

ERIGENIA

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ERIGENIA

Number 18, October 2000

The Illinois Native Plant Society Journal

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

ERIGENIA is named for *Erigenia bulbosa* (Michx.) Nutt. (harbinger of spring), one of our earliest blooming woodland plants. The first issue was published in August 1982.

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COVER ILLUSTRATION

Original drawing by Nancy Hart Steiber of the Morton Arboretum, Lisle, Illinois.

Nancy crossed the border to visit our neighbor to the east when she visited Pinhook Bog to draw these plants:

Cypripedium acaule moccasin flower
Sarracenia purpurea pitcher plant
Drosera intermedia narrow-leaved sundew

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This issue of *Erigenia* is dedicated to the memory of Floyd Swink (May 18, 1921 to August 2, 2000), beloved teacher and colleague of many INPS members, and a staff member of this journal. Editors, authors, and readers alike were the beneficiaries of Floyd's tireless verification of bibliographic material, nomenclature, and plant record documentation. All who knew him were infected by his generous spirit and love of life. Our deep sense of loss at Floyd's passing is accompanied by the knowledge that his inspiration and influence will continue to be felt as long as there is a natural world to engage our minds, delight our senses, and awaken our wonder.

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THE CORRESPONDENCE OF SOIL TYPES WITH PLANT COMMUNITY TYPES IN NATURAL AREAS OF COOK COUNTY, ILLINOIS

Thomas B. Simpson¹ and Christiane Rey¹

ABSTRACT: Soil surveys often are used by ecological restoration managers to infer the nature of pre-European vegetation. This study examined the correlation of current vegetation types with soil series at 145 locations in 32 forest preserves and other natural areas in Cook County, Illinois. The objectives of the study were to establish the association of soil series types with plant community types and to evaluate the accuracy of NRCS soil survey mapping in natural areas. Mapped series were judged to be incorrect if there were major differences between the type profile in the soil survey and the field description based on (1) A horizon depth, (2) presence or absence of the E horizon, (3) texture, (4) pH of the upper 50 cm, and (5) soil drainage class. The mapped soil series assignment was judged incorrect for 50.5% of the plots. The criteria that were most commonly in "error" were presence/absence of an E horizon (30.0% of plots) and depth of the A horizon (19.6%). Dry-mesic woodland (6 soil series), mesic woodland (8 soil series), dry-mesic savanna (5 soil series), and mesic savanna (6 soil series) have the most diverse soil associates. The ability to predict community type from a knowledge of mapped soil series is very limited.

INTRODUCTION

The importance of vegetation as a soil-forming factor long has been recognized, and modern soil classification (USDA 1975; Buol, Hole, and McCracken 1973) associates certain soil orders with particular vegetation types, including the two most common soil orders of upland areas in the Chicago region: Mollisol (grassland) and Alfisol (forest). Birkeland (1984) noted that the distinction between forest and prairie vegetation is reflected in changes in pH, the depth and content of soil organic matter, and translocation of clay. "Forest" soils are more acid and lower in clay content in the upper solum and have thinner A horizons than do "prairie soils." Miles (1985) reviewed the effects on soil development of coniferous forest, deciduous forest, and herbaceous species in Europe, noting that podzolization (acidification and leaching of carbonates, iron, aluminum, and organic matter from the surface to lower soil zones) was most rapid beneath coniferous forest, and least likely to occur in association with herbaceous-dominated vegetation. The effects of broadleaf forests on podzolization were variable, depending on the dominant tree species.

In the descriptions of soil series included within county soil survey publications of the Natural Resource Conservation Service (formerly the Soil Conservation Service), broad categories of native vegetation may be associated with each series, e.g., swamp grass, deciduous forest, or prairie grass (USDA 1970). In other cases (USDA 1979), associations of soil and natural vegetation are not stated (e.g., Lorenzo, Harpster, Watscka, Milford, Sawmill) or only indirectly implied:

Morley: "... most areas are wooded or pastured. . ."; and "A few areas of this soil are in native hardwoods, mainly northern red oak, bitternut hickory, and sugar maple."

Blount: "The areas that remain in trees contain northern hardwoods, chiefly oak and hickory."

Miami: "Many areas are idle or in trees."

Knowledge of pre-European settlement vegetation is important in evaluating the goals of ecological restoration management. In a state (Illinois) where only 0.45% of the land remains in a relatively undisturbed natural state, often extant vegetation has little floristic similarity to the pre-European settlement vegetation of the site. In such cases, the use of soil as an aid in determining pre-European vegetation takes on a special importance, especially where restorationists seek to reestablish or restore presettlement vegetation types.

Studies of soil-vegetation associations at a large scale have often found soil or surficial geologic mapping to be a good predictor of vegetation. Iverson (1988) found that soil and site-attribute data derived from a statewide map of soil associations were highly correlated with the historic vegetation of Illinois. Whitney (1986) studied the presettlement distribution of pine forests in relation to substrate, as depicted on surficial geologic maps, in Roscommon and Crawford counties in lower Michigan, and reported that coarse-textured soils derived from outwash and ice-contact deposits promoted a fire-dependent vegetation of Jack pine (*Pinus banksiana*), red pine (*Pinus resinosa*) and white pine (*Pinus strobus*). Grimm (1984) found that soil drainage as depicted on soil maps

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was the most important factor controlling vegetation within areas of similar fire probability in the Big Woods of Minnesota.

Field studies of soil-vegetation association have found soil properties rather than soil map units the better predictor of vegetation type. For instance, Neiman (1988) noted little relationship among habitat types (plant associations) in northern Idaho and soil taxonomic map units. Using information from 89 sites for which vegetation and soils data were recorded, however, Neiman (1988) found 14 soil variables, most related to texture and pH, that were useful in discriminating among the soils of habitat types.

Several studies have examined the accuracy of soil mapping. Powell and Springer (1965) found that between 10% and 40% of the soil map units of Cecil, Appling, and Lloyd soil series on the Georgia Piedmont were soils (inclusions) other than the stated map-unit type. McCormack and Wilding (1969) found that 63% of the field observations of two-storied (coarse- to medium-textured lake sediments over fine-textured glacial till) soils on the lake plain of northwestern Ohio were outside of the concepts of the soil series for that soil map unit. Grigal (1984) noted that soil mappers must rely on visual criteria—landscape boundaries obvious to visual inspection. Major problems arise when the ability to view terrain decreases in forested landscapes, and this problem is compounded by ambitious production schedules. Grigal (1984) felt that with so many problems in achieving accuracy in map unit delineation in forested landscapes, soil surveys should be conducted at 1:50,000 or 1:75,000 rather than the customary 1:15,840. At this scale, managers "will treat it [the soil survey] with the degree of uncertainty it merits" (Grigal 1984).

Classification of soil or plant communities is useful to people because it reduces the complexity of nature. Dozens to hundreds of species or characteristics are reduced to a few classes, which can more easily be remembered and manipulated in the mind. However, this reduction of complexity comes with an attendant loss of information. Because the soils and plant communities of a region are subject to endless variation in dozens to hundreds of characteristics, often with only loose functional relationships among them, any attempt to classify the plant communities and soils of a county into a manageable small number of classes can meet with only limited success. The choice of technique for reducing complexity, whether qualitative judgment or mathematical algorithm, is ultimately subjective.

For instance, plant communities contain exotic species, native adventives, and native species commonly thought to represent the area's presettlement composition. The last

group are often weighted disproportionately in classifying the community (and are in this study), but the choice to do so is subjective, based on a knowledge of recent historical influences and a desire to erase such influences in our conception of native plant communities. If two researchers differ in their models of presettlement vegetation or postsettlement vegetative change, they may classify the vegetation of a given area differently. The decision to weight all extant species equally eliminates these errors of historical judgment, but creates a taxonomy of disturbances confounded with underlying ecological and historical (presettlement) influences, which may be worth little for most management purposes.

Soil classification also works with many variables, and weights them according to the expert's knowledge of soil genesis and the intended use of the classification. Guthrie (1982) and Gibbons (1961) make the point that, prior to classification and mapping, the soil surveyor must determine what it is that the intended users of the survey need to know about the distribution of soils. A general purpose survey—one equally serviceable for all users of soil information—is not possible, because the criteria appropriate to one set of uses differs from those appropriate to another set of uses (Gibbons 1961). Grigal (1984) pointed out that the criteria for soil classification often are not those of greatest significance to the growth of vegetation. Soil classification has seen its most important economic use in agriculture, and the accurate classification of soil productivity and management potential were important purposes. For instance, the difference between 7.5 cm and 15 cm A horizon depth or the presence of an E horizon may be very significant in making judgments about pre-European settlement vegetation. Yet if the soil is plowed, planted, and fertilized for decades, the difference in soil morphology and productivity disappears. A soil classification intended for agriculture will weight soil factors differently than one devised for ecological restoration.

This discussion of the difficulties of classification should not obscure the fact that classification is both universal and necessary as humans conceive of a complex natural world. These conceptions guide our judgments and actions. To present and discuss openly our classifications or to look for relationships among them is a necessary step to improving them.

Critics of ecological restoration activities (such as cutting "overstocked" small trees and shrubs, using prescribed fire, and reintroducing native herbaceous plants) at certain Cook County forest preserves have cited soil types as evidence that restoration management goals were inappropriate (Mendelson, Aultz, and Mendelson 1992). At the present time, no research exists to confirm

or reject such statements. The objectives of this study were to establish the correlation of soil series types with plant community types (both the nature of this association and its predictive potential), to evaluate the accuracy of NRCS soil survey mapping in natural areas, and to describe quantitatively the associations.

METHODS

Soil Types and Community Types

Soil types used here follow the soil series classification recognized by the NRCS (USDA 1979). Plant community types follow those of Thomas (1998). Thomas presents a classification of natural plant communities based on relatively high quality remnant examples. It represents a modification of White (1978) and Curtis (1959). Thomas uses the physical environment of vegetation to describe plant communities. The classification of uplands is structured along gradients in plant community physiognomy (prairie, savanna, woodland, forest) and hydrology (xeric, dry-mesic, mesic, wet-mesic, wet). Communities were further differentiated by variation in soil parent material (sand, gravel, glacial till, bedrock). The classification of wetlands is based largely on hydrology (water source, seasonality, and chemistry), e.g., panne, streamside marsh, seep, sand seep, calcareous seep; vegetation, e.g., sedge meadow, shrub swamp; or a combination, e.g., graminoid fen, basin marsh (the word marsh implying dominance of herbaceous vegetation). In addition, the classification has "cultural area" units defined by recent human management or mismanagement (reforestation, unassociated woody growth, and Eurasian meadow). Thomas produced descriptions of community types by matching field plot data to the appropriate community types. The resulting descriptions are detailed, but are examples of extant vegetation in that type, rather than a definition of class boundaries.

Collection of Field Data

The purpose of data collection was to represent as many examples of as many different types of plant communities and soil series as was practical. Study sites in forest preserves and other natural areas were selected using three criteria: (1) good geographic coverage of Cook County, (2) good representation of the soil associations common to Cook County, and (3) a wide range of vegetation types. These criteria were assessed from existing maps and other information. A total of 145 plots at 32 forest preserves and other natural areas were sampled (table 1).

In areas of forest, woodland, or savanna vegetation, the presence of large (>50 cm dbh) individuals of oak or sugar maple was used as a criterion to identify areas whose

present overstory dominants are likely related to pre-European settlement overstory composition. In prairies, the abundance of native plants with a coefficient of conservatism (Swink and Wilhelm 1994) of ≥ 4 was used to exclude sites in which excessive postsettlement disturbance has produced a ground flora unrelated to its presettlement character. In addition, evidence in the soil profile of former plowing, grading, or filling was used to exclude the site. Any method of site exclusion or acceptance based on examination of the vegetation is subject to errors stemming from biases in one's conception of the nature of presettlement vegetation. By staying within the commonly accepted definitions of vegetative quality and disturbance, we sought to minimize these errors. Old trees of species similar to those commonly reported in General Land Office Surveys of the early nineteenth century, the presence of plant species known to disappear with severe postsettlement disturbance, and lack of evidence for extreme soil disturbance were reasonable criteria for site selection.

Sample plots were located randomly within areas of relatively uniform vegetation and topography. An effort was made to sample within all common soil series (as depicted on the soil survey map) in an area, wherever suitable vegetation was found. The following data were collected: GPS lat/long, location, mapped soil series, complete soil description to a depth of 75 cm, soil samples for pH, texture, and organic matter analysis (A horizon at 5 cm, E horizon at 15–25 cm, B horizon at 50 cm), landform class, and landscape position. Percent slope was measured in four directions—downslope, upslope, and to the right and left, the four measurements at right angles to one another. Slopes below the horizontal were recorded as negative (-), and slopes above the horizontal were recorded as positive (+). The sum of the four slope readings measured slope shape. According to this method, a planar slope, regardless of inclination, has a slope shape of zero. A concave site has a positive slope shape, and a convex site has a negative slope shape. The average of the absolute values of the upslope and downslope readings measured slope steepness.

Overstory trees (≥ 10 cm dbh) were sampled using a 3 m²/ha prism. Counts by species in 100 m² plots were recorded for understorey trees and shrubs (woody plants <10 cm dbh and >1 m tall). Cover of ground flora (woody plants less than 1 m tall and all herbs) were recorded in the same 100 m² plot. Cover classes used were dominant (>50% cover), subdominant (5–50%), associate (0.1–5%), or rare (<0.1%).

Understorey and ground flora were recorded in the above manner only for prairie and wetland community types. The present ground flora communities in most

Table 1. Location, total number of plots, and plant communities sampled for Cook County forest preserves (FP), nature preserves (NP), and other natural areas

Site	Location	No. of plots	Plant community types
Bemis Woods FPs, N & S	Sec 31, T39N, R12E	10	savanna (mesic), woodland (dry-mesic, mesic, wet-mesic), open vernal pond
Black Partridge Woods NP	Sec 19, T37N, R11E	3	woodland (dry-mesic, mesic)
Bluff Springs Fen NP	Sec 19 & 30, T41N, R9E	10	savanna (dry-mesic), prairie (dry gravel), gramminoid fen, calcareous seep
Brookfield Woods Prairie FP	Sec 26, T39N, R12E	2	prairie (wet), sedge meadow
Busse Forest NP	Sec 16 & 17, T41N, R11E	10	forest (mesic upland), woodland (dry-mesic, mesic, wooded vernal pond), savanna (mesic), shrub swamp
Chippilly FP	Sec 11, T42N, R12E	8	forest (wet-mesic floodplain), woodland (dry-mesic, mesic), savanna (dry-mesic)
Clayton Smith FP	T41N, R13E*	2	woodland (wet-mesic sand)
Cranberry Slough NP	Sec 9, T37N, R12E	1	sedge meadow
Edgebrook Flatwoods FP	T41N/ R13E1*	5	forest (wet floodplain), woodland (dry-mesic, mesic, wet-mesic sand)
Elizabeth A. Conkey FP	Sec 5, T36N, R13E & Sec 32, T37N, R13E	10	woodland (dry-mesic, mesic), savanna (dry-mesic, mesic)
Harms Woods and H. Flatwoods FPs	Sec 8 & 9, T41N, R13E	8	forest (mesic), woodland (mesic, wet-mesic)
Hidden Pond FP	Sec 3, T37N, R12E	6	woodland (dry-mesic, mesic), prairie (dry-mesic, mesic)
Jurgensen Woods NP	Sec 2, T35N, R14E	1	prairie (wet-mesic acid sand)
McCormick Woods FP	Sec 26, T39N, R12E	1	woodland (dry-mesic)
McMahon Woods FP	Sec 16, T37N, R12E	2	sedge meadow, seep
National Grove FP	Sec 26, T39N, R12E	1	forest (mesic)
Oakton Community College Woods	Sec 9, T41N, R12E	2	forest (mesic)
Paw Paw Woods NP	Sec 5, T37N, R12E	7	forest (mesic, wet-mesic floodplain), woodland (dry-mesic)
Poplar Creek FP	Sec 9 & 10, T41N, R9E	4	woodland (dry-mesic), savanna (dry-mesic, mesic)
Potawatomie Woods FP	Sec 18, T36N, R15E	3	woodland (dry-mesic, mesic), savanna (wet-mesic)
Sand Ridge NP	Sec 18, T36N/R15E	7	savanna (mesic, wet-mesic), prairie (mesic sand, wet-mesic sand, wet acid sand)
Schiller Woods FP	Sec 14, T40N, R12E	1	prairie (mesic gravel)
Shoe Factory Road Prairie NP	Sec 10, T41N, R9E	3	savanna (dry-mesic), prairie (dry gravel)
Somme Prairie NP	Sec 4, T42N, R12E	3	prairie (mesic, wet-mesic), sedge meadow
Spears Woods FP	Sec 4, T37N, R12E	2	basin marsh, streamside marsh
Spring Lake NP	Sec 5 & 6, T42N, R9E	4	savanna (dry-mesic)
Swallow Cliff Woods FP	Sec 21 & 28, T37N, R12E	6	woodland (dry-mesic, mesic), savanna (mesic)
Theodore Stone FP	Sec 21, T38N, R12E	5	savanna (dry-mesic), prairie (dry dolomite, mesic dolomite, wet-mesic dolomite)
Thatcher Woods FP	Sec 2, T39N, R12E	1	forest (wet-mesic floodplain)
Thomas Jefferson Woods FP	Sec 11, T39N, R12E	5	forest (wet floodplain), woodland (mesic)
Thornton-Lansing NP	Sec 35, T36N, R14E	7	woodland (wet-mesic sand), savanna (dry-mesic acid sand), prairie (dry sand, mesic sand, wet acid sand)
Wolf Road Prairie NP	Sec 30, T39 R, R12E	5	prairie (dry-mesic, mesic, wet), sedge meadow, streamside marsh

* Indian Boundary Exclusion, no section number.

