* Schw., causal agent of May Apple Rust, and *Gymnosporangium juniperi-virginianae* Schw., causal agent of Cedar Apple Rust, are examples of obligate parasites. One of the more curious aspects of such parasitic interactions is that the fungus does not ordinarily kill the host upon which it is living and thus does not destroy its source of nourishment.
For if the host dies, the parasite perishes as well.

Not all fungal pathogens are obligate parasites. Many can attack a host, kill it, and continue to thrive on the remains until the nutritive material has been exhausted (Manion 1981). These fungi are referred to as facultative parasites because they can exist on either living or dead organic matter. Examples include *Armillaria mellea sensu lato* and *Ganoderma lucidum* (Leysser: Fr.) Karst., both of which cause destructive root and heart rots in a variety of deciduous trees, and *Phaeolus schweinitzii* (Fr.) Pat. which causes a root and stump rot of old growth pines.

Fungi which flourish on dead organic matter are called saprobes (Park 1968, Hudson 1972). Saprobic fungi are described as being terrestrial when found growing in the humus or soil (*e.g., Russula compacta* Frost), foliicolous when observed on leaves (*e.g., Marasmius capillaris* Morgan), and lignicolous if they inhabit wood (*e.g., Pleurotus ostreatus* (Jacq.: Fr.) Kummer). Saprobic taxa such as *Agaricus campestris* L.: Fr. and *Chlorophyllum molybdites* (Meyer: Fr.) Mass. which thrive on dead grasses, are likely to have long-lived mycelia since their food supply is replenished each year. One can expect to find these fungi in the same general location over a long period of time. If there are no obstructions and food material is evenly distributed, the mycelium grows outward in all directions from the initiation site, and the sporocarps are likely to be produced at or near the perimeter of the mycelium in the form of "fairy rings."

Were it not for the activity of fungi, fallen trees, logs, and other debris would never decay (Park 1968, Hudson 1972). A considerable division of labor in a woodland habitat occurs between fungi whose activities are often obscured by the substrate within which they grow. In fact, only after the vegetative phase of a fungus becomes established and is digesting the substrate it occupies does the process we know as decay become evident. In nature, one might expect to find the mycelium of several different fungi colonizing a single rotting log and effectively competing with one another for the available supply of organic matter (Park 1968). In reality, however, not all the fungi in a particular substrate appear to compete with one another. In a fallen hardwood tree, for example, species A may digest only cellulose whereas species B may digest both cellulose and lignin. Although these two species digest cellulose, and cellulose and lignin, respectively, they may not break these compounds down into their ultimate products. Instead, different fungi appear subsequent to those which first attacked the log and further reduce the substrate into simpler forms. Thus a succession of fungi is expected in the process of reducing a log to humus (Park 1968, Hudson 1972).

One can also understand how disturbances in a forest can alter the kinds of fleshy higher fungi observed (Park, 1968). Fire, for example, may alter the fungi in a forest even if the forest is not completely destroyed or soon reproduces itself. When the litter layer is burned, fungi which live within it are often drastically reduced or eliminated and replaced within a season or two by fungi which appear in great numbers but may not have been found previously in the forest. For example, *Anthracobia melaloma* Boud. and *Peziza violacea* Pers. Fr. are rarely encountered except on charred debris and ashes around and under burned stumps and logs. Any disturbances which alter the soil surface in a forest, such as flooding, clear-cutting or road-cutting are also likely to influence the kind of fungi living there. For example, tillage or road-cutting often induces the formation of fungi such as stinkhorns (*e.g., Dictyophora duplicata* (Bosc) E. Fischer) or puffballs (*e.g., Scleroderma polyrhizon* Pers.).

Most mycologists recognize that many fleshy fungi are regularly found in close proximity to particular trees. For example, *Boletinellus merulioides* (Schw.) Murrill is found in association with ash, *Suillus* *americanus* (Peck) Snell ex Slipp and Snell is only collected beneath white pine, and *Amanita rubescens* (Pers.: Fr.) S. F. Gray is restricted to oak woods. These associations are readily explained by highly specific symbiotic associations called mycorrhizae which form between fungal hyphae and the roots of vascular plants (Harley and Smith 1983). The plants benefit because the fungal hyphae permeate the soil and are capable of absorbing water and inorganic nutrients which may be present in areas or forms that are inaccessible to plants. This is particularly important for plants which inhabit xeric, nutrient poor soils and may often make the difference between survival or mortality during a drought. In addition, the fungal hyphae may provide the plant with protection from certain soil borne pathogens such as nematodes, viruses, and bacteria. For its effort, the fungus receives a ready supply of carbohydrates for growth and reproduction.

Since many fungi form mycorrhizal or parasitic associations with specific plants or function as saprobes and agents of decay on a variety of substrates, there are considerable differences between the fleshy higher fungi observed in deciduous, mixed coniferous-deciduous or coniferous forests (Harley and Smith 1983). An oak-hickory forest, for example, will contain species of fungi not found in a beech-maple forest while pine plantations are characterized by another unique group of fleshy fungi. It is this diverse assemblage of fleshy higher fungi which mycologists in Illinois have finally begun to explore.

Initially we mentioned the paucity of information regarding fleshy higher fungi in Illinois forests and some of the reasons for it. The situation has begun to change dramatically within the last twenty years due to the arrival of a number of resident mycologists interested in systematics of fleshy higher fungi. These individuals have collected in poorly known and unexplored mycological areas and contributed substantially to the knowledge of Illinois fleshy higher fungi (Doyle 1987,1989, Methven 1990, Mueller 1992, Mueller and Sundberg 1981, Parody and Sundberg 1977, Wason 1989, Wason *et. al.* 1991, West 1976). In addition to these studies, the first in a series of publications on genera of Illinois fleshy higher fungi is in preparation. Although we currently lag far behind, the knowledge of Illinois' fleshy higher fungi may soon begin to approach that of other regions in North America.

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Illinois Department of Conservation Division of Forest Resources Nursery Program

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ABSTRACT

The Division of Forest Resources operates two nurseries--the Mason State Nursery at Topeka, Illinois in Mason County, and the Union State Nursery at Jonesboro, Illinois in Union County. Both facilities have been in operation since the early 1930's. A recent nursery expansion and rehabilitation program and new programs for diversifying stock production demonstrate that plant materials can be produced for a wide variety of natural community restoration programs.

PRODUCTION HISTORY

During the 1930's and into the 1940's, nursery produced seedlings were used for planting surface-mined lands, Department of Conservation properties, and Soil Conservation Service projects. Of the plants produced, less than 20% were used on private lands. Starting in the late 1940's, and into the 1960's, over 85% of the seedlings were used on private lands. Annual nursery production peaked at 11,745,000 seedlings in 1957. This production level was a result of the Federal Soil Bank Program.

In 1957, over 72% of the production was conifer species. Shrub species (mainly multiflora rose) accounted for 23% of the production. Less than 5% of the seedlings shipped were native hardwoods.

While this percentage breakdown (large emphasis on conifers) continued into the early 1980's, a change in production strategy occurred in 1983. This change in strategy resulted in a major shift in emphasis from conifers to native hardwoods and involved the discontinuation of the production of non-native plant species (such as amur honeysuckle and autumn olive). The distribution of production in 1992 was -- 25% conifers, 56% native hardwood trees, 16% native shrub species and 3% prairie forbs.

In 1957 the nurseries were involved in producing about 15 species. Today both the Mason and Union Nurseries are involved in the production of over 130 plant species. Production involves 35 native tree species, 18 native shrub species, 47 prairie forb species, 7 warm-season grasses, 20 woodland understory trees, shrubs and herbaceous species, and 11 wetland species. Table 1 shows the tree and shrub production goals for both nurseries for the 1993-1994 planting season.

SEED PROCUREMENT

Procurement of seed is a major activity for the nurseries. With the exception of conifer species and black locust, seeds are obtained from plants growing in Illinois. Seed collection assistance is provided by personnel from the Department's other divisions.

Seeds for the oak species, black walnut and several other hardwoods are obtained by means of a Permit Seed Collection Program. Table 2 is a list of species involved in the permit program.

District Forester offices located across the state are used as collection centers for the seeds purchased through the permit program. The foresters are given quotas of seed that they may purchase. Individuals must obtain a permit prior to bringing seed in for sale. The issuance of a permit controls the purchase of seed and prevents the various offices from purchasing seed in excess of budgeted amounts. State employees and family members are prohibited from participating in this program.

In 1991, over 400 individuals collected 387,873 pounds of seed. The cost of this collection effort was over $117,000. The 1992 collection program had been scaled back due to reductions in the Division's budget. The total dollar amount for this program in 1992 was $85,800.

The existing seed collection program enhances nursery production through increased genetic diversity. Prior to the introduction of this program, seed collection was done by nursery crews and occurred within a fifty (50) mile radius of the two nurseries. Plants produced under this old system had very limited genetic diversity. With the existing program, we are obtaining seeds from all areas of the state. Genetic diversity is important to our nursery program because of the climatic differences that occur over the approximately 400 mile north to south length of the State of Illinois.

As a part of our seed collection program, the state has been divided into three collection zones. In the case of the fine hardwoods (walnut and oaks), seedlings are shipped back to the zone where the seed originated. This provides landowners with seedlings best suited for their particular growing conditions.

Other tree and shrub species are collected, where possible, from the three zones but not kept separate by zones. The collection of seed from all three zones results in plants that can be expected to survive the range of climatic conditions that occurs from northwestern to southern Illinois.

In some cases seedlings and seeds are obtained through stock exchange agreements with other midwestern states. Illinois and Indiana have had a long standing stock exchange agreement. This agreement involves five or six species and allows each state to reduce the total number of species being grown. These two states can obtain additional species from each other through the exchange program.

TREE IMPROVEMENT PROGRAMS

In 1981, with assistance from the United States Forest Service (USFS), a black walnut seed orchard was started at the Union Nursery. This 14-acre orchard was designed to provide improved black walnut seeds for the production of seedlings for plantings in the southern half of Illinois. With the approval of a federally funded focus project through the USFS's State and Private organization, this orchard was completed in the spring of 1989. This orchard has 46 different clones. Many of these clones are second and third generation selections from ongoing tree improvement programs in the Midwest. The 1989 focus project also included funds to develop another 20-acre orchard to serve northern Illinois. This second orchard was established with grafted material in the spring of 1990.

In cooperation with the North Central Fine Hardwoods Tree Improvement Cooperative, we have been actively searching for superior selections of black walnut trees. Selections are from either natural stands or plantations. There have been 94 selections made in Illinois. Successful grafts have been completed for 90 of these selections. These grafts are located in orchards or sublines in Illinois, Wisconsin, and Missouri. These selections will result in the introduction of additional genetic diversity into the cooperative's eight state tree improvement programs.

In 1990 a 1.5-acre black walnut subline of Illinois selections was established at the Mason Nursery. In the spring of 1993 a second 2-acre black walnut subline will be planted at the Mason Nursery. The Union Nursery will also be establishing a two (2) acre black walnut subline in 1993. Sublines, while they will function as seed orchards, are a part of the long term breeding strategy of the North Central Fine Hardwoods Tree Improvement Cooperative.

In 1992 seed collection areas were established at the Union Nursery for the following species: red oak-10 acres, swamp white oak-1.3 acres, white oak-1 acre. In addition to the seed collection areas at the Union Nursery, a 10-acre cherrybark oak seed collection area was established at the Horseshoe Lake Conservation Area.

The seed collection areas were established using selected seedlings from the nurseries' production. All collection areas contain seedlings from the designated North, Central and Southern zones. The collection areas are blocked to allow for the collection of seed by zones.

In 1992, a 1.5-acre red oak seed orchard was established at the Mason Nursery. The red oak seed orchard was established with 121 selections taken from a 1988 Iowa State University root morphology study planting at the Mason Nursery.

PRAIRIE RESTORATION PROGRAM

In 1977, the Department began a prairie restoration program on state owned properties. In order to have a supply of native ecotype seeds, the Mason Nursery was requested to establish a warm-season grass seed collection area. As a result of this request, a seed collection area of 3 acres involving 5 different grass species was established in 1978. In 1985, an additional 8-acre grass collection area was established. Expansion plans called for a total grass production area of approximately 43 acres. This additional acreage was planted in 1992.

Since 1978, the Mason Nursery's prairie program has expanded to include 7 grass species and over 40 forb species. In 1991, 293,457 forb seedlings were distributed. Forb seed collection yielded 987 pounds of seed. Grass seed harvest from the Mason Nursery and other state sites totaled 3,260 pounds. Species of plants included in the Mason Nursery prairie plant and seed production program are listed in Table 3.

The completion of a grass seed processing facility and the purchase of new equipment that is used for tree, shrub, and forb species has resulted in a drastic improvement in seed quality. This will help insure the establishment of the many prairie restorations that are being undertaken by the Department's Division of Natural Heritage.

The Department's Division of Natural Heritage and Division of Wildlife Resources biologists supplement the nursery's grass and forb seed production with collections from native stands of grasses and forbs growing in their respective districts.

In addition to the production of prairie plant materials for restoration work on state lands, another important aspect of the Mason Nursery's prairie program involves the protection and production of Illinois endangered plant species. There are many endangered plant species in Illinois. In many cases there are only small communities or individual plants left of these species. The collection of seed and subsequent production of plants, as well as the establishment of the plants in our forb collection areas, is helping to assure the availability of these plants for future generations.

The production of the prairie plant materials involves about 20 to 30% of nursery work activities. The cost of producing these plant materials is approximately $126,000 yet it results in the production of plant materials worth over $500,000.

OTHER PLANT PRODUCTION PROGRAMS

In 1991 the Mason Nursery began growing woodland herbaceous plants. The nursery is currently working with twenty (20) species of small trees, shrubs, and woodland wildflowers. This is a pilot program designed to develop a source of plant material for the restoration of forest understory natural communities (Table 4).

In the fall of 1992 the Mason Nursery made some initial seed and plant collections of wetland species. Nursery personnel will be looking into the possibility of growing a variety of species, either from seeds or by vegetative propagation, for the purpose of developing plant material that can be used in wetland restorations (Table 5).

DISTRIBUTION OF PLANT MATERIALS

As a result of new nursery enabling legislation passed in 1987, landowners with management plans approved by their District Forester, Wildlife Biologist, or Heritage Biologist are able to obtain planting stock at no cost. The majority of seedlings distributed through the nursery program are utilized by landowners with management plans. Landowners with approved management plans have a priority for receiving plant materials until the end of January. This priority system has resulted in better utilization of our planting stock. Our district personnel now have the ability to better match soil types and species and to give preference to those landowners willing to implement approved management practices.

Landowners who do not have approved management plans may still purchase seedlings from the Department. These purchasers must wait until

February 1st before their orders may be submitted. In many cases there are limited amounts and species of plants available after this date.

This new legislative language also required a revision in the method used to price plant materials. Prior to 1987, planting stock sold through the nurseries was priced at 20 to 30% of its production cost. Prices for planting stock now reflect actual production costs. Landowners ordering plant materials without an approved management plans must pay the full cost of production.

NURSERY REHABILITATION AND EXPANSION

The following is a portion of an article about the Mason Nursery that appeared in the March 12, 1938 issue of "The Prairie Farmer":

> "... The ultimate aim of the Division of Forestry is to produce a minimum of 10,000,000 trees per year for reforestation purposes in this state. There is no question that this amount will be necessary. The 1935 census showed that Illinois contained approximately 7,000,000 acres of land that is neither producing farm crops, nor is used for ordinary pasture. Some 3,000,000 acres of this is classed as timber land. The greatest amount of our 3,000,000 acres of timber land is owned in small areas on farms. The balance of approximately 4,000,000 acres is neither producing nor is satisfactory for production of farm crops, is not producing timber and is not satisfactory for pasture.
>
> The State Department of Conservation, Division of Forestry, intends to expand its efforts to raise healthy planting stock in its nurseries at a price within the reach of those who own lands in need of reforestation. It is hoped that those who own that land will cooperate with the state and obtain this planting stock to adequately reforest that portion of their farms or lands that are unfit for agriculture, thereby insuring Illinois of proper supply of forests and timber..."

With the exception of the reference to the 1935 census, these paragraphs or ones very similar to them have appeared in recent justifications for nursery expansion. Expansion needs have been driven by demands generated by the Federal Conservation Reserve Program (CRP) and the State's Forest Development Act (FDA).

Illinois has had an exceptional response to CRP tree planting sign-ups. Federal Conservation Reserve Program sign-ups, as a result of the 1985 and 1990 Farm Bills, have resulted in over 30,000 acres being designated for tree planting. The demands for planting stock generated by the CRP program has not allowed the Department to meet all of the needs for plant materials. In order to meet the deadlines established by the two Federal Farm Bills production needs to exceed 15 million seedlings per year.

The expansion and rehabilitation of the Department's nurseries has resulted in approximately $6 million of work being completed or scheduled for completion at the two nursery facilities. This work has included--1) A new office/packing facility at the Mason Nursery. 2) Conversion of the old packing facility at the Mason to a seed processing building. 3) Construction of a warm-season grass processing facility. 4) Construction of a 3,000 square foot greenhouse for the container production of prairie plants. 5) Construction of center-pivot irrigation system for the warm-season grass production areas. 6) Construction of a shade house for the production of large container grown plants for plantings on Department facilities. 7) Seedbed development of eighty acres for the production of bare root trees and shrubs. 8) Construction of a equipment storage building at the Mason Nursery. 9) Construction of a new office complex at the Union Nursery. 10) Expansion and rehabilitation of cold storage facilities at the Union Nursery. 11) Construction of additional space at the Union Nursery for the storage of shipping materials and processing orders for shipping. 12) Construction of chemical storage rooms, service bays and additional storage space at the Union Nursery. 13) Rehabilitation of the seed cleaning facilities at the Union Nursery. 14) Addition of a standby pump at the Union Nursery for irrigation of seedbeds. 15) Repair and replacement of stream bed retaining walls to protect buildings and seedbeds at the Union Nursery. 16) Construction of residences at both nurseries. 17) Development of additional seedbed area at the Union Nursery. 18) Tiling and drainage improvements in the black walnut seed orchards at the Union Nursery.

With the completion of the Department's nursery expansion and rehabilitation program, the Division of Forest Resources will have the facilities necessary to meet the ever increasing demand for plant materials. These capital resource combined with the Department's willingness to support the production of a variety of native plant species has enabled Illinois' nursery program to become a model for the rest of the Nation's public nurseries. Illinois' program demonstrates that, with a willingness to abandon traditional nursery production patterns, plant materials can be produced for a wide variety of natural community restoration programs.

Table 1. Tree and shrub species, 1993/94 nursery production goals.

COMMON NAME	SCIENTIFIC NAME	PRODUCTION GOALS (1,000's)
PECAN	*Carya illinoensis*	30
HICKORIES	*Carya sp.*	50
HACKBERRY	*Celtis occidentalis*	50
WHITE ASH	*Fraxinus americana*	175
GREEN ASH	*F. pennsylvanica*	300
BLACK WALNUT	*Juglans nigra*	375
RED CEDAR	*Juniperus virginiana*	60
SWEETGUM	*Liquidambar styraciflua*	75
RED PINE	*Pinus resinosa*	175
WHITE PINE	*P. strobus*	1,000
BLACK CHERRY	*Prunus serotina*	40
WHITE OAK	*Quercus alba*	250
BUR OAK	*Q. macrocarpa*	150
PIN OAK	*Q. palustris*	150
RED OAK	*Q. rubra*	300
BLACK OAK	*Q. velutina*	150
SWAMP WHITE OAK	*Q. bicolor*	15
CHERRYBARK OAK	*Q. falcata*	50
MISC. NATIVE SP.	Various species	59
BALD CYPRESS	*Taxodium distichum*	275
BLACK LOCUST	*Robinia pseudoacacia*	5
RIVER BIRCH	*Betula nigra*	15
SYCAMORE	*Platanus occidentalis*	25
SILVER MAPLE	*Acer saccharinum*	20
SUGAR MAPLE	*A. saccharum*	20
RED MAPLE	*A. rubrum*	5
PERSIMMON	*Diospyros virginiana*	25
TULIP TREE	*Liriodendron tulipifera*	50
LOBLOLLY PINE	*Pinus taeda*	100
GRAY DOGWOOD	*Cornus racemosa*	90
SILKY DOGWOOD	*C. amomum*	75
HAZELNUT	*Corylus americana*	90
WASH. HAWTHORN	*Crataegus phaenopyrum*	20
NATIVE CRABAPPLE	*Malus ioensis*	5
AMERICAN WILD PLUM	*Prunus americana*	50
SMOOTH SUMAC	*Rhus glabra*	5
BLACKBERRY	*Rubus allegheniensis*	3
ELDERBERRY	*Sambucus canadensis*	10
CORALBERRY	*Symphoricarpos orbiculatus*	3
BLACK CHOKEBERRY	*Aronia melanocarpa*	10
RED OSIER DOGWOOD	*Cornus stolonifera*	5
COCKSPUR HAWTHORN	*Crataegus crus-galli*	3
FRAGRANT SUMAC	*Rhus aromatica*	5
STAGHORNN SUMAC	*R. typhina*	5
REDBUD	*Cercis canadensis*	12
H. B. CRANBERRY	*Viburnum trilobum/opulus*	25
OTHER VIBURNUM	*Viburnum sp.*	15
PRAIRIE FORBS	Various species	300
	TOTAL	4,725

Table 2. Permit seed collection program.

SPECIES	PRICE PER POUND	AMOUNT OF SEED (LBS)
HICKORIES	$ .75	6,000
HACKBERRY	$5.00	300
BLACK WALNUT	$ .10	275,000
RED OAK	$ .90	14,000
WHITE OAK	$ .90	12,000
BUR OAK	$ .60	12,000
BLACK OAK	$1.10	4,000
PIN OAK	$1.90	3,000
PECAN	$1.00	1,750
CHINKAPIN OAK	$1.90	600
SHUMARD OAK	$0.90	500
SWAMP WHITE OAK	$1.10	600
CHERRYBARK OAK	$3.00	1,500
SHINGLE OAK	$0.60	200
HAZELNUT	$5.00	600

Table 3. Prairie grass and forb species.

PRAIRIE GRASS SPECIES

COMMON NAME	SCIENTIFIC NAME	HABITAT TYPE
BIG BLUESTEM	*Andropogon gerardii*	MESIC
SIDEOATS GRAMA	*Bouteloua curtipendula*	DRY
SWITCH GRASS	*Panicum virgatum*	WET/MESIC
LITTLE BLUESTEM	*Schizachryium scoparium*	MESIC/DRY
INDIAN GRASS	*Sorghastrum nutans*	MESIC
NORTHERN DROPSEED	*Sporobolis heterolepis*	MESIC/DRY
EASTERN GAMA GRASS	*Tripsacum dactyloides*	MESIC

PRAIRIE FORB SPECIES

COMMON NAME	SCIENTIFIC NAME	HABITAT TYPE
NODDING WILD ONION	*Allium cernuum*	MESIC/DRY
LEAD PLANT	*Amorpha canescens*	MESIC/DRY
THIMBLE WEED	*Anemone cylindracea*	DRY
SULLIVANT'S MILKWEED	*Asclepias sullivantii*	MESIC
BUTTERFLY WEED	*Asclepias tuberosa*	MESIC/DRY
SMOOTH ASTER	*Aster laevis*	MESIC
NEW ENGLAND ASTER	*Aster novae-angliae*	MESIC
TENN. MILKVETCH	*Astragalus tennesseensis*	MESIC/DRY
WHITE FALSE INDIGO	*Baptisia leucantha*	MESIC/DRY

Table 3 continued. Prairie grass and forb species.

FALSE INDIGO	*Baptisia leucophaea*	MESIC/DRY
D. FALSE ASTER	*Boltonia decurrens*	WET
INDIAN PLANTAIN	*Cacalia tuberosa*	MESIC/DRY
WILD HYACINTH	*Camassia scilloides*	MESIC
NEW JERSEY TEA	*Ceanothus americanus*	MESIC/DRY
LANCE LEAF COREOPSIS	*Coreopsis lanceolata*	DRY
STIFF TICKSEED	*Coreopsis palmata*	MESIC/DRY
WHITE PRAIRIE CLOVER	*Dalea candida*	MESIC/DRY
LACEY PRAIRIE CLOVER	*Dalea foliosa*	DOLOMITE
PURPLE PRAIRIE CLOVER	*Dalea purpurea*	MESIC/DRY
ILLINOIS MIMOSA	*Desmanthus illinoensis*	DOLOMITE
CANADA TICK TREFOIL	*Desmodium canadense*	MESIC
ILL. TICK TREFOIL	*Desmodium illinoense*	MESIC/DRY
PURPLE P. CONEFLOWER	*Echinacea pallida*	MESIC/DRY
RATTLESNAKE MASTER	*Eryngium yuccifolium*	MESIC
WESTERN SUNFLOWER	*Helianthus occidentalis*	DRY
ALUM ROOT	*Heuchera richardsonii*	DRY
KANKAKEE MALLOW	*Iliamna remota*	DRY
WILD BLUE IRIS	*Iris shrevei*	WET
P. BUSH CLOVER	*Lespedeza capitata*	MESIC/DRY
NARROWHD BUSH LESP.	*Lespedeza leptostachya*	DRY
ROUGH BLAZING STAR	*Liatris aspera*	DRY
TALL GAYFEATHER	*Liatris pycnostachya*	MESIC
SPIKE BLAZING STAR	*Liatris spicata*	WET/MESIC
WILD BERGAMOT	*Monarda fistulosa*	MESIC/DRY
GLADE MALLOW	*Napaea dioica*	WET
AMERICAN FEVERFEW	*Parthenium integrifolium*	DRY
OBEDIENT PLANT	*Physostegia virginiana*	DRY
PRAIRIE CINQUEFOIL	*Potentilla arguta*	MESIC
GRAY HD. CONEFLOWER	*Ratibida pinnata*	MESIC
CAROLINA ROSE	*Rosa carolina*	MESIC/DRY
ROYAL CATCHFLY	*Silene regia*	DRY
ROSIN WEED	*Silphium integrifolium*	MESIC/DRY
COMPASS PLANT	*Silphium laciniatum*	MESIC
PRAIRIE DOCK	*Silphium terebinthinaceum*	MESIC/DRY
RIGID GOLDENROD	*Solidago rigida*	MESIC/DRY
SPIDERWORT	*Tradescantia ohiensis*	MESIC/DRY
GOLDEN ALEXANDER	*Zizia aurea*	MESIC/DRY

Table 4 . A list the plants grown in the forest understory plant production program.

FOREST UNDERSTORY SPECIES

COMMON NAME	SCIENTIFIC NAME
DOLL'S EYES	*Actaea pachypoda*
JACK-IN-THE-PULPIT	*Arisaema triphyllum*
COMMON PAWPAW	*Asimina triloba*
AMERICAN HORNBEAM	*Carpinus caroliniana*
SPRING BEAUTY	*Claytonia virginica*
TOOTHWORT	*Dentaria laciniata*
DUTCHMAN'S BREECHES	*Dicentra cucullaria*
SPICEBUSH	*Lindera benzoin*
CINNAMON FERN	*Osmunda cinnamomea*
GINSENG	*Panax quinquefolius*
MAYAPPLE	*Podophyllum peltatum*
SOLOMON'S SEAL	*Polygonatum commutatum*
AZALEA	*Rhododendron sp.*
BLOODROOT	*Sanguinaria canadensis*
FALSE SOLOMON'S SEAL	*Smilacina racemosa*
STARRY F. SOLOMON'S SEAL	*Smilacina stellata*
WHITE TRILLIUM	*Trillium gleasonii*
PURPLE TRILLIUM	*Trillium recurvatum*
LOW BUSH BLUEBERRY	*Vaccinium angustifolium*
COMMON VIOLET	*Viola papilionacea*

Table 5. A list of the plants grown in the wetland production program.

WETLAND SPECIES

COMMON NAME	SCIENTIFIC NAME
SWAMP MILKWEED	*Asclepias incarnata*
BLUE JOINT GRASS	*Cala magrostis canadensis*
SEDGE	*Carex sp.*
BONESET	*Eupatorium perfoliatum*
RICE CUT GRASS	*Leersia oryzoides*
CARDINAL FLOWER	*Lobelia cardinalis*
BLUE LOBELIA	*Lobelia siphilitica*
SWAMP ROSE	*Rosa palustris*
PUSSY WILLOW	*Salix discolor*
BULL RUSH	*Scirpus sp.*
CORD GRASS	*Spartina pectinata*

What is Killing the Pines in Illinois?

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It was not uncommon during the 1970's for homeowners to inquire from their local extension personnel the reason for their pine trees dying. Extension agents would contact research plant pathologists and entomologists for help. The researchers would examine the dead trees, but there was never any evidence to the cause of death. Often the trees were in a vigorous growing condition, when in late spring to late summer the color of the needles would sudden turn pale green and then brown. I recall one instance when a plant pathologist determined the cause of death as physiological disturbance. Indeed, death is the ultimate physiological disturbance.

In February 1979 at Columbia, Missouri, an interesting change of events took place. A trunk portion of an Austrian pine arrived at Einar Palm's diagnostic clinic at the University of Missouri, Columbia. Information with the sample explained that the 39 year old pine suddenly died during the previous summer. By chance a scientist from Japan was visiting that day, and suggested that in Japan a nematode, *Bursaphelenchus xylophilus,* was involved in the death of huge numbers of pines in Japan. That day the log was examined and found to contain large numbers of nematodes which were later identified by V. H. Dropkin, a University of Missouri nematologist, as the same nematode species that occurs in Japan. The species determination was later confirmed by Y. Mamiya, the scientist who had originally described the species in Japan. The discovery was published in 1979 (Dropkin and Foudin 1979). *B. xylophilus,* the pinewood nematode, was therefore implicated in causing pine wilt disease. The finding excited scientists throughout the nation to find more information.

Robbins (1982) compiled reports of the pinewood nematode in the United States and showed that the nematode was found to occur in 34 states and found in 20 species of pine with Scotch pine, *Pinus sylvestris*, being reported as the most common host. In the same report several non-pine conifers were found as hosts. These included atlas cedar, *Cedrus atlantica*, deodar cedar, *C. deodara*, balsam fir, *Abies balsamea*, European larch, *Larix decidua*, tamarack, *L. laricina,* blue spruce, *Picea pungens*, and white spruce, *P. glauca*. In all of the non-pine hosts the incidence of the nematode was indeed rare. Incidence of pine wilt in the Midwest is most common in Scotch pine, *P. sylvestris*, moderate in red pine, *P. resinosa*, Austrian pine, *P. nigra*, and occasionally found in jack pine, *P. banksiana*, loblolly pine, *P. taeda*, Virginia pine, *P. virginiana* and rare in mugo pine, *P. mugo*, and white pine, *P. strobus*.

Malek and Appleby (1984) gave a detailed account of the pine wilt symptom development in Scotch pine stating that there were 4 distinct stages in foliar coloration from light grayish green to totally brown. It was also indicated that there were two general periods of tree death, late winter to late spring and midsummer to late fall.

"The nematode was recovered in population densities up to 20,000/g of wood (dry wt) from sections of branches from dead, needle-bearing pines. It often was abundant in roots down to 2 cm in diameter and up to 2 m from the bases of young trees. The nematode was detected easier and usually in higher populations in trees that died during the summer-fall period. Though present in trunks, it frequently was absent from branch wood at any stage of symptom development in spring mortalities. It was never found in needles and cones and was rare in terminal twigs. The dispersal nematode stage was recovered in declining numbers from the trunks of standing pines up to 3 years after tree death (Malek and Appleby 1984)."

A bluestain fungus, *Ceratocystis* ssp., is evident in cross sections of wood from trees that die of pine wilt. The fungus appears as a dark blue-black stain, triangular in shape, with the tip radiating from the center of the wood. In laboratory cultures it was found that the nematode readily reproduced in agar plates infested with the fungus.

The disease cycle in Japan involves a beetle, nematode, and a fungus relationship. With this knowledge, investigations began in 1979 to find whether a similar relationship might exist in the United States. A longhorned beetle, *Monochamus alternatus*, is the primary nematode vector in Japan. This insect does not occur in the United States, but closely related *Monochamus* species are found throughout most parts of the U.S. Holdeman (1980) complied a list of insect species in the United States which were found to be infested with *B. xylophilus* nematodes; these include: *M. carolinensis, M. scutellatus, M. titillator, M. obtusus,* and *Arhopalus rusticus obsoletus.*

In Illinois and throughout the Midwest the primary insect vector of the pinewood nematode is the Carolina pine sawyer, *M. carolinensis* (Appleby 1982, Linit 1982). This sawyer is by far the most common species and the most abundant. Detailed studies of the biology of the Carolina pine sawyer were conducted by Pershing and Linit (1986, 1988), Walsh and Linit (1984, 1985) and Wingfield (1983). Other sawyer beetles in Illinois found to be pinewood nematode vectors were *M. scutellatus, M. notatus*, and *M. titillator.*

In life history studies of the Carolina pine sawyer conducted in Illinois, it was found that the adult beetles began emerging from pine wood in late May, with continued emergence until early August. Peak emergence occurred in the latter half of June. The average life span of an adult beetle is about 55 days. A sawyer beetle is capable of carrying thousands of nematodes. Nematode numbers of up to 90,000 per beetle were recorded with the average number being 21,000 (Malek and Appleby 1984). The newly emerged adult sawyer beetles feed on the current or one-year old pine twigs. Under favorable temperature and moisture conditions, the nematodes emerge from the beetles' spiracles and enter the twigs through the feeding wounds. The 0.5 mm long (1/30 inch) nematodes migrate to the resin canals of the pine branch. The adult nematodes mate and the females begin producing eggs. In laboratory studies Mamiya (1975) reported that the development from egg to adult takes 4 to 5 days at a temperature of 25 C° (77 F°). During the 28 day egg laying period, each female nematode produced an average of 28 eggs (Mamiya 1975).

During the summer months, nematodes reproduce rapidly and tree death can occur in as little as two months after the introduction of the nematodes. The dead wood is rapidly invaded by a blue stain fungus.

Female sawyer beetles deposit eggs in weakened, pine wilt killed or dead pines. At night the female beetle, after mating, chews small funnel-shaped depressions in the tree trunk after which a single egg is inserted at the bottom of the pit between the hardened and outer bark layer. The white elongate oval egg is about 2.9 mm long (1/8 inch). Eggs deposited in early August, 1981 at Urbana, IL hatched 8 days later. Upon hatching from the egg, the small beetle larva mines under the tree bark, and as it matures it invades the hardwood of the tree. The following year, spring or summer, the beetle changes into the inactive pupa stage. It is during the time that the beetle is in the pupa stage that large numbers of nematodes are attracted to the pupal chamber. During the development of the pupa and adult beetle stage, large numbers of nematodes invade the breathing tubes or tracheae of the adult beetle. It is generally the thoracic spiracles or breathing pores of the beetle that are invaded. Nematodes were found to leave the beetles' bodies during the entire time the beetles are in the adult stage.

Although the nematode appears to be the primary agent responsible for tree death, Oku *et al.* (1979, 1980), Kondo *et al.* (1982), and Bolla *et al.* (1982) have shown that a phytotoxin is involved in the death of trees. Extracts from pine wilt killed trees that contained no nematodes, fungi, virus, or bacteria when inoculated into pine seedlings resulted in the death of the seedlings. "It is possible that the phytotoxin is a product of the tree's synthesis. It might be suggested either that the phytotoxin is directly synthesized by the tree in response to the nematode or that a monoterpene material not toxic to the tree, but having phytoalexin activity against the nematode is synthesized by the tree in response to infection, that the nematode is capable of metabolically detoxifying this material and that the end product of detoxification is toxic to the tree (Bolla *et al.* 1982)."

One of the most effective means of preventing the spread of pine wilt is sanitation. All dead and dying pines should be cut to ground level and the wood converted to chips or the wood burned. The wood should not be stored for firewood, as the adult beetles would emerge from such wood in late spring and summer. Sanitation would greatly reduce the beetle population and thus reduce the spread of the nematode.

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Stewardship of Forested Nature Preserves

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ABSTRACT

As the Commission approaches its 30th Anniversary (July 1, 1993), it is appropriate to evaluate how Illinois forests are represented and managed within the Nature Preserves System. Reviewing the size and distribution of protected high quality forested tracts across the state as well as among natural divisions will provide the background for examining how they are managed, the research being conducted within them, and threats to their integrity.

INTRODUCTION

Created by the Natural Areas Preservation Act in 1963, the mission of the Illinois Nature Preserves Commission (INPC) is "to assist private and public landowners in protecting high quality natural areas and habitats of endangered and threatened species in perpetuity, through voluntary dedication of such lands into the Illinois Nature Preserves System. The Commission promotes the preservation of these significant lands, and once dedicated as Illinois nature preserves, oversees their stewardship, management and protection (INPC 1990a and 1990b)."

The Nature Preserves System includes 210 preserves (as of September 26, 1992) encompassing over 30,000 acres, and 10-15 preserves are added to the system every year. Nature preserves range in size from 1/4 acre to 2,000 acres, and are found in over 70 counties. The natural communities protected range from bogs to fens to sand prairies, wet prairies, glades, and an array of forest communities. One-quarter of the state's threatened and endangered species are found in nature preserves and 50% of the occurrences of all listed species are found in nature preserves.

Nature preserve dedication provides the strongest legal protection for land in Illinois, and is inviolable. The Illinois Department of Conservation (IDOC) owns 90 nature preserves, county conservation and forest preserve districts own 43 preserves, and the balance are owned by private individuals, municipalities, not-for-profit organizations, universities, The Nature Conservancy, corporations, cemetery associations, and others. The landowner retains ownership of the land upon dedication and signs a binding legal agreement to never develop the land and to manage it in accordance with the Natural Areas Preservation Act.

Following dedication as a nature preserve, day-to-day issues which nature preserve owners, managers, volunteers, and INPC staff may address include: planning and implementing management activities; evaluating applications for special use permits; and defending nature preserves against threats to their integrity.

The classification system known as the "Natural Divisions of Illinois" was developed twenty years ago as a means of delineating all the different natural regions that exist in the state (Schwegman 1973). There are 14 Natural Divisions and 33 Sections within the natural divisions; each section and division is distinguished by differences in topography, glacial history, bedrock, soils, flora and fauna. It is a primary goal of the Nature Preserves System to ensure that representative examples of all the natural features of Illinois are protected.

This classification provided the framework for the Illinois Natural Areas Inventory (White 1978). Conducted over a three-year period in the 1970's, the participating biologists classified the natural features of the state. The natural communities were described and graded (in terms of an A, B, C, or D).

Over 1,000 areas were identified by the INAI, 610 of them being high quality natural communities. The data from the inventory is managed and updated by the IDOC's Division of Natural Heritage in the computerized Biological Conservation Database (BCD).

While it is not mandatory that a site be identified by the Illinois Natural Areas Inventory (INAI) in order to be considered for dedication as an Illinois Nature Preserve, 189 sites on the INAI have been dedicated as nature preserves. Because one of the Illinois Nature Preserves Commission's goals is to preserve representative natural communities in all of the natural divisions of the state, the INAI is one of the key information sources guiding preservation efforts. For many landowners, the knowledge that their property possesses a high quality natural community catalyzes their efforts to protect it from future disturbance. Nature preserve dedication provides the legal protection to ensure such areas are preserved for, and by, future generations. To date the Nature Preserves System has protected most, but not all, of the extant examples of the presettlement forests of Illinois.

METHODS

The BCD was used to select nature preserves containing high quality forested tracts. Such tracts were defined as those graded as A or B in the Illinois Natural Areas Inventory, of at least 20 acres in size. Therefore, the areas described herein actually represent a subset of all forested lands occurring in the Nature Preserves System (unless otherwise specified, the phrases "high quality forested nature preserves" and "forested nature preserves" refer to this subset described above). The selected nature preserves were then ordered in terms of the types of forests occurring within them, from wet to mesic to xeric.

Approximately 100 applications are submitted annually to conduct research or special activities in nature preserves. Research permits issued from 1989-1992 for the high quality forested nature preserves were reviewed to identify the breadth of research topics investigated.

Increasingly, management activities on nature preserves are planned using three-year management schedules, which are reviewed and approved by the landowner, land manager and the Nature Preserves Commission. Preparing a Management Schedule involves first identifying and prioritizing Management Goals for a preserve (*e.g.*, maintain populations of endangered species, control invasive woody species, prevent motorized trespass). The schedule is designed to accomplish the goals; the schedule is usually prepared to cover the next three years; after this time a new schedule is prepared, keeping in mind the previously determined goals.

The Management Schedule consists of a labelled map and a chart delineating the natural communities on site, the locations of any endangered or threatened species, and specific management objectives (*e.g.*, "control bush honeysuckle in North unit") paired with specific management activities (*e.g.*, "cut and treat stumps with solution of 50% glyphosate"). Also planned are which units of a nature preserve with fire-dependent natural communities will be managed using spring or fall prescribed burning, and in even or odd-numbered years. For each activity the months or season in which the work will occur, and by whom is also stated on the schedule. Often several individuals or organizations share responsibilities at one nature preserve, and turnover occurs in all organizations. The Management Goals and Management Schedule have proven to be an efficient means of involving all parties in goal-setting, clarifying respective stewardship responsibilities, and summarizing concisely the history and status of management activities. Of the 39 high quality forested preserves, 25 have approved management schedules, which were used to identify the most common ongoing management activities in forested nature preserves.

Annual reports are prepared by nature preserve owners and/or managers for the Nature Preserves Commission. Review of these reports, which track illegal activities such as poaching or unauthorized collecting, disturbance, areas needing attention within the preserve, and changes in adjacent land use, provided an overview of potential threats to the integrity of each forested preserve. When a development is proposed near a nature preserve, the Illinois Nature Preserves Commission works with the nature preserve owner, developer, and the IDOC's Endangered Species Protection Program, if threatened or endangered species are involved, to avoid or minimize the impact of any development on the nature preserve and the species therein. Penalties for damages to a nature preserve range from $1,000 or 364 days imprisonment for a Class A misdemeanor, to up to $10,000 per day for civil penalties.

RESULTS

In Table 1, the 39 high quality forested nature preserves are listed, showing the acreage dedicated as nature preserve, totalling 7,878 acres. This represents 20% of the preserves -- and 25% of the land area -- protected in the Nature Preserves System.

The variety of types of forest communities protected in the high quality forested nature preserves is presented in Table 2. The sites are listed starting with the wettest, most poorly drained floodplain communities, continuing through the moderately well drained uplands, to the dry sand forest communities.

All but two of the 14 Natural Divisions of Illinois are represented by the 39 preserves in Table 1. Table 3 presents six high quality forest communities within five Natural Divisions which are not yet protected in the Nature Preserves System. These areas are scattered in roughly the western half of the state and are known from the Illinois Natural Areas Inventory.

In Table 4, a sampling of ongoing research activities is presented. Twenty percent of all research permits issued annually are for high quality forested nature preserves. The array of topics includes a statewide survey of amphibians and reptiles, butterfly inventories, a survey of fungi, identification of medicinally important species, and studying the impact a proposed tollway may have on a nearby nature preserve.

A prominent aspect of the stewardship of forested nature preserves is controlling invasive woody and herbaceous plant species. The most common vegetation management activity is controlling honeysuckle at 15 nature preserves (bush honeysuckle in northern Illinois; Japanese honeysuckle in southern Illinois), and garlic mustard at 12 preserves. Prescribed burns, one of the most effective management tools for controlling aggressive invasive species, are planned for the spring and fall at eight nature preserves. Also, deer reduction efforts occur annually at four preserves in tandem with research evaluating the impact of deer overpopulation on the natural features of the preserves.

For 13 of the forested nature preserves, attention to the boundaries is needed, such as a survey conducted to clarify an uncertain property line, installation of wire fencing, posting of nature preserve signs, or repair a fence damaged by vandalism. Vehicle trespass has occurred at ten nature preserves, such as snowmobile, off-road vehicles, or motorcycle use (note: in a few nature preserves, special provisions were made during dedication to allow snowmobiling, but it is otherwise not allowed). In some circumstances, posting nature preserve signs and/or installing fencing are adequate deterrents. In other situations, periodic surveillance by volunteers, natural areas managers, law enforcement officials, and possible legal actions are necessary.

At five preserves, trail establishment or repair and bridge replacement are needed. The fastest growing problem area concerning nature preserves is development of adjacent lands. Whether high or low density housing developments or commercial endeavors, possible impacts include siltation, hydrologic alterations, exhaust, noise, and other disturbance.

CONCLUSION

INPC has prepared the following management guidelines for nature preserves: Herbicide Application, Deer Control, Mosquito Control, Vegetation Management Guidelines (for 29 invasive woody and herbaceous species, based upon the experience of natural areas managers in Illinois), and a Guide for Preparation of Management Schedules. These documents are also useful for natural areas management generally. The Illinois Nature Preserves Commission provides nature preserve signs and technical assistance to nature preserve owners as staff and financial resources allow.

There are eighty-five different owners of nature preserves, ranging from private individuals to sizable public land managing agencies. Consequently, various owners' stewardship capabilities range widely. Natural areas professionals direct the management of their own lands, but also provide guidance and assistance to other nature preserve owners and managers. Thousands of members of The Nature Conservancy's Volunteer Stewardship Network provide site surveillance, brush cutting and prescribed burning on natural areas and nature preserves. Under a cooperative agreement with the Illinois Nature Preserves Commission, over 100 volunteers are licensed to judiciously apply herbicides where invasive plant species are jeopardizing natural communities. Cooperation among all groups and information exchange within and outside Illinois have been key to the successes in natural areas preservation and management during the last 30 years. This cooperation is even more critical for the future preservation of Illinois' natural heritage.

As the Nature Preserves System grows, so grows our knowledge about natural areas management and restoration ecology. Just as rapidly, development and other threats to nature preserves increase. In order to preserve representative examples of all of the natural communities in Illinois, we should work to protect the six forest communities listed in Table 3 which are eligible for consideration by INPC for dedication as nature preserves.

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Table 1. Nature preserves encompassing high quality forested tracts and acreage dedicated as nature preserve (acres dedicated as buffer not included).

Nature Preserve	Acres
American Beech Woods	21
Beall Woods	333
Black Hawk Forest	107
Black Partridge Woods	80
Bois Du Sangamon	30
Busse Forest	440
Carpenter Park	322
Dean Hills	70
Harper's Woods	40
Harper-Rector Woods	37
Hartley Memorial	40
Heron Pond-Little Black Slough	1861
Horseshoe Lake	492
Iroquois Woods	44
Johnson's Mound	185
Jubilee College Forest	64
Jurgensen Woods	120
Julius J. Knobeloch Woods	35
Laona Heights	20
Lloyd's Woods	105
MacArthur Woods	446
Marissa Woods	25
Massac Forest	245
Matthiessen	86
McMaster Woods	33
Middle Fork Woods	69
Momence Wetlands	72
Myer Woods	20
Norris	62
Ozark Hills	222
Red Hills Woods	32
Rocky Branch	138
Edward L. Ryerson	279
Spitler Woods	146
Starved Rock	582
Stemler Cave Woods	120
Thorn Creek Woods	500
Tomlin Timber	20
Ward's Grove	335
TOTAL	7878

Table 2. Forest types represented in high quality forested nature preserves (natural division in parentheses; Schwegman 1973).

Horseshoe Lake	Wet Floodplain (14b)
Momence Wetlands	Wet Floodplain (4e)
Heron Pond-Little Black Slough	Wet Floodplain/Mesic Upland (13b,14b)
	Dry-Mesic Upland
Julius J. Knobeloch Woods	Wet Floodplain/Dry-Mesic Upland(9a)
Massac Forest	Wet-mesic Floodplain (14b)
Beall Woods	Wet-mesic Floodplain (10ab)
	Wet-mesic Upland
Spitler Woods	Wet-mesic Floodplain (4a)
	Mesic Upland
	Dry-mesic Upland
Carpenter Park	Wet-mesic Floodplain (4b)
	Mesic Upland
	Dry-mesic Upland
American Beech Woods	Mesic Floodplain (10b)
Edward L. Ryerson	Mesic Floodplain (3a)
	Mesic Upland
	Dry-mesic Upland
MacArthur Woods	Mesic Floodplain (3a)
	Dry-mesic Upland
Harper-Rector Woods	Wet-mesic Upland (7a)
	Dry-mesic Upland
Dean Hills	Mesic Upland (9a)
Iroquois Woods	Mesic Upland (4e)
Lloyd's Woods	Mesic Upland (3a)
Bois Du Sangamon	Mesic Upland (4a)
Middlefork Woods	Mesic Upland (10c)
Black Partridge Woods	Mesic Upland/Dry-mesic Upland (3a)
Busse Forest	Mesic Upland/Dry-mesic Upland (3a)
McMaster Woods	Mesic Upland/Dry-mesic Upland (8b)
Johnson's Mound	Mesic Upland/Dry-mesic Upland (3a)
Jubilee College Forest	Mesic Upland/Dry-mesic Upland (7a)
Harper's Woods	Mesic Upland/Dry-mesic Upland (4a)
Starved Rock	Mesic Upland/Dry-mesic Upland (4a)
	Dry Upland
Stemler Cave Woods	Mesic Upland/Dry-mesic Upland (11a)
	Dry Upland
Jurgensen Woods	Dry-mesic Upland (?)
Myer Woods	Dry Upland (4a)
Rocky Branch	Dry Upland (10b)
Ward's Grove	Dry Upland (1)
Norris	Dry Upland (3a)
Mattheissen	Dry Upland (4a)
Black Hawk Forest	Dry Upland (8a)
Marissa Woods	Dry Upland (9b)
Thorn Creek Woods	Dry Upland (3a)
Hartley Memorial	Dry Upland (2a)
Laona Heights	Dry Upland (2a)
Red Hills Woods	Dry Upland (10b)
Ozark Hills	Dry Upland/Mesic Upland (11c)
Tomlin Timber	Dry Sand (6a)

Table 3. Extant high quality forest communities not currently represented in the Illinois Nature Preserves System.

NATURAL DIVISION # AND NAME		SECTION	COMMUNITY TYPE
2b	Rock River Hill County	Oregon	Dry Mesic & Dry Upland
5a	Upper Mississippi River & Illinois River Bottomlands	Illinois River	Wet Mesic Floodplain
5b*	Upper Mississippi River & Illinois River Bottomlands	Mississippi River	Floodplain
7b	Western Forest-Prairie	Carlinville	Dry-mesic Upland
8b*	Middle Mississippi Border	Driftless	Dry-mesic Upland & Wet-mesic Upland
12b	Lower Mississippi River Bottomlands	Southern	Wet-mesic Floodplain

*Natural Division and Section currently unrepresented in the Nature Preserves System by any habitat type.

Table 4. Topics of research in forested nature preserves (1989-1992).

Floristic inventories
Genetic analysis of eastern massasaugas
Archaelogical investigation
Identification of lichens
Population ecology - 3 threatened plant species
Population survey of silvery salamander
Census of higher fleshy fungi
Inventory & water chemistry of bald cypress swamps
Inventory leafhoppers, *Papaipema* spp., butterflies
Impact of sugar maple canopy on oak forests
Deer control
Inventory seep communities
Identify medicinally important species
Comparison of vegetation sampling methods
Evaluate blooming periods of woodland perennials
Propagation of Nuttall's oak
Evaluate proposed tollway threat to preserve
Compare soil/rock movement vs visitor impacts
Study plant regeneration in bottomland hardwoods

STATEWIDE STUDIES:

Treehole mosquitoes, stoneflies, amphibians & reptiles, land snails, deer ticks, butterflies

Vegetative Dynamics of the Prairie/Forest Interface of Cole Creek Hill Prairie

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INTRODUCTION

Cole Creek Hill Prairie is located 4 km south of Eldred, Greene County, on the eastern bluffs of the Illinois River valley. This hill prairie occupied about 1.8 ha when it was visited by Evers (1955) in 1950. He named it the South Eldred Hill Prairie, and later renamed it Cole Creek Hill Prairie (Evers and Page 1977).

The Cole Creek Hill Prairie is dominated by *Andropogon scoparius*, but *Sorghastrum nutans* and *Bouteloua curtipendula* are also common grasses. Interesting plants easily found include *Houstonia nigricans, Buchneria americana, Linum sulcatum, Penstemon pallidus, Monarda punctata, Kuhnia eupatorioides, Spiranthes magnicamporum, Gerardia skineeriana*, and *Gentiana quinquefolia*.

This hill prairie is covered by a thick layer of loess. The prairie consists of two parts, like the letter U, with one arm of the U parallel and closest to the Illinois River valley (the west spur), the other arm of the U also parallel to the River valley but farther east (the east spur). The loess was deposited since the Illinoian deglaciation (Evers 1955), and on the steep southern slope of the east spur the loose soil has slumped, exposing snails, indicating that in the years in which the loess was being deposited, the hills were covered with herbaceous vegetation on which the snails were feeding.

The slumps also reveal concretions formed from lime dissolved from the loess by rain water which seeped through the loess deposits and then precipitated out as stone. Such deposits are an indication of the pronounced drainage of the soil, contributing to the droughtiness of the hills, especially the southwest-facing slopes which are exposed to the summer sun and winds. The ends of the hills are unobstructed from the sun and wind because they rise abruptly at least 60 m above the floodplain. The broad floodplain, about 8 km wide, permits the full force of the winds to hit the high slopes. Hence, Evers (1955) states, "It seems probable that a shifting equilibrium was long ago reached between prairie and forest, especially on bluffs with high cliffs. As long as the present topography and climate persist, such hill prairies will remain apparently as they are." This study examines changes in Cole Creek Hill Prairie since 1964.

METHODS AND MATERIALS

In August, 1992, photographs taken in October 1964 were consulted in the field to determine the position of the photographs, and these scenes were rephotographed to document changes of vegetation in the intervening years. Notes were also taken of woody species that are presently invading the hill prairie, and data from annual trips of an ecology class to the prairie were utilized to help interpret changes observed since 1964. Photographs made at intervals between 1964 and 1992 were also consulted.

RESULTS AND DISCUSSION

Since 1964, the present topography has not noticeably changed at Cole Creek Hill Prairie. On the other hand, the area occupied by the prairie has diminished substantially through invasion of trees and shrubs. The western spur is no longer visible from the road at the base of the bluffs, nor from the east spur, due to growth in height of trees at the periphery of the hill prairie and to invasion of woody plants within the prairie. Only the uppermost (northern) segment of the west spur is still prairie, and it is also being invaded by *Juniperus virginiana* that are now about 5 m tall. The eastern and western spurs are no longer connected at the north end.

The eastern spur is still a substantial size (about 1.4 ha), but invasion of the southern end (with the steepest slopes, and most exposed to wind and sun) has been invaded by trees such as *Juniperus virginiana* and *Ulmus rubra*, and by shrubs including *Cornus drummondii* and *Rhus glabra*.

There are several conditions that create opportunities for woody invasion of this hill prairie. Slumping of the soil in the steepest southwest-facing slopes is common. On the top of the hill prairie there are animal activities that create bare soil, especially woodchuck dens. Here *Crataegus* sp., *Ulmus rubra*, and *Juglans nigra* have invaded. A deer trail leads down the crest of both the east and west spurs and causes some exposure of soil.

Human interference has also opened the prairie to invasion by woody species. In the late 1960s, three trenches were dug, about 2 m long, 1 m wide, and 1 m deep. These were made by a local family in search of Indian artifacts, and were not filled in. The trenches were invaded by *Cornus florida, Juniperus virginiana*, *Ulmus rubra* and *Malus ioensis*, and some of the trees are now about 4 m high.

What has caused this change in the dynamics of the forest/hill prairie? In one area near the north end of the east spur, I ran transects across the prairie/forest interface during the years my ecology class visited the area. In this area, with a slope of about 45 degrees, the vegetation at the interface is virtually unchanged. Common species of the forest at this site include *Quercus muhlenbergii*, *Cornus florida, Acer saccharum*, *Rhus aromatica, Ulmus rubra, Cornus drummondii*, *Juniperus virginiana, Ostrya virginiana, Celastrus scandens*, and *Vitis aestivalis*. One *Quercus muhlenbergii* with a trunk diameter of about 65 cm has horizontal limbs that extend out until they touch the hillside. Immediately beyond its branches there is intact prairie. In this same area there are specimens of *Cornus florida* with trunk diameters of about 15 cm, and their limbs also extend laterally to touch the ground, beyond which the prairie is not invaded by woody species. This sudden transition from forest to prairie that has not changed in 28 years indicates stability. Yet elsewhere, at sites where the steep topography (slopes of 45 to 60 degrees) should be expected to repel woody invaders, change to forest seems to be occurring rapidly.

There are several possible explanations for this change. In the past, the hill prairie was pastured, as evidenced by an old barbed wire fence, now on the ground, across the brow of the east spur. It is also possible that fire once occurred with enough frequency to help exclude woody invaders. There has not been a fire on this prairie in the last 28 years. Brush (1944) who in 1820 settled a few kilometers north of Cole Creek Hill Prairie, wrote concerning the bluffs of the Illinois River, "Grass covered the summits, which loomed up above the rock in rounded cones of varied heights, kept denuded of other growth than grass by annual fires that overswept the hills and the prairie ground below." Finally, perhaps the climate in the last several decades has been unusually wet, enough to allow establishment of woody species. However, if this is the case, it would seem it is an unusual event in the climatological cycle, because the west spur of the prairie has been so completely invaded in the past 28 years that it seems very unlikely that most of it could ever again become prairie.

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Exotics of Illinois Forests

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Illinois forests are negatively impacted by a number of noxious exotic species. Exotic weedy plants have the greatest ecological impact at present, with exotic diseases in second place and exotic animals third. Most of the problem exotic weedy plants are woody; trees, shrubs and woody vines. Of the 21 most serious weeds, 8 are shrubs or small trees, 4 are woody vines, 5 are trees, and only 4 are herbs (Table 1).

Unlike the vast numbers of our alien flora which are accidental introductions thriving in crop fields and disturbed sites, many of the problem weeds of the woods were introduced on purpose. Table 1 shows that 7 were once widely planted for conservation purposes and that 11 are sold by the horticulture trade.

Based on my observations, the potentially most serious weeds of our forests statewide are amur honeysuckle and garlic mustard. Leading regional problem species in northern Illinois include common buckthorn and tatarian honeysuckle, and in southern Illinois, Japanese honeysuckle and wintercreeper.

Efforts at control have concentrated on control through management and prohibition of selling and planting in the State. The development of biological controls offers hope, but is not under way for any of these species at present. Management controls include mechanical removal such as cutting or pulling, girdling, treatment with herbicides, and prescribed burning. While these help maintain the forest managed for nature preservation, most Illinois forests are not managed for this purpose and continue to deteriorate.

Biological controls, which unite problem weeds from foreign lands with the diseases and insects that control their numbers in their native habitat, hold the best hope for saving all of our woods from the most serious pests. It is an expensive process costing about 1 million dollars in research and development and takes at least 9 years to complete. However, when weighed against the costs of chemicals and manpower for management controls, it is very cost effective.

Biological controls are developed by the U.S.D.A.'s Agricultural Research Service, mostly for agricultural pests. We should all urge our representatives in Congress to support biological control development for wildland weeds. Our first priorities should be amur honeysuckle, garlic mustard, Japanese honeysuckle, and common buckthorn.

Illinois' only effort at control through regulation is the Illinois Exotic Weed Act which prohibits the sale or planting of multiflora rose, Japanese honeysuckle, and purple loosestrife. The latter species is a wetland weed that does not invade forests. Efforts to amend the Act to prohibit amur honeysuckle, autumn olive, and crown vetch (a weed of open habitats) have failed. Opposition from nursery interests have prevented the Illinois Legislature from adding them to the prohibited list.

There are many other potentially serious weeds getting started in Illinois forests at present, but the ones listed above are the main problems now. A serious weed of eastern forests that may eventually get to Illinois is mile-a-minute (*Polygonum perfoliatum* L.).

The principal exotic diseases affecting Illinois forests are Dutch elm disease, butternut canker, and American chestnut blight. Dutch elm disease entered the United States at Cleveland, Ohio, on unpeeled veneer logs in 1930 and had spread nationwide by 1975. Its fungal spores are spread by bark beetles. It has killed many of the American elms in Illinois' forests, being especially devastating in northern Illinois.

Butternut canker was first identified in Wisconsin in 1967 and is now killing butternuts throughout the range of the species. Many Illinois butternuts have died, but thanks to the scattered nature and low density of this tree in our forests, some of our trees still survive. The spores of this fungal disease are spread by the wind.

The American chestnut blight was introduced to the United States in 1903 in a shipment of Asiatic chestnut nursery stock. It has now top-killed nearly all native American chestnuts. Some root sprouts still persist a few years before being reinfected and killed back by the fungus, but in effect our tree has been eliminated as a component of the American forest. Illinois' only known native chestnut stand, located in Pulaski County, may have been killed by this disease. Isolated trees planted in our forests still persist, but it seems that the fungus eventually reaches even the most remote trees and kills them.

The most serious disease that may affect our forests in the near future is dogwood anthracnose. This exotic Asian fungal disease was first noted around New York City in 1977. It has since killed up to 80 percent of the flowering dogwood trees in many areas of the Appalachians, and is headed our way. It was last noted in central Tennessee, spreading toward southern Illinois. Flowering dogwood is a very important and beautiful small tree of the southern two-thirds of the State. Its loss or decline would have a major detrimental effect on our forests.

Other exotic diseases that may eventually impact our forests are white pine blister rust and beech bark disease. Both are fungal diseases.

The principal exotic animal threatening Illinois' forests is the gypsy moth. A few outbreaks have occurred in northeastern Illinois, but to date they have not had the devastating effect on our forests that they have had in the northeastern states. There, large numbers of caterpillars defoliate and eventually kill hardwood forests.

If Illinois' forests are to survive, government must get control of future pest introductions and effectively address the problem of controlling the species we already have. Congress' office of technology assessment is currently conducting a study of how this might be accomplished. Their report is scheduled for release in February 1993. Everyone interested in this problem should get a copy and let their elected representatives know that they want to see this problem addressed.

Table 1. Principal exotic weeds of Illinois forests.

Woody Species		
Amur honeysuckle#	*Lonicera maackii* (Rupr.) Maxim.	Mesic habitats, statewide
Japanese honeysuckle*#	*Lonicera japonica* Thunb.	Mesic habitats, south
Common buckthorn	*Rhamnus cathartica* L.	Mesic forests, north
Tatarian honeysuckle*	*Lonicera tatarica* L.	Mesic, north half
Autumn olive#	*Elaeagnus umbellata* Thunb.	Open habitats, statewide
Tall hedge*	*Rhamnus frangula* L.	Wet to mesic habitats, north half
Wintercreeper*	*Euonymus fortunei* (Turcz.) Hand.-Maz.	Mesic habitats, south half
Multiflora rose#	*Rosa multiflora* Thunb.	Mesic habitats, throughout
Winged wahoo*	*Euonymus alatus* (Thunb.) Sieb.	Mesic forests, throughout
Oriental bittersweet*	*Celastrus orbiculatus* Thunb.	Forests, statewide
Black locust#	*Robinia pseudoacacia* L.	Mesic to dry, throughout
Kudzu#	*Pueraria lobata* (Willd.) Ohwi	Mesic forest edges, south
Tree of heaven*	*Ailanthus altissima* (Mill.) Swingle	Mesic disturbed, throughout
Privet*	*Ligustrum obtusifolium* Sieb. & Zucc.	Woods, throughout
Goldenrain tree*	*Koelreuteria paniculata* Laxm.	River bluffs, south
Osage orange#	*Maclura pomifera* (Raf.) Schneider	Low woods and river banks
Amur maple*#	*Acer ginnala* Maxim.	Woods, throughout
Herbs		
Garlic mustard	*Alliaria petiolata* (Bieb.) Cavara & Grande	Forests in north two-thirds
Eulalia	*Microstegium vimineum* (Trin.) A. Camus	Low woods, south
Chinese yam	*Dioscorea batatas* Dcne.	Woods and brushy areas, south
Moneywort	*Lysimachia nummularia* L.	Wetlands throughout

*Plants currently in the horticulture trade.
#Plants once promoted for wildlife or soil conservation purposes.

Native Actinorhizal Plants of Illinois

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ABSTRACT

Actinorhizal plants are non-legumes nodulated by the symbiotic actinomycete *Frankia* that fixes atmospheric nitrogen. Actinorhizal plants occur on nitrogen-poor sites including sandy and gravelly soils, raw mineral soils, and wet soils. Virtually all known actinorhizal plants are trees or shrubs occurring in 25 genera and eight families of angiospermous plants. There are six native species of actinorhizal plants in Illinois. Four of these six species (*Alnus incana* ssp. *rugosa* (DuRoi) Clausen, *Ceanothus herbaceous* Raf., *Shepherdia canadensis* (L.) Nutt., and *Comptonia perigrina* (L.) Coult.) are listed as endangered in Illinois (Herkert 1991) but are common elsewhere. Actinorhizal *Alnus serrulata* (Ait.) Willd. (hazel alder or smooth alder) is a multistemmed shrub or small tree that is typically found in southern Illinois along stream banks on coarse, rocky soils sorted by periodic floods. *Alnus incana* ssp. *rugosa* is found on moist soils at a few locations in northern Illinois. The widespread actinorhizal plant *Ceanothus americanus* (New Jersey tea or redroot) and *C. herbaceous* (inland *Ceanothus*) are small shrubs that occur on drier sites in Illinois including native prairies, savannas, and open oak woodlands. *Shepherdia canadensis* (L.) Nutt. and *Comptonia perigrina* occur on dry sandy soils in a few restricted locales.