Note: All township and range locations are associated with the 3rd Principal Meridian.

wooded ecosystems are largely a product of farm era and recent influences. The warm-season flora in these communities is usually absent because of the shade caused by an understory of native and exotic trees and shrubs that have filled in below and among the oaks. Usually (except for the few remaining high quality oak woodlands or savannas), the present flora is not reliably indicative of

presettlement community composition. By contrast, the majority of larger oaks and hickories are 140–170 years old and represent the first-generation progeny of the presettlement overstory. Therefore, we felt that performing a ground flora sample in each woodland site was not time well spent. The time saved resulted in more plots sampled in the total study.

Laboratory Analyses

Texture analysis in the laboratory was conducted using the hydrometer method (McKeague 1978). Soil pH was determined in deionized water (Soil and Plant Analysis Council 1992), equal parts air-dried soil and deionized water. Organic matter content was determined by the loss-on-ignition method (Soil and Plant Analysis Council 1992). All analyses were conducted in the Department of Earth Science laboratory at Northeastern Illinois University.

DATA ANALYSIS

All sample plots were placed in a given plant community type by comparing the common species of that observation and its vegetative context to descriptive data provided by Thomas (1998). The name of the mapped soil series was recorded for all sample locations that occurred within the area of Cook County for which local soil maps exist. Much of the more urbanized portion of Cook County and many natural areas in the immediate vicinity were never mapped to the soil series level. To evaluate the accuracy of soil mapping, field profile descriptions and lab results were compared to the type description in the soil survey. Five criteria were used, and the soil series was judged incorrect for any of the following reasons.

1. The A horizon depth was more than 10 cm different from that of the type profile description given in USDA (1979), or 50% deeper or shallower than the type profile if the A horizon depth (of the type profile) was greater than 20 cm.
2. The field profile description differed from the type profile in terms of the presence or absence of the E horizon.
3. The texture classes of the upper 50 cm of the field profile description were markedly different from the type profile description. This difference was arbitrarily defined as the failure to differentiate accurately soils with silty and clayey textures (silty clay loam, silt loam, silty clay) from those with sandy textures (sandy loam, loamy sand, sand).
4. The pH of the upper 50 cm of the field profile description was markedly different from the type description. The type profile of the soil series was judged to be in error if it failed to accurately differentiate between field profiles with alkaline pHs (>7.0) and those with slightly acid to extremely acid upper solums. Either alkaline or acid pH measurements were considered to be not in disagreement with a type profile description that noted neutral pHs for the upper horizons.
5. The soil drainage class assigned to the field profile description was two or more soil drainage classes different from the type description.

These five criteria are important features of soil formation and important limiting environmental factors governing the distribution of plants. The dominant vegetation of an area—grassland or forest—influences soil properties of A horizon depth, presence or absence of the E horizon, and soil reaction (acid vs. alkaline). From the viewpoint of ecological restoration, these criteria have meaning in terms of the vegetative history of the site and its management potential. If the field soil profile description differed from the type profile description of the map unit (USDA 1979) and more closely resembled the type profile description of another series, it was assigned by the authors to the series it most closely resembled.

RESULTS

Soil Classification and Mapping

Data were recorded on a total of 105 plots in areas that had been mapped by the USDA soil survey and for 40 plots that were placed in unmapped areas. Eighty-two (79%) of the 105 plots were assigned by the authors to a soil other than the series of the map unit, in order to fit the field profile description more accurately. By contrast, the five criteria represented a more conservative method. Only 53 (50.5%) of the plots were judged to be incorrect, based on at least one of the five criteria. Criteria that were most commonly in "error" were presence or absence of an E horizon (30.0% error) and depth of the A horizon (19.6% error). Soil texture (13.1% error), pH (8.4% error), and drainage class (7.5% error) were less often in error.

Both A horizon depth and presence or absence of an E horizon are strongly influenced by historic vegetation. The depth of the A horizon (19.6% error rate) is strongly influenced by vegetation and, in particular, the difference between the more fibrous root systems of grasses and the coarser root systems of trees. The presence of an E horizon is a function of leaching, the rate of leaching being strongly influenced by the cycling of cations and organic acid deposition by vegetation.

In soil mapping, the mapper recognizes soil classes, determines the key properties associated with the classes, and looks for landscape boundaries that coincide with class limits (Guthrie 1982). Information from a small number of field samples must be extrapolated to infer the relationship between landscape boundaries and soil classes. The occurrence of soil type X on landscape position Y provides the basis for mapping soil type X on all other "similar" landscape positions. Aerial photography and topographic and geologic mapping provide evidence for locating landscape boundaries related to landform, parent material, and (in the case where local relief is pronounced) soil drainage. Maps and remotely sensed images, however,

would seem to provide less information for evaluating spatial variation in A horizon depth and presence or absence of an E horizon.

Plant Communities Encountered

Thirty-three plant community types are represented among the 145 plots. Of these, 101 plots belong to forest-woodland-savanna community types, 28 to prairie communities, and 15 to wetland communities. There are marked differences in the composition of savanna, woodland, and forest community types, yet little difference in basal area stocking in the present day (table 2). Mesic forest is dominated by sugar maple (*Acer saccharum*) and red oak (*Quercus rubra*), whereas the dominance shifts to red oak and white oak (*Quercus alba*) in mesic woodland, and to bur oak (*Quercus macrocarpa*) and scarlet oak (*Quercus coccinea*) in mesic savanna. In basal area stocking, mesic forest (28.08 m²/ha), mesic woodland (29.68 m²/ha), and mesic savanna (31.89 m²/ha) are not greatly different. Over 150 years of fire suppression, grazing, logging, and neglect have allowed what formerly were savannas and woodlands to fill in with a more dense stocking of trees.

Even though most of Cook County was prairie prior to European settlement (Hanson 1981), wooded vegetation predominates in forest preserves and protected natural areas. Most prairies and wetlands in Cook County disappeared because plowing, grazing, lack of fire, and drainage altered the land. The preservation bias in both wooded and prairie communities is toward dry to mesic communities as opposed to wet-mesic and wet community types. Eighty-one percent of plots in forest, woodland, and savanna communities were dry to mesic community types, and 68% of plots in prairie were in dry to mesic prairie. Artificial drainage by ditching and tiling allowed areas of flat, wet silt loam, and silty clay loam to be converted to profitable agriculture, whereas areas of steeply rolling morainal terrain, gravelly ice-contact hills, and sandy soils have been preserved in "natural" vegetation out of proportion to their original spatial extent.

Soil Series and Plant Community Types

Table 3 summarizes important soil and site characteristics by plant community type. The table confirms the "conventional wisdom" concerning the influence of vegetation on soil. For instance, E horizons are most frequent in dry-mesic savanna, mesic savanna, dry-mesic acid sand savanna, dry-mesic woodland, and mesic woodland. Two processes lead to lower pH and E horizon formation in these oak-dominated communities as compared with prairie vegetation: (1) the addition of organic acids from oak litter, and (2) the reduction (in comparison to grassland) in the recycling of cations,

resulting from a reduction in the biomass of grass-sedge cover relative to prairie. Calcium, the most abundant cation in soil, functions as a binding agent, causing clay particles to adhere to one another. Only when free calcium is removed from the soil by acid leaching do the clay particles become mobile, subject to translocation by water (Birkeland 1984). Only one of seven examples of the sugar maple-dominated mesic forest community type had an E horizon. Sugar maple litter has a higher nutrient content than oak litter, and this may have produced the higher soil pH in mesic forest (A horizon 5.6, B horizon 6.1) as opposed to mesic woodland (A horizon 5.1, B horizon 5.2). Acidification is a prerequisite to E horizon formation, and occurs most rapidly beneath oak trees.

The frequency of E horizon occurrence in wet-mesic woodland (33%), wet-mesic sand woodland (0%), and wet-mesic savanna (0%) is less than for drier woodlands and savannas. A horizons are deeper in wet-mesic woodlands and savannas in comparison with mesic and dry-mesic savanna and woodland communities. Therefore, the depth zone in which E horizons usually form is dominated by organic matter addition and mixing. Also, through rainy periods, these soils have a high standing-water table, inhibiting the vertical movement of water necessary for translocation of clay.

In general, prairie vegetation features higher rates of basic nutrient recycling than does woodland vegetation, buffering the acidification of surface soils. Therefore, one does not typically associate the formation of an E horizon with prairie vegetation. Dry-mesic prairie had an E horizon for one out of three plots. Whether this represents an exception to the rule in terms of soil formation, or a result of a shift from savanna-woodland vegetation to prairie vegetation in the relatively recent past is not known.

Note also that the conventional model of prairie versus forest influences on soil formation is consistent, but only in a relative sense. Mesic and dry-mesic prairie are slightly to very strongly acid through the upper 50 cm, as are all four sand prairie types (types 19 to 24). In comparison with the soils of roughly equivalent woodland vegetation on similar parent material, however, prairie soils are slightly less acid, e.g., dry-mesic prairie (A horizon 5.1, B horizon 4.8) compared with dry-mesic woodland (A horizon 4.8, B horizon 4.3), or mesic prairie (A horizon 5.5, B horizon 5.8) compared with mesic woodland (A horizon 5.1, B horizon 5.2). The neutral and alkaline pHs of wet floodplain forest soil (A horizon 7.0, B horizon 7.3) would seem to be the exception, though no corresponding floodplain prairie community was sampled. The soils of low terraces in floodplain soils are enriched by the addition of alkaline alluvial muds each year.

Table 2. Comparisons of mean basal area (m²/ha) of tree species for forest, woodland, and savanna community types (Thomas 1998)

Plant community type*	1	2	3	4	5	6	7	8	9	10	11	12
Number in sample	7	7	3	22	26	3	4	1	13	9	1	5
<i>Acer negundo</i>	0	0	0	0	0	0	0	0	0.47	0	0	0
<i>Acer rubrum</i>	0	0	0	0	0.12	3.07	0	0	0	0	0	0
<i>Acer saccharinum</i>	0	0	6.14	0	0	1.02	0	0	0	0	0	0
<i>Acer saccharum</i>	13.16	1.32	0	0.42	3.84	0	0.77	0	0	0	2.30	0
<i>Carya cordiformis</i>	0	0	0	0.42	0.12	0	0	0	0	0.26	0	0
<i>Carya ovata</i>	0.44	0	0	0.45	0.12	0	0	3.07	0.24	1.79	0	0
<i>Celtis occidentalis</i>	0	0	0	0	0.24	0	0	0	0	0	0	0
<i>Crataegus species</i>	0	0	4.09	0	0	0	0	0	0	0	0	0
<i>Fraxinus americana</i>	1.75	3.73	0	0.84	1.06	3.07	0	0	0	0.34	0	0
<i>Fraxinus pennsylvanica</i>	0	2.85	13.30	0	0.12	0	0	3.07	0.24	0.26	0	0
<i>Juglans nigra</i>	0.44	0.44	0	0	0.12	0	0	0	0	0	0	0
<i>Morus alba</i>	0	0	0	0	0	0	0	0	0.77	0	0	0
<i>Nyssa sylvatica</i>	0	0	0	0	0	0	1.54	0	0	0	0	1.23
<i>Ostrya virginiana</i>	0	0	0	0.14	0.83	0	0	0	0.71	0.34	0	0
<i>Populus deltoides</i>	0	0	1.02	0	0.35	2.06	3.84	0	0	0	0	0
<i>Prunus americana</i>	0	0	0	0	0.24	0	0	0	0	0	0	0
<i>Prunus serotina</i>	0	0	0	2.55	0.56	0	0	0	1.42	3.24	0	2.46
<i>Quercus macrocarpa</i> × <i>Q. alba</i>	0	0	0	0.11	0	0	0	0	0	0	0	0
<i>Quercus alba</i>	0	0.44	0	17.06	8.41	0	0	0	2.18	1.28	0	4.91
<i>Quercus bicolor</i>	0	2.37	0	0	0	2.05	5.37	15.35	0	0	0	0
<i>Quercus coccinea</i>	0	0.33	0	0.52	0.12	0	0	0	0	3.84	0	8.60
<i>Quercus macrocarpa</i>	0.44	6.91	2.05	0.42	0.44	7.16	2.30	3.07	16.52	17.82	6.90	0
<i>Quercus palustris</i>	0	0	0	0	0	0	17.65	0	0	0	0	0.61
<i>Quercus rubra</i>	8.34	1.32	0	5.30	10.18	4.86	0.77	0	0.24	1.02	2.30	0
<i>Quercus velutina</i>	0	0	0	0.42	0	0	0	0	0.18	0.68	0	7.37
<i>Rhamnus cathartica</i>	0	0.66	0	0	0	0	0	0	0.18	0	0	0
<i>Sassafras albidum</i>	0	2.30	0	0	0	0	0	0	0	0	0	2.46
<i>Tilia americana</i>	1.32	0.99	0	0.56	1.65	0	0	0	0	0	0	0
<i>Ulmus americana</i>	2.19	1.97	0	0.38	0.92	2.30	1.54	3.07	0	1.02	0	0
<i>Ulmus rubra</i>	0	1.32	5.12	0.14	0.24	0	0	0	0	0	2.30	0
Total	28.08	26.95	31.72	29.73	29.68	25.59	33.78	27.63	23.15	31.89	13.80	27.64

* Plant community types after Thomas (1998):

- | | |
|--------------------------------|---------------------------------|
| 1. Mesic forest | 7. Wet-mesic sand woodland |
| 2. Wet-mesic floodplain forest | 8. Wooded vernal pond |
| 3. Wet floodplain forest | 9. Dry-mesic savanna |
| 4. Dry-mesic woodland | 10. Mesic savanna |
| 5. Mesic woodland | 11. Wet-mesic savanna |
| 6. Wet-mesic woodland | 12. Dry-mesic acid sand savanna |

The A horizon depth for dry-mesic prairie (20 cm) is too shallow to qualify the soil for mollisol status (>25 cm), but it is almost twice as deep as the A horizon of dry-mesic woodland (12 cm). There is a general, though not consistent, trend for A horizons to be deeper and organic matter contents to be higher for wetter drainage classes as opposed to drier drainage classes, for instance, dry-mesic woodland (12 cm, 7.7%), mesic woodland (11 cm, 8.3%), and wet-mesic woodland (22 cm, 11.7%); or dry-mesic

savanna (19 cm, 9.4%), mesic savanna (14 cm, 7.7%), and wet-mesic savanna (33 cm, 10%).