INTRODUCTION

Frankia is the genus of actinomycetes that is able to nodulate the roots of plants belonging to 8 diverse dicotyledonous plant families and 25 genera (Table 1). These plants are termed actinorhizal plants. *Frankia* fixes atmospheric nitrogen symbiotically with these plant hosts. The word "actinorhiza" is formed from the base terms actino for the actinomycete *Frankia* and rhiza from the Greek for root. It is notable that all of these actinorhizal host plants are woody with the exception of two species of herbaceous perennials in the genus *Datisca*. Two genera, *Arctostaphylos* and *Rubus*, have been included in past lists of *Frankia*-nodulated plants (Bond 1967, 1983) but are now discounted as host genera because nodulation could not be confirmed (*i.e.* Stowers 1985).

Frankia are filamentous organisms that produce sporangia and thick-walled, spherical structures termed vesicles. Sporangia and vesicles are derived from hyphae. Sporangia contain many spores and are produced in culture and in some nodules of certain host genera. Vesicles are born on short branches attached to the hyphae and contain nitrogenase, the enzyme used to convert atmospheric dinitrogen to ammonium. The thick walls restrict the diffusion of oxygen into vesicles, thus protecting nitrogenase from the deleterious effects of atmospheric oxygen.

The Natural Occurrence of Actinorhizal Plant Associations

Actinorhizal plants are found primarily on nitrogen-poor sites such as sandy and gravelly soils, raw mineral soils, and wet soils. They occur in forest, swamp, riparian, shrub, prairie, and desert ecosystems. In temperate and cool climates actinorhizal plants seem to fill the ecological niche occupied by woody legumes in the tropics. Actinorhizal plants frequently occur as pioneer vegetation at early stages of plant succession following such disturbances as flooding, fires, landslides, glacial activity, and volcanic eruptions.

For example *Alnus*, *Hippophae*, and *Dryas* species were probably important in the initiation of soil formation immediately following the retreat of continental ice sheets over vast areas of Europe, Asia, and North America (Bond 1983). Similarly *Alnus rubra* Bong. was a major colonizer of mud flows covered with ash resulting from the recent eruption of Mount St. Helens volcano in the state of Washington, USA.

Exotic actinorhizal plants can become readily naturalized and sometimes weedy in disturbed landscapes. Examples include the widespread naturalization of *Casuarina* spp. in southern Florida, *Elaeagnus umbellata* Thunb. in the eastern US, and *Elaeagnus angustifolia* L. in the western US and Canada. *Elaeagnus umbellata* has been declared noxious by weed control agencies in some areas of the eastern US, and hence is locally subject to eradication efforts and planting bans. Actinorhizal *E. umbellata* is spread readily by birds which relish their fruit and is invasive on disturbed sites in Illinois. Consequently there are State restrictions on its production and use.

Many actinorhizal plants persist in the understory of open forest stands, particularly on excessively wet or dry sites, or as dominant species in stable plant communities. Examples include *Myrica cerifera* L. which is a common understory shrub in stands of *Pinus taeda* L. and *Pinus elliotii* Engelm. on sandy soils of the coastal plain in the southeastern U.S., *Cercocarpus* spp. in the understory of *Pinus ponderosa* Laws. stands in semi-arid regions of western North America, and stands of *Casuarina glauca* Sieber that dominate brackish coastal swamps in southeastern Australia. In Illinois *Ceanothus americanus* L. is characteristic of oak savannas and open oak woodlands.

Other actinorhizal plants that occur in forest ecosystems are *Coriaria* spp., which precedes forest vegetation in New Zealand; *Dryas* spp. and *Alnus* spp., which colonize raw glacial till in Alaska prior to succession by spruce; *Purshia* spp., which occurs as an understory plant in open pine stands of western North America; *Shepherdia* spp. and *Alnus* spp. on poor sites with aspen and spruce in the Rocky Mountains; *Comptonia perigrina* (L.) Coult. and *Alnus viridis* ssp. *crispa* (Ait.) with jack pine on sandy soils in eastern Canada; and *Ceanothus*, an indigenous North American genus that occurs primarily on dry sites, with a variety of forest trees and other vegetation (Dawson 1983).

In addition, actinorhizal plants are cultivated as ornamental, wildlife, timber, fuelwood, pulpwood, reclamation, nurse and windbreak plants (Dawson 1986). Others await culture and domestication. It is most probable that actinorhizal plants, so ubiquitous on poor soils, contribute substantially to the nitrogen economy and productivity of many ecosystems.

The Occurrence of Native Actinorhizal Plants in Illinois

There are six native species of actinorhizal plants in Illinois. Four of these six species (*Alnus incana* ssp. *rugosa* (DuRoi) Clausen, *Ceanothus herbaceous* Raf., *Shepherdia canadensis* (L.) Nutt., and *Comptonia perigrina*) are listed as endangered in Illinois (Herkert 1991). Although rare in Illinois, these four species are common elsewhere.

Comptonia perigrina (sweetfern) and *Shepherdia canadensis* (buffaloberry) are small shrubs that characteristically occupy infertile sandy soils. *Shepherdia canadensis* occurs on sandy bluffs and in sand dune plant associations near Lake Michigan in northeastern Illinois and is perhaps the rarest shrub in the state. *Comptonia perigrina* is restricted to sandy acidic soils in northeastern Illinois. Both species are more common on similar sites further north in the Lake States.

Alnus serrulata (Ait.) Willd. (hazel alder or smooth alder) is a multistemmed shrub or small tree that is typically found in southern Illinois along stream banks on coarse, rocky soils sorted by periodic floods. Consequently the typical soils in which this alder occurs are low in organic matter and nitrogen. This species is the common alder of the southeastern U.S.

Ceanothus americanus (New Jersey tea or redroot) and *C. herbaceous* (inland *Ceanothus*) are small shrubs that occur on drier sites in Illinois including native prairies and open oak woodlands. The genus *Ceanothus* is endemic to North America and the center of diversity for this genus is in the western U.S. where more than fifty species are known. Only four native *Ceanothus* species occur east of the Mississippi River in the U.S. *Ceanothus microphyllus* Michx. is the easternmost *Ceanothus* species and occurs on well drained pinelands in southern Alabama and Georgia south through Florida and the Bahamas. A single extant population of *Ceanothus sanguineus* Pursh occurs in northern lower Michigan, far removed from the northern Rockies and Cascade Range where it is a common gap species. It is interesting to note that our native *Ceanothus americanus* occupies similar habitats and is more closely related taxonomically to *Ceanothus sanguineus* than to Illinois' other native - *Ceanothus herbaceous* (Coile, 1988).

Ceanothus herbaceous (*Ceanothus ovatus* Desf.) is more typical of drier short grass prairies to the west and north. In Illinois this species is not common, but is associated with sandy soils along the Mississippi River near the driftless area in northwestern Illinois and the Lake Michigan dunes. It occupies drier sites than those typical of the most common and widespread actinorhizal plant in Illinois, *C. americanus*.

There are two recognized varieties of *Ceanothus americanus*, *C. americanus* var. *intermedius* (L.) Trel and *C. americanus* L. var. *pitcheri* T. & G. Both of these varieties are reported to occur in Illinois. Variety *pitcheri* is recognized by its obtuse leaf tips and hairy upper surfaces, while variety *intermedius* has nearly glabrous upper surfaces and acute to acuminate leaves. There appears to be considerable ecological variation in leaf morphology in *C. americanus* and we have noticed considerable morphological plasticity in our greenhouse specimens grown under different moisture regimes. *Ceanothus americanus* is easily confused with *C. herbaceous*, however, *C. herbaceous* can be readily distinguished by its leafy peduncles and terminal inflorescences, while *C. americanus* possesses naked peduncles and a combination of terminal and axillary inflorescences.

In dry soils where Illinois' two native *Ceanothus* species occur, periodic soil moisture deficits likely limit mineralization of organic nitrogen, hence its availability in soil solution. In prairies, savannas, and open oak woodlands where these shrubs are found, root competition for water and nutrients is often severe, creating a dearth of available nitrogen even where organic nitrogen levels are relatively high. The ability of *Ceanothus* to fix nitrogen in association with *Frankia* gives these shrubs a competitive advantage on these nitrogen-limited sites. *Ceanothus* is able to persist after fires and heavy browsing because it possess an enormous taproot and resprouts rapidly. Attempts at removal of mature plants from prairie soils by early settlers, and the ability of its taproot to abruptly stop sod-busting plows drawn by teams of oxen, resulted in *Ceanothus* earning the name "rupture root". The name New Jersey tea was given to *C. americanus* during the American revolution when the leaves were used as a patriotic substitute for imported teas. *Alnus incana* ssp. *rugosa* (*Alnus rugosa* (DuRoi) Spreng.), known as speckled alder, is a shrub or small tree that usually occurs in wetlands where often saturated soils have low oxygen levels and cooler temperatures which both retard mineralization of organic nitrogen. Cool, wet soils can have low levels of available nitrogen even where the organic nitrogen pool is large. *Alnus incana* ssp. *rugosa* is found only in the northeast corner of Illinois where it is an uncommon but locally abundant shrub of swamp and bog communities. This species probably occupied a larger range in northern Illinois prior to drainage of wetlands for agriculture. *Alnus incana* ssp. *rugosa* is known as the common "tag alder" in the northeastern and northern U.S. where it occurs along streams, lakes and in marshes. This species often occurs in dense, impenetrable thickets that are the bane of fishermen, being difficult to walk through and snaring many artificial flies and lures cast by anglers.

Nitrogen Contributions

One of the primary benefits of the natural association of actinorhizal plants with other plants is their input of fixed nitrogen to soil. Nitrogen accumulation rates ranging from 60 to 320 kg per ha per year have been estimated for *Alnus* spp. (Newton *et al.* 1968; Tarrant and Trappe 1971). Estimates of the amounts of nitrogen that actually become available to associated plants through mineralization of organic material in stands containing actinorhizal plants range from 48 to 185 kg per ha per year for stands with alder (Daniere *et al.* 1986; Paschke *et al.* 1989) and up to 236 kg per ha per year for a plantation containing *Elaeagnus umbellata* (Paschke *et al.*, 1989). Estimates of nitrogen mineralization more accurately reflect the influence of actinorhizal plants on soil nitrogen fertility than estimates of total nitrogen input.

At a montane cirque lake in California, *Alnus tenuifolia* Nutt. shrubs growing along the lakeshore and the banks of streams in the lake's watershed were probably a major source of nitrogen to the lake ecosystem, which included a productive trout fishery (Goldman 1961). Increased photosynthetic activity of the lake's phytoplankton and a better development of the aquatic plant Isoetes were associated with the presence of *Alnus* along the shore. The cold streams that support trout, and that are important for anadromous salmon spawning in the headwaters of larger rivers, are often infertile. It is possible that streamside alders are important sources of nitrogen to planktonic organisms at the beginning of the food chain for salmon, trout, and their fry. The importance of riparian alder vegetation to commercial salmon fisheries and sport fisheries has not been assessed. It is likely that riparian and wetland alders native to Illinois also contribute substantially to the nitrogen economy of their associated terrestrial and aquatic ecosystems.

Illinois' actinorhizal plants are interesting components of our native flora with a little-appreciated role as nitrogen-fixing soil improvers. Apart from their value as elements of our greatly-diminished native flora, many of these plants have potential for use as ornamental plants and in prairie, savanna, and forest restoration. For example, *Ceanothus americanus* possesses large nectaries that attract and support nectar-feeding insects including some rare moths and butterflies of native prairie and savannah ecosystems. Swink and Wilhelm (1979) point out that *C. americanus* "is one of the best species in our area, when in bloom, for the collection of interesting insects". Specimens of *C. americanus* in our collection annually attract a diversity of insects despite the barriers imposed by a greenhouse designed to exclude insects.

Because of their ability to fix atmospheric nitrogen in plant communities where nitrogen is scarce, actinorhizal plants are important sources of nitrogen-rich forage for herbivores. Most actinorhizal plants can sustain high levels of browsing, and some actinorhizal species exhibit stimulated growth when defoliated (Bilbrough and Richards 1989).

Increased knowledge of actinorhizal plants and their ecological characteristics should aid in our management of these species in their native Illinois habitats, in recreated and restored natural areas, as well as in cultivation. *Ceanothus americanus* seedlings are produced by the Illinois Department of Conservation Mason County Nursery for planting on state lands and are also available from private nurseries. Other actinorhizal species can also be obtained from private nurseries. Illinois' actinorhizal plants merit efforts to maintain them in their natural settings and to cultivate them in the urban and rural landscape.

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Table 1. Currently known actinorhizal plant families and genera [adapted from Bond (1983) and Baker and Schwintzer (1990)].

Family	Genus	Number of species
Betulaceae	Alnus	35
Casuarinaceae	Allocasuarina	54
	Casuarina	16
	Ceuthostoma	2
	Gymnostoma	18
Coriariaceae	Coriaria	16
Datiscaceae	Datisca	2
Elaeagnaceae	Elaeagnus	38
	Hippophae	2
	Shepherdia	2
Myricaceae	Comptonia	1
	Myrica	28
Rhamnaceae	Adolphia	2
	Ceanothus	51
	Colletia	4
	Discaria	5
	Kentrothamnus	1
	Retanilla	2
	Talguenea	1
	Trevoa	2
Rosaceae	Cercocarpus	5
	Chamaebatia	2
	Cowania	3
	Dryas	3
	Purshia	2

Fighting for Life: A Plan for Endangered Plants

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Most of us are familiar with these recent news items: "Tropical rainforests amounting to the size of Pennsylvania are being destroyed each year." "Seventy plant and animal species disappear each day." "One million species are at risk of extinction by the end of this century."

One you may not have heard, reported by Dr. Al Gentry of the Missouri Botanical Garden, is that a mountain ridge in Ecuador smaller than 20 square miles contained 96 species of plants known from no other place in the world. It was completely destroyed during a timber operation. This is frightening news.

Since I began talking a few minutes ago, another organism probably became extinct some place in our world; ten more acres of tropical rainforest were destroyed. The message about our natural resources is an urgent one. Waiting for the problem to go away will not happen. We must act, all of us, to preserve natural diversity.

Most of us are or should be appalled by the statistics just given, but to most of us, it just doesn't hit home because we don't really experience it. We go about our daily activities in the same world we had the day before. We see destruction of habitats in Illinois in the building of roads or the clearing of land for development, in mining and other activities, but we are not cognizant of any species becoming extinct before our eyes.

Yet the mass destruction of natural habitats and their species by us will eventually engulf us if we continue to permit isolated patches of natural areas and their species to be destroyed.

That is why I chose to talk today about some conservation efforts being made at the international level. In an effort to deal with conservation problems around the world, the *International Union for the Conservation of Nature* (IUCN), was created in 1948. The organization is today considered to be the leading international conservation body. With headquarters in Switzerland, the IUCN is like a United Nations of Conservation, with 119 member nations.

The stated purpose of the IUCN is to develop strategies for coping with preservation of our natural heritage while utilizing efficiently our resources. The organization is run by a handful of paid staff and hundreds of volunteers, such as myself.

I would like to give you an organizational diagram of the IUCN and show you where my committee's current work fits in. The leading person is the *Director General*, and he coordinates three major areas of activity.

The first area is the *Conservation for Development Center*. This unit sets up offices in countries that ask for assistance in designing and carrying out conservation projects. At the present time, there are regional offices established in 12 nations.

The *Conservation Monitoring Center* receives all pertinent data and computerizes them. Data are accepted for animals, plants, protected areas, and wildlife trade. I feed data on endangered plants of North America into this Center.

The largest unit is the *Technical Division*, staffed completely by volunteers. This division prioritizes conservation needs and designs and carries out action plans. There are six commissions within the Technical Division.

It is the *Species Survival Commission* (SSC) that I wish to concentrate on. The SSC is IUCN's primary source of the scientific and technical information required for the maintenance of biological diversity through the conservation of endangered and vulnerable species of fauna and flora.

There are 90 committees in the SSC. One of the last ones to be formed was the *North American Plants Group*, and I have the honor of being appointed the chairman of this group.

Of the 90 committees, 74 are devoted to various groups of animals—wolf, bear, otter, etc. Of the 16 plant groups, some are devoted to a particular group of plants, some to a particular region. Thus, there are orchid, fern, palm groups, etc., as well as a plant committee for China, Australia, South American, North America, *etc*.

As chairman of the North American Plants Group, I have selected a committee of volunteers to assist in planning and carrying out our projects. I attend an annual SSC meeting selected for somewhere in the world to give progress reports on our projects. Every three years I am required to attend the IUCN General Assembly where I not only give a triennial report and plans for the next triennium, but also participate in the lengthy plenary sessions that last two weeks. It is at these sessions that major world conservation strategies are proposed, debated, and voted upon.

I have a committee of 18 persons scattered around North America that I present project proposals to for their review. We are currently engaged in several projects to assist in the protection of plant diversity in North America.

I would like to give you some idea of our committee's activities by describing briefly our projects.

I. <u>Centers for Endemics in North America</u>

An endemic species is one that is confined to a specific and therefore usually limited area. There are several areas in North America inhabited by an exceptionally high number of endemic plants. Since endemics, by virtue of their restricted ranges, are frequently endangered species, a study locating and defining the endemic areas of North American plants is appropriate for our committee. We have identified major and minor areas of endemics.

The *Florida Scrub* is an area in central Florida, particularly associated with a range of hills near Lake Wales known as the Lake Wales Ridge. In what is virtually a dry desert habitat, the Florida Scrub consists of white or yellow surface sand that supports rather sparse vegetation. Sand pines usually stand above a mixture of saw palmettos and various species of scrub oaks.

In the understory is an unusually high number of endemic plant species that are adapted to growing in this mineral-poor substrate. In one field near the community of Lake Placid, I was able to count nine different endemic species. These include a wild plum (*Prunus geniculata*), a few wild mints including *Diceradra immaculata*, a type of golden aster (*Chrysopsis floridana*), a morning-glory (*Bonamia grandiflora*), and others. Most of the Florida Scrub is still in private ownership, and the habitat is being destroyed rapidly because of the population increase in that part of Florida. This is a key area that we are zeroing in on for protective action.

The *Roan Mountain Massif* is a gorgeous mountain in the Blue Ridge system that straddles the North Carolina-Tennessee state line. Although reaching an elevation of only 6,245 feet, and certainly not above treeline, a treeless area, known as a *bald*, has developed on top of Roam Mountain. The popular attraction here is the magnificent rhododendron garden, dominated by native Catawba rhododendron (*Rhododendron catawbiense*). But further exploration of the massif reveals other species endemic to the area, including the dwarf Roan Mountain goldenrod (*Solidago roanensis*). While part of the mountain receives some protection from the Pisgah and Cherokee National Forests, other parts, including the habitat for the goldenrod, are not as yet in a special management zone.

The *Uinta Basin* occurs in the extreme eastern part of Utah and across into adjacent Colorado. The basin is a huge natural depression surrounded by a rim dominated by the crest of the Uinta Mountains to the north and the Book Cliffs to the south. The ruggedly beautiful Green River bisects the area as it passes through Desolation Canyon.

The Uinta Basin is noted for its shale outcrops and sandstone formations. Most of the region is of the mixed desert and shrub type, although the area has sometimes been described as a badland type of habitat. Mineral resources are rich in the Uinta Basin, with large supplies of natural gas in the floor of the basin, great deposits of coal, and oil-rich shale. Because of this, mineral exploration is a continuous hazard for the plants that occur in the basin. The shale is so rich in oil that sometimes oil virtually drips from the plant when it is removed from the soil. Several endangered endemic species occur here, and although they are on public land administered by the Bureau of Land Management (BLM), the BLM does not own the mineral rights or have they set aside any of the basin for preservation. Some of the endemic plants found here are the debris milk vetch (*Astragalus detritalis*), Graham's penstemon (*Penstemon grahamii*), the shale phacelia (*Phacelia argillacea*), and the Townsend daisy (*Townsendia condensata*). Preservation of this endemic center is critical.

Other areas of endemism of concern to our committee include the Nordhouse Dunes on the eastern shore of Lake Michigan, Sycamore Canyon on the Arizona-Mexico border west of Nogales, the Coral Sand Dunes of southern Utah, the Florida Keys, the Eureka Sand Dunes of eastern California, the Amargosa Valley near Death Valley, San Clemente Island, and a part of the volcanic Mauna Kea in Hawaii.

II. Reputed Extinct Plants of North America

Scarcely anyone paid much attention when an occasional species of plant became extinct in North America. After all, a whole ark of dinosaurs became extinct from natural causes, so why should one become alarmed if an occasional plant bit the dust. Organisms will become extinct sooner or later, anyway.

But with the environmental revolution, along with passage of the Federal Endangered Species Act in 1973, we perhaps began to have a feeling of guilt when we realized that most extinctions in modern times have been caused by our own interventions. In addition, more and more scientific data were beginning to tell us that there may be some potential in every species, perhaps as a drug or medicinal plant, as an ornamental, as a source of fats or oils, or whatever. It behooved us, then, to try to preserve every living species and its gene pool so that scientists could have a chance to understand fully each species.

Suddenly the word *extinction* became important—and scary. A book entitled *Extinction is Forever* made clear the finality of this process.

One of the charges to our SSC committee is to do everything possible to prevent the extinction of our plant species. One way to approach this is to learn from history. If we could determine what caused the extinction of a certain species in the past, perhaps we could avoid a similar fate for some current plants.

Our committee chose to make a study of the extinct plants of North America, primarily with the hope of learning some of the causes of extinction. As an added interest, we wanted to see if these plants were really extinct through intensive field searches.

When the U.S. Fish and Wildlife Serve was asked by Congress in 1976 to evaluate the status of the nearly 21,000 native species of plants in North America, it suggested that about 125 plants which had not been reported for a number of years might indeed be extinct. This is the basic list we started from in our study of possibly extinct plants.

For each plant we study the literature and the herbarium to find information concerning past collections and locations. We record all the pertinent information, including its precise locality, its habits, when it flowers, etc. A trip to the field is then made to try to relocate the plant, or at least to find what may have been its habitat. In many cases, we do not have precise localities recorded. In essence, it is like looking for a needle in a haystack.

The results to date have been interesting, exciting, sometimes frustrating, sometimes gratifying. Let me give you a few case studies.

Most famous of the extinct plants is *Thismia americana*. This miniature species was found in the Chicago area between 1912 and 1914 and not seen since. Intensive searches for this plant by nearly 300 plant enthusiasts the last two years have failed to turn up this elusive species.

Equally famous is the Franklin tree, *Franklinia altamaha*. John and William Bartram, two of our nation's first naturalists, were looking for new plants that would make good ornamentals. When they found them, they would sell seeds and other plants parts to England where they would be introduced into cultivation. In 1765, while exploring along the banks of the Altamaha River near Fort Barrington, Georgia, John found a colony of beautiful flowering trees. These trees, related to camellias, had flowers almost as pretty. On a second visit in 1776, the naturalists did their usual thing. They collected parts of the plants, including seeds. And it is a good thing they did. Although Reverend Moses Marshall saw the same colony of Franklin trees in the wild in 1970, and John Lyon saw them on June 1, 1803, no one has ever seen this plant in the wild since. Although the forest still exists, apparently the Franklin tree does not. Seeds sent to England sprouted, however, and the plant has been maintained as a cultivated species ever since. We are unable to propose why it suddenly vanished and why it hasn't been found in other similar-appearing woods.

Nichol's Devil's-head Cactus is a foot-tall, blue-green species that was discovered in the mountains west of Tucson, Arizona, in 1930. The plant was apparently forgotten about and no one had reported seeing it when I decided to look for it with my family one year during preparation of my book, *Where Have All the Wildflowers Gone?*. We knew the species had been found on a mountain near the tiny mining town of Silver Bell. Selecting one of many possible mountains surrounding the town to begin our search, we set out for the side of the mountain. There was the long lost cactus! We were able to remove a plant from the potentially extinct list.

On the same trip, we attempted to relocate a small false buckwheat, *Eriogonum gypsophilum*, that had been found in gypsum-bearing soils in southern New Mexico on August 6, 1909. Having fairly good directions from the original collection, we headed for what we thought was a likely spot, and there it was! Although we didn't find very many of them, we had the evidence to remove it from the extinct list.

Near the turn of the century, a different kind of pondweed was found living in the water of Blackwater Creek in the vicinity of Pensacola, Florida. Considered to be a new species, it was called *Potamogeton floridanus*. Despite repeated efforts to relocate it, no one could find this aquatic. The U.S. Fish and Wildlife Service declared it extinct in 1976. While studying the plants of the Florida Panhandle, Gerry Wilhelm waded into a tributary of Blackwater Creek and pulled out a pondweed. After thorough study of the plant in the laboratory, Gerry realized he had rediscovered the Florida pondweed! Another success story, and there have been a few of them.

When I wrote *Where Have All the Wildflowers Gone?* in 1983, my closing chapter decries the extinction of plant species. Quoting from Chapter 9, I commented: "*Thismia* is not alone as an extinct plant. Many others have not been seen for years and are presumed to be extinct. That's too bad, because I would like to have seen *Hechtia texensis*, a prickly member of the pineapple family that was found on dry limestone bluffs in the Big Bend area of Texas and not seen since."

"Wouldn't it be nice to go to the Undive Falls in Yellowstone National Park and see the showy rock cress, *Arabis fructicosa*? Nobody has been able to do so since 1899. Or go to Klamath Falls in Oregon and see Applegate's milk vetch, *Astragalus applegatii*? It was found in 1927 and again in 1931, but not since."

I am happy to report that this last statement is no longer true. A few years ago, botanists from Oregon rediscovered Applegate's milk vetch alive near Klamath Falls.

III. <u>Red Data Books</u>

Despite what I believe is the significance of the centers of endemism and the extinct plants projects, our major current study and work are directed toward the preparation and publication of the *Red Data Books for North American Plants*. The ultimate goal of each SSC group is to publish one or more Red Data Books which contain an account of the most endangered species of a particular group or area. Only a few have been done to date. These books are written after detailed study. They provide the latest information about an endangered species—what it looks like, where it is found, how many are left, what are the threats to it, and what can be done about it.

Our initial task was to determine what species to include in our Red Data Books. We are fortunate in North America to have several organizations and individuals interested in and working on endangered species, and we are using this network to assist us in the Red Data Books project.

We have drawn up a list of native plant species most in danger of becoming extinct. Because the list became so voluminous, we decided to publish two Red Data Books--one for the plants of Hawaii, and the other for the rest of North America. Unlike previous Red Data Books, ours will be fully illustrated with line drawings of each species, as well as color photographs. Let me give you a few examples of plants we will be including in the Red Data Books.

The Pitkin Marsh Paintbrush is perhaps the most critical living species in North America. It occurs only in Pitkin Marsh, in southern California, where it displays beautiful spikes of yellow flowers. There is only one plant known for this species. It consists of several stems, all from the same rootstock. Its dilemma is that it does not reproduce. Fruits and seeds are not formed. Attempts to take cuttings or to grow this plant in tissue culture have failed. Unless some mechanism is found to induce reproduction of some kind, this plant is doomed. Researchers are working round-the-clock to find a way to save it.

Raven's Manzanita is a mounded shrub growing at The Presidio, a military park just outside the Gold Gate Bridge in San Francisco. There is only one living specimen in the wild, although two previously known wild populations have been destroyed. This plant does not produce seeds, but it does respond to cuttings. Plants grown from cuttings can now be seen in a few gardens.

A few summers ago, my wife and I were exploring in the LaSal Mountains in eastern Utah, researching the area for my series in the *Natural History* magazine. I learned from the Manti-LaSal National Forest headquarters that the very rare and peculiar Spineless Hedgehog Cactus had recently been found in the LaSal Mountains. This cactus, nearly devoid of spines, had originally been found in the mountains across the state line near Paradox, Colorado. With general directions, we set off for the ridge in the LaSal Mountains where the cactus reputedly grew. After considerable searching, we spotted one beautiful clump of this spineless hedgehog.

The Green Pitcher Plant is one of those strange species of flowering plants that derives some of its nutrition from living organisms that it is able to trap. Because of this unique feature, they are often sold as novelties. As a result, most of them are becoming scarce in the wild. Perhaps the rarest of them all is the green pitcher plant, known from a very limited area in Alabama and adjacent Georgia.

A few other species to be highlighted in the Red Data Books are the Magazine Mountain pipewort, a delicate semi-aquatic plant that occurs exclusively in a wet depression on top of Arkansas' Magazine Mountain, the Micosukee gooseberry, a shrub found only in the vicinity of Lake Micosukee in Florida and again 200 miles away along Stevens Creek in South Carolina, and the rockhouse goldenrod, a very rare species confined to areas beneath overhanging sandstone cliffs in the Red River Gorge of Kentucky.

One new project we are about to embark on is a Red Data Book for North American Lichens.

The work of the IUCN is crucial to the continued existence of the natural resources of the world. I know that our work with North American plants will be an important contribution to the total picture.

The Occurrence of Prairie and Forest Fires in Illinois and Other Midwestern States, 1679 to 1854

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ABSTRACT

Ring fires were used by the Native Americans of Illinois and other midwestern states in the annual hunts for bison and deer. Ring or partial ring fires were used during Indian Summer, a period of mild, dry weather in October and November that is known as a singularity in the meteorological literature. The Native American tribes had a very well developed system for hunting that included a "fire chief" that directed the hunt. Unlike the Native Americans of the western states who used fire for hunting in the spring and fall, the fire hunting in Illinois and other tall grass prairie areas was done almost exclusively in the fall. Fire was an asset to Native Americans, but it was a threat to the lifestyle of European pioneers. They began to use late spring burns, plowing, grazing, and overseeding with Kentucky bluegrass to reduce the danger of fire.

INTRODUCTION

Prior to the arrival of European man, what is now the State of Illinois was a mixture of forest, savanna, and prairie. Prairie, a plant community composed of grasses, wildflowers, and a few shrub species, occupied about 22 million acres of land, mostly in the northern two thirds of the state where a flat to gently rolling topography prevails. At the time of European Settlement, all but eight of the 102 counties of Illinois had large areas of prairie within their boundaries (McManis 1964). Forest occupied about 14 million acres in groves, narrow belts along streams, or in areas of rugged topography such as the Shawnee Hills Region in the Southern part of the state. Illinois was the first state that the pioneers encountered with large expanses of prairie, causing Illinois to be known as the "Prairie State", a nickname which persists to this day.

Floristically, Illinois is a part of the oak-hickory forest region (Braun 1950), a mosaic of prairie, savanna, and forest (Küchler 1964), or the eastern part of the prairie peninsula (Transeau 1935). The eastern edge of this prairie ecosystem was characterized by the tall prairie grasses, big bluestem (*Andropogon gerardii* and Indian grass (*Sorghastrum nutans*) (Risser *et al.* 1981). At the time of settlement by the Europeans, the largest expanses of prairie were located in central Illinois in what is known today as the Grand Prairie Division (Schwegman 1973).

Based upon pollen studies in sediments of wetlands, it appears that prairie vegetation entered Illinois from the west during a prolonged hot, dry era known as the hypsithermal period approximately 8300 years ago (King 1981, Axelrod 1985). Since this time, the climate has fluctuated between one capable of supporting prairie or forest, but periodic droughts probably continued to be a feature of the climate. Tree ring research indicates that Illinois has experienced several severe droughts during the last 300 years, including the decades of the 1930's, 1890's, 1820's, and 1700's (Blasing and Duvick 1984). The tendency for drought occurs about every 20 years and may be related to the Hale solar cycle of about 22 years and the lunar-tidal cycle of 18.6 years (Blasing and Duvick 1984).

NATIVE AMERICANS

Prior to the arrival of the Europeans, Illinois was inhabited by Native American tribes, including the Peoria's, Cahokia's, Kaskaskia's, Tamaroa's, Miami's, Kickapoo's, Sauk, Fox, Winnebago, and Potawatomie (Temple 1958). Although these people raised maize and other cultivated crops (Trigger 1978), their livelihood, particularity during the winter, was also dependent upon hunting. In the fall, these tribes prepared for the annual hunt for bison. Unlike Native Americans of the western plains, these people did not have horses, a deficiency that was compensated for by the use of fire (Schoolcraft 1953).

One of the first descriptions of the use of fire in hunting by Native Americans in Illinois was written in 1679 by Louis Hennepin, a Jesuit priest. He described a bison hunt by the Miami Indians near the present site of Kankakee:

> "When they see a herd [of bison], they gather in great numbers, and set fire to the grass every where around these animals, except some passage that they leave on purpose, and where they take post with their bows and arrows. The buffalo, seeking to escape the fire, are thus compelled to pass near these Indians" (Hennepin 1880).

This method of hunting bison is also described by Charlevoix (1761) in the year 1720 on the upper Mississippi:

> "The kind of hunting most in vogue, is that of the buffalo, which is performed in this manner: The huntsmen draw up in four lines, forming a very large square, and begin by setting the grass on fire."

These narratives are some of the first articles to describe the use of a ring or partial ring of fire for bison by Native Americans in Illinois. The use of ring fires by Native Americans in hunting bison apparently was widely practiced and was also used for deer (Table 1).

The bison apparently were very afraid of fire, a characteristic that caused them to retreat from the flames. When bison were pressed together by the advancing fire, the hunters advanced upon them with their arrows. Father Rale, about 1718, said that there is no year during which the Illinois Indians fail to kill more than 2,000 buffalo (Roe 1970). Perrot (In Blair 1969) states that the Illinois Indians and their neighbors have no lack of wood for drying the meat that was cut into thin strips. Deliette (1934) also describes the drying of buffalo meat following a summer hunt in which 1,200 bison were killed by the Illinois. The success of the Illinois appears to be substantiated in the writing of LaSalle as he travelled through the upper Illinois River in the 1670's:

> "On the right hand and on the left stretched the boundless prairie, dotted with leafless groves and bordered by gray wintry forests, scorched by the fires kindled in the dried grass by Indian hunters, and strewn with the carcasses and the bleached skulls of innumerable buffalo. The plains were scored with their pathways, and the muddy edges of the river were full of their hoofprints. ... At night the horizon glowed with distant fires, and by day the savage hunters cound be descried at times rooaming on the verge of the prairie" (LaSalle In Parkman 1891).

The use of fire in hunting by the Native Americans may seem at first thought to have been an unorganized, spontaneous, and haphazard procedure. Evidence indicates, however, that the organization of the fire hunt in Illinois was very carefully planned and organized. Perrot (In Blair 1969) states that a "fire chief" chosen by the tribe at a council meeting directed the fire hunt. He organized three separate crews, and at midnight on the designated day, directed the crews out onto the prairie to surround the bison. As dawn approached, the circle would be completed and once the morning sun had dried the dew from the grass, it was set on fire and the hunt began. Severe penalities were also imposed upon anyone that might scare the bison away, including the destruction of personal belongings, weapons, and their living quarters (Perrot, In Blair 1969; Charlevoix 1761).

The Native American hunters also utilized weather patterns and included them in their fire hunting plans. James Smith (In Washburn 1977), an individual who was captured, adopted, and lived with Native Americans from 1755 until 1759, described a fire hunt for deer on a prairie between the

Sandusky and Scioto Rivers in Ohio:

> "When we came to this place we met with some Ottawa hunters, and agreed with them to take what they call a ring hunt in partnership. We waited until we expected rain was nearly falling to extinguish the fire, and then we kindled a large circle in the prairie. ...The rain did not come on that night to put out the outside circle of the fire, and as the wind arose, it extended through the whole prairie which was about fifty miles in length and in some places near twenty in breadth. This put an end to our ring hunting this season, and was in other respects an injury to the hunting business."

The use of fire in hunting by the Native Americans apparently continued after the arrival of the Europeans in the early part of the nineteenth century. Numerous letters, diaries, and books written by the pioneers describe the prairies and the spectacular fires that occurred on them. Almost without exception in Illinois, these fires occurred in the fall of the year during a period of warm, mild weather that we know today as "Indian summer".

INDIAN SUMMER

Sauer (1950), in writing about grasslands throughout the world, stated that there were grasslands in areas of high rainfall and low rainfall. Locations that have a dominance of grassland at one site elsewhere have a dominance of forest under nearly identical climatic and edaphic conditions. Despite their differences, grasslands throughout the world have two characteristics in common which are: (1) a nearly level to gently rolling topography, and (2) a season of the year during which the vegetation becomes dry (Sauer 1950). These are the conditions ideally suited for the kindling and movement of fire.

In Illinois there is a season known as "Indian Summer" which occurs in late October and early November following the first killing frost (Wells 1819). At this time a mass of Pacific air dominates the weather pattern, producing days with clear skies, mild temperatures, low humidities, and westerly winds (Bryson and Lahey 1958; Huschke 1959). This season usually occurs every year and is known in the meteorological literature as a singularity (Wahl 1952, 1954). Today, most individuals are familiar with the name "Indian Summer" for this pleasant autumn time which is characterized by clear skies and mild temperatures. However, many circumstances associated with this season are much different today compared to historic times when the vast prairies of Illinois were the realms of the bison and the hunting grounds of Native Americans. Some early descriptions of the vegetation and weather during this season indicate the combustible conditions that existed:

> "It is by no means necesary that they (prairies) should be always dry; on the contrary, if they are sufficiently level to prevent the rains from running off immediataely, the grass will grow thicker and higher--but they must be sufficiently dry to burn, at least once in two or three years, during the long, dry season called Indian summer. .....commencing usually in October, and continuing a month and a half or two months, during which the vegetation is killed by the frosts, and dried by the sun" (Wells 1819).

> "Frosts have already put a stop to vegetation. The leaves have fallen, annual plants have become dry, and the fields, the swamps, the forests and the prairies are set on fire by Indians and hunters. .....We have had three weeks of Indian summer, with all that peculiar redness of the sky, mentioned above, in great perfection. The prevailing winds were west and north of west, with a dry atmosphere. The country was on fire in various places for forty miles around us" (Foot 1836).

The burning of thousands of acres of prairie had profound effects upon the atmosphere for hundreds of miles. Some of the descriptions of the smoky atmosphere indicate the conditions that existed for two to four weeks in the areas of the tall grass prairie:

> "About the middle of October or beginning of November, the Indian Summer commences, and continues from fifteen to twenty days. During this time, the weather is dull and cheerless, the atmosphere is smoky, and the sun and moon are sometimes almost totally obscured. It is generally supposed that this is caused by the burning of the withered grass and herbs on the extensive prairies of the north and west" (Mitchell 1837).

> "So long back as we have any knowledge of the country, it has been the custom of the Indians to set fire to the prairie grass in autumn, after frost set in, the fire spreading with wonderful rapidity, covering vast districts of country, and filling the atmosphere for weeks with smoke" (Caird 1859).

> "The thick and tall grass that grows in the prairies that abound through all the country, is fired; most frequently at that season of the year, called Indian Summer. The moon rises with a broad disk, and of a bloody hue, upon the smoky atmosphere. Thousands of acres of grass are burning in all directions" (Flint 1826).

> "The sky in the night time is of a fiery red, and the smoke in the day prevents the sun from being seen until 10 o'clock in the forenoon. This smoky season is what is called here Indian Summer" (Newhall 1821).

> "The season, called the Indian Summer, which commences in October, by a dark blue hazy atmosphere, is caused by millions of acres, for thousands of miles around, being in a wide-spreading, flaming, blazing, smoking fire, rising up through wood and prairie, hill and dale, to the tops of low shrubs and high trees" (Faux 1817).

Dr. Lyman Foot, a physician located at Fort Winnebago in what is now Columbia County, Wisconsin, stated: "If you ask a 'Native American' when he is going to his hunting ground, he will tell you , when our fall summer comes, or when the Great spirit sends us our fall summer, meaning that time in October and November when a period of warm, mild weather dominates the weather pattern" (Foot 1836).

The pioneers apparently were the ones that gave the mild season that occurred toward the end of October the name of Indian Summer. The Native Americans apparently continued their ancient practice of fire hunting for about 150 years following the arrival of the Europeans. These pioneers, upon seeing and experiencing these tremendous prairie fires, gave the name Indian Summer to this time of the year.

ARRIVAL OF EUROPEAN MAN

The arrival of the pioneers heralded the beginning of a prolific number of books, journals, letters, and manuscripts which described the new country. Although many of these descriptions are very general and are largely directed at enticing others to the new country, some documents describe actual fires and many of these are fires within Illinois. Descriptions of 54 prairie or woodland fires were discovered, and some give very detailed accounts of the fires, including wind direction and an estimate of the size of the area burned (Table 2).

The prairie fires were one of the most dreaded fears of the pioneers throughout the prairie regions of Illinois. The uncontrolled grassland fire destroyed crops, fences, buildings, livestock, and sometimes took the lives of the settlers (Reynolds 1887, Gerhard 1837). Because of this danger, farms and homesteads were established at the woodland edge instead of the dense grass of the open prairies. Due to the high danger of fire, pioneers "slept with one eye open" from the time of the first killing frosts in the fall until snow covered the ground (Baldwin 1877).

The presence of buildings, crops, livestock, and a growing number of settlers made the occurrence of widespread prairie fires more undesirable with each passing year. Eliminating the prairie fires became a primary goal of the pioneers, and that meant the elimination of the prairies and their tall grasses which became tinder dry in the fall. By burning the prairies late in the spring, some pioneers learned that the danger of fire could be reduced the following fall (Baldwin 1877). However,this practice did considerable damage to nesting prairie chickens (Kennicott 1855, Schorger 1944), but this was sometimes the objective of the burn because the birds were eating too much of the farmer's grain (Schorger 1944). Others found that cool season grasses such as bluegrass could be sown on a prairie following a fire. This grass would germinate, easily establish itself, and further reduce fire danger because it would never burn as readily or produce as much biomass as the native grasses (Baldwin 1877, Short 1845, Mitchell 1837).

Prairies were also burned in the spring to facilitate plowing. Mary Sackett, a young girl in Winnebago County, wrote the following description:

> "In the forenoon Papa measured off some land for Mr. Cole to break, and set fire to the grass, as it is better to be burned over" (Sackett 1842).

Plowing had long been a method of reducing fire danger around homes, crops, and other property since the arrival of the Europeans (Baldwin 1877, Gerhard 1857). Despite the efforts to reduce fires, they continued to be an annoyance and a menace to crops, livestock, and property. Some form of legal protection from these prairie fires was demanded, and anyone caught setting a fire certainly aroused the rath of the public, particularly if the fire caused damage to personal property.

In 1794, Louis Giroux was indicted in St. Clair County Court for setting fire to the commons at Prairie du Dupont (currently known as Dupo), resulting in the loss of fence rails in Cahokia and Prairie du Pont (St. Clair County Circuit Court Case 355, Illinois State Archives). In 1807, while Illinois was still a territory, a petition was prepared by the citizens of Gallatin County, Illinois complaining about the lack of legal protection against prairie fires and the damage they were doing to their buildings and livestock (Anonymous 1815). Due to the increased demand for legal protection, the territorial legislature passed a law in 1815, making it a misdemeanor to burn prairies except those on an individuals own property. Individuals found guilty of this misdemeanor were subject of a fine of not less than $5 or more than 100 dollars while a servant had to pay the fine and be whipped not more than 39 stipes (Philbrick 1930). This act also defined the season during which prairies could be legally burned, and may have contributed to the emphasis placed on spring burning by the European pioneers:

> "Nothing in this act shall be so construed as to prevent any person or persons from setting on fire prairies or cleared land (on their personal property) between the first of December and the 10th day of March" (Philbrick 1930).

The law in effect in 1845 made the negligent, careless, intentional, or wilful burning of prairies or woods illegal except for the necessary preservation of personal property after giving two days notice to neighbors. Such firing of the woods or prairies could be done from the first day of March until the last day of November (Brayman 1845). However, this act was rarely enforced, and few convictions were ever made. One notable exception is Peter Johnson of Kane County, whose son, John Johnson, set fire to the prairie on Peter Johnson's property on November 15, 1845 (Johnson versus Barber 1846, Kane County Circuit Court, April Term, Illinois State Archives). The fire passed onto the land of his neighbor, Newman Barber, burning up his crops (500 bushels of wheat, 500 bushels of oats, and 15 tons of hay), and 6,500 rails for fences, having a presumed value of $1,480. Johnson was indicted and the case went to the Illinois Supreme Court which affirmed the ruling of the circuit court and awarded the plaintiff, Newman Barber, $489 for his losses due to the fire (Johnson versus Barber 1846, 1886). For some unknown reason (perhaps to pay the judgement), 385 acres of land belonging to Peter Johnson was seized and sold at public auction by the Kane County Sheriff, B. C. Yates (Johnson versus Barber 1846). Ironically, the land was purchased by none other than the plantiff, Newman Barber

(Johnson versus Barber 1846).

DISCUSSION

A total of 12 sources of fires attributed to Native Americans were located in the literature (Table 1). Information on an additional 54 fires was located in the literature during the period of European settlement from 1818 to 1860 (Table 2). The source of the ignition for most of these fires in Table 2 is not known, but it is assumed that most were deliberately set or were started accidentally by Europeans or the Native Americans that remained in Illinois until the 1830's. However, three fires in Livingston County almost certainly were caused by lightning (Woods 1861). The paucity of lightning caused fires is at least partially explained by the difficulty in observing lightning strikes on the prairies, and the sparse populations of the time, especially the Grand Prairie region of Illinois which remained unsettled until the advent of the railroads in the 1860's.

Moore (1972) found that the Native Americans on the prairies of the great plains utilized fire during the spring and the fall months in the Central and Northeast regions of his study area. The data that were collected during the present study indicate that the Native American tribes of Illinois used ring fires in their annual bison or deer hunts which were performed by these tribes to ensure a food supply for the winter months (Table 1). The tall grass prairies of Illinois and adjacent states were burned in the fall during that time of the year that we call "Indian Summer".

These fires were widespread and burned over considerable acreages. During dry years, these fires did extensive damage to trees, and appear to have entirely eliminated areas of forest in some localities (Reynolds 1887, Caton 1869). The sound of falling trees during a woodland fire in the vicinity of Princeton, Indiana in 1819 was described by Faux (1823) as like "the discharge of an ordance". During wet falls, the fires were not nearly as much of a threat (Woods 1822, Blane 1825).

The fires had long been an asset used in deer and bison hunting by the Native Americans, but widespread fires were a liability to the Europeans and a source of much apprehension and loss. They began a program of fire protection and eradication by using a combination of plowing, grazing, spring burning, or the overseeding of bluegrass or other cool season grass on the prairie sod following a burn in efforts to eliminate the dense prairie grasses (Baldwin 1877, Short 1845, Beckwith 1880). Eliminating the fires was a primary objective and that meant the elimination of the prairie. During early pioneer times the desire to eliminate fires appears to be as much a reason for destroying prairie as was the desire for farmland. The sentiment of most of the pioneers was expressed by George Ogden when he stated that "these awful conflagrations take place in autumn" (Ogden 1966).

One of the tools used to prevent large dangerous fires, spring burning, appears to be an introduction of European man. Not one record or reference to spring burning was found during the early settlement and exploration of the Illinois Territory (Table 1), but observations of spring fires were located in literature pertaining to the settlement of Illinois from 1816 to 1866 (Table 2). This practice apparently was used extensively during the settlement of Illinois (Baldwin 1877, Short 1845, Gerhard 1857). In Kentucky, following the removal of the Native Americans, F. A. Michaux reported that the inhabitants set fire to the grass of the barrens during March or April (Thwaites 1904). Many of the pioneers that moved to Illinois were from Kentucky, and they may have continued this practice of spring burning on the prairies of Illinois.

Following the cessation of the prairie fires, forest began to invade the prairies at a rapid rate. As early as 1819, Bourne (1820) stated:

> "When the white people settle on the barrens or near them, the Indians recede, fires are seldom seen, and a young growth of trees, healthy and vigorous soon springs up, far superior to the stinted growth which the frequent fires have scorched."

Some of these trees probably were "grubs" in the prairie that managed to survive the repeated fires as sprouts, but never could reach tree size. The cessation of prairie fires approximately 150 years ago appears to coincide with the beginning of the successional changes that are continuing in midwestern oak-hickory forests (Ebinger and McClain 1991, Cottam 1949, Kline and Cottam 1979).

Transeau (1935) stated that the environmental extremes such as a very severe drought were the factors that had the greatest influence upon modifying the plant communities of an area. During years of severe drought, the prairie fires were much more widespread than those during wetter falls (Woods 1822). It thus seems likely that severe droughts produced conditions for severe fires and these two forces, acting together greatly modified and shaped the plant communities of Illinois.

As natural area managers, much of the prescribed burning that we conduct is done in the spring instead of during Indian summer as in historic times. Could it be, due to differences in weather, that we are not achieving the best results from prescribed burning because we are not utilizing Indian summer, the season that was historically the season of fire on the prairies and in the woods of Illinois?

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Table 1. Ring fires and fire hunting by Native Americans in Illinois and other Midwestern states, 1673-1831.

DATE	LOCATION	TRIBE	PURPOSE	SIZE (ha)	REFERENCE
November 9, 1836	Ft. Winnebago,	Unknown	-	1,000's	Foot 1836
Fall 1679	Kankakee, IL	Miami	Bison hunting	-	Hennepin 1679
Fall 1831	Winnebago Co., IL	Potawatomie	Deer "	-	Letts In Angle
Fall 1819	General	Unknown	-	-	Ernst 1903
Fall 1820	General	Unknown	-	-	Williams 1953
Fall 1812	General	Unknown	Deer hunting	-	Stoddard 1812
Fall 1766	Illinois	Unknown	Bison "	-	Carver 1792
Fall 1720	Upper Mississippi	Illinois	Bison "	-	Charlevoix 1761
Fall 1683	Illinois	Miami	Bison "	-	Shea
Fall 1720	Illinois	Illinois	Bison "	-	Perrot,In Blair 1967
October 1763	Ohio	Ottawa	Deer "	1,000's	Smith, In Washburn 1977
1820's	Mississippi Valley	Unknown	Deer "	-	Reynolds 1887
1820's	Central Illinois	Unknown	Bison "	-	Flint 1826
Fall 1673	Upper IL River	Illinois	Bison "	-	LaSalle, In Parkman 1891

Table 2. Prairie and woodland fires in Illinois and other Midwestern states, 1816-1866.

DATE	LOCATION	WIND	FIRES	REFERENCE	WEATHER
Fall 1816	Bond Co., IL	-	1	Perrin 1882	-
Fall 1816	Bond Co., IL	-	1	Perrin 1882	-
Fall 1825	Bond Co., IL	-	1	Oliver 1843	-
Nov. 3, 1821	Bond Co., IL	-	2	Newhall 1836	-
Oct. 15, 1835	Bureau Co., IL	W	6	Brunson 1835	Dry
Fall 1822	Clinton Co., IL	-	2	Blane 1824	Dry
Oct. 21, 1843	Coles Co., IL	-	1	Hendrick and Hendrick 1981	-
Oct. 7, 1850	Cook Co., IL	-	1	Cunyhame	-
Oct. 30, 1818	Edwards Co. IL	S	6	Fordham 1906	-
Oct. 6, 1819	Edwards Co., IL	W	2	Faux 1823	-
Fall 1819	Edwards Co., IL	-	1	Flower 1822	Dry
Fall 1822	Gallatin Co., IL	-	1	Tillson 1919	-
Oct. 30, 1819	Gallatin Co., IL	-	3	Wood 1822	Dry
Fall 1860	Livingston Co., IL	W	3	Woods 1867	-
Fall 1836	Logan Co., IL	-	1	Stringer 1911	-
Fall 1836	Logan Co., IL	-	1	Stringer 1911	-
Fall 1821	Madison Co. IL	-	1	Ogden 1823	-
Fall	Madison Co., IL	-	1	Rambler in the	-
Fall 1854	Marshall Co., IL	W?	1	Elsworth 1880	Dry
	Mason Co., IL	S	1	Onstot 1902	-
Oct. 21, 1853	Mercer Co., IL	-	3	Marsh 1853	-
Fall 1866	Pochontas Co, IA	S	1	Flickenger 1904	Dry
Fall 1833	Putnam Co., IL	-	2	Hoffman 1835	-
Fall 1819	Sangamon Co.,IL	W	1	Selby 1912	Dry
Fall 1829	Schyler Co., IL	-	1	Larkin 1830	-
Fall 1825	St. Louis, MO	-	1	Flint 1826	-
Nov. 1836	Stark Co.,IL	S	-	Matson 1872	-
	Stephenson Co., IL	-	1	Bateman and Selby 1914	-
Oct. 1836	Tazewell Co., IL	W?	3	Farnham 1846	-
Fall 1849	Wisconsin	-	1	Gerhard 1857	-
Fall 1832	Lee Co., IL	-	1	Kennedy 1893	-
Fall 1852	Woodford Co., IL	-	1	Wilson 1857	-
Fall 1830's	St. Louis, MO	-	1	Catlin (No date)	-
Aug. 27, 1833	Dekalb Co., IL	-	1	Benton 1957	-
Feb. 12, 1817	Edwards Co., IL	-	1	Monaghan 1946	-
Dec. 16, 1818	Edwards Co.,IL	-	1	Monaghan 1946	-

Overstory Vegetation along an Upland to Swamp Gradient in Southern Illinois

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INTRODUCTION

Bottomland forests comprise one-fifth of all commercial forest land in Illinois. From data presented by Telford (1926) and the U.S.D.A. (1978), I estimate that the bottomland forests of Illinois have been reduced in area by 98% as a result of clearing and draining. In Missouri, 96% of the original 1,000,000 ha of bottomland forest have been lost (Korte and Fredrickson 1977). In southern Illinois, only a few relatively undisturbed bottomland hardwood forests remain. These undisturbed forests provide an excellent opportunity to study the compositional and structural characteristics of this vegetation type near the northern limits of the Southern Floodplain Forest. It is in these relatively undisturbed stands that relationships between species and soil-site variables most closely represent the potential vegetation of this forest type. Also, these stands offer an opportunity to study tree growth in relation to flooding and climate.

STUDY AREAS

Little Black Slough and Goose Pond (MacKenzie 1980) are included in a 1,102 ha tract along the Cache River floodplain and backwater lowlands in Johnson County, Illinois. On the northern edge of the tract is the 35 ha Goose Pond study area which contains a pure stand of virgin *Taxodium distichum* along with the adjacent floodplain and uplands. Along the southern edge of Little Black Slough is the 100 ha Boulder Slope Woods and its associated floodplain and swamp. Boulder Slope Woods is the least disturbed upland portion of the Little Black Slough tract and Goose Pond contains the least disturbed swamp stand. The floodplains of both the Boulder Slope area and Goose Pond have experienced some selective removal of canopy trees. Little Black Slough and Goose Pond are located in the Shawnee Hills Section of the Interior Low Plateaus Province in southern Illinois. However, the uplands of this area contact the Coastal Plain Province along the floodplain.

The Horseshoe Lake study site is located about 19 km northwest of the confluence of the Ohio and Mississippi Rivers. The old-growth forest occupies about 35 ha on a floodplain island about 5 km east of the Mississippi River channel (Robertson *et al.* 1978). There is little evidence of logging in the Horseshoe Lake stand but some large trees are falling and creating gaps in the canopy. Horseshoe Lake is located entirely in the Coastal Plain Province (Schwegman 1973).

Pine Hills is located on a peninsula adjacent to an abandoned channel of the Big Muddy River on the Mississippi River alluvial plain in Union, County Illinois about 48 km north of Horseshoe Lake. Pine Hills is a second growth forest following extensive cutting in 1944, although some large old trees remain in the canopy. This site was used only for tree growth measurements.

The Stanley Creek area of Mingo Wildlife Refuge is located 65 km west of the Mississippi River in Stoddard and Wayne counties, Missouri (Elliott 1981). Much of Mingo was logged and drained in the late 1800's (Korte and Fredrickson 1977, Fredrickson 1979, Elliott 1981). Clearing was incomplete and some old-growth forest remained. A 32 ha tract near Stanley Creek was selected for study because of the lack of man-caused disturbance.

Soils of the study areas range from very rocky on the slopes to very clayey in the lowlands. For a more detailed description of the soils of the study areas, see Fehrenbacher & Walker (1964), Parks *et al.* (1968), Fredrickson (1979), and Gurley (1979). Maximum relief of the study areas is about 60 m. Slope angles are nearly level on the alluvial flats to

70% on the uplands. At Horseshoe Lake and Pine Hills, the gently undulating relief varies less than 3 m. The region has mild winters, warm summers and abundant rainfall. Average annual precipitation of the study sites ranges from 1050-1150 mm (Page 1949, Fehrenbacher and Walker 1965, Fredrickson 1979).

METHODS

A total of 181, 98, 129 and 72 plots were sampled in Little Black Slough, Goose Pond, the old-growth stand on Horseshoe Lake Island, and Mingo Wildlife Refuge, respectively. In all four study areas, transects were established about 100-150 m apart and perpendicular to the predominant topographic gradient (high to low elevation). Along each transect, 0.04 ha rectangular plots (66.6 x 6.0 m) were placed 15-30 m apart. Distance between plots depended on topography. When topographic change was rapid (*i.e.* steep slopes), plots were close together and when topography was level, plots were apart. Within each plot, all trees (≥6.6 cm) were recorded by diameter breast high (dbh) or diameter above the buttress (dab). Nomenclature follows Mohlenbrock (1975). Depth to and texture of the least and most permeable soil horizons and maximum depth of flooding were measured in each plot. Flooding was either measured directly (Horseshoe Lake and Goose Pond) or determined from the high water mark on the trees. Soils were sampled using a tube sampler and texture was estimated in the field. In addition, soil samples from all plots in Goose Pond, Horseshoe Lake, and from about 10% of the Little Black Slough plots were analyzed in the laboratory for texture (Bouyoucos 1951) to verify field estimates. The vegetation at the Pine Hills site was sampled as above to obtain structural and compositional information for comparative purposes (Robertson 1992). These data were not analyzed with the vegetation data from the other four sites.

Data from the four sites were combined in separate basal area and soil-site matrices for analysis. The 15 rarest species were deleted to reduce the influence of zero values in the analysis. Vegetation data were ordinated by Detrended Correspondence Analysis (DECORANA; Hill 1979a, Hill & Gauch 1980). The ordination sequence from DECORANA was used to fit Gaussian response curves for the major species (Gauch and Chase 1974, Westman 1980). The DECORANA ordination was interpreted by multiple regression. Environmental variables were used as predictors and the ordination scores for the plots were used as the dependent variable. TWINSPAN (Two-way Indicator Species Analysis, Hill 1979b) was used to identify community types in the study areas.

Data on historical tree growth were obtained by extracting increment cores from individuals of the dominant oak species at the Pine Hills, Horseshoe Lake and Little Black Slough sites. Four hundred and seventeen cores from 8 oak species were analyzed. An attempt was made to include species common to all sites; however, certain species were found on only one or two sites. Increment cores were taken from opposite sides of the tree, checked for integrity and mounted in the field in grooved wooden trays. In the laboratory, cores were shaved with a sharp razor blade and sanded with white fine grit sandpaper to emphasize ring boundaries. Before measuring, all cores were dated and decade intervals marked on the core (Stokes and Smiley 1968). Ring widths were measured to the nearest 0.01 mm using a Henson University Model incremental measuring machine. See Robertson (1992) for more detail on dendrochronology methods.

The biological variance in the tree-ring measurements was removed by calculating standardized ring-width indices using program ARSTAN from the Laboratory of Tree-Ring Research (Holmes *et al.* 1986). Detrending of each ring-with series is essential to remove variance due to differential mean growth among trees, biological growth trend and other low-frequency variance before averaging each ring-width series into the chronology. Average monthly temperature and precipitation from Cairo, Illinois from October preceding the growth year through September of the current year were the environmental variables used in these analyses. Average monthly river stage values for the Big Muddy River (Murphysboro IL., about 28 km NE of Pine Hills) were correlated with growth indices for the Pine Hills site while discharge values from the Mississippi (Thebes, IL., about 16 km NW of Horseshoe Lake) and Cache (Forman, IL., about 5 km SE of Little Black Slough) rivers were used for the Horseshoe Lake and Little Black

Slough study areas, respectively.

RESULTS

Structural characteristics for the three study areas are shown in Table 1 to indicate variation among the areas. Tree density was lowest at Horseshoe Lake and highest at Mingo Wildlife Refuge. Basal area was highest at Goose Pond and species richness highest at Horseshoe Lake. The Pine Hills study site supported a tree density of 568.8 stems/ha and a tree basal area of 24.2 m^2/ha.

Ordination of the overstory data sets resulted in a uniform scatter of samples from upland and swamp sites on opposite ends of the first axis and floodplain sites in the middle. Gaussian curves were fit for each species on the basis of the DECORANA ordination scores to form a coenocline. The coenocline accounted for 54% of the variance with curves for individual species accounting for as much as 95% of the variance (Fig. 1). When the ordinations are related to soil-site variables, it is evident that species are distributed along a complex flooding-soil textural gradient. Multiple regression analysis of the overstory ordination indicated that 63% of the variance (R^2) in the ordination sequence could be accounted for by depth of flooding and percent clay in the most and least permeable horizons.

TWINSPAN classification of the overstory samples from all four study areas revealed eight groups which can be ordered along a topographic-moisture gradient (Table 2). Dominant species in the upper slope community are oaks and hickories while mesophytic species such as *Acer saccharum* and *Quercus rubra* dominate lower slopes and well drained ridges in the floodplain. These areas are characterized by minimal flooding and low clay and relatively high sand content. Two lower slope-shallow floodplain communities had different dominant species; one area dominated by *Quercus phellos* and *Q. palustris* and the other dominated by *Liquidambar styraciflua* and *Ulmus americana*. Flooding depth, clay content and silt content were similar for these two areas; however, sand content was lower in the shallow floodplain than in the lower slope-floodplain transition. Two floodplain types were identified, one dominated by *Quercus lyrata* and the other by *Acer rubrum*. The soil-site environment of the two floodplain types differed primarily in that clay is higher in the *Acer rubrum* type. The two swamp groups differ primarily in the shift in dominance between *Nyssa aquatica* and *Taxodium distichum* and in depth to the least permeable horizon and maximum depth of flooding (Table 2).

In the tree growth analysis, the most frequently occurring (14 of 16 species-site groups) significant correlation was the negative relationship between mean June temperature and the ring-width indices. The second most frequently occurring (11 of 16 species-site groups) relationship was the significant positive correlation with June precipitation. Generally high summer temperature were negatively correlated and growing season precipitation totals were positively correlated with growth indices. In several species-site groups, monthly precipitation and temperature of the winter months preceding the growing season, particularly December moisture, showed a significant positive correlation with tree growth (Table 3).

Correlations between river discharge and growth indices were positive for all species at the Pine Hills and Little Black Sough sites while only one species at Horseshoe Lake, *Q. alba*, had a significant correlation to June discharge of the Mississippi River. At Pine Hills and Little Black Slough, summer discharge (June-August) and spring discharge (March-May) were significant for most species-site groups. Discharge during the winter (November-February) preceding the growing season was significant in 4 of the 16 groups. Significant correlations for all species-site groups are not exceptionally strong and are often strengthened by a few extreme values in discharge rates. Response function analysis (Fritts 1976) indicated that the proportion of variance in ring-width indices accounted for by river discharge was low at all sites.

DISCUSSION

Average density of woody stems, basal area and species richness for the three study areas are characteristic for relatively undisturbed forests of this region. Basal area of the upland sites are within the range of values reported for similar sites in the Western Mesophytic and Oak-Hickory forest regions (Braun 1950, Rochow 1972, Fralish 1976, Adams and Anderson 1980). Basal area of lowland sites is similar to those reported for the Wabash and Tippecanoe rivers in Indiana (Lindsey *et al.* 1961, Schmelz and Lindsey 1965), a floodplain site in northern Florida (Brown 1981), and higher than the 28 and 24 m^2/ha of the floodplain hardwood and flatland hardwood types described in the Big Thicket of Texas (Marks and Harcombe 1981). Adams and Anderson (1980) reported the basal area of a lowland forest in central Illinois to be 45.4 m^2/ha which is slightly higher than in the floodplain types defined in this study or than the 41.4 m^2/ha encountered in the Horseshoe Lake floodplain stand (Robertson *et al.* 1978). The higher basal area in the Horseshoe Lake old-growth woods relative to the three study areas is probably due, in part, to the less disturbed condition of that stand. High basal area in the swamp is due to the large *Taxodium distichum* in Goose Pond and the high density of *Nyssa aquatica* in Little Black Slough. The swamp basal area is similar to the 62.8-90.1 m^2/ha reported for Heron Pond which is adjacent to Little Black Slough and Goose Pond on the Cache River (Anderson and White 1970), but lower than the exceptionally high 138 m^2/ha reported for one stand in the Big Thicket of southern east Texas (Marks and Harcombe 1981). Swamp forest of this region support basal areas similar to those elsewhere in the Southern Floodplain Region (*cf.* Schlesinger 1978). Lowland forests throughout this region are capable of supporting a relatively high basal area which may be maintained by nutrient subsidies from periodic flooding (Mitsch 1978).