A study of the correspondence of soil series and community types (table 4) revealed that the community types are associated with a more diverse group of soil series than indicated by Thomas (1998). Community types having the most diverse soil series are dry-mesic woodland (6 soil series), mesic woodland (8 soil series), dry-mesic savanna (5 soil series), and mesic savanna (6 soil

Table 3. Comparisons of mean soil and site conditions in plant community types for 145 plots in remnant natural areas in Cook County, Illinois

	n	A-dep	E-freq	E-thk	Clay50	Sand50	Silt50	OM	ApH	EpH	BpH	Slope	SS
Mesic forest	7	16	14	3	26	28	46	8.7	5.6	4.9	6.1	3.4	-5.5
Wet-mesic floodplain forest	7	27	0	.	35	24	42	9.0	6.0	.	6.4	1.3	-3.5
Wet floodplain forest	3	18	0	.	34	16	51	13.0	7.0	.	7.3	1.4	+2.8
Dry-mesic woodland	22	12	75	15	40	21	39	7.7	4.8	3.9	4.3	7.1	-3.5
Mesic woodland	26	11	58	15	41	17	42	8.3	5.1	4.0	5.2	7.4	-5.6
Wet-mesic woodland	3	22	33	10	40	16	44	11.7	5.0	3.9	5.5	1.3	-3.5
Wet-mesic sand woodland	4	26	0	.	19	47	34	10.5	5.2	.	5.8	0.4	+1.6
Wooded vernal pond	1	20	0	.	42	18	40	10.8	6.2	.	6.2	1.5	+2.0
Dry-mesic savanna	13	19	46	15	33	26	41	9.4	6.5	5.6	6.6	15.9	-2.6
Mesic savanna	9	14	78	13	16	26	36	7.7	4.8	3.8	4.2	3.3	-4.4
Wet-mesic savanna	1	33	0	.	16	50	34	10.0	7.1	.	7.4	2.5	-9.0
Dry-mesic acid sand savanna	5	10	80	12	3	86	12	8.5	4.5	4.1	4.2	0.8	-1.1
Shrub swamp	1	64	0	.	51	11	38	22.6	4.8	.	6.1	1.0	+0.0
Dry-mesic prairie	3	20	33	12	52	14	34	7.7	5.1	3.6	4.8	5.2	-6.0
Mesic prairie	4	30	0	.	42	21	37	12.5	5.5	.	5.8	2.1	-5.0
Wet-mesic prairie	1	15	0	.	44	16	40	23.1	7.1	.	7.5	1.25	-5.5
Wet prairie	2	31	0	.	46	16	38	14.8	6.7	.	7.5	0.4	+1.2
Dry sand prairie	1	10	0	.	2	92	6	5.9	6.3	.	5.5	0.5	+0.0
Mesic sand prairie	2	26	0	.	3	86	11	6.4	5.5	.	4.5	1.1	-5.7
Wet-mesic sand prairie	2	23	0	.	2	84	14	15.4	4.3	.	4.0	2.0	+2.5
Wet acid sand prairie	3	31	0	.	7	70	23	11.4	4.7	.	5.9	1.6	+3.3
Dry gravel prairie	5	21	0	.	19	52	28	9.5	7.2	.	7.7	17.7	-25.0
Mesic gravel prairie	1	15	0	.	20	28	58	9.3	7.4	.	8.3	1.0	-5.0
Dry dolomite prairie	1	9	0	.	.	.	.	7.7	.	.	.	0.5	-2.5
Dry-mesic dolomite prairie	2	17	0	.	53	11	36	10.3	7.0	.	7.2	0.6	-1.5
Wet-mesic dolomite prairie	1	23	0	.	54	11	35	12.3	6.9	.	8.0	1.5	-1.0
Sedge meadow	5	29	0	.	41	20	39	17.6	6.8	.	7.2	1.3	+3.0
Basin marsh	1	25	0	.	43	11	46	13.1	3.9	.	4.7	3.0	+2.0
Streamside marsh	2	39	0	.	43	21	36	16.2	5.2	.	6.2	0.9	-0.25
Open vernal pond	2	40	0	.	54	15	32	12.8	4.3	.	5.0	1.0	+2.0
Graminoid fen	2	52	0	.	.	.	.	38.2	7.2	.	8.0	4.0	+5.3
Calcareous seep	2	11	0	.	13	43	44	21.6	7.8	.	8.1	1.7	+1.0
Seep	1	21	0	.	29	18	53	20.8	6.6	.	7.5	0.0	+1.0

n=number of samples in the community type, A-dep=depth of the A horizon or organic soil layer (cm), E-freq=frequency of occurrence of E horizon (%), E-thk=thickness of the E horizon (when present, cm), Clay50=clay content at 50 cm (%), Sand50=sand content at 50 cm (%), Silt50=silt content at 50 cm (%), OM=organic matter content (%) of the surface horizon (0-10 cm), ApH=A horizon pH, EpH=E horizon pH (when present), BpH=B horizon pH at 50 cm, Slope=slope steepness (%), SS=slope shape (sum of % slope in 4 directions measured from plot center: upslope [+], down slope [-], right, and left)

series). Based on our analysis, there is limited ability to predict the community type on the basis of the mapped soil series.

Because there were so many soil series and plant communities sampled, sample size for most soil series and community types was small. For the Morley series, however, 26 plots were sampled, allowing closer examination of this series. If we assume that Morley soils are randomly distributed among four physiognomic categories (i.e., community types of forest, woodland, savanna, prairie), the percentage of Morley plots in each physiognomic type will be approximately equal to the percentage of the total sample in each physiognomic type. The ratio of these two percentages can be used as an index of representation (IR). For example, if one-half of all plots

occurred in the woodland physiognomic category, then a random distribution of Morley soils would result in one-half of the Morley soils occurring in the woodland physiognomic category. If only one-quarter of the Morley soils occur in the woodland physiognomic category, then the index of representation is one-half (0.5), and the Morley is underrepresented in this category. Thus, indices of less than one imply less representation than likely by random chance. Indices of greater than one imply more representation in that physiognomic type than likely by random chance. The Morley soil series as mapped in forest (IR 0.67), savanna (IR 0.49), and prairie (IR 0.56) physiognomic types has indices of representation of less than 1. Only in the woodland physiognomic category is Morley overrepresented (IR 1.86). If soil series assigned by

Table 4. Comparison of the occurrence of soil series as mapped in USDA (1979) with plant community types (Thomas 1998) for 145 plots in remnant natural areas in Cook County, Illinois

Soil Series	Community Type*																																								
	1	2	3	4	5	6	7	8	9	10	11	12	14	15	16	17	18	19	21	22	24	27	35	36	37	38	39	40	41												
23 Blount					4																																				
27 Miami			1	1																																					
49 Watsika												2							1	2	1	1																			
93 Rodman									1															1																	
107 Sawmill			2																																						
125 Selma										1																															
146 Elliot				1																																					
152 Drummer					1																																				
192 Del Rav		1	1																																						
194 Morley	1		12	6					2	1					2	1																			1						
201 Guilford								1																																	
232 Ashkum														1	1	1																				1					
290 Warsaw									1																																
298 Beecher										1					1																										
318 Lorenzo									2																											4					
327 Fox				2																																					
329 Will																																					1	1			
330 Peotone																																					1				
494 Kankakee		2																																							
531 Markham									2																																
696 Zurich	1		1	2					1																																
697 Wauconda		3	1	3					1																																
698 Grays				1					1																																
741 Oakville		2							1	3													1																		
904 Muskego-Peotone																																					1				
1330 Peotone, wet								1																																	
1903 Muskego-Houghton, wet																																				2	2				

* List of plant community types after Thomas (1998):

1. Mesic forest	12. Dry-mesic acid sand savanna	29. Mesic gravel prairie
2. Wet-mesic floodplain forest	14. Shrub swamp	30. Dry dolomite prairie
3. Wet floodplain forest	15. Dry-mesic prairie	32. Mesic gravel prairie
4. Dry-mesic woodland	16. Mesic prairie	33. Wet dolomite prairie
5. Mesic woodland	17. Wet-mesic prairie	35. Sedge meadow
6. Wet-mesic woodland	18. Wet prairie	36. Basin marsh
7. Wet-mesic sand woodland	19. Dry sand prairie	37. Streamside marsh
8. Wooded vernal pond	21. Mesic sand prairie	38. Open vernal pond
9. Dry-mesic savanna	22. Wet prairie	39. Graminoid fen
10. Mesic savanna	24. Wet acid sand prairie	40. Calcareous fen
11. Wet-mesic savanna	27. Dry gravel prairie	41. Sand seep

the authors to the Morley series based on the field profile description are used, the degree of overrepresentation is more pronounced. Twenty-one of 27 samples assigned to the Morley series occurred in woodland communities (IR 2.01). Of the 27 plots assigned to the Morley soil series, none was in a forest community. The most common vegetation associated with the Morley soil series is dry-mesic woodland, making up 46% of the plots mapped as Morley, and 59% of the plots assigned to the Morley series. These data do not suggest that a land manager or restorationist is wrong in predicting prairie, savanna, or

forest vegetation on a site where Morley soil is mapped, only that such vegetation is less common than woodland in areas of Morley soil.

DISCUSSION

Soil survey maps and soil series classifications and descriptions are excellent resources for any land manager. Soil surveys provide descriptions of spatial variation in soil properties, such as soil drainage, soil reaction, and soil texture, that may have an important relationship to management objectives. As long as the scale of one's

interpretations is broad—not judgments on an acre-by-acre basis—the patterns depicted in county soil surveys are usually reliable. For those doing soil-related research, soil surveys provide examples of soil profile descriptions prepared by experts. The problem is both in the level of detail depicted in survey maps, and in the manner in which the survey is interpreted by land managers.

Survey maps are inadequate for characterizing spatial variation in soil properties to a degree of precision sufficient for ecological restoration management purposes such as inferring pre-European settlement vegetation or setting specific goals for species reintroduction on an acre-by-acre basis. The problems fall into two categories: inadequate level of detail and inadequate concepts. Inadequate or incorrect detail is a product of insufficient sampling within the local landscape in question, leading to the need to extrapolate a small base of information beyond its usefulness. Given the enormous scope of a single survey—an entire county or several counties—such shortcomings are understandable. Improving the detail of the map is relatively straightforward, if difficult in practice, requiring additional field sampling by qualified personnel.

Inadequacy of concepts is more serious. The problem lies not with the concept of soil series in and of itself, but rather, the ways in which soil series are defined by soil scientists, and how they are used to infer the character of pre-European settlement vegetation by plant ecologists and managers. It is commonplace to use the terms "prairie soil" and "forest soil." As restorationists have rediscovered the oak savanna, it is not uncommon to hear of "savanna" soils. The search within county soil surveys, however, for "forest, woodland, prairie, or savanna" soils as predictive categories for interpreting local variation in soil and vegetation represents an overinterpretation of the survey, which was created for other purposes. If savannas existed, so must the soils of savannas, yet there may be no savanna soil series—that is, a currently recognized soil series that developed exclusively under savannas.

Rodman, Warsaw, Blount, Beecher, Markham, Zunch, Wauconda, Grays, and Oakville series all occur in association with savanna vegetation, but they are all relatively rare in occurrence overall (one or three plots for each series). Such data can be used only to pose a hypothesis about their association with savanna. It seems more likely that there is no current soil series indicative of savanna, but rather that many soil series occur often or occasionally in association with savanna vegetation. Savanna soils may be only slightly different from soils developed in adjacent grasslands, and, because their function for agriculture and development is not greatly different, they are mapped together with adjacent grassland

soils. In other cases, they may be only slightly different from soils commonly developed under more continuous tree cover, and are then mapped along with these "forest" soils in such cases.

Thirteen soil series are mapped in association with savanna plant community types. However, only for Oakville and Rodman were the majority of plots mapped in savanna communities. Mendelson, Aultz, and Mendelson (1992) state that the Markham and Beecher series are indicative of savanna vegetation. In the Cook County forest preserve system, areas of Markham and Beecher soil series under remnant vegetation are rare. Of the two plots mapped as Markham series in this study, both occur under dry-mesic savanna. Both of these plots, however, after examination of the field profile description and lab results, were reclassified (by the authors) to other series. Three (different) plots were assigned (by the authors) to the Markham series, two in the mesic woodland community type and one in mesic savanna. Of the two plots mapped as Beecher, one occurred in the mesic savanna community type and one with the mesic prairie community type. The soil profile of the savanna plot, however, was reclassified (by the authors) to another soil series. The remaining plot classified as Beecher and another plot assigned to the Beecher series both occurred with the mesic prairie community type. This is an insufficient sample from which to accept or deny the relationship of Markham or Beecher soils and savanna vegetation. Even if areas of Markham and Beecher soil often developed under savanna vegetation, it remains an open question as to what other soils developed in savannas and whether or not the Markham and Beecher series occur more commonly under other community types.

Only three soil series (as assigned by the authors) occur under both wooded community types (forest, woodland, and savanna) and prairie community types: Milford, Morley, and Oakville. These three series however, make up 25% of the study. Also, sample size for most series is small, therefore the ability to make predictive statements about soil series and community type associates, even to the level of major physiognomic categories of wooded versus prairie, is limited.

In this discussion, the assumption is made that the classification of vegetation in Thomas (1998) accurately represents ecological differences among native plant communities. In addition, although most sample plots were unambiguously placed in a community type, there were borderline instances in which the decision was more arbitrary. Had the study been restricted to ecosystems with a relatively undisturbed ground flora and the composition of all vegetative strata used to characterize the community

type, the placement of sample plots in community types would have been less problematic. Results may have shown a higher degree of correlation between plant community type and soil series.

The purposes of the study, however, were to apply currently used classifications of vegetation and soil, to test the accuracy of soil mapping, and to examine the association of soil series types and plant community types – and to do so in a wide variety of sites across the county. Restoration management is not restricted to undisturbed sites, and managers must apply readily available resources such as existing plant community classifications and soil surveys. This study accurately represents the results of such application.

The Classification and Mapping of Soils and Plant Communities

Classifications ideally should provide both the power to generalize, i.e., to link the individual to a class of other similar individuals, and the precision and accuracy needed to make statements about objects treated by the classification. Thus, the statement that a segment of oak woods is a mesic woodland should inform the user about this oak wood's fundamental similarity to other mesic woodlands, and it should provide the user with the power to infer specifics concerning biotic composition prior to disturbance and the levels of important environmental factors. A very general classification that divides communities into wooded, open, and wetland areas may accurately group together extant examples into the three types, but would have little usefulness in terms of specifying details about the communities. A classification that identified a separate unit for each plot of natural area in the Chicago region could provide great specificity of description, but no power of generalization.

Plant communities and soils are creations of their local surroundings and histories, and can be treated only approximately by large-scale approaches that seek to find "universal" types across broad areas. Instead, plant communities, soil types, and the associations among them are probably best treated by local mapping and classification efforts, which seek first to partition spatial variation in local phenomena. Secondly, these local map-based classifications may be merged according to similarities of process, function, structure, and composition. At higher (hierarchical) levels, in which local types are described for a large region, the power of generalization is high, but the level of precision is low. At the local level, the precision of description is high, though the power of universal generalization is low. It would seem that these are inherent limitations in the classification of complex ecological phenomena, for which (unlike

organisms) there is no genetic code and evolutionary history to create inherently similar types.

The two classifications used in this study are similar in that they place phenomena of local origin, map units of soil, or small segments of vegetation into a relatively small number of classes that are generalized countywide. Both systems sacrifice precision and accuracy of local interpretation for the power to make regionwide generalizations. Not surprisingly, the power to predict plant community type from soil type on a point-by-point basis is poor. The power even to predict general physiognomic categories is limited. A more reliable interpretation might result from a change in the scale of the analysis from point or plot samples to 100-hectare blocks. Within these blocks, one could relate the frequency of occurrence of a soil series to frequency of occurrence of community type or physiognomic category. Restoration management activities, however, are differentiated on a much finer spatial scale, creating a problem for the use of existing soil survey maps in restoration.

Soil properties and soil types are too often used in restoration management and science to predict pre-European settlement vegetation on an acre-by-acre basis, and too seldom used to understand the structure and function of ecosystems. Predicting vegetation from soil or predicting soil from vegetation implies an independence of the relationship that does not exist in nature. The two are related in a milieu of other influences, such as frequency, intensity, and seasonality of fire, and variation in microclimates. More importantly, they relate to one another in the context of a local landscape. Soil takes on its greatest usefulness for understanding the structure and function of local ecosystems when it is integrated with landform, parent material, vegetation, estimated fire regime, hydrology, microclimate, historical information, and immediate ecological context. To know that a site has a Morley soil may tell you little about its vegetation, other than, for example, it probably never supported a bog, fen, or marsh. To know that the Morley soil sits on a 3–6% slope of a glacial moraine, near the western edge of an oak grove reported in the original PLS notes, and that the current overstory dominant is bur oak, on the other hand, tells you a great deal about what other plants and animals might have used the site in the past. The study of soil and its usefulness to restoration science and management should move in the direction of such integrative studies, in particular, to integrative ecosystem approaches to the study of land.

ACKNOWLEDGMENTS

We would like to thank the Forest Preserve District of Cook County for its generous support of this research, the Illinois Nature Preserve Commission for allowing us to use many nature preserves in Cook County, the Department of Earth Science at Northeastern Illinois University for allowing us to use their laboratory facilities for the soil analysis, and Rebecca Janssens, lab technician, whose work in conducting the soil analyses was an important part of this research.

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THE GENUS *AGRIMONIA* (ROSACEAE) IN ILLINOIS

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ABSTRACT: *Agrimonia parviflora*, *A. striata*, *A. pubescens*, *A. gryposepala*, and *A. rostellata* are the five species of *Agrimonia* native to Illinois. Plants of *A. parviflora* are usually correctly identified, inasmuch as the number and shape of its leaflets are distinctive. The other four cannot be consistently distinguished by these easily observed characters, but must be identified by suites of less readily apparent characters. Sixteen of the 47 characters examined during our study of the genus *Agrimonia* in North America were found to be most useful in describing and distinguishing the species in Illinois. These 16 characters describe the dispersion and types of hairs; leaflet number, shape, and size; stipule shape; flower position; mature fruiting hypanthium shape and size; and the presence or absence of tuberous roots. A key for identification of the Illinois agrimonies is presented here along with a detailed description of each species. *Agrimonia striata*, reported here from three counties, was heretofore unknown in the Illinois flora; on the other hand, the previous report of *Agrimonia microcarpa* was based upon a misidentification.

INTRODUCTION

The *Agrimonia* (Rosaceae) species of North America are readily confused with each other, especially in the field. All are herbaceous perennials with a similar habit and with similar flowers and fruits. The plants occur along margins and in open spaces of mesic deciduous or mixed deciduous woods, in thickets, and in meadows. A combination of somewhat variable morphological characters distinguishes each species. We have undertaken an examination of the patterns of morphological variation within the genus across North America to circumscribe species limits, to accurately apply the names described in the literature, and to develop a key that will facilitate identification in both vegetative and reproductive conditions.

METHODS

After preliminary field and herbarium studies and an examination of the literature, 47 morphological characters were chosen as potentially informative. These characters were measured or scored for about 600 herbarium specimens from across the range of the genus in North America. Sixteen characters (table 1) of the 47 measured were found most useful in delimiting and distinguishing the *Agrimonia* species. They describe the dispersion and types of hairs; leaflet number, shape, and size; stipule shape; flower position; mature fruiting hypanthium shape and size; and the presence or absence of tuberous roots. The utility of our set of 16 distinguishing characters was further tested in the field, during the examination of more than 1,000 additional collections, and in the construction of species descriptions and keys for identification. After

Table 1. Morphological characters that best discriminate among species

1. Number of major leaflets on a mid-cauline leaf
2. Number of minor leaflets between major ones
3. Size of the largest terminal leaflet
4. Shape of the major leaflets
5. Shape of the major leaflet apex
6. Vestiture of the leaflet abaxial surface
7. Shape of the stipule
8. Vestiture of the stem
9. Vestiture of the inflorescence raceme rachis
10. Arrangement of the flowers along the inflorescence raceme rachis
11. Vestiture of the mature fruiting hypanthium
12. Shape of the mature fruiting hypanthium
13. Size of the mature fruiting hypanthium
14. Number of rows of hooked bristles
15. Position of the lowermost row of hooked bristles on mature fruit
16. Presence or absence of tuberous roots

examining specimens from the major regional herbaria during this study, we recognize the following five species as native in Illinois: *Agrimonia parviflora*, *A. pubescens*, *A. striata*, *A. gryposepala*, and *A. rostellata*.

Collection sites recorded on the species distribution maps are taken from the labels of specimens we have examined and identified. The counties for which we document the presence of each *Agrimonia* species differ somewhat from those presented in Mohlenbrock and Ladd (1978).

The North American species of *Agrimonia* share a large number of characteristics synthesized in the following generic description:

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Agrimonia Linnaeus, Sp. pl. 1: 448. 1753. Gen. pl. ed. 5: 206. 1754.

Type species: *Agrimonia eupatoria* L.

Herbaceous perennials, rhizomatous, the rhizome internodes very short. Roots fibrous, sometimes also with slender fusiform tubers. Stems 1–several, frequently branched in the flowering portion. Leaves alternate, stipulate, pinnately compound, the major leaflets interspersed with 1–several pairs of minor leaflets, the number of minor pairs between each pair of major leaflets usually increasing distally along the rachis (see fig. 1). Inflorescence a raceme, terminal and often also axillary, simple or compound, each axis with 9–100 flowers, branched below from the primary peduncle, flexible; bract subtending each pedicel \pm ovate, usually 3-toothed with acuminate lobes; pedicels ascending; bracteoles usually a 3-toothed pair, connate at the base. Flowers 10 mm or less in diameter; hypanthium becoming indurate in fruit, enclosing an achene, sulcate, stipitate; stipe reflexed at maturity, throat occluded by means of an annular disk; bristles in 2–5 circumferential rows from the rim, hooked, erect to reflexed in fruit; sepals 5, persistent, connivent in fruit; petals 5, yellow; stamens 5–15; ovaries separate, 2, rarely more, styles exserted. Fruit top-shaped, consisting of the indurated hypanthium enclosing the achene and topped by the connivent sepals with hooked bristles spreading from the rim; achene 1, rarely 2.

Ascertaining the kinds of hairs and their location on the plant surfaces is necessary for accurate determination of the species. Nonglandular hairs are of two types: (1) soft and either straight or wavy, described as pilose, pubescent, or villous, and (2) stiff and straight, described as hirsute. Glandular hairs are either short stalked or glistening and appearing as sessile dots.

KEY TO THE ILLINOIS *AGRIMONIA* SPECIES

1. Major leaflets 5–9 on mid-cauline leaves; obovate to \pm rhombic; apex \pm obtuse to acute to acuminate
 2. Stem hairs hirsute and pubescent to villous, glandular hairs glistening dots or not conspicuous
 3. Abaxial leaflet surface with glistening-glandular dotlike hairs; stipule outer margin only proximally incised or nearly entire; major leaflets \pm rhombic to elliptic, apex usually acuminate 2. *Agrimonia striata*
 3. Abaxial leaflet surface without glistening-glandular dotlike hairs; stipule outer margin incised along entire length; major leaflets \pm obovate to elliptic, apex \pm obtuse to acute, rarely acuminate 3. *Agrimonia pubescens*
 2. Stem hairs hirsute with conspicuous short-stalked glandular hairs
 4. Lower portion of the floral axis with hirsute hairs more than 1.0 mm long, usually \pm 2.0 mm long, and perpendicular to the axis 4. *Agrimonia gryposepala*
 4. Lower portion of the floral axis with hirsute hairs less than 1.0 mm long and \pm ascending 5. *Agrimonia rostellata*
1. Major leaflets 9–13 on mid-cauline leaves, \pm lanceolate to narrowly elliptic, apex acuminate 1. *Agrimonia parviflora*

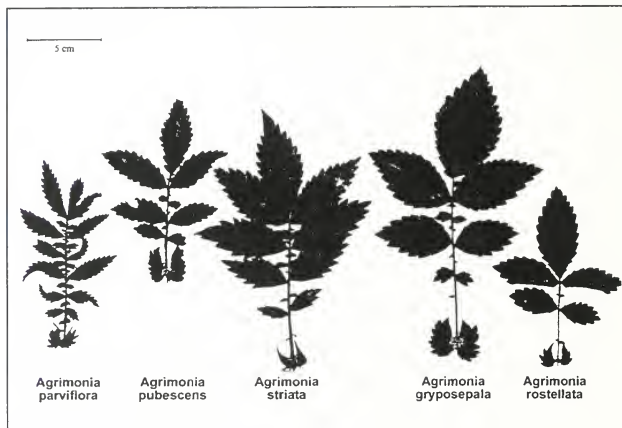


Fig. 1. Mid-cauline leaves

DESCRIPTION OF THE ILLINOIS SPECIES

1. *Agrimonia parviflora* Sol. in Aiton. Hortus Kew. 130, 1789.

Agrimonia polyphylla Urban, Symb. Antill. 7: 227, 1912.
Agrimonia sauevolens Pursh, Fl. Amer. Sept. 1: 336, 1814.
Agrimonia serrifolia Wallr., Beitr. Bot. 1: 40, 1842.

Herbaceous perennial 5–16 dm. Roots fibrous, tubers absent. Stems with glistening-glandular dots, often only in the upper portion, pubescent to villous and hirsute, the stiff hairs scattered, perpendicular, 2.0–3.0 mm long. Stipules falcate, the apical lobe long attenuate. Major leaflets 3–19 (mid-cauline 9–13), lanceolate to narrowly elliptic to rarely narrowly rhombic, the apex acuminate to long acuminate to infrequently acute; abaxial surface pubescent to villous and hirsute along the veins, the stiff hairs \pm scattered, 1.0–3.0 mm long, nonglandular hairs most densely disposed along major veins, and usually with glistening-glandular dots; terminal leaflets the largest, the largest of these 3.4–8.5 \times 1.0–2.4 cm; minor leaflets 1–4 pairs. Raceme with most flowers \pm subopposite in the middle and upper portions; rachis with glistening-glandular dots, pubescent to villous and hirsute, the stiff hairs scattered, \pm perpendicular, 1.0–2.0 mm long, usually disappearing upwards. Mature fruiting hypanthium broadly campanulate to broadly turbinate to rarely obconic or hemispherical, moderately to shallowly sulcate, with hooked bristles in 3–4 circumferential rows, the lowermost row spread at \pm right angles to reflexed; hypanthium surfaces usually with glistening-glandular dots, the ridges sometimes sparingly hirsute. Mature reflexed fruit with hypanthiums 1.3–3.0 \times 1.7–3.8 mm. Flowering mid-July to early September.

Agrimonia parviflora occurs most frequently in meadows, wetlands, and along margins of lakes, streams, and sloughs throughout Illinois (fig. 2). The species is reported for Lake County by Swink and Wilhelm (1994), but they indicate that no voucher specimen has been seen by them. Joyce Proper, steward at Grant Woods Forest Preserve, Lake County, confirms the presence of *A. parviflora* in this county (pers. comm.).

Of the five Illinois species, *A. parviflora* is the one that is seldom misidentified. In addition to its distinctive morphology, especially its foliage (see fig. 1), it occupies habitat that is markedly more moist than the habitat in which the remaining four are likely to occur.

2. *Agrimonia striata* Michx., Fl. Bor.-Amer. 1:287, 1803.

Holotype: Canada: in Canada. *Flores albid*, ?, Michaux, Andre, s.n. (P).

Agrimonia brittoniana E. P. Bicknell, Bull. Torrey Bot. Club 23: 517, 1896.

Agrimonia striata var. *campanulata* Fernald, Rhodora 40: 333, 1938.

Herbaceous perennial, 4–19 dm. Roots fibrous, tubers absent. Stems with glistening-glandular dots, at least above, pubescent to pilose and hirsute, the stiff hairs scattered, perpendicular, \pm 2.0 mm long. Stipules \pm falcate, the outer margin proximally incised or sometimes \pm entire. Major leaflets 3–11 (mid-cauline 5–7), blades elliptic to rhombic, the apex acute to acuminate to long acuminate; abaxial surface with glistening-glandular dots, pubescent to pilose and hirsute, the stiff hairs scattered, 1.0–2.0 mm long, nonglandular hairs most densely disposed along the major veins; terminal leaflets the largest, the largest of these 4.3–10.7 \times 1.9–4.2 cm; minor leaflets 1–4 pairs. Raceme with most flowers in the middle and upper portions \pm subopposite; rachis with glistening dotlike glandular hairs, pubescent to pilose and hirsute, the stiff hairs scattered, \pm perpendicular and 1.0–2.0 mm long below to \pm ascending and \pm 1.0 mm above. Mature fruiting hypanthium obconic to \pm campanulate to rarely turbinate, deeply sulcate, with hooked bristles in 3–4 circumferential rows, the lowermost spreading at \pm right angles (pressed upward on dried specimens); hypanthium surfaces with both stalked and glistening dotlike glandular hairs, grooves strigose, the

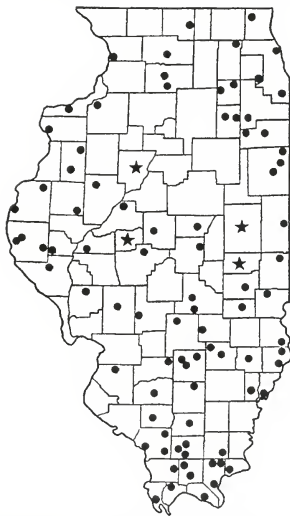


Fig. 2. Distribution of *Agrimonia parviflora* in Illinois. A dot indicates a collection site; a star indicates a collection identified by county only.

ridges usually sparingly hirsute. Mature reflexed fruit with hypanthiums 2.1–6.6 × 2.4–5.2 mm. Flowering late June to early August.

Known only from Boone, Cook, and DeKalb counties (fig. 3): Boone Co., north of Hunter, roadside; Evers, R. A. 96823, 17 Jul 1968 (ILLS); Cook Co.: Evanston; Blatchford, P. 2516, 15 Aug 1873 (ISM); DeKalb Co., CMS&P RR east of Route 72 overpass; Hutson, Thomas 17, 15 Jul 1972 (DEK).

Stipules with margins nearly entire or incised only along the lower portion and the ± subopposite arrangement of flowers along the raceme rachis distinguish this species from both *A. gryosepala* and *A. pubescens*, with which it might occur and for which it may be mistaken. *A. striata* is also separated from *A. pubescens* by the glistening-glandular dots on stem, abaxial leaflet, and raceme rachis surfaces.

3. *Agrimonia pubescens* Wallr., Beitr. Bot. 1:45-46, 1842.

Agrimonia bicknellii (Kearney) Rydb., N. Amer. Fl. 22(5): 394, 1913.

Agrimonia eupatoria γ. *mollis* Torrey & A. Gray, Fl. N. Amer. 1: 431, 1840.



Fig. 3. Distribution of *Agrimonia striata* in Illinois. A dot indicates a collection site; a star indicates a collection site identified by county only.

Agrimonia mollis (Torrey & A. Gray) Britton, Bull. Torrey Bot. Club 19: 221, 1892.

Agrimonia mollis γ. *bicknellii* Kearney, Bull. Torrey Bot. Club 24: 565, 1870.

Agrimonia platycarpa Wallr., Beitr. Bot. 1: 38, 1842.

Agrimonia microcarpa Wallr., Beitr. Bot. 1: 39-40, 1842, *pro parte*.

Herbaceous perennial 5–16 dm. Roots fibrous and with slender fusiform tubers. Stems pubescent to villous and hirsute, the stiff hairs scattered, perpendicular, 2.0–3.0 mm long. Stipules ± broadly half-ovate, the outer margin shallowly incised, the apical lobe sometimes long acuminate. Major leaflets 3–13 (mid-cauline 5–9); blades elliptic to lanceolate to sometimes ± obovate, lateral leaflets sometimes ± falcate, the apex obtuse to acute to acuminate; abaxial surface pubescent to pilose and sparingly hirsute with the stiff hairs 1.0–2.0 mm long, all hairs usually most densely disposed along the major veins; terminal leaflets the largest, the largest of these 3.3–9.8 × 1.4–5.5 cm; minor leaflets 1–3 pairs. Raceme with most flowers alternate; rachis pubescent to villous and hirsute, the stiff hairs ± scattered, usually perpendicular and 1.0–2.0 mm long below to ± ascending and ± 1.0 mm long above. Mature fruiting hypanthium turbinate to campanulate, sometimes broadly so, to ± obconic, deeply to shallowly sulcate two-thirds to the entire hypanthium length, with hooked bristles in 3–4 circumferential rows, the lowermost row spreading at ± right angles (pressed upward on dried specimens); hypanthium surfaces with short-stalked glandular hairs, grooves strigose, the ridges sparingly hirsute. Mature reflexed fruit with hypanthiums 1.9–4.5 × 2.0–4.6 mm. Flowering mid-July to August (–September).

The specimen (Eggert *s.n.*, 1875) at MO, on which Mohlenbrock (1986) based his report of *Agrimonia microcarpa* in St. Clair County, is a misidentification of *A. pubescens*. These species sometimes differ only in mature fruit shape and size, stipule shape, and the length of hirsute hairs on the stem. Without mature reflexed fruit, which is lacking on the Eggert specimen, accurate discrimination between *A. microcarpa* and *A. pubescens* can be difficult. *Agrimonia pubescens* occurs throughout most of Illinois (fig. 4). It should be sought in those counties from which no collections are presently known.

Agrimonia pubescens is a polymorphic species with 3 recognizable morphs and their various intermediates. All 3 of these principal patterns are found in Illinois: (1) leaves with major leaflets broadly obovate to ± elliptic, with 5–7 leaflets on mid-cauline leaves and 1 minor pair; (2) leaves with major leaflets ± narrowly obovate to elliptic, with 7 leaflets on mid-cauline leaves and only 1 or 1–3 minor pairs (fig. 1); and (3) leaves with major leaflets elliptic to

lanceolate, with 7–9 leaflets on mid-cauline leaves and only 1 or 1–3 minor pairs. Lateral leaflets are frequently falcate in morphs 2 and 3. Stipules with long-acuminate apical lobes prevail in morph 3 and are frequent in morph 2. More than one morph may sometimes occur in a population. Although all 3 morphs and intermediates are found across the state, the geographic distribution of morphs among the herbarium specimens examined suggests that morphs 2 and 3 are more frequent in the northern and central portions and morphs 1 and 2 in the southern part.

4. *Agrimonia gryposepala* Wallr., Beitr. Bot. 1:49, 1842. Lectotype: United States: Pennsylvania: *In graminosis Pennsylvaniae*, Aug 1824, Poeppig s.n. (W, acq. 1889, No. 342339. [Kline and Sorensen 1990]). *Agrimonia hirsuta* sensu E. P. Bicknell non Bong, auct. non Muhl., Bull. Torrey Bot. Club 23: 508–512, 1891. *Agrimonia macrocarpa* (Focke) Rydb., N. Amer. Fl. 22(5): 392, 1913. *Agrimonia pariflora* Sol. in Aiton var. *macrocarpa* Focke in J. D. Smith, Bot. Gaz. 16: 3, 1891.

Herbaceous perennial 3.5–15 dm. Roots fibrous, tubers absent. Stems with short-stalked glandular hairs and hirsute, the stiff hairs scattered, perpendicular, ± 2.0 mm

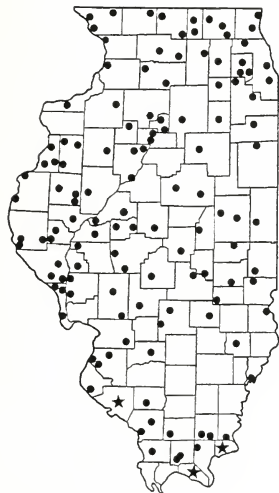


Fig. 4. Distribution of *Agrimonia pubescens* in Illinois. A dot indicates a collection site; a star indicates a collection identified by county only.

long. Stipules \pm half-ovate, incised. Major leaflets 3–13 (mid-cauline 5–7); blades obovate to elliptic to rhombic, sometimes broadly so, the apex \pm obtuse to acute to rarely acuminate; abaxial surface with short-stalked glandular hairs and often also with scattered glistening-glandular dots, very sparsely to moderately hirsute along the veins, the stiff hairs 0.5–2.0 mm long; terminal leaflets the largest, the largest of these 3.2–10.5 \times 1.4–5.6 cm; minor leaflets 1–3 pairs. Raceme with \pm alternate flowers, the rachis with short-stalked to glistening dotlike glandular hairs and sparsely to scattered hirsute, with the stiff hairs perpendicular, ± 2.0 mm long. Mature fruiting hypanthium \pm obconic to turbinate to campanulate, deeply to shallowly sulcate two-thirds to almost the entire length, the rim often expanded, with hooked bristles in 4–5 circumferential rows, the lowermost reflexed; hypanthium surfaces with short-stalked to glistening dotlike glandular hairs, the ridges and base often sparsely hirsute. Mature reflexed fruit with hypanthium 2.3–5.8 \times 2.8–6.2 mm. Flowering July to mid-August (–September).