Indirect gradient analysis of the overstory using DECORANA provided a plot sequence which was related to the environmental variables as indicated by the regression analyses. This indirect, integrative approach is useful in interpreting vegetation and soil-site relationships along complex gradients and has been used successfully by others (Robertson *et al.* 1978, Marks and Harcombe 1981, Muller 1982). The coenocline portrayed in this paper should be interpreted with some reservation as not all species occurred in all study areas.

Environmental relationships of overstory species are similar to patterns reported in other studies (Wells 1942, Bell 1974, MacKenzie 1980, Robertson *et al.* 1978, Fredrickson 1979). The studies by Hosner (1957), Hosner and Boyce (1962), Broadfoot (1969), Broadfoot and Williston (1973), Keely (1979), and Bedinger (1979) indicated the importance of flooding as it affects the growth and survival of many lowland species. Depth of flooding is the most important variable related to ordination sequence and vegetation plot classification. Generally the distributions of the more common species in relation to flooding in our study areas coincide with the scheme presented by McNight *et al.* (1981) with some exceptions. *Populus heterophylla* and *Quercus lyrata* appeared to be more tolerant of flooding in our area than indicated by McNight *et al.* (1981). However, flooding does not account for all the vegetation variation supporting the idea that the existence of strong trends in the vegetation data need not imply a single controlling environmental influence (Hill and Gauch 1980). Along, the upland-swamp gradient in the region, several environmental variables are needed to explain the coenocline. Percent clay is important throughout the gradient and may affect species distribution by controlling water holding capacity and affecting aeration (Brady 1974). Wharton *et al.* (1982) point out that the 'moisture' gradient of the floodplain is misleading as it is not the availability of water but the lack of oxygen due to saturated soils that controls species distributions. McNight *et al.* (1981) indicate that is often difficult to determine species distributions based only on the flooding regime.

The eight community (dominance) types identified by TWINSPAN are, for the most part, related to soil-site conditions in the study areas and are similar in composition to community types throughout the Western Mesophytic Forest region and lowlands of the Gulf Coastal Plain (Braun 1950). The floristic composition on the slopes is comprised of species with broad geographical distributions while many floodplain species show southern affinities (Voigt and Mohlenbrock 1964). Species with southern affinities include *Liquidambar styraciflua, Quercus pagodaefolia, Q. michauxii Q. lyrata, Q. phellos, Q. shumardii, Taxodium distichum* and *Ulmus alata* (Voigt and Mohlenbrock 1964).

The upper slope and mesic communities are similar to those found in the Ozarks (Ashby and Kelting 1963) and Shawnee Hill (Fralish 1976) of southern Illinois as well as the Western Mesophytic Forest Region (Braun 1950). In southern Illinois, the *Quercus velutina-Q. alba* community is probably climax as indicated by the reproduction of both oak species in the understory. Fralish (1976) reported the *Quercus rubra* communities of the Shawnee Hills merge into *Acer saccharum* communities on lower slopes. Such is not the case in the four study areas although large *Acer saccharum* occur in the Boulder Slope Woods of Little Black Slough and the well-drained ridges of Horseshoe Lake.

Most of the lowland types described in this study have been described in the Southern Floodplain Forest Region and correspond to the NWTC types (Larson *et al.* 1981). The *Liquidambar styraciflua, Ulmus americana, Acer rubrum* and *Quercus michauxii* type is similar to the 1) Sweetgum-bottomland Oak community described by Shelford (1954), the 2) Rufacer-Liquidambar-Quercus (Red Maple-Redgum-Oak) shallow transitional freshwater swamp described by Penfound (1952) and the 3) Floodplain Hardwood Forest in southeast Texas (Marks and Harcombe 1981). Characteristics species include: *Liquidambar styraciflua, Ulmus americana, Quercus phellos, Gleditsia triacanthos, Acer rubrum* and *Diospyros virginiana*. The transitional type defined in the Horseshoe Lake old-growth stand (Robertson *et al.* 1978) is a mixture of the mesic, mixed hardwood type described above and this shallow floodplain type. The environment of this type often includes saturated soil with periodic flooding (Penfound 1952).

The *Quercus phellos-Q. palustris* type corresponds somewhat to the Flatland Hardwood type described by Marks and Harcombe (1981) and may be successional to the *Liquidambar styraciflua* and *Ulmus americana* type. Both *Quercus phellos* and *Q. palustris* are light intolerant and considered to be subclimax (Fowells 1965). Also, site conditions may be important in differentiating these two floodplain types in this region. Weaver (in Eyre 1980) indicates that where drainage is improved, *Liquidambar styraciflua* persists in later successional stages and *Quercus palustris* disappears relatively early in the successional scheme. Where *Liquidambar styraciflua* is dominant in the study areas, sand content is relatively high, possibly facilitating drainage. Generally, species in this type are tolerant of periodic flooding and poor drainage (Putnam and Bull 1932). However, McNight *et al.* (1981) indicated both *Quercus phellos* and *Q. palustris* are less tolerant of flooding than *Liquidambar styraciflua*. This characteristic may relate to the difference in our two shallow floodplain types as the flooding depth was less in the *Quercus phellos-Q. palustris* type.

The *Quercus lyrata-Acer rubrum* deep floodplain type may be dominated by various species including *Quercus lyrata, Ulmus americana, Fraxinus pennsylvanica,* and *Acer rubrum* and is common in backwater lowlands. According to Wharton *et al.* (1982), this type occurs on the most poor drained flood plains where the hydroperiod extends well into the growing season and where soils are clayey (Putnam and Bull 1932). Vegetation, flooding regime and soils of the study area are similar to the NWTC Zone III classification for the southeastern United States (Larson *et al.* 1981). The *Acer rubrum-Nyssa aquatica* type described in this study is not well described elsewhere. Since the environment is not greatly different between these two types, the *Acer rubrum-Nyssa aquatica* type may be transitional between the deep floodplain and the swamp, or it may be successional to a *Quercus lyrata* dominated type. *Acer rubrum* may be associated with at least 51 forest types and is considered to be seral (Fowells 1965).

The swamp types defined in this study represent variants of the *Taxodium distichum-Nyssa aquatica* deep, fresh-water swamp described by Penfound (1952) which is typical for the southeastern Evergreen Forest Region (Braun 1950). The *Nyssa aquatica-Taxodium distichum* type described in this study may be a variant of the above resulting from the selective removal of *Taxodium distichum* (Putnam *et al.* 1960). Also, *Nyssa aquatica* may replace *Taxodium distichum* on some sites because of the erratic reproduction, slower growth and minimal sprouting ability of the latter species (Wharton *et al.* 1982). Because of the low species diversity and uniform conditions in which this type is found, it appears to be the least variable, throughout its range, of lowland forest types in the Eastern Deciduous Forest Region. Throughout the region as well as in this study area this forest type (NWTC Zone II) occurs in depressions where soil is often permanently saturated or submerged (Putnam and Bull 1932, Penfound 1952, Larson *et al.* 1981)

Results of the correlation analysis of the climatic variables on tree growth were consistent with other studies on eastern deciduous forest species and indicate that lowland tree species respond similarly to their upland counterparts. Precipitation and temperature of spring and early summer months significantly influence growth of *Quercus macrocarpa* in Nebraska (Lawson *et al.* 1980), northern hardwoods in New Hampshire (Kim and Siccama 1987), *Quercus alba* in Indiana (Fritts 1982) and *Carya glabra* in Maryland (Hill 1982). Fritts (1962) found that high summer temperatures depress ring widths and that high early spring temperatures enhance tree growth. Several studies have emphasized the important effect of precipitation on tree growth (Shulman and Bryson 1965, Duvick and Blasing 1981, 1983, Holdaway 1987). December precipitation of the previous year was positively correlated with growth in 11 of 16 species-site groups. Kim and Siccama (1987) showed that high winter precipitation enhances tree growth in the northeastern United States. High precipitation in the winter contributes to soil moisture which will support growth resumption in the spring (Broadfoot 1967, Broadfoot and Williston 1973, Gosselink *et al.* 1981).

The significant relationships between June temperature and precipitation and growth of oaks in this area occur when the climate changes from "spring" to "summer" and is about the time when the trees are shifting from spring wood to summer wood production (Fritts 1966). If June is wet and cool, growth is prolonged and if June is hot and dry, ring widths are narrow. The fact that *Quercus lyrata*, one of the most flood tolerant of the oaks studied (Fowells 1965), was significantly related only to temperature suggests that the lower floodplain sites have sufficient moisture for tree growth during the dry years.

The positive growth response to increased river discharge for most of the species-site groups was apparently related to higher precipitation which resulted in the increased discharge. On sites where the relationship was significant, high discharge or flooding was not of sufficient duration to depress tree growth but did reflect an increase in moisture available for tree growth. Stockton (1975) reported that wide rings are associated with increased discharge rates in the western United States. Apparently, duration of flooding on these three sites has been insufficient to inhibit tree growth. Bell and Johnson (1974) found that flooding duration over 30 days was needed to affect tree survival. High discharge during two flood years, 1943 and 1973, lasted about two weeks during April and May, and tree-ring indices show no strong decline in growth. One of the largest floods on record for the Mississippi River occurred in the spring of 1973 and appeared to have little effect on growth of trees at Horseshoe Lake or in Mississippi (Kennedy and Krinard 1976). In fact, growth index of *Q. alba* was relatively high in 1973.

At Horseshoe Lake, the lack of significant correlations with river discharge may relate to the flooding regime of this site compared to Pine Hills and Little Black Slough. The discharge of the Mississippi River is affected by precipitation elsewhere in its large watershed and is less strongly related to local precipitation. Also, the Mississippi River stages are controlled more by snow melt in the upper watershed than by local precipitation. In contrast, the Cache and Big Muddy Rivers are less regulated and have smaller watersheds which respond more to local precipitation. Undoubtedly, levee construction and river flow regulation have affected discharge regimes and floodplain forests. Our understanding of the natural relationships between flooding and growth in floodplain forests is limited by lack of long-term, pre-levee discharge for these river systems.

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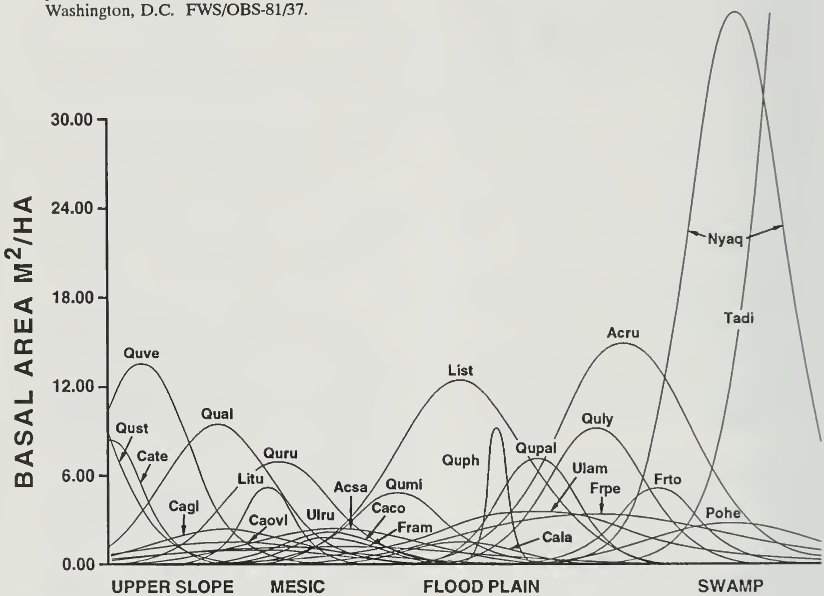

DFL	0.0	0.0	6.9	28.2	52.7	79.2	95.5	98.6	101.4	128.2
CLP	44.0	24.6	29.2	34.4	38.4	41.7	46.2	56.4	56.1	66.9
SILP	30.0	54.4	44.9	37.9	35.3	40.7	36.8	30.3	29.8	17.1
SALP	26.0	21.0	26.2	28.4	27.9	22.6	22.6	16.8	20.5	22.5
CMP	18.9	18.4	17.4	17.0	27.4	38.6	40.7	53.8	54.3	64.9
SIMP	36.6	45.3	49.9	48.9	38.4	39.0	33.8	31.3	29.2	17.3

Figure 1. Coenocline of important overstory species along an upland to swamp gradient in the southern Illinois area. Data are from Horseshoe Lake, Little Black Slough, and Goose Pond in Illinois, and Mingo Wildlife Refuge in Missouri. See Table 2 for abbreviations of environmental factors.

Table 1. Structural characteristics of the vegetation of Little Black Slough, Goose Pond, Mingo Wildlife Refuge and Horseshoe Lake, Illinois.

Attribute	Little Black Slough		Goose Pond		Horseshoe Lake		Mingo WLR	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Tree density stems/ha	486	100-2625	475	225-850	416	50-1675	622	225-2025
Basal area m^2/ha	33.8	7.6-105.4	40.3	7.9-92.4	36.8	6.8-62.0	30.2	12 -57
Tree richness	7	1-13	6.5	1-12	7.4	1-12	8	3-13
N	181		98		129		72	
Study area size ha	100		35		35		32	

Table 2. Overstory basal area (m^2/ha) of major species and means of soil-site variables from TWINSPAN classification of plots from Little Black Slough, Goose Pond, Horseshoe Lake, Illinois and Mingo Wildlife Refuge, Missouri.[a] *Denotes species upon which dominance type is named.

SPECIES	Upper slope	Lower slope	Lower slope/flood-plain	Shallow flood-plain	Floodplain	Deep flood-plain	Swamp	Deep Swamp
Acer negundo		0.07	0.80		0.19	0.33		
A. rubrum			2.34*	0.40	9.64*	13.46*	4.94	0.20
A. saccharum	0.40	2.00*	0.77		0.05			
Carya glabra/ovalis	3.66	2.05	0.08		0.18			
C. laciniosa		0.15	1.04	0.01	0.06	0.05		
Fraxinus americana	1.06	1.00	0.75	0.78	0.03	0.25		
F. pennsylvanica	0.10	0.77	1.80	0.18	1.61	4.29*	2.77	0.04
F. tomentosa			0.15		0.65	3.31*	2.38	0.03
Liquidambar styraciflua	0.18	1.74	11.08*	3.32*	4.28*	0.11	0.14	
Liriodendron tulipifera	0.11	2.20*	0.02					
Nyssa aquatica			0.03		0.24	0.74	24.27*	28.30*
Platanus occidentalis		0.04	1.51	0.02	0.32			0.12
Populus heterophylla			0.05		0.78	0.37	5.15	1.11
Quercus alba	6.24*	3.21*	0.10					
Q. lyrata			1.00	0.94	9.80*	2.15	0.04	0.29
Q. michauxii		1.15	2.00*	1.01	0.11	0.10		
Q. muhlenbergii	0.11	0.94	0.61		0.03			
Q. pagodaefolia	0.10	0.61	1.00		0.01	0.25		
Q. palustris			1.61	6.70*	5.41*	0.52	0.19	0.14

Q. phellos			0.08	12.77*	0.27			
Q. rubra	2.39	4.80*	0.29					
Q. velutina	8.62*	0.09						
Sassafras albidum	0.13	0.73	0.13		0.15			
Taxodium distichum			0.15		2.24	0.55	10.13*	39.28*
Ulmus americana	0.78	0.31	2.69*	1.59	2.77	2.33	0.10	0.14
U. rubra		1.23	0.10	0.99				
Average basal area m^2/ha	29.0	29.3	34.5	27.9	39.7	40.0	50.1	70.6
Soil-site variables[b]								
Clay most permeable	16.5	17.4	34.0	37.2	39.6	52.4	60.5	63.4
Silt most permeable	43.7	50.1	35.9	44.1	36.7	30.5	23.4	20.6
Clay least permeable	23.6	31.4	41.2	38.7	46.0	54.0	61.8	65.6
Silt least permeable	55.6	42.1	37.4	44.2	38.8	29.9	24.2	18.4
Depth least permeable	11.7	28.3	26.5	30.1	21.1	18.9	28.9	8.4
Depth of flooding	0.0	12.4	60.8	50.3	92.4	99.5	100.0	124.0
N	20	167	143	27	45	43	14	30

[a]Minor species include *Aesculus discolor, Asimina triloba, Betula nigra, Carya cordiformis, C ovata, C texana, C tomentosa, Cercis canadensis, Celtis laevigata, C. occidentalis, Ilex decidua, Juglans nigra, Morus rubra, Ostrya virginiana, Prunus virginiana, Quercus shumardii, Q. stellata, Salix nigra, Ulmus alata* and *Vitis spp.* [b]Textural variables expressed in percent; depth variables in cm; most and least permeable refer to the respective soil horizons.

Table 3. — Significant ($P \leq 0.05$) correlation coefficients from Response Function Analysis of Residual Chronology of Oaks growing on three bottomland sites in southern Illinois in relation to monthly temperature and precipitation at Cairo, Illinois. T = average temperature, P = average precipitation. Underscore indicates coefficient is negative. Priors is number (up to 3) of significant prior years growth. Analysis includes years from 1890 to 1985.

Species/ site groups	Prior growth variance	No. of priors	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Climatic variance
Pine Hills															
Quercus alba	0.8	0		T	P					P	$\underline{T}$P				48.3
Q. macrocarpa	3.00	0			P					P	$\underline{T}$P				39.7
Q. michauxii	11.9	3			$\underline{T}$P					P	$\underline{T}$P				37.4
Q. pagodaefolia	0.6	0		T	P					$\underline{T}$P	$\underline{T}$P	$\underline{T}$			54.8
Q. shumardii	0.0	0			P					$\underline{T}$P	$\underline{T}$P	$\underline{T}$			51.2
Horseshoe Lake															
Q. alba	3.9	0								$\underline{T}$P	$\underline{T}$P			$\underline{P}$	40.1
Q. michauxii	2.6	0			P					$\underline{T}$	$\underline{T}$P				26.3

Q. pagodaefolia	3.8	0								T	TP	T	T		31.9
Q. rubra	6.0	1									T				25.4
Q. lyrata	3.2	0									T				16.2
Little Black Slough															
Q. alba	1.9	0			P					P	TP	T			48.1
Q. michauxii	0.0	0									TP				46.4
Q. pagodaefolia	2.3	1	T		P						TP				41.6
Q. palustris	62.3	3	T		P										12.3
Q. rubra	2.1	0		P								T			32.38
Q. lyrata	0.39	0									T				28.5

A Sampling of Arthropod Diversity From a Central Illinois Woodland

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ABSTRACT

Trelease Woods, a remnant of a much larger forested tract in Champaign County, was sampled six times over a period of several years by walking a diagonal transect across the 60-acre woods and photographically recording any arthropods encountered. Samples were taken during spring, summer, and fall. A summary of the major taxa of arthropods found is included.

INTRODUCTION

Trelease Woods, a 60-acre remnant of the "Big Grove", once occupied 10 square-miles in a bend of the Salt Fork River near Urbana, Illinois. Such forested areas were typically isolated from the main bodies of timber that occurred chiefly along watercourses and were known as "prairie groves." They were believed to have been cut off from larger forested areas by the repeated action of prairie fires and were usually protected by streams, sloughs, or rough morainal lands.

Trelease Woods has been maintained as a natural area for research and educational purposes by the University of Illinois since its acquisition in 1917. It is classified as mixed-mesophytic in composition, with sugar maple (*Acer saccharum* Marsh.) being dominant, followed by hackberry (*Celtis occidentalis*) L., white ash (*Fraxinus americana* L., slippery elm (*Ulmus rubra* Muhl.), basswood (*Tilia americana* L.), red oak (*Quercus rubra* L.), and Ohio buckeye (*Aesculus glabra* Willd.) in order of importance (Boggess 1964). The topography is gently rolling; the maximum difference in elevation is about 4 m. Numerous low areas are found where water stands during wet periods. These stay moist even during the dry months.

This study represents a superficial look at some of the common arthropods found while walking six transects on a diagonal path (Figure 1) through the woods during spring, summer, and fall. Any species of arthropod observed was photographed. The duration of each walk was approximately two hours and occurred over a period of six years, 1986-1992.

RESULTS

Three classes, 13 orders, and 64 families of arthropods were found and photographed during the six walks (Table 1). The above included: 2 orders of diplopods, 2 orders of arachnids, and 9 orders of insects. Identification to the family level revealed 5 familes of spiders (Order Araneida), 1 family of daddy longlegs (Family Phalangiidae), and 59 families of insects. The milipedes were not identified to family.

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Boggess, W.R. 1964. Trelease Woods, Champaign County, Illinois: Woody vegetation and stand composition. Illinois State Academy of Sciences Transactions 57:261-271.

Table 1. Arthropod taxa found in Trelease Woods during study.

- Class Diplopoda
  - Order Polydesmida
  - Order Spirobolida
- Class Arachnida
  - Order Araneida
    - Family Thomisidae
    - Family Salticidae
    - Family Tetragnathidae
    - Family Pisauridae
    - Family Araneidae
  - Order Phalangida
    - Family Phalangidae
- Class Insecta
  - Order Odonata
    - Family Coenagrionidae
    - Family Lestidae
    - Family Libellulidae
    - Family Gomphidae
    - Family Aeschnidae
  - Order Orthoptera
    - Family Tettigoniidae
    - Family Tetrigidae
    - Family Acrididae
  - Order Phasmida
    - Family Phasmatidae
  - Order Homoptera
    - Family Cicadidae
    - Family Flatidae
    - Family Membracidae
    - Family Aphididae
  - Order Hemiptera
    - Family Gerridae
    - Family Phymatidae
    - Family Pentatomidae
    - Family Coreidae
    - Family Miridae
    - Family Lygaeidae
    - Family Reduviidae
  - Order Lepidoptera
    - Family Papilionidae
    - Family Nymphalidae
    - Family Lycaenidae
    - Family Hesperiidae
    - Family Arctiidae
    - Family Saturniidae
    - Family Pterophoridae
    - Family Geometridae
    - Family Lasiocampidae
    - Family Noctuidae
    - Family Sphingidae
    - Family Lymantriidae
  - Order Coleoptera
    - Family Carabidae
    - Family Cincindelidae
    - Family Buprestidae
    - Family Lycidae
    - Family Meloidae
    - Family Cantharidae
    - Family Lampyridae
    - Family Scarabaeidae
    - Family Lucanidae
    - Family Cucurlionidae
    - Family Cerambycidae
    - Family Coccinellidae
  - Order Diptera
    - Family Tipulidae
    - Family Rhagionidae
    - Family Asilidae
    - Family Bombyliidae
    - Family Anthomyiidae
    - Family Syrphidae
  - Order Hymenoptera
    - Family Pelecinidae
    - Family Braconidae
    - Family Sphecidae
    - Family Apidae
    - Family Halictidae
    - Family Megachilidae
    - Family Andrenidae
    - Family Formicidae

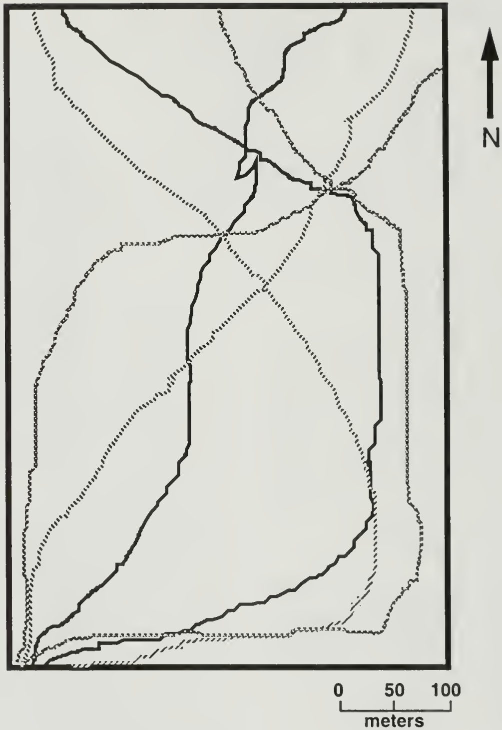

Figure 1. Path of transects through Trelease Woods.

Forest Birds in Illinois: Changes in Abundances and Breeding Ecology

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ABSTRACT

Forest habitat over much of Illinois is a series of loosely connected or isolated woodlots. Fragmentation adversely affects the viability and persistence of many songbird populations, especially neotropical migrants (*e.g.*, warbler and vireos). Here, we discuss two aspects of fragmentation and Illinois' songbirds: long-term trends in the breeding abundances in east central Illinois and reproductive success in central and southern Illinois. Bird populations and communities have clearly changed during the 20th century, but we found considerable variation among species in trends of abundance. As a group, neotropical migrants appear to be less common now than they were 50 years ago. Nesting success of birds breeding within woodlots is characteristically low (*e.g.*, < 40%) owing to high rates of predation. Fecundity is further reduced by brood parasitism by Brown-headed Cowbirds (*Molothrus ater*). Data on immigration from and emigration to local populations are critical for understanding the dynamics of Illinois' wildlife populations.

INTRODUCTION

Large contiguous tracts of forest habitat seldom persist in areas that are intensively farmed or urbanized. Illinois is no exception, where only 31% of the forest cover present in 1820 remains today (Iverson *et al.* 1989). Whereas the extent of deforestation varies among the state's regions, even moderately large (*i.e.*, 2000 ha) tracts of forest are primarily restricted to southern Illinois. Habitat for forest wildlife over much Illinois has therefore been reduced to a series of loosely connected or isolated woodlots, a condition referred to as fragmentation.

Fragmentation is known to affect communities and populations of forest birds. In general, abundances of forest birds vary inversely with the extent of local fragmentation. During the breeding season, few species are found within small fragments of forest habitat (*e.g.*, less than 2 ha). Species vary in their sensitivity to fragmentation and a large proportion of permanent resident species persist even in the most intensely fragmented areas of the state (Kendeigh 1982). In contrast, many species of neotropical migrants such as warblers and vireos that winter in Central and South America are among the most sensitive to fragmentation and abundances of these species have declined in certain parts of their breeding ranges (Terborgh 1989, James *et al.* 1992).

Decreased species richness in fragmented landscapes can stem from simple habitat loss or more subtle effects such as increased rates of nest predation and brood parasitism (Martin 1992, Robinson 1992). With time, these factors may promote local extinctions or reduce the viability of resident populations to the point where their persistence is maintained only by immigration from more productive regions (Temple and Cary 1988, Robinson 1992).

Here we report on certain aspects of our studies of forest birds and fragmentation in Illinois. We present results organized about two research questions: 1) what are trends in abundances and community structure of forest birds in Illinois? and 2) what rates of nest success are forest birds experiencing and how important are nest predation and brood parasitism?

METHODS

Long-term data are essential for analyses of temporal trends in populations because abundances of birds fluctuate through time even under the best of ecological conditions. A formidable challenge is to discriminate this "background variation" from unusual trends that signal a need for intensive study and conservation measures. Owing to the work of the late Dr. S. Charles Kendeigh (University of Illinois), studies of forest birds in the heavily farmed landscapes of east-central Illinois extend back to the late 1920's and, in some cases, were continued through the mid-1970's (see Kendeigh 1982). In 1992, one of us (JB) began to census birds on two of Kendeigh's former study areas: Trelease Woods and Allerton Park. Trelease Woods is a 24 ha woodlot surrounded by agricultural land and located in Champaign County. The Allerton Park study area is a 24 ha plot within a 600 ha forest located in Piatt County. Data on breeding birds are considerably more comprehensive for Trelease Woods.

We chose these areas because of the duration and "reach" of Kendeigh's data. Most data on breeding bird communities elsewhere in the state extend back only to the mid-1960's. We believe that data from the areas are representative for forest birds within intensively farmed areas, but trends in different regions may vary significantly. The information presented here includes all of Kendeigh's data and the 1992 census.

Two trends are considered in the report; numbers of species found breeding and relative abundances of neotropical migrants. For the latter trend, relative abundances (*i.e.*, the percentage or proportion of all birds detected in a given area) were used because of differences in the census methods used by us (point counts, see Hutto *et al.* 1986) and Kendeigh (spot-map, see Kendeigh 1944). The two estimates, however, should be similar because the point count method we used generates distributional maps. Efforts are currently underway to reconcile these differences and analyses will be presented elsewhere.

To estimate rates of nest success, we attempted to locate nests throughout the breeding season. The data reported here are primarily from studies around Lake Shelbyville in Moultrie and Shelby Counties and in the Jonesboro Ranger District, Shawnee National Forest. Forests in the former areas form an archipelago of woodlots that border the lake and are surrounded by agricultural land (see Robinson [1992], for a more detailed description of study sites). The woodlots were generally small, ranging up to 65 ha. Tracts in the Shawnee National Forest ranged from 1100 ha (South Ripple Hollow) to 2000 ha (Pine Hills). When possible, we determined the fates of located nests by checking them 2-3 times weekly. Daily survival rates of nests were estimated using the Mayfield method, which minimizes sampling bias (Mayfield 1975).

RESULTS and DISCUSSION

Trends in abundances. - Numbers of species breeding did not decrease appreciably within either Trelease Woods or Allerton Park. Annual fluctuations were common, but we detected no systematic decrease (Figure 1). In fact, numbers of species breeding within Trelease woods increased during the 1950's and have remained greater than those recorded during the early census years. Species richness within Trelease Woods was especially low during the early 1940's. Data are comparatively sparse for Allerton Park, but the number of species recorded in 1992 was slightly greater than that found during the previous 6 census years (Figure 1).

Effects of woodlot size were evident in comparisons of Trelease Woods and Allerton Park. Total numbers of breeding species were similar on the two areas, but neotropical migrants were consistently more diverse within Allerton Park. With the exception of edge species such as Indigo Buntings (*Passerina cyanea*), all species typical of Trelease Woods were also found in Allerton Park. Several species, however, were found only within Allerton Park, including neotropical migrants such as Blue-gray Gnatcatchers (*Polioptila caerulea*), Ovenbirds (*Seiurus aurocapillus*), and American Redstarts (*Setophaga ruticilla*). Numerous studies have found these species to be absent from small woodlots (Blake and Karr 1987, Hayden *et al.* 1985). Whereas the ecological mechanisms underlying "area sensitivity" are not completely understood, it is clear that large tracts of forest are needed to preserve regional species diversity of forest birds.

Relative Abundances of Neotropical Migrants. - We detected trends in the relative abundances of neotropical migrants within both study areas. When analyzing relative abundances, we found it necessary to factor out the effects of Brown-headed Cowbirds (*Molothorus ater*) and European Starlings (*Sturnus vulgaris*). These species have increased significantly throughout Illinois and the Midwest since the beginning of Kendeigh's studies.

From the late 1920's through the mid-1950's, relative abundances of neotropical migrants (collectively) were commonly above 50% and ranged as high as 70%. After this period, relative abundances of the migrants were never > 50% and were as low as 28% in 1973. This seeming "break point" stemmed in large part from sharp decreases (> 50%) in Indigo Buntings and Red-eyed Vireos (*Vireo olivaceus*). We also detected slight decreases in Great Crested Flycatchers (*Myiarchus crinitus*) and Eastern Wood-Pewees (*Contopus virens*). No species of migrant became more common during this period.

Relative abundances of migrants were greater within Allerton Park than in Trelease Woods. Nonetheless, we observed a similar pattern over time within both areas. Decreases in relative abundances of the migrants in Allerton were also evident in the late 1950's or early 1960's (Figure 2). Migrants accounted for over 65% of the breeding birds counted on the plot from 1949-1951, but decreased to less than 50% during the last three census years. Species undergoing comparatively sharp decreases within Allerton Park included Kentucky Warblers (*Oporornis formosus* - 43%), and American Redstarts (88%).

In sum, most species of neotropical migrants have persisted on the study areas during the census periods, but it appears that several are decreasing - even within comparatively large tracts of forests. The ecological factors underlying these decreases are unclear. Loss of habitat at wintering grounds may be influential (Terborgh 1989, Greenberg 1992), but we believe that events during the breeding season are also involved (see below).

Another factor may be structural changes in the forests. Effects of successional changes within and near the study areas on resident birds communities are discussed at length by Kendeigh (1982). One possibility (also pointed out by Kendeigh) is the demise of American Elms (*Ulmus americana*) in the 1950's. Loss of elms opened up the canopy and undoubtedly affected the availability of foraging substrates, food, and potential nest sites. For some species such as woodpeckers, the die-off enhanced populations. The coincident loss of elms and declines in relative abundances of several migrants is not generally appreciated and merits further study.