Widely distributed in northern Illinois, becoming less frequent in the central part of the state; the southernmost occurrences in Fayette and Macoupin counties (fig. 5).

Its large size and lowermost row of fully reflexed bristles make the fruit of *Agrimonia gryposepala* the most distinctive and recognizable. The presence of nonglandular hairs that are only hirsute, perpendicular and ± 2.0 mm long on the inflorescence rachis also distinguishes this species from any other in Illinois or North America. Leaflets of *A. gryposepala* (fig. 1) often differ only in vestiture from those of *A. pubescens* or *A. striata* and only in size from those of *A. rostellata*.

5. *Agrimonia rostellata* Wallr., Beitr. Bot. 1:42–43, 1842.

Herbaceous perennial 4–14 dm. Roots fibrous and with slender fusiform tubers. Stems with short-stalked glandular hairs and hirsute, the stiff hairs very sparse to scattered, perpendicular, 1.0–2.0 mm long. Stipules \pm falcate to \pm half-ovate, often deeply incised. Major leaflets 3–11 (mid-cauline 5–7), blades obovate to broadly elliptic to elliptic, the apex obtuse to acute; abaxial surface sparingly hirsute, the hairs 1.0–2.0 mm long, and with short-stalked glandular hairs, usually also with glistening-glandular dots; terminal leaflets the largest, the largest of these 4.0–10.5 \times 2.4–5.6 cm; minor leaflets 1 pair. Raceme with \pm alternate flowers; rachis \pm ascending hirsute, the hairs scattered, sometimes very sparsely so, ± 1.0 mm long, and with both short-stalked and glistening dotlike glandular hairs. Mature fruiting hypanthium hemispherical, rarely \pm turbinate, obscurely sulcate, with hooked bristles in 2–3 circumferential rows, the lowermost spreading at right

angles to reflexed, with short-stalked and glistening dotlike glandular hairs. Mature reflexed fruit with hypanthiums 1.0–3.1 × 1.8–3.9 mm. Flowering July to mid-September.

Agrimonia rostellata occurs in Illinois northward to Cook, DuPage, Ford, LaSalle, Peoria, and McDonough counties (fig. 6). The report by Jones (1994) of *Agrimonia rostellata* in Winnebago County is based upon a misidentification of *A. pubescens*.

A terminal raceme with multiple, usually 2, branches in the primary peduncle gives *Agrimonia rostellata* a distinctive look in the field, which can be recognized with practice. Some morphs of *A. pubescens* and occasional plants of *A. gryposepala* have only 1 pair of minor leaflets, and major leaflets resembling those of *A. rostellata* (fig. 1), so the presence of only stiff, hirsute hairs on the plant surfaces and ascending hirsute hairs ±1.0 mm long on the raceme rachis is critical in distinguishing this species. The hemispherical, glistening-glandular fruiting hypanthium can only rarely be confused with that of *A. parviflora*, but the foliage of the two species is quite different.

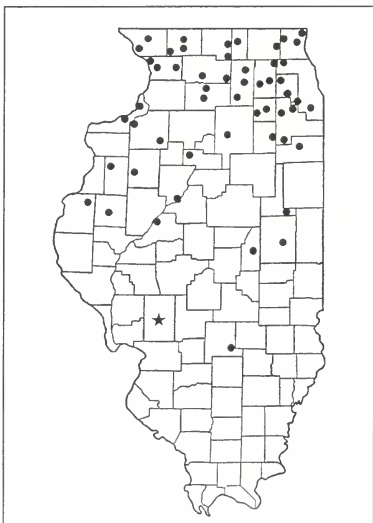


Fig. 5. Distribution of *Agrimonia gryposepala* in Illinois. A dot indicates a collection site; a star indicates a collection identified by county only.

DISCUSSION

The habitat in which *Agrimonia* can occur, mesic woodland and thickets, is fragmented and found most frequently along waterways and within protected areas in our state. Within this habitat *Agrimonia* species occur in open, often disturbed, areas or along the margin. We encourage field workers to look diligently for agrimonies and to collect specimens if found in those counties without documented populations. *Agrimonia pubescens* and *A. gryposepala* are the most frequent species in the state; *A. pubescens* and *A. parviflora* have the most extensive ranges. *A. parviflora* occurs most often in mesic sites or along river, stream, or lake edges. *A. rostellata* occurs with *A. pubescens* most commonly in the southern portion of the state, particularly in the Shawnee Hills. The three northern Illinois populations of *A. striata* are disjunct from the range of the species, which extends northward from northern Iowa, central Wisconsin, and northern Michigan.

From our field experience, we suggest that fruiting specimens, i.e., those with at least some fully reflexed fruit, make the most informative herbarium specimens both for

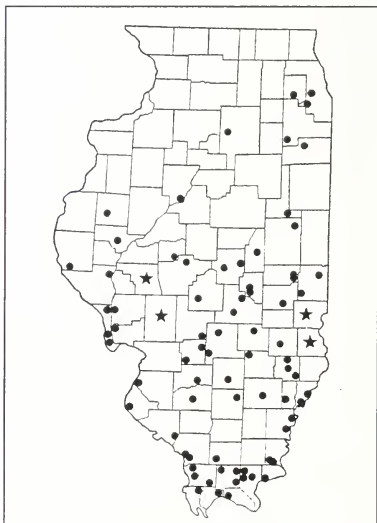


Fig. 6. Distribution of *Agrimonia rostellata* in Illinois. A dot indicates a collection site; a star indicates a collection identified by county only.

documentation and sometimes for identification, e.g., *Agrimonia microcarpa*. When collecting, it is worthwhile to cut the stem at ground level and press the whole plant, using a second sheet if necessary. In sites where the plants are abundant, however, it is desirable to excavate the roots and include them with the specimen even though the presence or absence of root tubers is not essential for the identification of the Illinois species.

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EFFECTS OF ANNUAL BURNING ON POPULATIONS OF *CASSIA FASCICULATA* (FABACEAE: CAESALPINIOIDEAE) WITH A REVIEW OF ITS SYSTEMATICS AND BIOLOGY

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ABSTRACT: This report summarizes data collected during 18 years of observing plant populations of *Cassia fasciculata* (partridge pea). Populations varied greatly from year to year. Following burning, however, populations consistently increased compared with those populations in areas that were not burned. There was a mean population ratio of 5.2:1 for burned to unburned areas. This was further demonstrated by reversing the burned and unburned quadrats, which resulted in a reversal of population counts. Observations of changes in the abundance of other plant species during the study are noted. Included are reviews of morphological and ecological characteristics of *C. fasciculata*, and of earlier reports of fire effects on the species.

INTRODUCTION

Many people frequently encounter *Cassia fasciculata* Michaux (partridge pea), but have never taken the time to look at it closely and are unaware of its many fascinating aspects. The biology and systematics of *C. fasciculata* are well studied, at least compared with other species native to Illinois, but this information is widely scattered in the scientific literature. To make this information more widely available, the first section of this paper presents a summary of the systematics, morphology, pollination, seed dispersal, and other interesting biological features of *C. fasciculata*.

The behavior of *Cassia fasciculata* in remnant and restored habitats is less well documented. Some years ago, the senior author noted an apparent increase in population density of *C. fasciculata* during about five growing seasons following annual burning on a small, high quality relict railroad prairie in Livingston County, Illinois, southwest of Kempton. A nearby old field with a population of *C. fasciculata* was selected in 1982 for the purpose of evaluating the long-term effects of annual burning on the fecundity of *C. fasciculata* and its tendency to usurp other species. This paper reports on new observations of demography in burned and unburned systems.

SYSTEMATICS AND ECOLOGY

Cassia fasciculata is a member of the bean family (Fabaceae) and the Caesalpinia subfamily (Caesalpinioideae). Some taxonomists prefer to divide the bean family into three separate families, in which case *Cassia* is placed in the family Caesalpinaceae. The genus *Cassia*, in the broad sense, is one of the largest genera of

legumes and indeed of flowering plants. Bentham (1871) recognized 338 species, and about 350 additional species worldwide have been described since then (Irwin 1964). The genus exhibits greatest diversity in the tropics and subtropics, especially in the Western Hemisphere (Robertson and Lee 1976).

There are five species of *Cassia* native to Illinois (Mohlenbrock 1986). Today, some botanists, such as Irwin and Barneby (1982), divide *Cassia* into several segregate genera, in which case partridge pea is called *Chamaecrista fasciculata* (Michaux) Greene. Two recent papers with detailed studies of floral development (Tucker 1996a,b) support the recognition of segregate genera. According to Irwin and Barneby (1976), if this species is retained in *Cassia*, then the correct name is *Cassia chamaecrista* L., which is also used by Bentham (1871), instead of *Cassia fasciculata* Michaux. The latter name is so well established in common use, however, that a strong case could be made for its conservation.

Like nearly all plant species that occur in tallgrass prairie, the geographical range of *Cassia fasciculata* is much more expansive than the tallgrass prairie region. The general distribution of this species is from Florida to Texas northward to Massachusetts, New York, Ontario, Ohio, Indiana, Illinois, Wisconsin, Minnesota, and South Dakota (Fernald 1950; Steyermark 1963; Great Plains Flora Association 1986). In Illinois, it is known from nearly all counties, except for Lake, McHenry, and a few other scattered counties (Mohlenbrock and Ladd 1978; Swink and Wilhelm 1994). *Cassia fasciculata* is most often associated with sandy soils, such as sand prairies and sand savannas. Disturbances in sand habitats by small mammals can lead to an abundance of *C. fasciculata* (Fulk and

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Ebinger 1999). Other habitats for *C. fasciculata* include blacksoil prairies, woodland borders, and open alluvial soils. It also is found along roadsides and railroads and in other weedy places.

MORPHOLOGY

Cassia fasciculata is quite variable morphologically, and a number of varieties are sometimes recognized (Fernald 1950; Pullen 1963; Steyermark 1963; Isely 1975). However, Irwin and Barneby (1982) and Isely (1998) concluded that there was so much intergrading variation within the species that it was futile to recognize infraspecific taxa. Variation in *C. fasciculata* from Illinois has not been studied, but if varieties are recognized, var. *fasciculata* and var. *robusta* occur in the state.

This species is an upright, herbaceous summer annual that is usually 25–50 cm tall (rarely exceeding 1 m in height). Normally, the stem is unbranched or sparsely branched, though damage by browsing or mowing can result in numerous branches from the base. In an established prairie habitat dominated by native perennials, the persistence of a native annual seems incongruous. While most annual pioneering species are displaced by expanding populations of perennials, partridge pea persists and often thrives in relict native prairies, though abundance certainly seems related to disturbance, except perhaps in sand prairies.

The leaves are alternately arranged along the stem and are evenly pinnately compound; two linear, persistent stipules are found at the base of each leaf. Toward the base of the petiole is a short-stalked, cup-shaped nectariferous disk that is about 1 mm in diameter. This disk, a secretory gland, functions as an extrafloral nectary that attracts insects (Barton 1986; Boecklen 1984; Durkee et al. 1999; Kelly 1986). Each leaf has 6–15 pairs of leaflets that are narrowly elliptic, 2–5 mm wide and 6–20 mm long, with rounded, mucronate apices and oblique bases.

A small pulvinus is found at the base of each leaflet. This pulvinus is responsible for the movement of leaflets, which draw upwards at night and cause the leaves to appear "closed"; hence, another common name for this species is "sleeping plant." The leaflets are also somewhat sensitive when touched, although not to the degree of *Mimosa pudica*, sensitive plant. Pulling a leaf from a plant will also cause the leaflets to close, as will pulling a plant from the ground. Herbarium specimens nearly always have "closed" leaflets. The physiology of leaflet movement has been studied extensively (see Bourbouloux, Fleurat-Lessard, and Roblin 1994; Everat-Bourbouloux, Fleurat-Lessard, and Roblin 1990). There are various ideas on the

functionality of leaf movements, but none have been specifically investigated in *Cassia fasciculata*. It is generally thought that this phenomenon reduces water loss through transpiration. Leaves sensitive to touch may also reduce browsing by animals.

The flowers are borne in short axillary racemes, with only one flower per raceme opening each day. They are rather large (25–35 mm in diameter), perfect, zygomorphic, and yellow in color, although a white form is known from Missouri. They do not produce nectar. Each individual flower is open only for one day, opening before dawn and closing in the evening. The five sepals are yellow-green, lanceolate, long acuminate, and 6–10 mm long. There are five yellow petals 12–20 mm long; the upper two often have a purple spot inside at the base. One of the lateral petals, called the "cucullus" by Thorp and Estes (1975) and Wolfe and Estes (1992), is stiff and erect with incurved margins that partially enclose the tips of eight or nine of the ten anthers. The other petals are softer and more pliable, and have a crumpled appearance. The lowest petal is somewhat larger than the others.

The androecium is composed of ten anthers, each with a short, straight, yellow filament. The anthers are yellow, reddish purple, or bicolored (usually reddish purple in Illinois), and are elongate and tubular, opening by terminal pores; they are unequal in length, varying from 7 to 9 mm. The stamens are divided into two sets. The first, arising between the bases of the carpel and the cucullus, comprises eight or nine stamens whose anthers are upright, with their tips curved into the cucullus. The second set consists of one or two stamens that arise from the opposite side of the carpel and bend away from the other anthers, becoming more or less parallel to the curved style. Hardin et al. (1972) noted that this differentiation into two types of anthers is similar to the "feeding" and "pollination" anthers described for some other species of *Cassia* by Faegri and van der Pijl (1966). As is characteristic of legumes, there is only one carpel (simple pistil). The ovary is green, laterally compressed, covered with hairs, and only a bit wider than the style. Four to 16 ovules are contained within the ovary (Martin and Lee 1993). The style is slender and strongly curved upward, and at its tip is a stigmatic orifice, which is obscured by numerous beak-forming papillar hairs (Dulberger, Smith, and Bawa 1994).

POLLINATION BIOLOGY

The pollination biology of *Cassia fasciculata* has been studied by several investigators over the past hundred plus years (Todd 1882; Robertson 1890, 1928; Harris and Kuchs 1902; Hardin et al. 1972; Thorp and Estes 1975;

Wolfe and Estes 1992). The more recent papers have added to work reported in earlier papers with new observations, some corrections, and various hypotheses on pollination mechanisms in this species. The flowers of *C. fasciculata* exhibit the characteristic of enantiostyly — the presence of left- and right-handed flowers. The flowers differ in the direction in which the style and a lateral hooded petal are bent in relation to the floral axis (Todd 1882; Thorp and Estes 1975; Robertson and Lee 1976). When they are turned to the left, a bee receives pollen on its right side. When the insect moves to a right-handed flower, the left side of the bee contacts the stigma (Robertson 1890).

The probable principal bee pollinators of *Cassia fasciculata* are female *Xylocopa*, *Bombus*, and *Svastra* (Robertson 1890; Thorp and Estes 1975). The pollinating behavior of the bees was described by Thorp and Estes (1975). Bees alight directly on the stamens and curve their abdomens around or reflex them beneath the terminal pores of the anthers. Most bees then strip the anthers by extending their heads, grasping a single anther near its base with their mandibles and pulling toward the apex of the anther with a series of stroking movements that cause the pollen to be extruded through the pores. Alternatively, and sometimes simultaneously, the anthers are vibrated in an activity known as buzz pollination (Buchmann 1983; Michener 1962). One or more groups of anthers are grasped with the legs and mandibles. This is followed by a shivering of the indirect flight muscles of the thorax while the wings remain still. Both methods release pollen on the venter of the bee. These activities attracted attention long ago (Robertson 1890).

Although flowers of *Cassia fasciculata* are insect pollinated, the plants can be self-compatible (Hardin et al. 1972; Lee and Bazzaz 1982a,b; Sork and Schemske 1992; Martin and Lee 1993). The flowers are perfect, but male sterile plants (plants that produce little, if any, functional pollen) occur at low frequencies in populations of *C. fasciculata* (Williams and Fenster 1998). Male sterility is sometimes considered to be the first step in the development of dioecy.

FRUITS AND DISPERSAL BIOLOGY

The leguminous fruit is 2.5–5 cm long, 4–4.5 mm broad, and strongly flattened; each fruit contains 4–16 seeds. The seeds are 3.5–5 mm long and 2.5–4 mm wide, rhomboid in shape, dark brown to black, and flattened, with the upper and lower surfaces covered with parallel rows of tiny pits (Bragg and Bridges 1984). The seed coat is extremely hard and impermeable, and scarification of

some kind is required to break dormancy (Everitt and Heizer 1984).

Another notable feature of *C. fasciculata* is the method of seed dispersal. When dry, the two valves of the mature pods suddenly separate and ballistically eject seeds to a distance of up to several meters (Ridley 1930). More recent observations of this dramatic event (Lee 1984) recorded a mean distance of 140 cm for seed dispersal for five-seeded fruit and 201 cm for four-seeded fruit. The greatest dispersal distance recorded was 478 cm. As the common name “partridge pea” implies, the seeds are relished by various species of ground-dwelling birds, such as quail and wild turkey.

Ants can often be seen moving along stems and then seeking out the extrafloral nectaries. In a Florida study (Barton 1986), more than 50 insect species were observed visiting the nectaries, ants being the most numerous. Ants occupied more than 50% of the *C. fasciculata* plants, while their presence was recorded on less than 10% of the nonnectiferous background plants. The ants did not appear aggressive to most other nectary visitors, but they did remove eggs and small larvae of Lepidoptera from the plants. Among *C. fasciculata* plants in natural populations, there were greater numbers of pods set, more seeds per plant, and fewer damaged pods compared with populations from which ants were excluded. This research supports the hypothesis that extrafloral nectaries can function to increase reproduction of *C. fasciculata* by diminishing flower predation.

PHYSIOLOGY

Cultivated legumes are a source of protein in livestock feed and contribute to soil fertility through nitrogen enhancement (Stewart 1966). While less is known about native legumes, data show that most mimosoid and papilionaceous legumes have root nodules, but only about one-third of caesalpinoid species have them (Stewart 1966). One rapid and effective method used to determine the nitrogen-fixation capacity of different organisms is the acetylene-ethylene assay (Hardy et al. 1968). Becker and Crockett (1976) used this tool with several native grassland legumes from relict prairie sites in southeastern Nebraska. Among the species studied were *Amorpha canescens* (lead plant), *Psoralea argophylla* (silvery-leaved scurf-pea), *Lepedeza capitata* (round-headed bush clover), and *Cassia fasciculata*, the only annual species. *Cassia fasciculata* had significantly more root nodules and greater fresh nodular weight than any other species in the study. It had the greatest nitrogen-fixing potential. The results implied that species associated with pioneering through intermediate

stages of grassland succession have greater nitrogen-fixing capacity than species restricted to mature or climax prairie, or that annuals may have younger, more active nodules.

The foliage of *Cassia fasciculata* is palatable to domestic livestock, and the plant is considered a nutritious legume. The leaves and seeds, however, contain a cathartic substance that is effective in both fresh plant material and dry hay. Although deer are not affected by it, this substance is potentially dangerous to cattle (Gates 1930; Voigt and Mohlenbrock 1985; Stubbendiek and Conrad 1989). Russell et al. (1997) report that the cathartic compound anthraquinone is found in the seeds and is responsible for diarrhea, but only if large quantities of seeds are eaten. Some studies have been done using partridge pea in a crop rotation system to control nematodes in agricultural crop fields (McSorley, Dickson, and Brito 1994; Rodriguez-Kabana et al. 1988; Rodriguez-Kabana and Canullo 1992; Rodriguez-Kabana et al. 1989; Rodriguez-Kabana et al. 1991).

Cassia fasciculata has also proved to be a useful species for researching the degree to which selection acts on life history and morphological traits. For details, the interested reader is encouraged to see the papers by Farnsworth and Bazzaz (1995); Fenster (1991a,b); Fenster and Sork (1988); Garrish and Lee (1989); Kelly (1992, 1993); Lee (1984); Lee and Bazzaz (1982a,b); Martin and Lee (1993); Sork and Schemske (1992); and Williams and Fenster (1998).

EFFECTS OF FIRE ON *CASSIA* DEMOGRAPHY IN ILLINOIS

There have been some previous reports of fire and its effect on populations of *Cassia fasciculata*. In one study (Cull 1978), prairie reconstruction plots were planted at three Illinois highway right-of-way sites in 1966, 1971, and 1973; *C. fasciculata* was one species in the seed mix. Two of the plots were managed with burning, and one was mowed; *C. fasciculata* became established on all plots. In another study, a 0.2 ha barrens in Pope County, Illinois, was selected as a study site to observe vegetational change (Anderson and Schwegman 1991). Before burning in 1968, the quadrat frequency of *C. fasciculata* was 16. Following burns in 1969 and 1970, the quadrat frequency rose successively to 43 and 64. In 1971, when there was no burn, the number dropped to 27. There were burns again in 1972 and 1973, for which no population numbers were recorded. In following years there was no burning, and by 1988 the quadrat frequency of *C. fasciculata* had fallen to 2. The observation was that *C. fasciculata* became prominent after two fires, but decreased in abundance in

the absence of fire. The senior author of this paper observed similar changes on a prairie remnant. He then started a long-term controlled study of the effects of annual burning on populations of *C. fasciculata*.

METHODS

The study area was part of a former pasture with no history of tillage during the twentieth century. Before initiation of the study in 1982, the site had not been grazed for 17 years. Although it usually had been mowed annually, it had not been burned for four years. Cool-season grasses, such as *Poa pratensis* (Kentucky bluegrass), *Phleum pratense* (timothy), and *Agrostis alba* (redtop), were present throughout and were the predominant cover (Gardner 1995a). Nomenclature of plant names follows Mohlenbrock (1986). The soil type is Bryce, a poorly drained, firm, silty clay loam formed in loess and lacustrine sediments or glacial outwash and in the underlying glacial till (Fehrenbacher 1990).

Four 1 m² quadrats were centrally located and permanently marked within a 0.466-acre plot. This plot was serving as a control for other studies within a 7.3-acre prairie restoration (Gardner 1995a). The control area received no interventional seeding or disturbance except for burning. The quadrats were arranged as the corners of a square, with 4 meters separating each quadrat. The number of individuals of *Cassia fasciculata* was recorded in each quadrat to establish a baseline. Mowing ceased on the quadrats and adjacent areas, except for firebreaks. In March 1983, all quadrats were burned. After burning, *Schizachyrium scoparium* (little bluestem) seed was sown in each quadrat for the purpose of introducing a native grass into the largely Eurasian plant community. There was no soil disturbance accompanying the seeding.

Annually, from 1984 through 1991 (except for 1987, when all plots were inadvertently burned), two quadrats (A and B) were burned in late winter and two quadrats (C and D) remained as controls, with no burning or mowing. The control plots were invaded over time by the woody species *Fraxinus pennsylvanica* var. *subintegerrima* (green ash) and *Morus alba* (white mulberry). These were removed by cutting at soil level to prevent them from dominating and changing the grassland aspect of the quadrats. There was no other intervention with existing plant species. From 1992 through 1995, there was a reversal of the quadrats that were burned (now C and D) and those left unburned (now A and B). From 1996 through 1999, all quadrats were burned. Annual population counts of *C. fasciculata* were made in late July or early August. Other species present in each quadrat were identified.

RESULTS AND DISCUSSION

There were greater numbers of *Cassia fasciculata* on the burned quadrats than on the unburned quadrats every year following 1983 (table 1). Population numbers of *Cassia fasciculata* in all plots varied greatly from year to year. Growing conditions may have been a major factor in these variations. However, precipitation records from the Pontiac, Illinois, recording station (about 25 miles from the study site) do not show a consistent correlation between May–July rainfall and stem numbers of *C. fasciculata* (table 1). This lack of correlation could have been due to differences in precipitation at the site and at the recording station, the greater importance of timely rainfall over total rainfall for the period, or the effects of other factors not identified.

When quadrats A and B were left unburned, and quadrats C and D were burned, starting in March of 1992,

Table 1. Average population counts 1982–1999 of *Cassia fasciculata* under different burning regimes in quadrats A and B versus quadrats C and D, including total precipitation for months May–July

Year	A, B	C, D	Precipitation May–July
Average populations counts			
1982	6.0	4.0	12.7"
1983	12.0	21.5	8.6"
Burning starts for half of quadrats			
1984	23.5	9.5	no data
1985	9.5	7.0	13.3"
1986	131.0	54.0	17.9"
1987*	318.0	173.0	7.8"
1988	54.0	1.5	2.2"
1989	135.5	20.5	7.6"
1990	221.0	9.5	15.9"
1991	211.5	4.0	6.9"
Reversal of burned and unburned quadrats			
1992	15.0	36.5	11.5"
1993	18.0	73.5	17.0"
1994	41.5	215.0	7.4"
1995	11.0	88.0	16.2"
All quadrats burned			
1996	44.0	37.0	17.3"
1997	49.5	34.5	5.3"
1998	46.5	26.5	17.3"
1999	28.5	15.0	12.7"

* all plots burned inadvertently

Notes: Population counts are in **bold** for quadrats burned that year. Precipitation was recorded at station 116190 in Pontiac, Illinois.

there was an immediate reversal of population numbers that year. Numbers of *Cassia fasciculata* in the burned quadrats exceeded those in the unburned areas by 2.4:1. This increased annually to an 8.0:1 ratio in 1995 (table 2).

In all years when control quadrats were maintained, *Cassia fasciculata* numbers in burned quadrats exceeded those in unburned quadrats by a mean of 5.2:1 (table 2). Toward the end of the study, when all quadrats were burned in 1996 and 1997, the observed numbers of *C. fasciculata* became similar in all quadrats (table 1).

The average number of stems of *Cassia fasciculata* was 5/m² in 1982, before burning. It was 211.5/m² in burned quadrats in 1991, the last year before the burning treatment was reversed. Although *C. fasciculata* became a prominent forb in those quadrats, other native taxa also became established. *Andropogon gerardii* (big bluestem), *Sorghastrum nutans* (Indian grass), and *Liatris aspera* (rough blazing star) appeared. These were apparently introduced by windblown seed from a prairie restoration initiated in 1974 and located about 25 meters to the west (Gardner 1995a).

By 1986, *Schizachyrium scoparium* was well established in all quadrats, but by 1991, its observed numbers diminished in the unburned quadrats. This may have been due to the increasing accumulation of thatch covering the soil surface. By 1991, the predominant cool-season grasses observed at the beginning of the study had greatly reduced populations in the unburned plots. *Poa pratensis* and *Phleum pratense* were not observed in the unburned plots, and only scattered *Agrostis alba* culms were noted. This appeared to be due to thatch accumulation. In the burned quadrats, the alien grass populations were reduced, but to a lesser extent. They remained as thinly scattered stands in those quadrats. Heavy thatch accumulation

Table 2. Ratios of *Cassia fasciculata* populations in burned to unburned quadrats in years when controlled burns were maintained

Year	Ratio
1982	none burned
1983	all burned
1984	2.5:1
1985	1.4:1
1986	2.4:1
1987	all burned
1988	36.0:1
1989	6.6:1
1990	23.3:1
1991	52.9:1
1992*	2.1:1
1993	4.1:1
1994	5.2:1
1995	8.0:1
1996	all burned
1997	all burned
1998	all burned
1999	all burned

* start reversal of burned sites

appeared to inhibit the growth of certain alien cool-season grasses to a greater extent than burning.

During the last two years of the study (1998–1999), the average population numbers of *Cassia fasciculata* decreased for all quadrats, even though they were all burned. It appears that another factor emerged. During the years of the study, greater populations of warm-season prairie grasses became established. A vegetation analysis conducted in 1993 (Gardner 1995b) revealed that the 0.466-acre plot, which included the quadrats, was dominated by alien species such as *Poa pratensis*, *Daucus carota*, and *Pheum pratense*. The vegetation analysis was repeated in 1998 (Gardner, unpublished data), and by then the dominant species was *Andropogon gerardii*.

A comparison of the relative density (RD), relative frequency (RF), and importance value (IV) of grasses from these vegetation analyses is presented in table 3. Importance value is expressed as RD+RF. In 1993, the combined IV of the cool-season non-native grasses was 54.2. In 1998, that IV had fallen to 15.9. Over the same period the combined IV for the major warm-season native grasses rose from 8.1 to 79.8. These results are consistent with those obtained by Anderson and Schwegman (1991).

Table 3. Relative changes in populations of cool-season and warm-season grasses

	1993			1998		
	RD	RF	IV ₂₀₀	RD	RF	IV ₂₀₀
Cool-season alien grasses						
<i>Agropyron repens</i>	2.1	1.7	3.8	0.5	0.4	0.9
<i>Pheum pratense</i>	8.6	8.4	17.0	1.6	2.4	4.0
<i>Poa pratensis</i>	16.6	16.8	33.4	5.0	6.0	11.0
TOTAL			54.2			15.9
Warm-season native grasses						
<i>Andropogon gerardii</i>	2.1	2.2	4.3	35.8	28.2	64.0
<i>Sorghastum nutans</i>	2.1	1.7	3.8	8.9	6.9	15.8
TOTAL			8.1			79.8

RD = relative density, RF = relative frequency, IV = importance value

CONCLUSIONS

Long-term monitoring of the effects of fire provides a strong indication that *Cassia fasciculata* populations respond favorably to annual late winter burning, until warm-season native grasses become established. There were increases in populations of *C. fasciculata* in burned areas. Reversal of burned and unburned quadrats provided further verification of these observations. The data also suggest that populations of *C. fasciculata* are suppressed at the stage of prairie succession when tall native grasses are dominant.

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STRUCTURAL COMPOSITION AND SPECIES RICHNESS INDICES FOR UPLAND FORESTS OF THE CHICAGO REGION

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Abstract: Few baseline data have been published on the composition and structure of high quality upland forests in the Chicago region of northeastern Illinois. This information is needed for forest classification, monitoring, and management. In 1976, the Illinois Natural Areas Inventory (INAI) identified and sampled 26 high quality dry-mesic and mesic forest stands in the Chicago region. In this paper, we describe and classify these forests using the original INAI data and supplementary canopy cover and ground layer plot data collected in 1996. We compare differences in woody and herbaceous vegetation composition and canopy cover among forest types, and compare stands with and without fire management histories. An unbiased Native Richness Index, which incorporates plot species richness and total sample richness, was developed to measure differences among stands and forest types. The INAI data classified into 3 distinct forest-stand types dominated by either maple, red oak, or white oak. There was an inverse relationship between sapling and shrub abundance across these stand types. Maple-dominated stands had comparatively high percent canopy cover and low shrub layer stem densities dominated by maple saplings. White oak stands had high shrub layer stem densities dominated by shrub species, whereas red oak stands had intermediate composition. Ground layer species composition was highly heterogeneous within and among stands, but several differences occurred among stand types. In pairwise comparisons, greater percent similarity occurred within maple stands than among comparisons with other stand types, while red and white oak-dominated stands were similar. Spring ephemerals tended to be more important in maple stands, while other ground layer species functional groups tended to be more important in oak-stand types. The Native Richness Index was significantly lower for maple than for oak stands, and was higher in fire-managed than in unmanaged stands. Fire management also significantly reduced the numbers of live maple stems. However, the invasive alien garlic mustard had higher frequencies in fire-managed stands.

INTRODUCTION

Few quantitative data have been published on the structural composition of upland forests of the Chicago region of northeastern Illinois, yet such data are needed to compare with other Midwestern forest types and to provide a context for regional forest classification. The Illinois Natural Areas Inventory (INAI) defined forests as having > 80% canopy cover, classified them based on soil-moisture classes, and used primarily woody vegetation sampling data to describe dominant and characteristic species of each community (White and Madany 1978). For example, the INAI identified and then sampled 28 high quality upland forest stands in 1976, classifying them as dry-mesic and mesic. Until now, sampling data from these sites have not been published or analyzed. In this paper we describe and classify 26 of the upland forest stands (2 have been destroyed) using the original INAI data and supplementary canopy cover and ground layer plot data collected in 1996. Nomenclature follows Swink and Wilhelm (1994), except where noted.

Data on these forests are also needed to provide a baseline that will facilitate monitoring and restoration in the face of fragmentation and other human impacts. Conservationists are concerned that oak-forest species are declining due to change in forest structure as shade-intolerant fire-resistant oaks (*Quercus* spp.) are replaced by shade-tolerant fire-intolerant species such as sugar maple (*Acer saccharum*). This well-known process is attributed to fire protection in Midwestern forests (e.g., Curtis 1959; McIntosh 1957; Lorimer 1985; Anderson 1991; Burger, Ebinger, and Wilhelm 1991; Abrams 1992; Leach and Ross 1995). Change in forest understorey composition and structure is also related to other factors, such as overgrazing by white-tailed deer (Anderson 1994; Strole and Anderson 1992), and invasion by the alien buckthorns *Rhamnus cathartica* and *R. frangula* (Apfelbaum and Hanson 1991), and garlic mustard, *Alliaria petiolata* (Anderson, Dhillon, and Kelley 1996).

Our objectives were to (1) provide baseline descriptions of the original woody composition and structure of 26 high quality dry-mesic and mesic forest

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stands identified and sampled by the INAI in northeastern Illinois in 1976, (2) reclassify the stands using multivariate analysis of the stand data, (3) quantify ground layer vegetation, fire effects, and forest canopy cover of these stands based on data collected from them in 1996, and (4) develop an unbiased species richness index that will quantify ground layer differences among stand types and management effects on this vegetation.

STUDY AREAS

The study areas include 14 dry-mesic and 12 mesic forest stands located in 22 forests (table 1). All sites are on fine-textured glacial tills in the Morainal Natural Division or the Grand Prairie Natural Division (fig. 1). The INAI described dry-mesic sites as well drained and dominated by *Quercus alba* (white oak), *Q. rubra* (red oak), and *Q. velutina* (black oak), while mesic sites were moderately well drained and dominated by sugar maple and red oak (White and Madany 1978). Mesic sites are in landscape positions, such as ravines or east of rivers, that would have provided for greater fire protection and survivorship of maples than would have dry-mesic sites (Leitner et al. 1991; Bowles, Hutchison, and McBride 1994).