<u>Nesting Success</u>: <u>Lake Shelbyville</u>. The first indications that forest fragmentation causes problems for nesting migrants in Illinois came from a preliminary study of small (<70 ha) woodlots surrounding Lake Shelbyville in Shelby and Moultrie counties. Nesting success of most Neotropical migrants in these woodlots was almost too low to measure as a result of high levels of nest predation (>80% of all nests) and cowbird brood parasitism (76% of all nests) (Robinson 1992). Wood Thrushes (*Hylocichla mustelina*) were particularly hard hit; clutches averaged 4.6 cowbird eggs and only 1.2 host eggs per nest. On average, 10 Wood Thrush nests produce only a single fledgling, a rate of productivity far less than that necessary to compensate for adult mortality (Robinson 1992). As a result, these Shelbyville woodlots were likely to be population "sinks" (sensu Pulliam 1988) for the Wood Thrush and possibly, for most other forest-dwelling Neotropical migrants. The Shelbyville Wood Thrush population is probably maintained only by immigration from "source" populations, which may be located hundreds of kilometers away in more extensively forested areas such as the Ozarks and Hoosier National Forest in Indiana. The only two forest species that experienced moderate (30-60%) levels of nest predation and parasitism were the ground-nesting Ovenbird and Kentucky Warbler. Most ground-nesters in Illinois hide their nests extremely well and may be less affected by fragmentation than shrub-and canopy-nesting species.

Results from larger (1000-2000-ha) tracts in the Shawnee National Forest showed similar, albeit less extreme problems with nesting success of Neotropical migrants (Table 1). Cowbird parasitism and nest predation levels were high throughout the forest with no appreciable or consistent decline even 600 m from nearest edge (Figure 3). These results contrast with those from Wisconsin (Temple and Cary 1988) and Maryland (Gates and Gysel 1978) where predation and parasitism levels began to decline dramatically 200m from the nearest edge. Once again, the Wood Thrush suffered the highest levels of parasitism with at least 75% of all nests parasitized at all of the major study sites (C.L. Trine, unpubl. data). Given current estimates of adult and juvenile survival, it is unlikely that most Wood Thrush populations in the Shawnee National Forest (C.L. Trine, unpubl. data) or in northwestern Illinois (R. Jack and S.K. Robinson, unpubl. data) produce enough young to compensate for adult mortality. The recent declines of Wood Thrushes in small woodlots (Robinson 1992) and state-wide (C.L. Trine, unpubl. data) may be caused by high levels of brood parasitism and nest predation. Other species suffering from high (>70%) predation and parasitism levels include the Scarlet (*Piranga olivacea*) and Summer (*P. rubra*) tanagers, Hooded Warblers (*Wilsonia citrina*), and Red-eyed Vireo. Several other species such as the Acadian Flycatcher (*Empidonax virescens*) and Worm-eating Warbler (*Helmitheros vermivorus*) are abundant throughout the forest and suffer relatively little from predation or parasitism (Table 1).

In contrast to the apparent vulnerability of many forest species, most edge and second-growth species appear to be resistant to cowbird parasitism. American Robins (*Turdus migratorius*), Gray Catbirds (*Dumetella carolinensis*), and Northern Orioles (*Icterus galbula*) all reject cowbird eggs. Prairie Warblers (*Dendroica discolor*), Bell's Vireo (*Vireo bellii*), Indigo Buntings, and Yellow Warblers (*Dendroica petechia*) abandon some, although not all parasitized nests. Other edge species that are rarely parasitized include the Yellow-breasted Chat (*Icteria virens*), Blue-winged Warbler (*Vermivora pinus*), Red-winged Blackbird (*Agelaius phoeniceus*), White-eyed Vireo (*Vireo griseus*), and Chipping (*Spizella passerina*) and Field (*S. pusilla*) sparrows. The only heavily parasitized second-growth species we have found is the Orchard Oriole (*Icterus spurius*), which is only heavily parasitized in parts of the state (D. Enstrom and S. Robinson, unpubl. data). Problems with cowbird parasitism therefore appear to be most severe in forest-nesting species.

Unanswered Research Questions. - Major questions provoked by these results involve interspecific variation in persistence and seeming viability within fragmented landscapes. Specifically, are demographic processes different for persistent and sensitive species? We know that the productivity of many species within woodlots is consistently below replacement level. Yet, most of these species are reliably present within these woodlots. As mentioned above, immigration from more productive areas is a possibility, but we have very few data on natal dispersal. The scale of the so-called "source-sink" dynamic is virtually unknown for birds and could vary substantially for migrant versus permanent resident species. Estimating dispersal distances with telemetry is a possibility and pilot studies are being planned by personnel at the Illinois Natural History Survey. Data from these studies will be mandatory for understanding and defining populations of wildlife in agricultural and urban landscapes.

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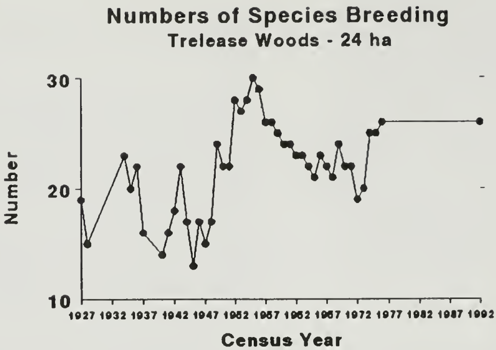
Table 1. Nest parasitism and predation rates for the Pine Hills study area, 1989-1991, Jonesboro Ranger District, Shawnee National Forest. All nests were located within 2.0 km of the Pine Hills campground.

Species	% Parasitized (n)[1]	% Depredated (n)[2]
Acadian Flycatcher	31.8 (85)	43.2 (1343)
Wood Thrush	90.0 (150)	53.5 (2048)
Kentucky Warbler	48.1 (52)	72.3 (399)
Worm-eating Warbler	40.0 (5)	--
Indigo Bunting	53.8 (13)	59.0 (150)
Northern Cardinal	40.0 (20)	82.9 (222)

[1]Number of nests located.
[2]Number of exposure days (Mayfield 1975).



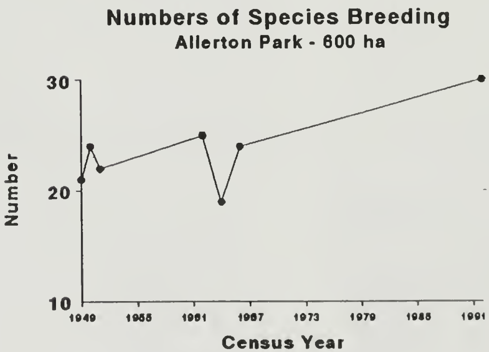


Figure 1. Numbers of songbird species found breeding within two woodlots in east central Illinois.

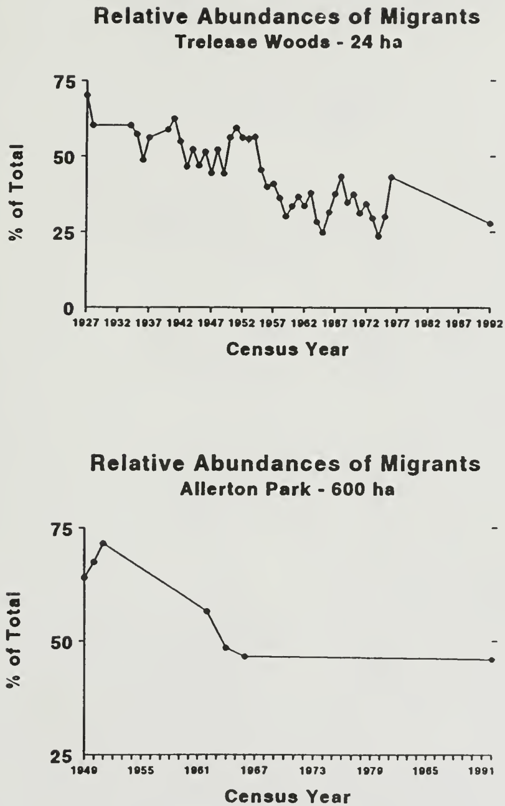


Figure 2. Relative abundances of neotropical migrants within two woodlots during the breeding season.

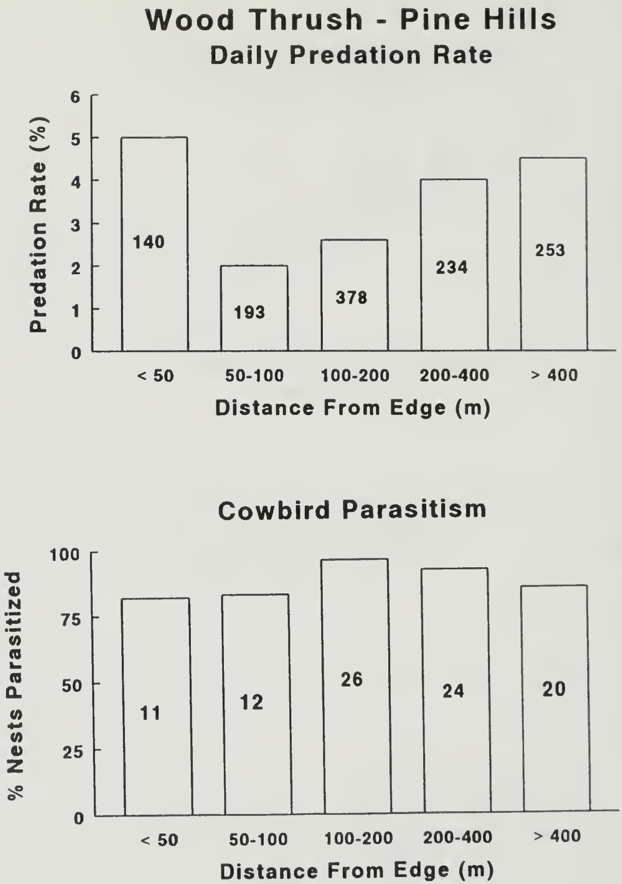


Figure 3. Cowbird parasitism and daily nest predation levels in relation to distance from edges of openings of at least 0.5 ha, 1989-1990, in the Pine Hills study site. Numbers in bars on top graph indicate exposure days (see text). Numbers in bars on bottom graph indicate number of nest within each interval.

Effects of Riparian Buffers in Reducing Agricultural Pollution in Champaign County, Illinois

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ABSTRACT

The effectiveness of riparian vegetation in reducing nutrient losses from an upland terrestrial system dominated by rowcrop agriculture was examined. Nitrate concentrations in soil water at three subsurface depths (60 cm, 120 cm, and > 120 cm) from a perennial grass buffer composed of Reed Canary Grass (*Phalaris arundinacea*) and a forested buffer dominated by mature Cottonwoods (*Populus deltoides*) were compared to a cropped treatment with no buffer. Dramatic reductions of nitrate-N occurred in both the forested buffer and grass buffer. The 18 m wide riparian buffer reduced nitrate-N 85-95%. The 67 m wide grass buffer reduced nitrate-N 69-85%. Riparian vegetated buffer strips may be used as effective tools in reducing nutrient transport from agroecosystem uplands to adjacent surface waters. Riparian buffer strips may be effective when used at the watershed scale to improve surface water quality.

INTRODUCTION

Agricultural lands are highly modified ecosystems (Conway 1987) that characteristically "leak" nutrients (Loucks 1977). As a result, agriculture has been implicated as the major land use contributing to nonpoint source (NPS) degradation of surface waters in the United States (Humenik *et al.* 1987, Odum 1989). It has been estimated that 44% of the 4.2 million metric tons of nitrogen fertilizer (as N) applied in the Mississippi River watershed between 1981-1985 was lost or "leaked" into the Gulf of Mexico (Turner and Rabalais 1991). One reason for the correlation between agriculture and water quality degradation is the industry's reliance on nitrogen fertilizer (Omernik 1976, Farnworth *et al.* 1979, National Research Council 1982). Typically, 168 kg ha-1 (150 lbs. acre-1) as nitrogen are applied to the Midwest cornbelt. Although nitrogen is usually applied in the form of ammonium which is relatively immobile in soil, it is rapidly converted by nitrifying bacteria to nitrate. Nitrate is highly mobile in the soil and rapidly leached under wet conditions. As a result, concentrations in central Illinois streams often exceed 10 mg nitrate-N L^{-1} (the EPA's standard for safe drinking water). Consequently, many drinking water reservoirs exceed the safe drinking water nitrate limits at certain times of the year (*e.g.*, Lake Vermilion near Danville, Illinois and Lake Decatur in Decatur, Illinois).

Odum (1989) states that NPS can only be controlled by input management; that is, reducing the amount of agricultural chemicals applied to crops. He further states that past production has focused on increasing yields by increasing fertilizers without much regard to efficiency or the amount of resulting NPS pollution. Agriculturalists as well as environmentalists recognize the need for input management and strategies to decrease N losses from croplands to surface waters. A major obstacle to improving N fertilizer management is the accurate prediction of the soil's capacity to supply N to the crop (Saint-Fort *et al.*, 1990). This problem occurs because the dynamics of N in the environment are complex and the number of cultural and environmental factors that can alter N availability are many.

Although input management will reduce losses of NPS nitrate it will probably never be the sole solution to nitrate pollution. Multiple strategies will require a combination of techniques to control water quality including input, output and land use management. One management alternative recommended by several authors is the use, maintenance, and restoration of vegetative stream-side buffer strips in agricultural regions (e.g., Cooper *et al.* 1986). The fundamental objective behind this practice is to reduce nutrient export to surface waters by increasing nutrient cycling, retention time, and the rate of denitrification in the watershed.

Stream-side vegetation has been shown to be important in maintaining stream water quality (Moring 1975, Borman and Likens 1979, Cooper *et al.* 1986, Osborne and Wiley 1988). Research in the eastern United States indicated that riparian vegetation acted as a filter for Ca, Mg, K, sulfate-S and NO_3^--N (Lowrance *et al.*, 1984, Peterjohn and Correll, 1984) and that filter-strips of 18 m in width could effectively reduce NO_3^--N inputs (Cooper *et al.* 1986). There remain some questions about the efficiency of different vegetated buffer strips. Despite the apparent benefits of riparian buffer strips on Coastal Plain soils, little work has been done on buffer strips effectiveness in agricultural soils of the Midwestern cornbelt.

Recognizing the need to develop effective methods to reduce NPS pollutants from agricultural lands, we examined the role of riparian vegetation in mitigating nutrient losses from a Midwestern upland terrestrial agroecosystem dominated by row crop agriculture. In this study we asked two main questions: 1) Are vegetated riparian buffer systems effective in reducing nitrate transport from terrestrial to aquatic systems in loess derived soils of the Midwest; and, 2) If vegetated filter strips are effective, do riparian forests differ from grassland sites in their ability to reduce nutrient transport to surface waters.

DESCRIPTION OF STUDY SITE, RESEARCH DESIGN AND METHODS

The study site on the East Branch of the Embarras River in southeastern Champaign County, Illinois is located within the Central Corn Belt Plains Ecoregion, a low relief glacial till plain overlain with loess. The dominant soil association is Drummer-Kendall-St. Charles which overlies a dense basal till. Much of the area is tile drained with exceptions being the two riparian buffers utilized in this study. The predominant land use is row crop agriculture. Agricultural practices contribute to stream nitrate-N levels periodically in excess of the EPA standard (10 mg nitrate-N L^{-1}). Using U.S.G.S. discharge and water quality data from January 1989 to May 1990 at Camargo sampling station on the Embarras River (24 km south of the study site) nitrate-N loading was estimated at 492 metric tons. This is an average of 1.5 metric tons nitrate-N per kilometer over a 326 km stream length.

The site was divided into an upland zone planted in a corn/soybean rotation and a riparian zone divided into the three following treatments paralleling the west bank of the Embarras River: 1) rowcrops planted down to the stream bank; 2) a riparian forest (approximately 18 meters wide) dominated by 70 year-old cottonwood trees (*Populus deltoides*) and silver maple (*Acer saccharinum*); and, 3) a 67 meter wide strip of Reed Canarygrass (*Phalaris arundinacea*) between the stream and rowcrops.

Within each riparian treatment (rowcrop, forest, and perennial grass) three lysimeter transects, 15 meters apart, were installed perpendicular to the stream channel to follow the sub-surface lateral movement from the upland site toward the stream. Lysimeter transects on each treatment consisted of a center row of five paired lysimeters placed at 60 cm (shallow lysimeters) and 120 cm (deep lysimeters) below the soil surface. Piezometers were installed (>120 cm, see below) in the center transect of the first, third, and fifth row in close proximity to the paired lysimeters. This design allowed the monitoring of the downward and lateral movement of nutrients in sub-surface flow from the cropped upland to the stream through the different riparian zones. Osborne and Kovacic (1993) give a detailed description of the sampler construction, placement, sampling design and sample analysis procedures.

RESULTS AND DISCUSSION

There was no significant difference in nitrate-N concentrations among shallow lysimeters in the upland and riparian crop sites. In the two other cases (*i.e.*, the forest and the grass sites) the concentrations of nitrate-N in ground water in the upland crop areas were significantly higher than were mean concentrations at comparable sampling depths in the riparian zone (Figure 1). The significant reductions in nitrate-N concentrations from the upland crop zone to the RBS (Riparian Buffer Strip) suggest that nitrates were being removed from the system. Denitrification in RBS has been suggested as the primary mechanism for the reduction of nitrate concentrations in solution (Cooper *et al.*, 1986). Others have also provided evidence that denitrification is an important mechanism contributing to the loss of nitrate-N. Bromide used as a tracer verified that subsurface groundwater moved laterally from the cropland through the forest and grass buffer strips to the stream.

In the riparian zone, concentrations of nitrate-N in shallow lysimeters were significantly greater in the grass RBS (2.43 ± 0.43 mg L^{-1}) than in the forested RBS (0.87 ± 0.23 mg L^{-1}, Figure 1). There were no significant differences in nitrate-N concentrations in solution between the forest and grass RBS at 120 cm and >120 cm (Figure 1). It is noteworthy that between the 60- and 120-cm depths the greatest proportional decrease in nitrate-N concentration (77.5%) occurred in the riparian crop site (*i.e.*, from 16.86 ± 2.29 mg L^{-1} at 60 cm to 3.79 ± 1.22 mg L^{-1} at 120 cm, Figure 1). The proportional decreases between the 60- and 120-cm depths in the forest and grass RBS (34.0 and 51.0%, respectively) were substantially lower than in the riparian crop site (Figure 1). In the riparian crop sites the greater loss of nutrients in solution between the 60- and 120-cm depths is attributable to subsurface transport in drainage tiles directly to the stream channel, rather than to denitrification and plant uptake.

The evidence suggests that RBS can reduce N inputs to streams in Midwest agricultural systems. Osborne and Wiley (1988) concluded that the mitigating benefits of RBS will be maximized if they are sited in the smaller headwater streams whose lengths dominate any drainage network. In much of the Midwest, most lands in the headwaters of the catchment are privately owned. Undoubtedly, government support incentives will be required for large scale adoption of RBS in many regions of the U.S.

In areas that are tile drained the effectiveness of riparian buffer strips in removing nitrate-N will be reduced as nitrate-N is shunted past the RBS. One solution to this problem is to remove the tiles; however, this is not a viable solution because it would render the land unfarmable. Another more viable solution would be the creation of small wetlands fed by agricultural drainage and designed to optimize nitrate-N removal through plant uptake and denitrification. We are now studying the efficiency of artificial constructed wetlands for removing nitrate-N in lowland areas that are tile drained. To create such wetlands, tile drains are surfaced upland (sunlighted) rather than laid directly to the stream (Figure 2). A berm is created adjacent to the stream (width of berm and distance from stream depend on the size of the drainage basin) to cause water to pool and thus increase retention time. It is anticipated that nutrient removal will occur in a fashion similar to that of RBS and natural wetlands (Lee *et al.*, 1975). Preliminary investigations indicate that constructed wetland buffers with a 1:20 wetland to drainage area ratio could effectively treat 65% of the water entering them for 5 days and 55% for 15 days.

We believe that RBS and constructed wetlands can effectively reduce the movement of nitrate-N from croplands to agricultural surface waters. Riparian buffer strips and constructed wetlands are two techniques that should help meet the needs of both the farmer and the Federal government by: 1. Supporting non-tiled and tiled croplands; 2. Improving water quality through the natural biological processing of nitrate; and, 3. Reestablishing wetlands and riparian corridors in areas where they once existed. It should, however, be recognized that no single method or technique will eliminate all nitrate-N input into surface waters, nor will it be universally applicable in every water quality mitigation program. A combination of options must be considered for any comprehensive water quality program, these options should include RBS, constructed wetlands, changes in farming practices such as no-till agriculture and fertilizer input management.

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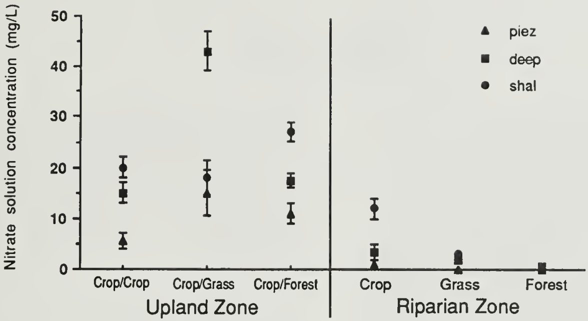

Figure 1. Mean concentrations of nitrate-N in solution from shallow and deep lysimeters, and piezometers in each adjacent upland crop zone and each riparian (crop, grass and forest) zone during the study. (crop/crop = cropped upland adjacent to the cropped riparian zone, crop/grass = cropped upland adjacent to the grassed riparian zone, crop/forest = cropped upland adjacent to the forested riparian zone)

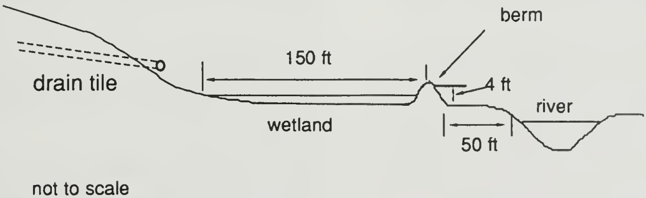

Figure 2. Conceptual design of a constructed wetland buffer for facilitating the removal of nitrate-N from agricultural drainage water.

Endangered and Threatened Animal Species of Illinois Forests

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Due to the structural complexity of forest ecosystems, forests support a diverse array of plant and animal species. In fact, although forests covered only 38% of the presettlement land area in Illinois (Iverson *et al.* 1989), Graber and Graber (1963) estimated that forests supported perhaps as much as 55-60% of the state's presettlement bird fauna. Due to the great variety of organisms that occur in Illinois forests, the conservation and protection of the state's forest resources and their dependent species is an important component of preserving the natural diversity of Illinois. At least 115 native plant and animal species are presumed extirpated in Illinois (Post 1991), of which 36 (roughly 31%) of these species could be considered forest species.

The list of extirpated forest animal species includes some high-profile species that are probably well known to many residents of the state, such as the wolf (*Canis lupus*), elk (*Cervus canadensis*), mountain lion (*Felis concolor*) and black bear (*Ursus americanus*), (Hoffmeister 1989). Species that were all once relatively common and widespread in Illinois - but were eliminated sometime between 1850 and 1900 (Hoffmeister 1989).

A few of these extirpated Illinois forest animal species are now globally extinct, such as the passenger pigeon (*Ectopistes migratorius*) and Carolina parakeet (*Conuropsis carolinensis*). Once arguably the most abundant bird in the world, the passenger pigeon was an inhabitant of deciduous forests throughout the eastern United States (Ehrlich *et al.* 1988). Audubon once wrote of having watched a single flock pass overhead for three consecutive days and estimated that at times more than 300 million birds flew by each hour. Unregulated slaughter, however, very quickly drove this species to the brink of extinction. The passenger pigeon apparently last bred in Illinois in 1893 (Bohlen 1989), and the last known individual died in captivity in the Cincinnati Zoo in 1914 (Ehrlich *et al.* 1988). The Carolina parakeet, also an inhabitant of mature deciduous woodlands, was once relatively common in southern and in parts of central Illinois. However, Carolina parakeets were persecuted as agricultural pests and were rapidly wiped out due to "pest control" measures, sport hunting, and habitat destruction and degradation. The last Illinois sighting of a Carolina parakeet was in 1912 (Bent 1940).

Other former Illinois forest species are nearly extinct, such as the ivory-billed woodpecker (*Campephilus principalis*). The ivory-billed woodpecker once inhabited mature forested swamps and mature river bottoms in the southeastern United States and is now believed to be extinct in the United States and found only in a few remote areas of Cuba (Ehrlich *et al.* 1988). There are only three known records for the ivory-billed Woodpecker in Illinois, the last of which occurred in the fall of 1900 (Bohlen 1989).

Several other species have disappeared from Illinois with little fanfare and are probably unknown to most residents of the state. The reasons for the disappearance of these forest species are varied, but loss and degradation of habitat, and direct human exploitation, are probably the greatest factors. Many of these species (at least for the vertebrates) were lost by 1900, almost 100 years ago (Hoffmeister 1989, Bohlen 1989).

Somewhat surprisingly, it appears that relatively few animal species have been lost from Illinois in the last fifty years. During this period, however, a tremendous number of species have been pushed to the brink of elimination from the state. Presently there are 500 species of plants and animals that are listed as either Endangered or Threatened in Illinois (Herkert 1991, 1992). By definition that means that roughly 21% of the state's resident vertebrate species and 18% of the state's plant species (excluding Bryophytes) are presently in danger of extinction in Illinois or are likely to become in danger of extinction in the foreseeable future. Of the 500 state-listed species 356, or roughly 70%, are plants and 144, or about 30%, are animals. A majority of state listed plant species are inhabitants of forest habitat (Figure 1), whereas for animals the majority of state-listed species occur in aquatic habitats (Figure 1). For forest species, there are 161 plant and 33 animal species listed as either Endangered or Threatened in Illinois. Of the 33 state-listed forest animal species, nearly half are birds (Table 1). Over one-third of all birds listed as either Endangered or Threatened in Illinois are inhabitants of forest habitat. Similar numbers for other groups are 80% for state-listed mammals, 55% for Reptiles, 66% for Amphibians, and less than 1% for Invertebrates.

The list of Endangered and Threatened forest animal species in Illinois (Table 1) ranges from the relatively obscure to the majestic - from the Iowa pleistocene snail to the Bald Eagle. The Iowa pleistocene snail, a federally endangered species, is known in Illinois from only one population in the northwestern part of the state. The bald eagle, also a federally endangered species, is a fairly common winter and rare summer resident in Illinois (Bohlen 1989). In January, 1992, the state's mid-winter bald eagle survey recorded nearly 2000 bald eagles in the state. Illinois also has an increasing nesting population of Bald Eagles. In 1992, there were at least 11 active eagle nests in Illinois, including the first nesting attempt in the Illinois River valley in more than 40 years.

Somewhat surprisingly the number of Endangered and Threatened forest animal species per county in Illinois is only moderately correlated with the total amount of forest cover in that county ($r=.45$, $p < 0.01$). Counties with high numbers of Endangered and Threatened forest animal species include Johnson (14), Alexander (11), Pope (10), Pulaski (9), Union (8), Carroll (7), and Pike (7) (Figure 2). For comparison, the relationship between the number of state-listed forest plant species per county and the total amount of forest cover in that county is even weaker than the relationship for animal species ($r=.35$, $p < 0.01$). Counties with more than 10 state-listed forest plant species are Pope (34), Lake (20), Jo Daviess (19), Cook (19), Union (19), Johnson (17), Ogle (17), Massac (15), Alexander (14), Jackson (12), and Pulaski (12).

In terms of numbers, roughly 40% of all Endangered and Threatened forest animal species in Illinois are known to occur at five or fewer locations in the state. Four of these species have been found in only a single location in the state. One of these species, the eastern woodrat, may be the most imperiled forest animal in the state. In Illinois, eastern woodrats are presently known only from the cliffs and talus slopes of the Pine Hills in southern Illinois (Union County). Recent population estimates (based on nest counts) for the Pine Hills population show that the population of woodrats at this site probably reached an all time low in 1990, with perhaps fewer than 20 animals inhabiting the area (Herkert 1992). Other forest species known from only a single location in Illinois are the great plains rat snake, green water snake, broad-banded water snake and silvery salamander. The broad-banded water snake may be extirpated in Illinois (Post 1991) and was last seen in the Horseshoe Lake area (Alexander County) in the mid-1950s (Herkert 1992).

In contrast to the rarity of the aforementioned species, three state-listed forest animal species are known from more than 30 sites in Illinois - the river otter, bobcat and great egret. The river otter was relatively common and widespread in Illinois prior to extensive European settlement (Cory 1912, Mohr 1943); but had become scarce by the mid-to-late 1800s and was considered to be completely extirpated from Illinois by the early 1940s (Brown and Yeager 1943). River otters have recently been reported from 33, or roughly one-third, of the counties in the state (Herkert 1992), yet the actual status of this species in the state is uncertain. There is an established breeding population in the northwestern part of the state in Jo Daviess, Carroll and Whiteside counties (Anderson and Woolf 1984). There also appears to be a breeding population in the southern part of the state in the Cache River area (Anderson and Woolf 1984). For the remaining records, however, it is not clear whether these represent dispersing individuals or small isolated breeding populations.

The bobcat was also once fairly common in the timbered areas throughout Illinois at the time of settlement (Wood 1910, Cory 1912, Mohr 1943) but began to disappear from most of the northeastern and central sections of the state soon after settlement. By the mid 1900s the conversion of many woodland areas to cropland and pastureland, along with mining, logging, and draining of woodland swamps, in addition to persecution as a destructive predator, had driven the bobcat to the brink of extirpation in the state (Brown and Yeager 1943, Hoffmeister 1989). Bobcat numbers in Illinois have remained fairly low and, as recently as 1989, Hoffmeister (1989) listed only 14 recent bobcat records from 13 Illinois counties. Since 1980 bobcats have been sighted in nearly 40 locations from 19 Illinois counties (Illinois Department of Conservation, Natural Heritage Database).

The Illinois breeding population of great egrets has fluctuated greatly in modern times (Graber *et al.* 1978). In the early and mid 1800s great egrets were considered somewhat common in Illinois (Ridgway 1895, Barnes 1926). By the late 1800s, however, the state's breeding population had been seriously depleted, primarily due to plume hunters (Woodruff 1908, Barnes 1912, 1926). By 1921 this species was considered to be probably extirpated as a breeding species in Illinois (Musselman 1921). Isolated reports of breeding great egrets began to reappear in the early 1930s (*e.g.*, Jones 1937, Bellrose 1939) and the state's population continued to increase at least into the 1950s (Graber *et al.* 1978). Graber *et al.* (1978), however, found that great egret numbers in the 1970s were again declining. The state's population of great egrets may have declined by as much as 80% during the 1970s (Graber *et al.* 1978). Presently, the Illinois population of great egrets is apparently increasing again. In 1991, there were 32 active great egret colonies in Illinois, 15 with fewer than 15 nests, eight with 50-100 nests, and eight with more than 100 nests (Herkert 1992).

The protection of areas in which state-listed forest animal species occur has proved to be more difficult that protecting areas of occurrence for state-listed plant species. Nearly 54% of all known locations for Endangered and Threatened forest animal species in Illinois are on private land. This is considerably higher that similar numbers for Endangered and Threatened forest plant species. Only 30% of all known locations for Endangered and Threatened forest plant species in Illinois are on private land. Slightly more than one-third of all known locations for state-listed forest animal species are somewhat protected by public ownership, but only 11% occur within dedicated State Nature Preserves. Comparatively, 48% of all known locations for state-listed forest plant species are in public ownership and 22% are within dedicated State Nature Preserves.

In summary, the outlook for Illinois' Endangered and Threatened forest animal species is uncertain. A few species are showing definite signs of recovery and some others are exhibiting weak signs of improving. Many other species, however, are showing no sign of recovery and a few others are continuing to decline. There is a great need for a major increase in awareness of the problems facing the state's natural resources in general and forest resources in particular by both the scientific community and the public, in order to sufficiently protect these vulnerable and valuable resources. Without such a change the prospects for recovery for many of Illinois Endangered and Threatened forest species remains clouded with uncertainty.

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Table 1. Endangered and Threatened animal species of Illinois forests.