To evaluate stand quality, the INAI relied initially on

canopy structure, using ground layer composition as an important secondary criterion. Ten sites were described as grade A (old growth) and 16 as grade B (old second growth or selectively logged). Eight of the sites have been managed with prescription burns as part of restoration programs (table 1). Eastern white-tailed deer are present throughout most of the study areas and have damaged the woody and herbaceous ground layer of some sites by overbrowsing (e.g., Witham and Jones 1990; Anderson 1994).

METHODS

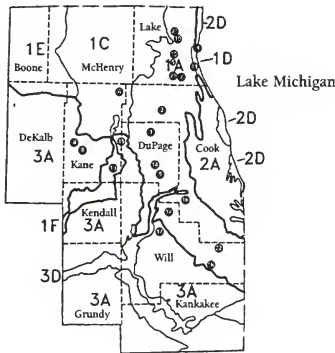
Data collection

In 1976, the INAI sampled a total of 20 points along transects in each stand. Tree species basal area (BA) was determined from each point using a 3 Basal Area Factor metric wedge prism. Trees > 10 cm dbh (diameter at 1.4 m) were also tallied by size class in the 0.025 ha circular plots (radius = 8.92 m) at each sample point, while stem densities of shrub layer species (stems ≤ 10 cm dbh and > 1 m high) were recorded in 0.001 ha circular plots (radius = 1.78 m) at 10 of the sample points. To sample ground layer vegetation in 1996, we relocated the original sampling areas by using community transect maps prepared by the

Table 1. Community classification, quality, and size of Chicago-region forest stands sampled by the INAI

Site no.	Site name	County	Dry-mesic	Mesic	Size in hectares
1.	Meacham Grove F. P.	DuPage Co.	B*		17
2.	Busse Woods F. P.	Cook Co.	B	A	262
3.	Crabtree Farm Woods	Lake Co.	A		15
4.	Elburn F. P.	Kane Co.	B*		23
5.	Glen A. Lloyd Woods N. P.	Lake Co.		B	54
6.	Helm's Woods F. P.	Kane Co.	B		28
7.	Herrman's Woods	Lake Co.	A		15
8.	Johnson's Mound F. P.	Kane Co.	B	B	43
9.	Maple Grove F. P.	DuPage Co.	B*		21
10.	MacArthur Woods F. P.	Lake Co.	B		157
11.	McCormick Ravine Preserve	Lake Co.	A*	A	45
12.	Messenger Woods F. P.	Will Co.	B	A	68
13.	Mooseheart Ravine	Kane Co.	B*		17
14.	Morton Arboretum	DuPage Co.		B	50
15.	Norris (Jones) Woods	Kane Co.	B*		33
16.	Paw Paw Woods F. P.	Cook Co.	B		55
17.	Pilcher Park	Will Co.		A	120
18.	Raccoon Grove F. P.	Will Co.	B*		38
19.	River Road Woods F. P.	Lake Co.		A	8
20.	Ryerson Conservation Area	Lake Co.	B*		133
21.	St. Francis Boy's Camp F. P.	Lake Co.	A		27
22.	Thorn Creek Woods N. P.	Will Co.	B		33

Notes: Site numbers refer to fig. 1. Stands with an asterisk (*) have been fire managed. Letter codes: A = old growth, B = old second growth or selectively logged.



MORAINAL NATURAL DIVISION
 1A - Western Morainal Section
 1B - Eastern Morainal Section
 1C - Kettle Moraine Section
 1D - Racine Till Plain Section
 1E - Waunebago Drift Section
 1F - Fox River Bluff Section

LAKE PLAIN NATURAL DIVISION
 2A - Chicago Lake Plain Section
 2D - Illinois Dunes Section

GRAND PRAIRIE NATURAL DIVISION
 3A - Grand Prairie Section
 3D - Belvidere Valley Section

Fig. 1. Study site locations in relation to the Natural Divisions of the Chicago Region (Swink and Wilhelm 1994). Map numbers refer to table 1.

INAI, and marked our new transects with permanent stakes. We were confident that we sampled within the original communities, although precise location of original transect lines was not possible. Along the 1976 transects, we sampled ground layer species presence per 1 m² in 20 plots. Part of the mesic forest stand at the Ryerson Conservation Area was prescribe-burned in spring 1996, prior to ground layer sampling. At this site, we sampled live and dead ground layer (stems < 1 m high) sugar maple densities in $n = 40$ circular 0.01 ha (radius = 5.64 m) plots along 2 transects that crossed the burned and unburned habitat, yielding 15 burned and 25 unburned plots. In all stands, the tree canopy cover over each sampling plot was photographed on color transparency film with a 35 mm camera equipped with a 180° fish-eye lens. For each photograph, the camera was positioned above the shrub layer with its lens axis oriented vertically.

Woody vegetation – 1976 data analysis

To quantify canopy tree composition, we calculated BA and dominance (relative basal area) from the 1976 wedge-prism sampling data for each tree species, where $BA = \text{no. of trees tallied}/\text{no. points} \times 3$. Because the probability of prism sampling a tree is proportional to its diameter, small trees are sampled only if close to the observer, and prism sampling data are biased toward larger size-class trees. We also estimated BA from the 0.025 ha size-class data by using size-class midpoints as an estimate of the dbh of each tree in each class. Thus, $BA = \text{total no. of stems}/\text{size-class} \times \pi r^2$, summed across all size classes, and $r = \text{each size-class midpoint}/2$. To classify the forest stands, we analyzed their 1976 species BA in a Flexible Beta cluster analysis using PCORD (McCune and Mefford 1999). This analysis clustered 3 stand groups dominated by either sugar maple ($n = 10$ stands), red oak ($n = 8$ stands), or white oak ($n = 8$ stands). With PCORD, we ordinated the 26 upland stands using species BA as a metric with Non-Metric Multidimensional Scaling (NMS) and a Euclidian Distance measure on PCORD software. To assess size-class structure of these stand types, we compiled the INAI 0.025 ha plot data into stems/ha at 10 cm size-class intervals, and plotted the data for 4 groups: all species combined, maples, oaks, and all other species.

To compare shrub layer species among stand cluster groups, we partitioned them into (1) tree saplings, which also represent potential canopy trees, (2) understory tree species, which do not enter the tree canopy, and (3) true shrubs. For each species, we calculated stem density per ha from the shrub plots sampled in 1976 from each stand, where density = no. of stems sampled \times total plot area sampled \times 100. These species stem densities were then

averaged across each cluster group, producing mean (\pm std. err.) species stem densities/ha for each stand type. We used PCORD to calculate the Simpson's diversity index (D) for shrub layer data from each stand. PCORD calculates this index as $D = 1/\sum p_i^2$, where p_i is the relative stem density of each species. D is the probability that 2 randomly chosen individuals will be different species and is maximal when all species are present in equal abundance (McCune and Mefford 1999). We used a one-way ANOVA to test whether the mean value of this index differed among stand types.

Each tree canopy transparency photo was projected through a video camera to a Delta-T Area Meter, which measured canopy cover as a percentage of transmittable light. A dark magenta filter was used to increase contrast and reduce color bandwidth, and the meter was calibrated for 66% area cover. We tested for differences in mean percent canopy cover among the sugar maple, red oak, and white oak stands in a single factor ANOVA, using arcsine-transformed percentage values.

Ground layer vegetation – 1996 data analysis

Native ground layer species were organized into 5 native functional groups (e.g., Mahall and Bornmann 1978; Rogers 1982): (1) spring ephemerals, (2) persistent spring-flowering herbs, (3) summer-flowering herbs, (4) graminoid species, and (5) woody plants. Alien species were treated as a sixth functional group. We used these groups to examine species abundance within and among stands. Relative frequency of each species was calculated from its average stand frequencies and summed within functional groups. Thus, the relative frequencies of all 6 groups sum to 100 within each stand type. To compare species functional group abundance at the stand-type level, we calculated the total number of species stand occurrences within functional groups for each stand type, and expressed this as a percentage of the potential total stand occurrences (i.e., the total number of species per functional group \times total number of stands).

To assess whether ground layer species composition differed among stand types, we tested for significant differences among the 3 stand types with Multi-Response Permutation Procedures (MRPP) using a Bray-Curtis distance measure (Bray and Curtis 1957) of species frequencies on PCORD software. MRPP is a nonparametric test appropriate for plant distributional data that do not meet assumptions of normality (McCune and Mefford 1999). To further determine which stands might differ, we calculated Bray-Curtis dissimilarity indices for all pairwise stand combinations on PCORD. This index is calculated as $1 - 2W/(A+B)$, where $W =$ the sum of shared

species abundances (frequencies), and A and B are the sums of abundances in the individual sample units. We converted these to similarity indices by subtracting each value from 1, and then calculated mean % similarities for each within and among stand-type comparisons. ANOVA was used with a Fisher Protected Least Significant Difference (PLSD) *post hoc* test to determine whether comparisons within stand type (i.e., maple-maple, red oak-red oak, and white oak-white oak) were on average higher than comparisons among stand types.

Species Richness Index

A Species Richness Index (SRI) was developed to provide an unbiased testable measure of ground layer vegetation (Bowles and Jones 1999). This index combines small- and large-scale measures of species richness, using mean plot richness of ground layer species (\bar{x}_R), which is the small-scale measure, and the natural log (Ln) of total species sampled (S), which is the large-scale measure. Its basic formula is $SRI = \bar{x}_R \times \text{Ln}S$. Using LnS normalizes skewed S distributions and dampens the area effect on S when different sample sizes are compared. The Native Richness Index (NRI) uses the mean plot richness of native ground layer species (\bar{x}_{R_N}) and the total number of native species sampled (S_N), where $NRI = \bar{x}_{R_N} \times \text{Ln}S_N$. The difference between SRI and NRI reflects the Alien Component (AC) of species richness, and NRI/SRI (which ranges from 0 to 1) reflects the relative abundance of native richness. To evaluate the index, we used ANOVA to test hypotheses of no significant differences among maple-, red oak-, and white oak-dominated stands for this index of species richness. To better understand the effectiveness and meaning of the index, we compared it against stand plot values for the mean Coefficient of Conservatism (\bar{x}_C) and Floristic Quality Index (FQI), using native species C values and calculations following Wilhelm and Masters (1994).

Fire management

We used a 2×3 factorial ANOVA to compare species richness indices and abundance of *Alliaria petiolata* in fire-managed vs. unmanaged stands across the 3 stand types. The results of these tests must be interpreted with caution, as specific information is not always available on the nature, timing, or exact location of these burns, nor on the condition of stands prior to burns. To determine effects of burning on ground layer maple stems at the Ryerson Conservation Area, we compared the mean % survivorship of these stems in burned and unburned plots in replicated transects, using the nonparametric Mann-Whitney test.

RESULTS

Forest canopy vegetation in 1976

Wedge-prism sampling recorded 23 canopy tree species and 2 subcanopy trees among the 26 stands (table 2). Basal area based on prism sampling averaged about 25 m²/ha for all stand types, but was > 30 m²/ha based on calculations from size-class midpoints (table 2). INAI quality grades also corresponded to size-class distribution of BA. For example, grade A white oak stands had > 20% of their basal area in size classes above 60 cm dbh and > 5% above 80 cm, while grade B white oak stands had < 20% basal area above 60 cm, and none above 80 cm.

Cluster analysis produced 3 groups in which sugar maple, red oak, or white oak attained > 40% mean dominance (fig. 2). All but 2 of the stands classified by the INAI as mesic clustered as maple stands, while all but one of the original dry-mesic stands clustered as red oak or white oak stands. There was also a strong ordination gradient among dominant and subdominant tree species across the stand types (fig. 2). Sugar maple had < 10% dominance in oak-dominated stands, while red oak had < 20% dominance in white oak and maple stands, and white oak had < 30% dominance in red oak stands and < 10% dominance in maple stands. Among subdominant species, *Fraxinus americana* was least important in white oak stands, while *Tilia americana* was most important in maple stands, and red elm had little variation among stands. Although infrequent, *Quercus velutina*, *Q. macrocarpa*, and *Carya ovata* were also most abundant in white oak stands. In one white oak cluster stand, on the west slope of Johnson's Mound, both *Ulmus rubra* and *Juglans nigra* dominance exceeded that of white oak.

In all stand types, size-class distributions for all species combined followed negative exponential curves, with about 100 stems/ha in the smallest size class and < 40 stems/ha for trees > 50 cm dbh (fig. 3). However, species and species groups differed between the maple- and oak-stand types. In maple stands, lower and mid size classes were dominated by maple, which shared dominance with oaks and other species (primarily *Fraxinus americana* and *Juglans nigra*) in upper size classes. In oak stands, maples were less than half as abundant as in maple stands and were represented primarily in the 2 smallest size classes. Oaks had unimodal size-class distributions in all stands and were least abundant in maple stands. These distributions were due primarily to red oak in red oak stands and white oak in white oak stands. *Fraxinus americana*, *Tilia americana*, *Ulmus rubra*, *Prunus serotina*, and (to a lesser extent) *Ostrya virginiana*, were primarily responsible for the negative exponential distributions of all species in oak stands.

Table 2. Mean (\pm se) dominance (Dom), and basal area (BA) of tree species prism sampled by the INAI in Chicago-region maple, red oak, and white oak stands in 1976

Species	Maple stands			Red oak stands			White oak stands		
	Dom	\pm se	BA	Dom	\pm se	BA	Dom	\pm se	BA
<i>Quercus alba</i>	0.074	0.022	1.89	0.249	0.037	6.07	0.472	0.073	11.96
<i>Quercus rubra</i>	0.157	0.042	3.99	0.413	0.062	10.06	0.168	0.053	4.25
<i>Acer saccharum</i>	0.451	0.048	11.44	0.053	0.029	1.29	0.038	0.025	0.97
<i>Fraxinus americana</i>	0.080	0.021	2.03	0.081	0.014	1.96	0.035	0.021	0.89
<i>Tilia americana</i>	0.101	0.022	2.57	0.032	0.010	0.77	0.009	0.007	0.22
<i>Ulmus rubra</i>	0.038	0.013	0.97	0.047	0.014	1.14	0.038	0.023	0.96
<i>Quercus velutina</i>	0.001	0.001	0.02	0.020	0.012	0.48	0.052	0.034	1.32
<i>Prunus serotina</i>	0.003	0.001	0.07	0.019	0.008	0.46	0.042	0.021	1.07
<i>Ostrya virginiana</i>	0.029	0.017	0.73	0.014	0.004	0.35	0.019	0.016	0.49
<i>Quercus macrocarpa</i>	0.013	0.007	0.33	0.014	0.011	0.33	0.027	0.021	0.69
<i>Quercus bicolor</i>	0.010	0.008	0.25	0.022	0.018	0.53	0.018	0.011	0.47
<i>Juglans nigra</i>	0.019	0.011	0.49	0.008	0.003	0.19	0.019	0.011	0.48
<i>Carya ovata</i>	0.002	0.001	0.05	0.009	0.007	0.22	0.020	0.008	0.52
<i>Ulmus americana</i>	0.005	0.005	0.12	0.007	0.007	0.18	0.013	0.010	0.33
<i>Quercus coccinea</i>	0.001	0.001	0.03	0.001	0.001	0.02	0.015	0.011	0.38
<i>Carya cordiformis</i>	0.001	0.001	0.03	0.004	0.002	0.10	0.007	0.007	0.18
<i>Populus deltoides</i>	0.005	0.004	0.14	0.003	0.002	0.06			
<i>Fraxinus quadrangulata</i>	0.002	0.002	0.06				0.004	0.004	0.11
<i>Juglans cinerea</i>	0.001	0.001	0.03	0.004	0.002	0.11			
<i>Betula papyrifera</i>	0.003	0.003	0.08						
<i>Populus grandidentata</i>	0.002	0.002	0.05				0.001	0.001	0.03
<i>Fraxinus pennsylvanica</i>	0.001	0.001	0.03				0.001	0.001	0.02
<i>Carpinus caroliniana</i> v. <i>virginiana</i>	0.001	0.001	0.03	0.001	0.001	0.02			
<i>Acer rubrum</i>							0.001	0.001	0.02
<i>Prunus virginiana</i>	0.001	0.001	0.02						
<i>Crataegus prinosa</i>				0.001	0.001	0.02			
Total prism BA			25.40			24.40			25.40
Total size-class BA			35.40			33.94			30.27

Notes: *Quercus bicolor* includes hybrids with *Q. macrocarpa*. Total size-class BA is based on size-class midpoints (see text for methods).

The range in percent canopy cover measured by canopy photographs was narrow, extending from 70% in white and red oak stands to > 71% in maple stands (fig. 4). However, percent cover was significantly higher in maple than in oak stands, which corresponded to lower shrub layer and ground layer species richness (see below).