Species	Illinois Status
INVERTEBRATES	
Iowa Pleistocene Snail (*Discus macclintocki*)	Endangered**
Cobweb Skipper (*Hesperia metea*)	Threatened
Amphipod (*Stygobromus iowae*)	Endangered
AMPHIBIANS	
Silvery Salamander (*Ambystoma platineum*)	Endangered
Dusky Salamander (*Desmognathus fuscus*)	Endangered
REPTILES	
Great Plains Rat Snake (*Elaphe guttata emoryi*)	Threatened
Western Hognose Snake (*Heterodon nasicus*)	Threatened
Coachwhip Snake (*Masticophis flagellum*)	Threatened
Green Water Snake (*Nerodia cyclopion*)	Threatened
Broad-banded Water Snake (*Nerodia fasciata*)	Endangered
BIRDS	
Great Egret (*Casmerodius albus*)	Endangered
Snowy Egret (*Egretta thula*)	Endangered
Little Blue Heron (*Egretta caerulea*)	Endangered
Black-crowned Night-heron (*Nycticorax nycticorax*)	Endangered
Mississippi Kite (*Ictinia mississippiensis*)	Endangered
Bald Eagle (*Haliaeetus leucocephalus*)	Endangered**
Sharp-shinned Hawk (*Accipiter striatus*)	Endangered
Cooper's Hawk (*Accipiter cooperii*)	Endangered
Red-shouldered Hawk (*Buteo lineatus*)	Endangered
Common Barn-owl (*Tyto alba*)	Endangered
Long-eared Owl (*Asio otus*)	Endangered
Brown Creeper (*Certhia americana*)	Threatened
Bewick's Wren (*Thryomanes bewickii*)	Endangered
Veery (*Catharus fuscescens*)	Threatened
Swainson's Warbler (*Limnothlypis swainsonii*)	Endangered
MAMMALS	
Southeastern Myotis (*Myotis austroriparius*)	Endangered
Gray Bat (*Myotis grisescens*)	Endangered**
Indiana Bat (*Myotis sodalis*)	Endangered**
Rafinesque's Big-eared bat (*Plecotus rafinesquii*)	Endangered
Golden Mouse (*Ochrotomys nuttalli*)	Threatened
Eastern Woodrat (*Neotoma floridana*)	Endangered
River Otter (*Lutra canadensis*)	Endangered
Bobcat (*Lynx rufus*)	Threatened

** Federally Endangered

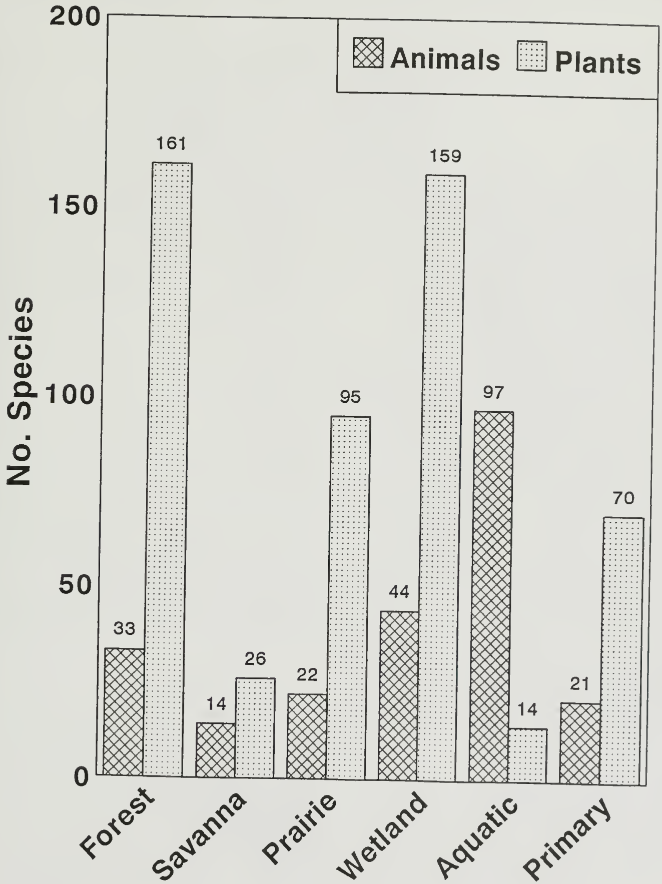

Figure 1. Major habitat associations of Endangered and Threatened plant and animal species in Illinois. Primary habitat is areas with little or no soil development such as dunes, cliffs, rock outcrops, and caves. Other habitat categories are self-explanatory. Note: many species are listed in multiple habitat categories, so the sum total in this figure exceeds the number of state-listed species (500).

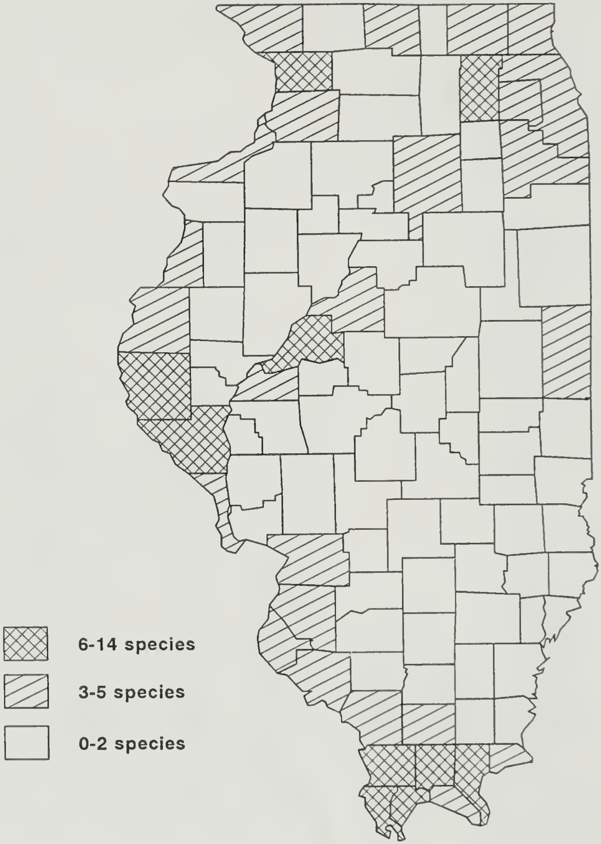

Figure 2. The number of Endangered and Threatened forest animal species known from Illinois counties.

Native Trees for Urban Use: Urbanization of Illinois Forests

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Urbanization of stands of native trees is a continuing trend that is disrupting or destroying large areas of forest as functioning ecosystems. Fortunately, some of the forests in urban and suburban areas are being preserved and managed by public agencies such as forest preserve districts, park districts and conservation districts, and there are notable examples of private preservation. The challenge in urbanizing wooded neighborhoods is to prolong the lives of the remaining trees by preserving or simulating natural conditions near the retained trees that have lost their forest. Success in preserving trees is dependent on species, age, and size. The older the tree the less the resilience following construction activities. The larger the tree the larger the spread of the root system and the greater the likelihood that the detrimental impact from soil disturbance will be serious. Urban tree problems often begin underground with damage to the extensive shallow, spreading root systems that are vulnerable to a host of soil-air interface changes associated with construction activities. Protection by fencing of the "drip-line" area under trees is generally effective, but encroachment lists are long: driveways, walks, patios, trenching, compacting, grade-changing, liming, sodding, impounding of runoff, rototilling, *etc*.

The most extensive urbanization in Illinois is occurring in the northeastern region where the forests are dominated by oaks. This discussion concentrates on urbanization of these oak forests but conclusions are thought to be applicable much more widely. The oaks over a period of hundreds of years have had a significant role in producing the soils on which they are found. Oak trees are at home on acid soils, and their fallen leaves help to create and maintain acidic surface layers that differ greatly from the underlying alkaline clayey glacial till from which the regional soils are derived. There are three major oak species in the forests of northeastern Illinois: white oak (*Quercus alba* L.), northern red oak (*Q. rubra* L.), and bur oak (*Q. macrocarpa* Michx.).

Oak forests are highly appealing places to build human dwellings and other kinds of buildings. However, rapid decline of oak trees often follows the invasion and conversion of woodlands with the abrupt transforming changes accompanying construction. There is usually an initial dieback and death of trees that fail to leaf out during the first or second spring following completion of construction. Dieback may become progressively more conspicuous on remaining trees as years pass. Unless resuscitative measures are soon taken, a high proportion of declining trees may ultimately die - sometimes a decade or more later. Because decline usually begins with the death of small branches in the top of an oak, the health of an oak can be assessed by scanning the top of the crown. Both dead branchlets and stunted twigs can be easily spotted, especially at the time of appearance of new foliage in springtime. When dieback of the tips of branches of an oak provides a warning of trouble in the root system, there are two possible resuscitative approaches: increase the root system, or reduce the quantity of foliage in the crown. Because an adverse root environment in the soil is responsible for root deterioration, promoting new rootlet development may be difficult, perhaps requiring several years. On the other hand, removal of branches and branchlets from the crown can immediately reduce the demands on a root system, restoring a favorable root/crown ratio.

A kind of forest especially vulnerable to construction impacts is one that is thickly stocked, with trees in keen competition for space. Close observation usually reveals scattered stunted, declining, and dead trees within the forest even though the forest appears to be in good condition. Closely spaced trees have long trunks and small crowns. The sheltering and the microclimate tempering of the closed canopy maintain a relative evenness of levels of humidity, soil moisture, and temperature, making possible the existence of large trees in limited spaces with limited root systems. But abrupt removal of numerous trees drastically changes the microclimate, permitting environmental fluctuations and adversities that were not present in the intact forest system. Even without additional man-inflicted insults, the stage is set for detrimental episodes of excessive soil drying and damaging high levels of transpiration. The root systems are no longer sufficient to serve properly the same crowns that were in equilibrium with the root systems before the forest was disturbed. Thus, additional modifications of the environment, especially soil changes, often have drastic negative effects on the remaining trees.

Oaks in forests tend to have dual root systems: a highly proliferative fine-root system in the upper 15 cm of porous organic soil and a less freely branching system at a depth of 30 to 80 cm. A healthy fine-root system is a very effective absorber of water, mineral, nutrients, and oxygen. But it is also very easily destroyed or impaired by activities changing the nature of the soil-air interface. Restoration of a fine-root system can be facilitated by the application of mulches. Mulches not only supply organic matter but also suppress existing grass, which soon decomposes. The use of mulches around stressed oaks appears to have a favorable effect in arresting decline. Additionally, ground cover may be planted in the mulch without producing root competition nearly so severe as that of sod. Interception and incorporation of falling leaves by the ground cover further promote the build-up of organic matter and the simulation of the surface soil layer of nature woodland. Ideally, a layer of well-decomposed leaves should be laid down first with coarser wood chips or bark chips forming a top layer.

An example of a long-time change of the soil environment following urbanization involves chlorosis (foliage yellowing). The widespread prevalence of chlorosis in older wooded neighborhoods is directly related to changes associated with decades of separation of the trees from their forests. Soils of the lawns surrounding the trees have been slowly alkalinized by the yearly removal of leaves which in past times (in the forest) had been recycled as acidifiers of the forest soil. Chlorosis is especially evident in white oak during hot and dry summers. Application of organic mulches (leaf compost, wood chips, bark nuggets, *etc.*) initiates acidification processes but significant reversal of changes in soil pH may require years. There is much evidence that runoff from paved surfaces, both concrete and blacktop, tends to alkalinize soils. Indeed acid rain may accelerate the dissolution of limey surfaces, further alkalinizing nearby soils.

Oaks provide for us some constructive examples of the necessity for understanding ecological attributes and requirements that are closely linked to natural soil and tree-growth processes measured on a time-scale of decades or more. Oaks are a near-irreplaceable legacy that we can utilize and maintain only if we live and work with them on their terms.

Some of the recommendations for saving oak trees in the path of detrimental construction activity are:

1. Retain natural conditions of the forest floor wherever possible and fence off an area under the drip-line as a "no-violation" zone.

2. Retain groups of trees as "mini-forests" so that detrimental encroachment is more difficult and preservation of a larger area of soil-air interface is possible.

3. Preserve understory trees and saplings wherever possible. Released saplings usually show surprisingly fast growth following removal of overtopping crowns. Young trees almost always have a greater chance of survival following soil disturbance than do old trees.

4. Utilize future driveways for construction traffic from the beginning of construction activity so that the extent of compaction by vehicular traffic will be minimized.

5. Selectively remove branches from the interior of the crown in anticipation of loss of roots or impaired root efficiency.

6. Utilize augering to avoid the damage caused by trenching or installation of utilities.

7. Concentrate utility corridors in ways to avoid encroachment on oaks and other trees.

8. Cut roots cleanly and avoid tearing should root-cutting be unavoidable.

9. Do not cut or add soil near oak trees. The vital surficial fine-root system can be suffocated by a mere 5 to 8 cm of fill material. Similarly, cutting to a depth of 15 cm may remove much of the fine-root system.

10. Follow the rationale that a desirable procedure is to set a home into dedicated space (an "envelope") where necessary trees have been removed, but all of the remaining trees and their soil environment remain intact.

Effects of Simulated Stratospheric Ozone Depletion on Seedling Growth of Several Species of Hardwood Trees

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ABSTRACT

The potential effects of stratospheric ozone depletion on the growth of six species of deciduous hardwood tree seedlings were examined under artificial lighting in a greenhouse. Two shade-tolerant (*Amelanchier arborea* and *Cercis canadensis*) and four shade-intolerant species (*Betula papyrifera*, *Morus alba*, *Nyssa sylvatica*, and *Robinia pseudoacacia*) were examined. Ultraviolet-B radiation (UVB, 280-320 nm), simulating a 40% depletion in stratospheric ozone, was administered to the treatment plants and the control plants received no UVB radiation. Four of the six species were unaffected by the treatment. However, total biomass, plant height, and leaf area were significantly reduced by the UVB treatment for *Cercis canadensis* (shade tolerant) and *Morus alba* (shade intolerant). There was no difference between the response of shade-tolerant versus intolerant species to UVB radiation for the limited number of species examined in this study. The artificial lights and filters used to generate the UVB exposure also altered incident doses of UVA radiation (320-400 nm). These wavelengths induce a number of UV protection and damage repair processes. Extrapolating the potential responses of the two UV-sensitive species to the natural setting is limited by our inability to administer realistic UVB enhancements without simultaneously altering ultraviolet-A radiation (UVA, 320-400 nm). That growth inhibition was caused by relatively short exposures to UVB radiation, however, leads us to predict that *Cercis canadensis* and *Morus alba* will be susceptible to future reductions in stratospheric ozone.

INTRODUCTION

Ultraviolet-B radiation (UVB, 280-320 nm) is potentially damaging to plants. It is absorbed by a wide array of macromolecules, including proteins, lipid membranes, and DNA, and can disrupt many physiological processes (Caldwell *et al.* 1989, Tevini and Teramura 1989). Extraterrestrial UVB radiation impacting the atmosphere is approximately 22 W m-2, although only 5 W m-2 actually reaches the surface (values are for 1977; Hader and Tevini 1987). Thus, 77% of incident UVB radiation is absorbed by the atmosphere. The primary absorber of this radiation is stratospheric ozone. As a result of the anthropogenic release of chlorofluorocarbons (CFCs) into the atmosphere, this protective layer is being destroyed at an alarming rate; there has been an approximately 11% decrease in ozone concentration at mid-northern latitudes in the past decade (Kerr 1988, 1991). Because these compounds persist in the atmosphere for a long time, in excess of 100 years, efforts to reduce or eliminate their release will not mitigate rates of ozone depletion within the foreseeable future.

Many aspects of plant function are inhibited or damaged by UVB radiation-- photosynthesis is particularly sensitive (Sisson and Caldwell 1977, Bornman 1989). Alteration of physiological functions is manifest at higher levels of biological organization, and UVB is known to cause reductions in height growth and biomass accumulation, as well as interfering with pollination and flowering (Tevini and Teramura 1989; and references therein). These perturbations in plant function potentially alter ecological interactions, such as competition, among species (Barnes *et al.* 1988).

Susceptibility of terrestrial plants to damage caused by enhanced levels of UVB radiation varies widely among species and even between different varieties or populations within a species. For example, exposure to UVB levels that simulated a 40% decrease in the ozone column caused a significant decrease in biomass for the Essex variety of soybean but an increase for the Forest variety (Teramura and Sullivan 1987). Similar variation in susceptibility has been observed for native plants distributed along natural latitudinal or elevational UVB gradients (Robberecht *et al.* 1980, Caldwell *et al.* 1982, Sullivan *et al.* 1992, Ziska *et al.* 1992). Much of this variation in susceptibility is caused by differential ability to screen UVB radiation from entering photosynthetic tissue by the production of UV-absorbing pigments in the vacuole of epidermal cells or in the leaf cuticle (Caldwell *et al.* 1983b, Day *et al.* 1992).

Relatively few studies have examined the potential impact of enhanced levels of UVB radiation on native plants, particularly trees. Because forest ecosystems contribute roughly 50% to global net primary productivity (Leith and Whittaker 1975), damage to trees by UVB may have far-reaching consequences for global carbon cycling. In a study of Pinaceae that included representatives from three genera, Sullivan and Teramura (1989) found that exposure to enhanced levels of UVB radiation caused a 30 to 40% reduction in biomass for some members of the genus *Pinus*. *Pinus taeda* was the most susceptible species. In contrast, representatives of *Abies* and *Picea* were unaffected. The objective of this study was to examine the effect of a simulated 40% decrease in stratospheric ozone on seedling growth and biomass allocation of several deciduous hardwood trees species. Two shade-tolerant and four shade-intolerant species were included in this initial study. These two types of trees were included to determine if susceptibility to UVB damage is correlated with genetic potential to tolerate shade. We predicted that adaptations to low light, such as high leaf area/leaf mass ratio and a monolayer leaf display may increase absorbance of UVB radiation and increase the degree of damage.

MATERIALS AND METHODS

Six species of hardwood trees were grown from seed (F.W. Schumacher Co., Inc., Sandwich, MA) in a greenhouse. They included two shade-tolerant species (*Amelanchier arborea* and *Cercis canadensis*) and four shade-intolerant species (*Betula papyrifera*, *Morus alba*, *Nyssa sylvatica* and *Robinia pseudoacacia*). Other features of the ecology of these species are presented in Table 1. Where necessary seeds were stratified or scarified (Schopmeyer 1974). Seedlings were germinated in flats containing vermiculite and grown in 1.5-L pots for 11-28 days prior to initiating the treatment. The growth medium was a sand:soil:calcite clay mixture (1:1:1, v/v) and plants were watered and fertilized as needed to maintain maximum growth rates. Thirty seedlings were selected for uniformity and randomly divided into a treatment and a control group. Because of limited space under the UV lamps, experiments were conducted with 2 or 3 species simultaneously, in consecutive experiments. Individual species were grown under the experimental conditions for various lengths of time. This was done to minimize the potential for pot binding for the more rapidly growing species. Duration under the treatments varied from 45 to 112 days (Table 1).

A "plus UVB" and "minus UVB" exposure was administered to seedlings in a greenhouse. Ultraviolet-B radiation was supplied by filtered fluorescent UV lamps (UVB-313, Q-Panel Co., Cleveland, OH). The lamps were mounted (20-cm spacing) in two adjustable racks above a 1.8 x 4.3-m greenhouse bench. Visible light was supplemented with 4 HID mixed-vapor lamps mounted above each rack of UV lamps. The UV lamps were wrapped with either pre-solarized cellulose acetate (.005-mm thick) or Mylar (.005-mm thick). The cellulose acetate film absorbed irradiance below ca. 280-nm wavelength (UV-C portion of the spectrum) and was used to provide the +UVB treatment. The Mylar film absorbed irradiance below ca. 313-nm and provided the -UVB control. The dose was maintained as the filters aged by varying the height of the lamps relative to the tops of the plants.

Spectral irradiance under the lamps was measured with a portable UV/VIS spectroradiometer (OL 752, Optronics Lab., Inc., Orlando, FL). The spectroradiometer employs a double monochrometer with dual holographic gratings and was configured with 0.25-mm slits, that produced a nominal half-band width of 1.5 nm. The input optic was an integrating sphere with a flat quartz window. Prior to measurements the spectroradiometer was calibrated with a NIST-traceable 200-W tungsten-halogen lamp, and wavelength alignment was checked against the mercury-emission lines from a fluorescent bulb. The dose under the lamps was checked daily with a broad-band radiometer (SED240, International Light, Inc., Newburyport, MA; DeLucia *et al.* 1991), that was calibrated against the spectroradiometer using the generalized plant-damage action spectrum weighted to 300 nm (Caldwell *et al.* 1983a).

The treatment plants received 19.1 KJ of biologically effective UVB radiation daily (*i.e.* weighted by the plant action spectrum). This simulates a 40% depletion of stratospheric ozone for Beltsville, Maryland on the summer solstice. The dose was administered for 6-10 hours around noon to avoid providing high UVB and low visible irradiance. The HID lamps extended the photoperiod to 14 hours; and the maximum and minimum photosynthetic photon flux density provided with the supplemental HID lamps were 1600 and 400 mmol m-2 s-1, respectively. The mean day and nighttime air temperatures were 25o and 20oC, respectively. Humidity in the greenhouse was uncontrolled and varied from ca. 20 to 60%.

At the end of the treatment period plants were harvested, separated into components, dried at 70oC (48 h) and weighed. Leaf area was measured with a video area meter (Delta-T, Decagon Devises, Inc., Pullman, WA). Following a test for homogeneity of variances, mean values were compared using a t-test (STATISTIX 3.0, Analytical Software, St. Paul, MN).

RESULTS AND DISCUSSION

The response of these 6 hardwood tree species to enhanced levels of UVB radiation was highly variable, and there was no difference in the response of shade-tolerant versus intolerant species. Total biomass of *Amelanchier arborea*, *Betula papyrifera*, *Nyssa sylvatica*, and *Robinia pseudoacacia* were unaffected by the treatment (Table 2). Of these four species, *A. arborea* is shade tolerant. Total biomass of *Cercis canadensis* and *Morus alba* were reduced by 24 and 8%, respectively, by the UVB treatment ($p<.05$, Table 2). The former species matures into a relatively small tree and is characterized as tolerant of shade in the seedling stages; whereas the later, a naturalized Asian exotic, typically grows in open disturbed areas and is considered intolerant of shade. Shade-grown plants are more susceptible to UVB damage than sun-grown plants (Teramura *et al.* 1980, Chen and Bornman 1990). This may be attributable in part to the lack of appreciable accumulation of protective pigments, the production of which are stimulated by exposure to high levels of UVB and visible irradiance (Caldwell *et al.* 1983b, Tevini *et al.* 1989). Our results indicate that this difference in susceptibility does not hold for species genetically characterized as having differences in shade tolerance, although the limited number of species examined in this study precludes a definitive conclusion.

For the two UVB-sensitive species the components of total biomass (root biomass, shoot biomass, *etc.*) were inhibited proportionately. Although statistically significant differences were not observed for all components, shoot, root, stem, and leaf biomass were all reduced by the UVB treatment (Table 2). Enhanced UVB radiation did not, therefore, drive major biomass allocation shifts as indicated by the lack of differences in root/shoot ratio between the treatment and control plants.

For *C. canadensis*, *M. alba*, and *A. arborea*, the UVB treatment significantly altered aspects of canopy architecture. Total leaf area was reduced for *C. canadensis* and *M. alba* (Table 3). There was no effect on the number of leaves for these species, therefore the area per leaf was 9-25% lower in the treatment plants. Total leaf area of *A. arborea* was unaffected, but an increase in the number of leaves also caused a reduction in area per leaf under the UVB treatment. The reduction in photosynthetic leaf area for *C. canadensis* and *M. alba* may have contributed to lower total biomass accumulation for these species.

In addition to reduced total biomass, the UVB treatment also caused a reduction in height for the two sensitive species. Seedling height was 10% lower for *M. alba* and 14% lower for *C. canadensis* grown under the UVB treatment (Table 3). For *M. alba* the reduction in height was attributed to fewer and shorter internodes, while the treatment caused a decrease internode length only for *C. canadensis*.

Height growth is controlled by several environmental variables including incident light. The phytochrome system is involved in responding to alterations in the visible light environment, and results from recent studies suggest that UVB interferes with phytochrome interconversion (Lercari *et al.* 1989, Fernbach and Mohr 1990) and, possibly, hormone production (Giese 1964). Reduced height growth for the two sensitive species in this study could alter their competitive ability in a natural setting (Barnes *et al.* 1988).

Although this experiment was designed to examine the effects of differential UVB radiation on the growth of hardwood seedlings, the experimental treatment was confounded by different quantities of UVA (320-400 nm wavelength) produced by the the CA-filtered and Mylar-filtered lamps (Figure 1). Both treatment and control lamps enhanced UVA relative to the HID lamps and sunlight alone; and the +UVB lamps also enhanced UVA relative to the control (-UVB). Although damaging to phytoplankton (Cullen *et al.* 1992), the extent to which short wavelength UVA radiation is damaging to plants is not known. However, longer wavelength UVA irradiances, extending into the blue portion of the spectrum, are important for inducing molecular repair processes (Pang and Hays 1991) and the production of protective pigments (Tevini *et al.* 1991).

Plants exposed to UVB radiation in greenhouses, particularly if they have had no previous exposure, tend to be more susceptible to this damaging radiation than plants exposed to natural sunlight regimes (Caldwell *et al.* 1989, Tevini and Teramura 1989). Therefore, our data may provide an overestimate of the potential impact of stratospheric ozone reduction on the growth of these species. It is, however, striking that inhibition of the two sensitive species was apparent after a relatively short exposure. The magnitude of inhibition is comparable to that observed for other sensitive species exposed for considerably longer time. Thus, we predict that *C. canadensis* and *M. alba* will be sensitive to enhanced UVB under field conditions.

As is the case for other growth forms, the response of hardwood tree seedlings to enhanced UVB radiation was highly variable. The mechanisms underlying resistance to UV damage are not clearly understood; however, differential ability to produce soluble (Caldwell *et al.* 1983b, Tevini *et al.* 1991) or insoluble (Day *et al.* 1992, DeLucia *et al.* 1992) UVB-screening pigments may account for some of these differences in susceptibility. In addition to the potential for stratospheric ozone depletion to reduce forest productivity, the differential sensitivity of species suggests that this additional anthropogenic assault on native ecosystems may lead to changes in species composition.

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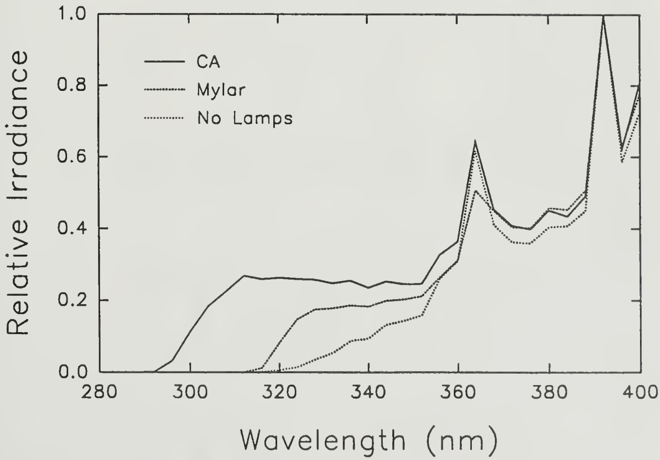

Figure 1. The relative spectral irradiance under the +UVB treatment (.005 mm cellulose acetate film, CA) and the -UVB control (.005 mm Mylar film). The "No Lamps" scan includes sunlight filtered through the greenhouse and light from the HID lamps. Curves were normalized 390 nm.

Table 1. Ecological characteristics and growth form. Data were derived from Burns and Honkala (1990). Days after planting (DAP) designates when plants were moved into the treatment, and DURATION designates the time in the UVB treatment.

Species	Family	Common Name	Habitat	Shade Tolerance	DAP	Duration of Treatment
Amelanchier arborea (Michx. f.) Fern.	Rosaceae	Shadbush	wooded slopes cliff edges	tolerant	57	86
Betula papyrifera Marsh.	Betulaceae	Paper Birch	riparian, wooded slopes	intolerant	63	81
Cercis canadensis L.	Caesalpiniaceae	Redbud	rich woods	tolerant	46	73
Morus alba L.	Moraceae	White Mulberry	roadside	intolerant	53	101
Nyssa sylvatica Marsh.	Nyssaceae	Sour Gum	dry wooded slopes	intolerant	47	112
Robinia pseudoacacia L.	Fabaceae	Black Locust	woodlands, roadsides	intolerant (very)	34	45

Table 2. Biomass (g) and root/shoot ratio of tree seedlings exposed to UVB radiation. The root/shoot ratio (g/g) is designated by RT/ST. Values are means of 14-15 plants, and values designated with an asterisk are different at $P<.05$.

Species	UV-B	Shoot	Root	Stem	Leaf	Total	RT/ST
Amelanchier	+	32.27	9.74	14.49	17.77	42.01	0.298
arborea (Michx. f.) Fern.	-	30.25	8.12	14.09	16.16	38.36	0.267
Betula papyrifera Marsh.	+	27.79	12.62	11.03	16.76	40.41	0.458
	-	29.05	13.25	11.01	18.04	42.31	0.458
Cercis canadensis L.	+	15.40 *	4.14 *	6.21	9.19	19.55 *	0.265
	-	20.04	5.83	7.59	12.45	25.87	0.283
Morus alba L.	+	52.92 *	23.55	22.36 *	30.56 *	76.47 *	0.450
	-	59.21	27.00	25.13	34.08	86.20	0.455
Nyssa sylvatica Marsh.	+	10.08	3.03	3.47	6.61	13.11	0.311
	-	9.35	3.02	3.11	6.23	12.36	0.323
Robinia pseudoacacia L.	+	32.68	8.14 *	13.09	18.57	40.75	0.254
	-	29.94	6.86	12.00	17.94	36.70	0.227

Table 3. Growth characteristics of tree seedlings exposed to UVB radiation. Lengths (*e.g.* Height and Node Length) are expressed in cm, and area (Leaf Area) is in m2. The ratio of leaf area to total biomass is indicated by LAR (m2/g), and the ratio of leaf mass to leaf area is indicated by SLM (g/m2). Values are means of 14-15 plants, and values designated with an asterisk are different at P<.05.

Species	UV-B	Height	Area	LAR	SLM	#Leaves	#Nodes	Node Length
Amelanchier	+	95.50	0.241	59.72	0.0073	76 *	40	2.23
arborea (Michx. f.) Fern.	-	101.30	0.225	59.95	0.0072	63	44	2.15
Betula papyrifera Marsh.	+	80.79	0.660	161.70	0.0026	88	28	2.92
	-	76.25	0.680	162.00	0.0027	94	27	2.84
Cercis canadensis L.	+	108.60 *	0.150 *	81.59	0.0061	23	23 *	4.51 *
	-	125.90	0.210	82.37	0.0059	52	25	4.86
Morus alba L.	+	82.72	1.200 *	154.60	0.0039	366	44	1.81 *
	-	91.58	1.300	161.60	0.0025	369	46	1.98
Nyssa sylvatica Marsh.	+	46.54	0.160	124.60	0.0042	276	31	1.43
	-	40.21	0.146	123.10	0.0043	239	27	1.42
Robinia pseudoacacia L.	+	109.20	0.470	118.00	0.0040	90	31	3.27
	-	109.30	0.460	126.90	0.0039	94	30	3.38

Floristic Changes After Five Growing Seasons in Burned and Unburned Woodland

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ABSTRACT

Five years of transect data were taken in a burned and unburned woodland during the spring, summer, and fall of each year from 1988 to 1992. The data indicate that consistent and directional changes occurred in the burned tract, while the floristics of the unburned tract remained virtually unchanged. Native species diversity increased each year in the burned tract, as did the floristic quality index and the number of conservative species. All indices were relatively stable in the unburned tract, except for a consistent and marked decrease in floristic quality as the season progressed each year. In the burned tract, the total number of species in bloom in any given week increased over the five-year period, but there was a greater increase among those species which bloom in summer and fall. In the unburned tract, there was no demonstrable change in the preponderance of flowering species from season to season. In the burned tract, woody species such as *Parthenocissus quinquefolia* decreased in relative importance, while late-season forbs such as *Helianthus strumosus* and *Solidago ulmifolia* increased. In the unburned tract, there were fewer species overall than in the burned tract, and the top three remained constant in relative importance. The dominance of *Parthenocissus quinquefolia* was unchanged in the unburned tract, with an overall relative importance of 25% each year. Light-meter readings showed that there was about 2.5 times as much light reaching the ground during the middle of the growing season in the burned tract than in the unburned tract.

INTRODUCTION

In the spring of 1988, monitoring was begun on two adjacent tracts of woodland, at the Morton Arboretum in Du Page County, Illinois. The woodland, dominated originally by Bur and White Oak (Ewing 1840), had been heavily grazed during the early part of the century, then kept mechanically cleared of underbrush until the middle 1960's, at which time all active management of the tract ceased. The woods is located on the west side of a morainic pothole marsh, known at the Arboretum as the Bur Reed Marsh. The elevation of the woodland rises slightly, but perceptibly, as one moves west from the marsh. An old but well-maintained woodchip path divides the woods north and south. By the fall of 1984, the woods on the east side of the path had become a dense, impenetrable tangle of Eurasian shrubs and fallen trees. The shade was so intense that little ground cover was apparent except right along the trail where light was still available; there was an even thicker edge of shrubbery along the border between the woods and the marsh. The western side of the trail lacked much of the tangle of fallen timber, but was otherwise quite similar in its inhabitancy by Eurasian shrubs.

During the spring of 1985, a fire was set along the east edge of the trail and allowed to backburn into the woods. Another fire was set within the matrix of *Carex lacustris* in the marsh and allowed to enter the shrub thicket from the west. Controlled burning was administered in a similar manner during the early spring months of 1986, 1987, and 1988, and has continued to date. Fire was not allowed to enter the woods to the west of the path. By the spring of 1988, monitoring of the vegetation began in the burned woods on the east side of the trail and in the unburned woods west of the trail.

METHODS

During the spring of 1988, an 80-meter line transect were placed at random intervals along the transect. A transect of similar dimensions was laid out through the woodland tract on the west side of the trail, beginning at a small American Elm opposite the above-mentioned Bur Oak, and trended north-northeast, ending usually 2-4 quadrats north of another large Bur Oak. The transects were repeated in summer and fall of that year, and 3 times yearly since.

Within each quadrat, an inventory of the vascular plant species was made and a Braun-Blanquet (1932) cover-abundance coefficient (1-5) assigned to each species. With the exception of *Rubus* species, which arch over the quadrat, only species with stems originating within the quadrat were included in the inventory. Cotyledons, seedlings, and juveniles were included when identity was certain. The same taxonomist conducted all of the sampling identifications in the field, so a measure of consistency, if not accuracy, was ensured. Nomenclature follows Swink and Wilhelm (1979).

The data were analyzed in two ways. We looked at quadrat averages and at the transect as a whole. We also combined the three seasonal transects into one to arrive at the yearly totals. For each quadrat, coefficients of conservatism (Swink & Wilhelm 1979 and Wilhelm & Ladd 1988) were assigned to each species present. The mean coefficient was determined and a floristic quality index calculated as described by Wilhelm (1991), resulting in a quadrat coefficient of conservatism and a quadrat quality index. Average quadrat coefficients and quadrat indices were calculated, both for each season and for the year as a whole.

Each year the mean coefficient of conservatism and floristic quality index were calculated for all species which appeared in the transects over the three seasons. From this aggregate transect data, the number of species with coefficients of conservatism ranging from 4-10 were totaled. Also, from the combined transects, the number of species in bloom in any given week were totaled. For example, a species known locally to bloom from 1 May (week 9) to 1 June (week 14) was counted once for each of the blooming weeks 9-14.

Frequency values and cover values were relativized, and relative importance values were calculated by summing the relative frequency and cover values for each species and dividing by 2. Light availability was measured along each transect, on a cloudless day at noon, 23 July 1990, using a Sekonic Studio Deluxe (model #L-398) light meter. Measurements were taken wearing drab clothing and with the meter held about 3 dm above the ground.

RESULTS

By the spring of 1988, the woods on the east side of the trail had been burned four times. While we did not have pre-burn data, it is apparent from the graph in Figure 1 that the number of native species per quadrat has increased yearly in the burned tract since 1988, while the number of species has remained virtually constant in the unburned tract. A one-way ANOVA showed significant differences among years ($F = 12.51$, $df = 4, 266$, $P < 0.001$) for the burned tract, while there was no significant difference in the unburned tract ($F = 12.51$, $df = 4, 262$, $P = 0.5322$). For the burned tract, a Bonferroni Post Hoc analysis showed no statistical differences between 1988 and 1989 or among the years 1990-1992, but both 1988 and 1989 differed from each of the years 1990-1992.

To examine species richness trends further, linear regressions were conducted for the total number of native species and the total number of conservative species for each of the years 1988-1992. For the burned tract, a strong positive trend of increasing total richness *versus* year ($y = 77.659 + 4.7x$, $r^2 = .6776$, $p = 0.087$), and a significant positive trend in conservative species richness *versus* year ($y = -170.4 + 2.2x$, $r^2 = 0.91$, $p = 0.012$). No trend was found for the unburned tract for either total species richness or conservative species (Figure 2).

Quadrat data showed that for both the burned and unburned tract, the mean coefficient of conservatism has experienced no discernible change over the five years (Figure 3). There also is no measurable change in the transect as a whole, there being an offsetting enrichment by both conservative and non-conservative species (Figure 4). Floristic quality indices have risen each year in the burned tract, both at the quadrat level (Figure 5) and for the transect as a whole (Figure 6). Little or no change has been indicated in the unburned tract.

There were marked differences in the data from season to season in the burned and unburned tracts. Figure 7 shows that the seasonal floristic quality has nearly equilibrated in the burned tract, while in the unburned tract the quality dropped off steadily from spring, through summer to fall (Figure 8). Figure 9 shows that in the unburned tract, the species present have blooming ranges prevailing in the spring, with little change from 1988 to 1992. The burned tract shows a similar peak in spring, but an increase over the five years in the total number of species in bloom in any given week, and with a marked increase in the late summer and fall weeks.

Table 1 shows changes in the relative importance values of the species in the top 50% over the five-year period. Note that in both the burned and unburned tracts, the weed, *Alliaria officinalis,* is an important and persistent element, but controlled annual burns do not appear to have caused its relative importance to have increased. Notable increases in the importance of moderately conservative, fall-blooming species such as *Helianthus strumosus* and *Solidago ulmifolia* are occurring in the burned tract, while little discernable, consistent change has occurred in the unburned tract. There are more species making up the top 50% of important species in the burned tract, with *Parthenocissus quinquefolia* remaining preemptively important and virtually unchanged in the unburned tract.

Light data taken along the two transects showed that in July, 1990, the mean light availability in the unburned tract was 480 footcandles, with a median availability of 320. In the burned tract, light availability was 1280 footcandles on the average, with a median value of 575. In full sun during the same period there were about 10000 footcandles.

DISCUSSION

If one were to regard regular increases in native biodiversity to be a positive trend in remnant plant communities, one could conclude that annual controlled burns may result in system improvement. The study has not shown, however, that over this five-year period fire suppression in a degraded woodland remnant has been measurably deleterious. In the burned tract, average quadrat quality has yet to show a change. We speculate that overall increases in the number of conservative species has not yet resulted in the degree of coalescence necessary to offset increases in non-conservative species which also proliferate when a system is opened to increased light levels. Swink & Wilhelm (1979) gave only 10% of the native flora, about 160 species, conservatism values from 0-3, so such species are far outnumbered potentially by more conservative species. Since the number of conservative species is increasing in the burned tract, it may be hypothesized that, if they continue to burgeon, their presence will be reflected in the data by increases in quadrat coefficients of conservatism.

Many studies, still in progress, as well as this one, have shown that the mean coefficient of conservatism can be a difficult datum in which to register change in remnant areas over short periods of time such as 5 years. In our experience in the Chicago region, natural areas usually have mean coefficients of conservatism ranging from 5-7 at the quadrat level, so it is clear that the Bur Reed Woods, with values ranging from 2.3-2.7, has a long way to go before it can be said to have reached natural area quality. Actually, the likelihood that such conservatism still exists anywhere within the wooded remnants of the Morton Arboretum is remote (Wilhelm 1991). It is probable that the most one could expect would be values stabilizing in the 3.3-3.7 range. Additional increases probably will require the introduction of chronically absent or locally extirpated conservative species. For the time being, it would seem that the benefits of controlled burning are still being realized. Continued monitoring will identify the point at which controlled burn management no longer mediates system improvement.

It is probable that the seasonal variations noted in the burned and unburned tracts are related to available light levels. In the unburned tracts, the floristic quality indices are similar to the burned tract in spring, when the leaves of the shrubs and canopy trees are absent or only just unfolding (Hutchison & Matt 1977). As the growing season progresses, the amount of available light is diminished more completely in the unburned tract. While the controlled burns have not had much effect on canopy trees, the coverage of the understory and shrub layer has been much reduced, allowing more light availability throughout the growing season.

While the controlled burns have not had much effect on canopy trees, the coverage of the understory and shrub layer has been much reduced, allowing more light availability throughout the growing season. The somewhat larger drops in floristic quality indices shown in the fall seasons of 1988 and 1991 for both the burned and unburned tracts might be related to summer drought periods during those years.

ACKNOWLEDGEMENTS

We are grateful to Christopher Whelan, of the Morton Arboretum, for providing us with the statistical analysis.

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Table 1. Comparisons of relative importance values from 1988 to 1992 in burned and unburned tracts of woodland at the Morton Arboretum. Values shown without brackets are in the top 50% of the relative values. Values shown in brackets are species which have appeared in one year or more years in the top 50%, but not in the year shown above. Non-native species are designated with an asterisk.

BURNED					
	1988	1989	1990	1991	1992
Alliaria officinalis *	13.0	8.7	12.4	8.8	9.4
Sanicula gregaria	8.4	10.1	5.0	5.2	7.9
Polygonatum canaliculatum	8.0	4.7	4.7	7.0	6.8
Helianthus strumosus	[0.7]	[1.4]	[1.7]	5.0	6.1
Eupatorium rugosum	6.8	6.4	8.0	5.7	6.1
Circaea quadrisulcata v. *canadensis*	7.3	7.1	8.0	6.9	5.9
Solidago ulmifolia	[0.6]	[0.3]	[1.4]	[2.8]	4.1
Smilacina racemosa	6.2	5.3	4.5	4.6	3.7
Smilax ecirrhata	[5.6]	[3.0]	4.0	4.7	[3.6]
Rubus occidentalis	[1.7]	[2.3]	[3.2]	4.5	[3.6]
Menispermum canadense	6.3	[4.3]	4.3	[3.3]	[1.8]
Parthenocissus quinquefolia	[4.4]	8.6	[2.0]	[2.1]	[1.0]
UNBURNED					
Parthenocissus quinquefolia	24.9	24.7	24.6	25.9	23.4
Alliaria officinalis *	18.2	11.6	11.4	11.9	14.7
Smilacina racemosa	8.0	7.4	6.8	6.6	8.1
Arisaema atrorubens	[0.8]	[3.1]	[3.1]	[1.9]	4.1
Geranium maculatum	----	[3.7]	[2.5]	5.2	[3.1]
Viburnum recognitum *	[2.9]	5.4	5.3	[2.4]	[2.6]
Circaea quadrisulcata v. *canadensis*	[3.6]	[4.0]	3.9	[4.3]	[1.8]

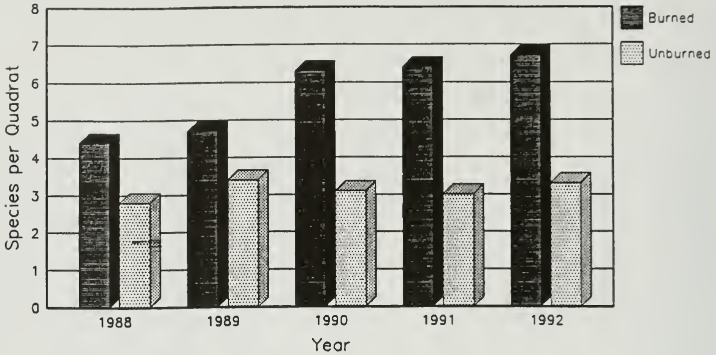

Figure 1. Number of native species per quadrat from 1988-1992, based upon averages of spring, summer, and fall in burned and unburned tracts.

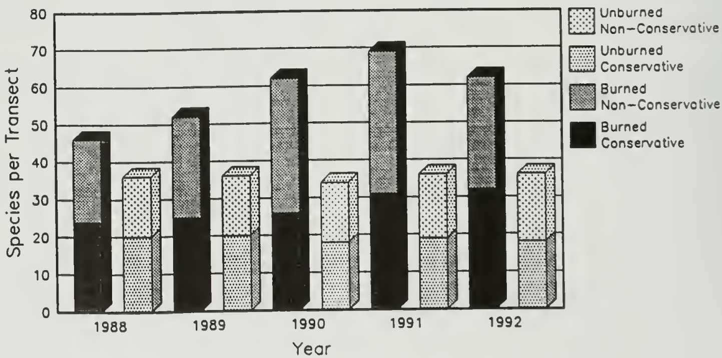

Figure 2. Total number of species per transect, showing the ratio between the number of conservative *versus* non-conservative species in burned and unburned tracts over five years.

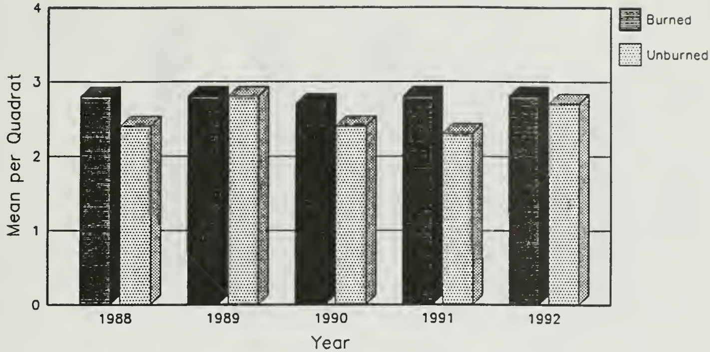

Figure 3. Mean coefficient of conservatism per quadrat from 1988-1992, based upon averages of spring, summer, and fall in burned and unburned tracts.

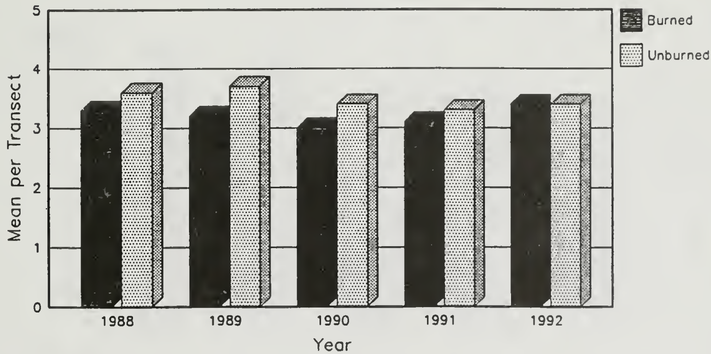

Figure 4. Mean coefficient of conservatism per transect from 1988-1992, based upon averages of spring, summer, and fall in burned and unburned tracts.

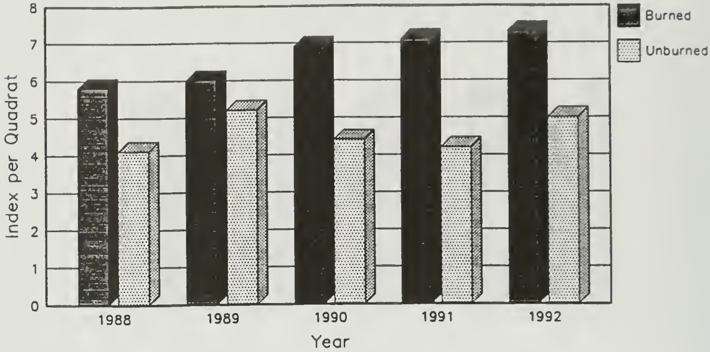

Figure 5. Floristic quality index per quadrat from 1988-1992, based upon averages of spring, summer, and fall in burned and unburned tracts.

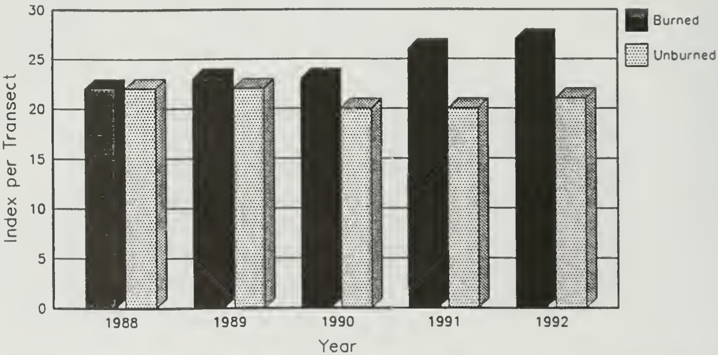

Figure 6. Floristic quality index per transect from 1988-1992, based upon averages of spring, summer, and fall in burned and unburned tracts.

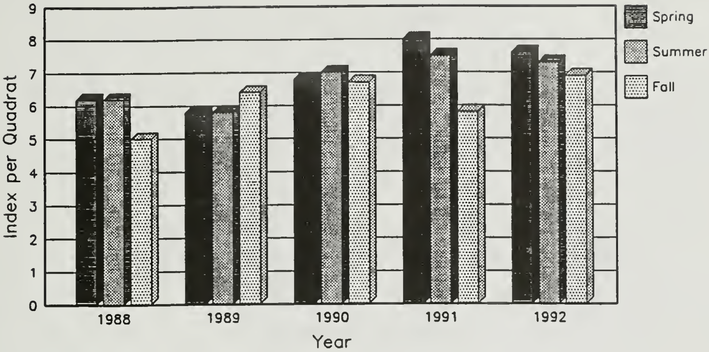

Figure 7. Floristic quality index per seasonal transect from 1988-1992 in the burned tract.

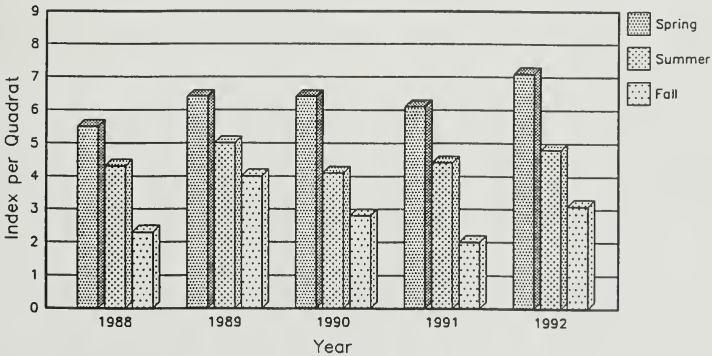

Figure 8. Floristic quality index per seasonal transect from 1988-1992 in the unburned tract.

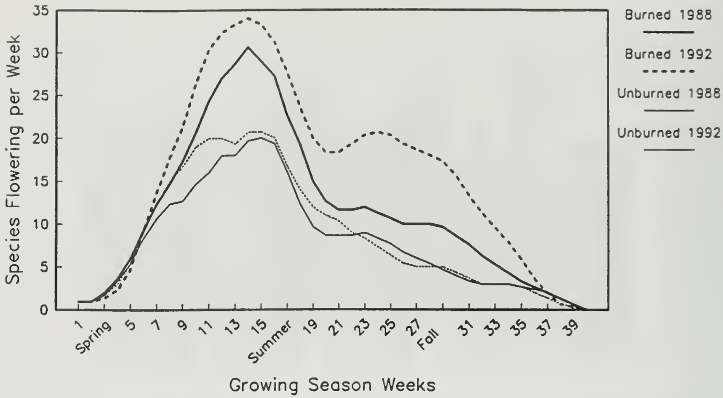

Figure 9. Changes in the number of species in bloom during any given week of the growing season, 1988 *versus* 1992.

Abstracts of Other Papers Presented

The Forest Stewardship Program in Illinois

Gary L. Rolfe and Stephanie S. Brown, Department of Forestry, University of Illinois

The Forest Stewardship Program offers technical assistance to qualified non-industrial private forest owners who agree to follow a state-approved forest stewardship plan for their property. This new federal program also provides funding support to each state for educational projects that promote the forest stewardship concept and increase program awareness and participation. Illinois has a diversity of new and innovative projects including a stewardship magazine, a third grade educational kit and a landowners stewardship program based on a comprehensive landowners guide and in service workshops.

Diseases of Illinois Forests

H. Walker Kirby, Department of Plant Pathology, University of Illinois

This talk will focus on major and minor forest diseases and disorders throughout Illinois. Emphasis will be on all factors which influence diseases and disorders including weather, choice of tree species, planting site, and related management activities. Identification of major problems and management activities to lessen the impact for both the short term and the long term will also be addressed.

Wild Flowers of Illinois Forests

Floyd Swink, The Morton Arboretum

In this talk, a survey will be made of the principal herbaceous plants associated with the forest communities of Illinois.

State and Federal Programs to Assist Forest Management and Stewardship

R. Daniel Schmoker, Division of Forest Resources, Illinois Department of Conservation

Presentation will include description of technical services, advice and plans to landowners. Also included will be descriptions of the cost share programs available to help landowners carry out forest management practices. Included programs: Illinois Forestry Development Act, Agricultural Conservation Program, Forestry Incentives Program and the Stewardship Incentives Program.

Diversity and Management of Forest Communities in the Shawnee National Forest

Lawrence R. Stritch, Shawnee/Wayne-Hoosier National Forests, U.S.D.A. Forest Service

Encompassing in excess of 267,000 acres, the Shawnee National Forest contains a rich and unique diversity of forest and woodland natural communities. The Shawnee National Forest is divided into five distinctly different natural divisions: Shawnee Hills, Coastal Plain, Lower Mississippi River Bottomlands, Wabash Border, and Ozark Hills. Forest natural communities range from the true swamps of the Coastal Plain to xeric pygmy oak woodlands of the Shawnee Hills. This paper will present an overview of the vegetation and structure of these natural communities and management strategies that are being developed and implemented to restore these remnants of our natural national heritage.

Structure and Function of Illinois Forested Wetlands Under Disturbed Hydrologic Regimes

Sandra L. Brown, Department of Forestry, University of Illinois

Many of the forested wetlands in southern Illinois have been subject to alterations in their hydrologic regime. The effects of these alterations on the composition, regeneration and growth rates of several wetland forests in Illinois were measured. In altered stands, growth rates were significantly lower regardless of tree age than unaltered areas, and recruitment of dominant species was practically non-existent. However, the magnitude of these changes was different for different tree species. Changes in sedimentation patterns and mean high and low water depth and duration were important in explaining these trends.

The Challenge: Biography of Illinois

Jon Duerr, Kane County Forest Preserve District and Past President, Illinois Native Plant Society

The diversity of plants in Illinois is related to all of the physical and cultural influences present. The physical features are created by historical events and processes. Not only in the State over 500 miles from north to south, but the exposed land forms range from a few thousand years to well over ten million years in age. The challenge is to relate and map this diversity. I am challenging you to look closely at your home area--your favorite nature area--your drive to work. Where are the plants growing? Examples: *Quercus muhlenbergii* is found at four sites in Kane County and numerous locations in Kendall, all along the Fox River. *Crataegus pruinosa* is scattered in northern Kane County, *Crataegus macrosperma* in very northern Kane County, while *Aralia nudicaulis* occurs at four sites in northern Kane County. A closer look at these species shows a definite pattern in Kane County. *Aralia nudicaulis*, a very common plant in central and northern Wisconsin, is only found behind (north) of a sublobe of the Wisconsin glaciation. *Crataegus macrosperma* is only behind the same sublobe and only on well drained soils. *Crataegus pruinosa* is scattered, but a closer look reveals it only on sandy soils. I am asking you to record your finding by longitude and latitude and Township Section from USGS maps. A committee of the Society is planning a means to record these data. We do not have to only deal with rare species. The changing landscape calls for us to know all of our native species. This is a program in which we can all become involved.

Cultivating a Land Ethic: Who are the Stewards of Illinois Forests?

Timothy D. Marty, Department of Forestry, University of Illinois

Forest stewardship in Illinois is influenced by many factors including land ownership. Over ninety percent of the forestland in the state is owned by private landowners who possess a great diversity of individual attitudes and circumstances. Efforts to improve forest stewardship can be enhanced by more fully understanding those who make land management decisions. Recent surveys of forest landowners in Illinois provide information useful for guiding forest stewardship activities.

Deer in Illinois Forests

Todd Strole, Division of Natural Heritage, Illinois Department of Conservation

A brief history of the Illinois deer herd during the past 100 years will be presented, as well as current populations parameters and herd densities for white-tailed deer in Illinois. A general review of current literature and knowledge concerned with large herbivores browsing will include topics such as: the effects of browsing on forest communities, selective browsing, and forest recovery. The implications this knowledge has on our management strategies from a community ecology perspective is far reaching.

Upland Forests of Central Illinois: Past and Present

Roger C. Anderson, Department of Biological Sciences, Illinois State University

Central Illinois upland forests range from xeric communities occurring on deep sand deposits along the Illinois River, dominated by black and blackjack oak, and black hickory, to forests dominated by shade-tolerant mesophytes on sites with silt loam soils. On finer textured soils, forests segregate on the basis of topography, and include dry-mesic communities dominated by black and white oak on exposed upper slopes grading into mixed oak-hickory, elm, ash dominated forests on gentle slopes and level topography to sugar maple, elm, black walnut, and red oak dominated forests in sheltered locations. Historically, periodic fires maintained open canopies in these forests and encouraged oak regeneration. Because of canopy closure, oak reproduction has been markedly reduced and tree species diversity is markedly declining.

The Presettlement, Present, and Future Forests of the Shawnee and Ozark Hills Regions of Illinois: Management Implications

James S. Fralish, Department of Forestry, Southern Illinois University

Witness-tree data from the 1806-7 original land survey records were used to reconstruct presettlement forest community landscape patterns. Section and quarter-section corners were located on topographic maps and categorized by aspect and slope position. Six site types were recognized: rocky south slope, south slope, ridgetop, high north slope, low north slope and stream terrace. Species importance values and community basal area, average diameter and density were calculated for each type.

The Shawnee Hills region is characterized by massive sandstone bedrock, a thin loess cap which often contains a fragipan, and gently to moderately rolling topography. In the Ozark Hills region, the fractured limestone bedrock is covered by a deep loess cap on the ridges; the valleys have steep slopes and are relatively narrow and deep. The Ozark Hills is situated along the east bank of the Mississippi River which protected the area from eastward moving wildfire; the Shawnee Hills has no natural firebreak.

Data on relatively undisturbed, compositionally-stable (henceforth called "old growth") and disturbed second-growth forest communities were obtained from about 275 circular 0.04-ha plots in the Shawnee Hills and 92 circular 0.01-ha plots in the Ozark Hills. Sapling (0.004 ha) and seedling (0.003 ha) plots were nested within the larger tree plots. Relative basal area and relative density were used as an importance value for trees and saplings/seedlings, respectively.

In the Ozark Hills region, white and black oak were found to be the dominant species on mid to upper south and north slopes and ridgetops; American beech, sugar maple and white oak dominated the community of low slopes and alluvial sites. No land survey corners were located on rocky south sites that presently are dominated by post oak. On five of six site types, oak and hickory were found to have higher importance values in the present forest than in the presettlement forest. However, the sapling and seedling stratum of the present forest on all sites was dominated by sugar maple, American beech and other mesophytic species.

In the drier Shawnee Hills region, post oak was the dominant species on the south rocky sites; white oak was the dominant species on all other site types including stream terraces. This pattern suggests that fire was either more severe or frequent since only one or two maples were recorded in a sample of over 600 witness trees. The old-growth and second-growth communities on rocky south, south and ridgetop sites have a composition similar to that of the presettlement community. On high and low north slopes and stream terraces, the second-growth community is similar to that of presettlement community while the old-growth community is primarily dominated by sugar maple.

The eventual development of a forest composed of sugar maple, beech, ash, and other mesophytes accompanied by a mid canopy of flowering dogwood, ironwood and pawpaw is expected to have a long term effect on forest diversity. First, there will be a systematic loss of oak and hickory with the next forest (perhaps 50 to 70 years away). Second, the multilayer canopy of the mesophytic forest will reduce the amount of light reaching the forest floor with a resulting loss of herbaceous species. Finally, the loss of herbaceous plants with its associated insect herbivores and pollinators will likely impact neotropical migrant birds. These relationships suggest that over protection which permits the completion of succession to sugar maple will substantially reduce biodiversity and be substantially more detrimental to the integrity of the forest ecosystem than timber harvesting.

Illinois Savannas: Past and Present

Victoria Nuzzo, Native Landscapes, Natural Areas Consultants

At the time of settlement, oak savanna covered some 11,000,000 to 13,000,000 hectares in the Midwest. Presettlement aspect ranged from brush prairie (oaks hidden by prairie vegetation) to scrub savanna (dense oak sprouts overtopping a prairie matrix), to open savanna (widely spaced oaks above prairie), to closed savanna (closely spaced oaks above prairie and/or forest herbaceous vegetation). Present day management for oak savanna is influenced by the existing structure of the community, presence of alien species, and condition of overstory oaks. Management options include prescribed burning, selective removal of understory vegetation, and introduction of native ground layer species. Oak savannas that have succeeded to oak forests may be difficult to restore to presettlement structure.

Poster Session Abstracts

Relation Between Bark Properties and Fire Tolerance of Central Hardwood Tree Species

Gretel E. Hengst and Jeffrey O. Dawson, Department of Forestry, University of Illinois

Increased use of fire as a silviculture management tool in central hardwood forests has prompted a study to determine, in selected species, the protective properties of bark in relation to fire resistance. Measurements of stem diameter and bark thickness were made for several upland and bottomland species to determine the relationship of the two measures across several age and size categories, bark thickness being a widely accepted indicator of fire tolerance. Moisture content, density, dry weight, ignition point, and volatile constituents within the bark were determined as well. Simulated fires conducted in the field provided information about heat flux and maximal cambial temperatures. This combination of data allowed study of heat transfer through bark tissue relative to external and internal bark components and characteristics.

Floristic Surveys on the Shawnee National Forest

Jody P. Shimp and Elizabeth L. Shimp, U.S.D.A. Forest Service, Shawnee National Forest

The Ecosystems Management Unit of the Shawnee National Forest is currently conducting floristic surveys forest-wide. The Botany Program, established in 1989, employs 2 full-time and 1 half-time botanists. In addition, the program also includes botanists employed on a temporary basis, student interns, and volunteers. Surveys have been initiated to locate and identify areas with special vegetation, unique communities, and potential restoration or management needs. Within the last year, over 50 new sites with Illinois endangered and threatened plants have been located and numerous county records documented. During floristic surveys, voucher collections are taken, mounted, information entered into the Forest Service's computer database, and then the specimens are deposited at the Illinois Natural History Survey herbarium. This poster presentation outlines and describes the

survey process from the onset of field date collection to implementation of management.

Monitoring and Status of Endangered and Threatened Plant Species in the Shawnee National Forest

Elizabeth L. Shimp, U.S.D.A. Forest Service, Shawnee National Forest

There are approximately 130 Illinois endangered and threatened plant species that have potential to occur on the Shawnee National Forest. Of these species, 75% are extant on the Forest. As part of the ecosystem management strategy, the Forest Service is actively searching for these species in order to protect and manage the communities in which they exist. In cooperation with the Illinois Department of Conservation, The Morton Arboretum, Southern Illinois University, and other institutions, we have selected and applied methods of monitoring to a number of listed species. Some of the species being monitored on the forest and discussed in this poster presentation include: *Armoracia aquatica*, *Asclepias meadii*, *Botrychium biternatum*, *Calamagrostis porteri* var. *insperata*, *Cimicifuga rubifolia*, *Lilium superbum*, *Matelea obliqua*, *Pinus echinata*, *Plantago cordata*, *Rhododendron prinophyllum*, and *Rhynchospora glomerata*.

Guidelines for Manuscripts Submitted to *Erigenia* for Publication

Manuscripts pertaining to the native flora of Illinois and adjacent states, natural areas, gardening/landscaping with native plants, new distribution records, threats to native species, and related topics are accepted for publication. At least one author must be a member of the Illinois Native Plant Society, otherwise a $25.00 fee will be charged. Non-technical papers from the membership are encouraged. Authors will be charged $15.00 per printed page to help defray the costs of publication. Black and white photos are also accepted. Cost of each photo to the author is $20.00. These charges may be waived upon written request to the editor. Book reviews and art work will be published at no charge when space permits.

Manuscripts submitted to *Erigenia* for publication should be double-spaced throughout except for Literature Cited or References. Three copies must be submitted; photo copies of original manuscripts are acceptable during the review process. Pages should be numbered, and tables and figures should be numbered consecutively. Longer articles should follow as much as possible this general format: abstract, introduction, materials and methods, results, discussion, summary, acknowledgments, and literature cited. Titles of journals should be spelled out completely. The style for citing literature is that of the most recent issue of *Erigenia* (excluding *Erigenia* 13). All measurements should be expressed in metric units with English equivalents when appropriate.

Each manuscript received will be reviewed by three or more members of the editorial board or outside reviewers. After review, authors will be notified of the acceptance or rejection of manuscripts. Accepted articles will be returned to authors for revision. *Erigenia* is prepared on a Personal Computer using WordPerfect 5.1 and 6.0. If a manuscript is prepared on a word processor, the editor will furnish the author with basic instructions to simplify program conversions.

Manuscripts and inquiries should be sent to:

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Note from the Editor regarding *Erigenia* 13

Erigenia 13 did not go through the normal editorial process as described above due to the nature of its contents. A special editorial committee was appointed to review the submitted manuscripts following the conference. The members of the committee were Jeffrey O. Dawson, John E. Ebinger, Kenneth R. Robertson, and myself. Due to time constraints, many of the manuscripts were reviewed by only one or two committee members. For the most part, the contents of the manuscripts were left intact to reflect the essence of the talks presented at the Illinois Forest Conference. In addition to the submitted papers, we have also included in this issue the original conference schedule, abstracts for papers which were not submitted, and poster session abstracts. We thank everyone that was involved in making the conference a success.

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(Contents continued)

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