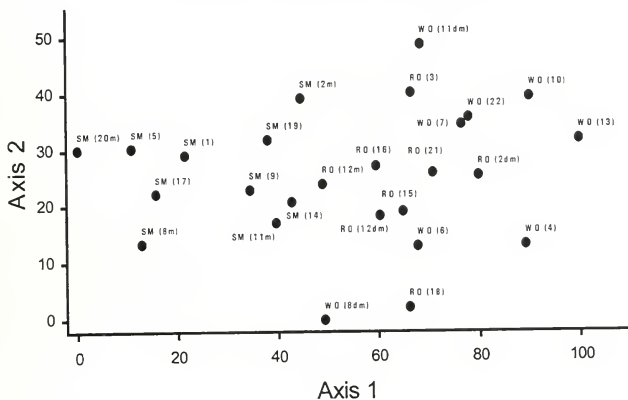
Shrub layer vegetation in 1976

Shrub layer composition and structure differed among stand types (fig. 5). Maple stands had a significantly lower Simpson's Diversity Index ($F = 8.54$, $P = .0017$) and averaged 5.4 (± 0.93 std. err.) species/stand in comparison to 10.25 (± 1.10 std. err.) species in red oak stands and 10.375 (± 1.35 std. err.) species in white oak stands. Overall, maple stands averaged almost 6,000 stems/ha, red oak stands 7,400 stems/ha, and white oak stands > 11,000 stems/ha, and there was an inverse relationship between sapling and shrub density across stand types (fig. 5). Saplings constituted 80% of all stems in maple stands, 50% of all stems in red oak stands, and only 15% of all white oak-stand stems, while native shrubs accounted for 18% of all stems in maple stands, 43% of all red oak-stand stems, and 75% of white oak-stand stems.

Understory trees were rare in maple stands, but densities exceeded 2,500 stems/ha in red oak stands and 1,000 stems/ha in white oak stands.

Maple was by far the dominant sapling in maple stands, but was less abundant than *Prunus serotina* and *Fraxinus americana* in oak stands. The oaks *Quercus alba*, *Q. coccinea*, and *Q. macrocarpa* had lowest sapling densities. *Crataegus prinosa* and *Ostrya virginiana* were the predominant understory trees, especially in oak stands, while *Carpinus caroliniana* var. *virginiana*, *Malus ioensis*, and 4 other *Crataegus* species were less abundant. The alien buckthorns *Rhamnus cathartica* and *R. frangula* occurred at relatively low stem densities, constituting < 1% of the shrub layer. *Viburnum prunifolium*, *Viburnum rafinesquianum*, *Cornus racemosa*, and *Prunus virginiana* were the most abundant shrubs in oak stands, while *Hamamelis virginiana* and *Viburnum acerifolium* were more characteristic of maple stands. *Cornus alternifolia* and *C. rugosa* were sampled only in maple stands.

NMS Forest Stand Ordination



Species Dominance Among Stand Types

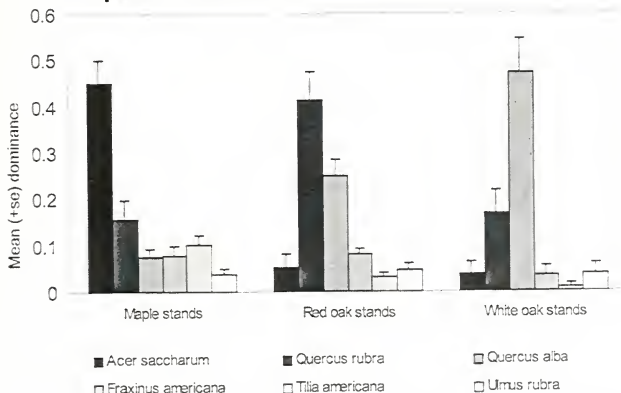


Fig. 2. Non-metric Multidimensional Scaling (NMS) forest stand ordination (upper graph) and species dominance among forest stand cluster groups (lower graph)
 Ordination codes: SM = sugar maple stands, RO = red oak stands, WO = white oak stands. Numbers in parentheses are site numbers from table 1; for sites with multiple INAI stands, dm = dry-mesic, m = mesic.

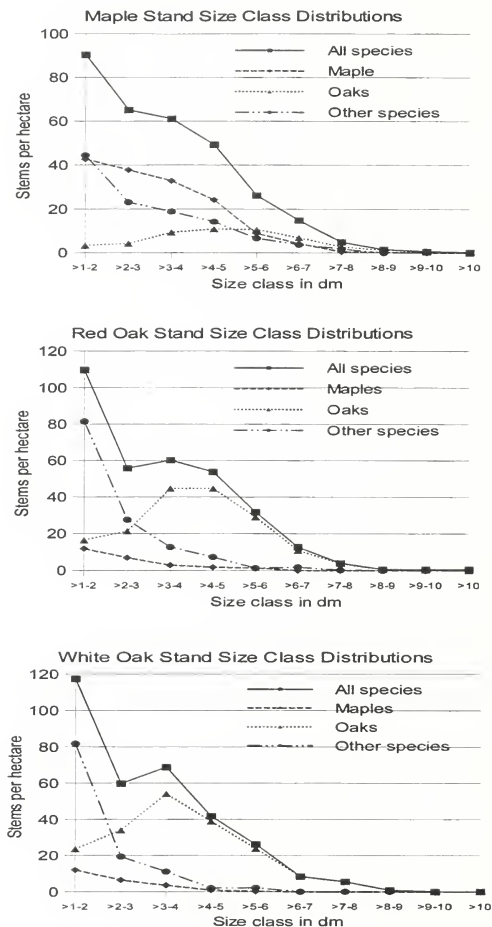


Fig. 3. Size-class distribution curves in stems/ha for all species (—■—), maples (-◆-), oaks (···▲···), and other species (···•···) sampled by the INAI in Chicago-region maple, red oak, and white oak stands in 1976

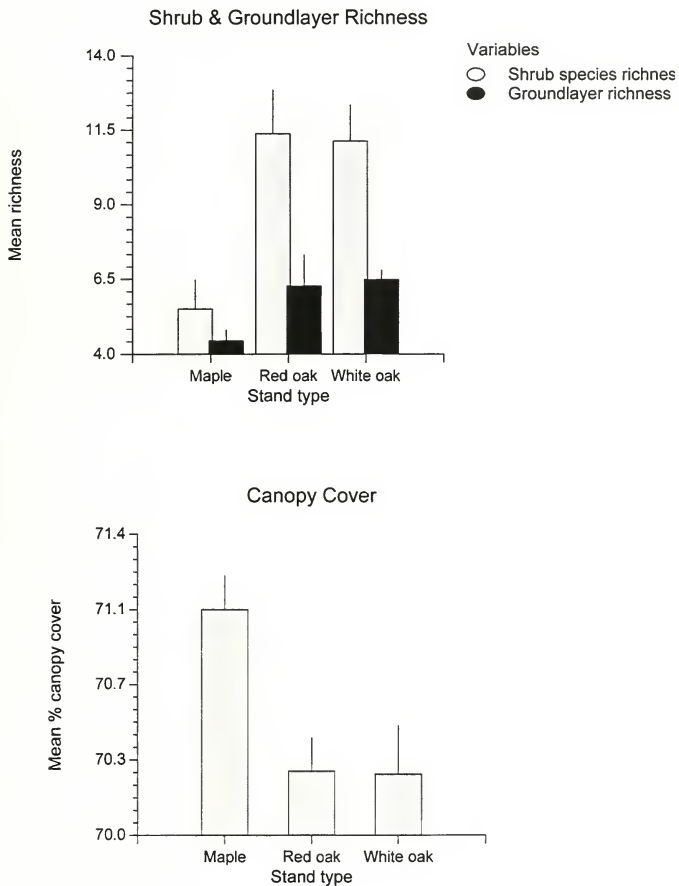


Fig. 4. Relationship between stand type, native shrub species richness, and native ground layer plot species richness (upper graph), and percent canopy cover (lower graph)
 ANOVA: shrub species richness ($F = 6.21$, $P = .007$), ground layer richness ($F = 3.45$, $P = .049$), and percent canopy cover ($F = 6.37$, $P = .002$).

Shrub Layer Structure

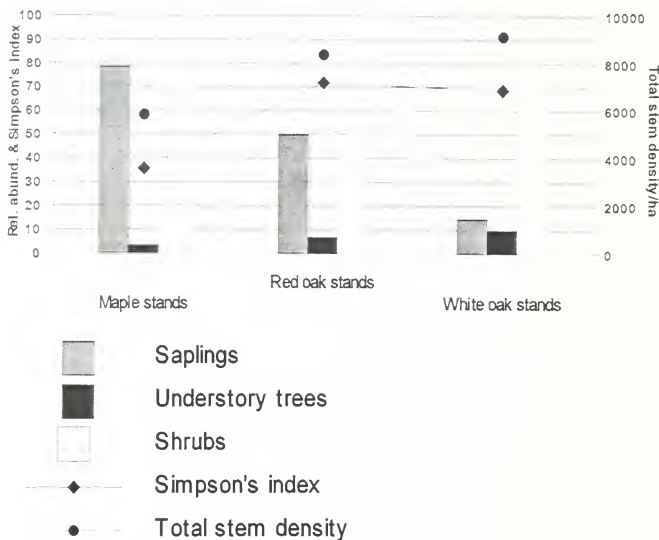


Fig. 5. Inverse relationship in shrub layer structure among Chicago-region upland forest stand types. Relative abundance is percent of total stem density of sapling, understory tree, and shrub species (left axis). Simpson's Index (left axis) is the average for all stands in each stand type. See text for calculations and all species stem densities.

Ground layer vegetation in 1996

Ground layer sampling encountered 181 species, including 105 native herbs, 44 native woody species, 19 native grasses, and 14 alien species. Herbs included 15 spring ephemerals, 29 spring-flowering herbs, and 61 summer-flowering herbs. Most species were rare, with more than 90% averaging less than 10% plot frequency across all stands, and > 90% of all species restricted to < 30% of all stands. The 29 most abundant species averaged > 5% frequency across all stands, and the 4 most abundant species (*Smilacina racemosa*, *Circaea lutetiana* var. *canadensis*, *Dentaria laciniata*, and *Erythronium albidum*) were native herbs (fig. 6). Sugar maple seedlings were fifth most abundant, and this was the only species with > 50% average stand frequency (in maple stands). The alien *Alliaria petiolata* was the seventh most abundant species,

with > 40% frequency in white oak stands. Maple stands had 86 native species sampled, with greater abundance, for example, of *Erythronium albidum*, *Acer saccharum*, *Allium tricoccum* var. *burdickii* and *Isopyrum biternatum* than in oak stands. *Mertensia virginica*, *Hydrophyllum appendiculatum*, and *Dicentra canadensis* were sampled only in maple stands. Red oak stands had 111 native species sampled, and white oak stands had 120 native species. Oak stands also differed from maple stands by greater frequencies of most common species. Although some species sampled were unique to red and white oak stands, their frequencies were so low as to be unreliable as oak-stand indicators.

Among functional groups, spring ephemerals tended to be more frequent in maple stands, and spring herbs more frequent in red oak stands; however, these trends were not significant (fig. 7). Summer herbs, woody plants,

and graminoid species had significantly fewer occurrences in maple stands than in red or white oak stands, and white oak stands had more stand occurrences of alien species. Patterns of species relative abundance also differed by functional group among stand types (fig. 7). Within maple stands, spring ephemerals and woody plants (maple seedlings) were most abundant. Summer herbs were slightly more abundant in red oak stands, and summer herbs and woody species more abundant in white oak stands. Graminoid and alien species were the least important groups in all stand types. The MRPP test indicated a highly significant difference in ground layer vegetation composition among stand types, and pair-wise comparison of mean Bray-Curtis similarity indices indicated that this was due to significantly different composition of maple stands in comparison with oak stands (fig. 8). Red and white oak stands were not significantly different from each other.

Measures of ground layer vegetation species richness differed significantly among stand types (table 3). Mean native richness (S_N), native plot species richness ($\bar{x}R_N$), and Native Richness Index (NRI) values were lower in maple stands, intermediate in red oak stands, and higher in white oak stands. White oak stands had higher alien richness. Although the NRI and FQI were highly correlated ($r^2 = 0.645$, $P < 0.000$), $\bar{x}R_N$ and $\bar{x}C$ were not ($r^2 = 0.003$, $P = 0.784$), and $\bar{x}C$ and FQI values did not differ significantly among stand types.

Comparisons among fire-managed and unmanaged stands

Fire-managed and unmanaged stands differed significantly in their abundance of native and alien species. For example, across all stand types, $\bar{x}R_N$ and NRI values, but not $\bar{x}C$ or FQI values, were higher for stands with fire management histories (fig. 9). The alien *Alliaria petiolata* was more abundant in stands with management fire histories (fig. 10). Dormant-season fire significantly reduced survivorship of maple seedlings at the Ryerson Conservation Area (fig. 11). Mean survivorship was 100% in unburned sections of 2 transects, but was reduced to 26.15% and 16.67% in burned sections of these transects. Despite the significantly lower maple survivorship in burned plots, their stem numbers still reached 4000 stems/ha (fig. 11).

DISCUSSION

Woody vegetation composition and classification

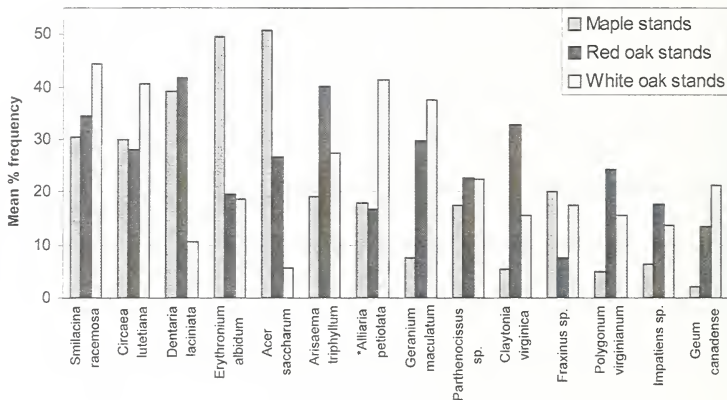
In the Chicago region of Illinois, dry-mesic and mesic forests differ along a species gradient, in which either sugar maple, red oak, or white oak is the dominant overstory species. This species gradient is similar to the upland forest

continuum identified in Wisconsin (Curtis and McIntosh 1951). It is also part of a much broader landscape forest continuum that includes wet to wet-mesic lowland *Acer saccharinum*-dominated forest, mesic *A. saccharum* forest, dry-mesic *Quercus velutina*-*Q. alba* forest, and dry upland (on sand) *Q. marilandica* Münchh. forest (White and Madany 1978; Adams and Anderson 1980; Anderson 1991). Further, this gradient corresponds to a presettlement landscape fire gradient characteristic of the prairie peninsula region. Greater fire frequency and oak dominance occur in forests on drier sites that received little landscape fire protection, while less fire frequency and greater tree density and maple abundance occur in forests afforded protection by landscape firebreaks such as rivers or ravines (Anderson 1991; Leitner et al. 1991; Bowles, Hutchison, and McBride 1994; Bowles, McBride, and Bell 1999). Fire in these prairie peninsula forests apparently promoted oak dominance, or codominance with maple, even in mesic sites. More eastern "climax" mesophytic maple forests differ because of codominance of beech (*Fagus grandifolia*), while mesophytic maple forests west of the "beech border" in Minnesota tend to have codominance of *Tilia americana* (e.g., Rogers 1981). The low *T. americana* importance in Chicago-region mesic sites indicates different composition from "climax" mesophytic central hardwood mesic forests, possibly because of the early stage of succession from oak dominance.

The continuum nature of a species-environmental gradient complicates moisture gradient classification. The INAI resolved this in part by describing a bimodal distribution of red oak, placing it as codominant in both dry-mesic and mesic forest stands (White and Madany 1978). Dominant species, such as oaks and maple, however, tend to occupy narrow portions of the environmental gradient (Adams and Anderson 1980), and our analysis indicates that red oak-dominated stands should be given a "dry-mesic *Q. rubra*" classification intermediate between what might be better described as "mesic *A. saccharum*" stands and "mesic-dry *Q. alba*" stands. As expected with a species continuum, red oak stands share some species characteristics with maple stands and others with white oak stands. For example, red and white oak stands have lower *Tilia americana* dominance than maple stands, but red oak and maple stands have greater *Fraxinus americana* dominance than white oak stands (fig. 2).

Shrub layer structure and composition also differ among stand types, with an inverse relationship between sapling and shrub densities across stand types, and lower diversity in maple stands (table 3). Many ecological factors, such as canopy cover, moisture, fire history, and grazing or browsing may affect these gradients (e.g., Loucks and

Mean Species Frequencies Among Stands



Mean Species Frequencies Among Stands

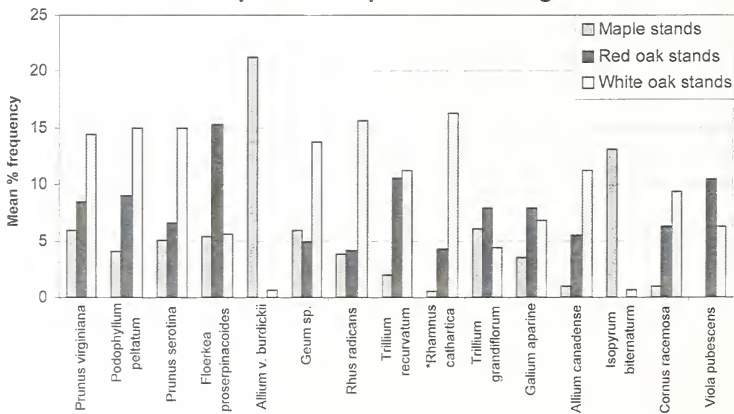


Fig. 6. Mean % frequencies of dominant ground layer species sampled in maple, red oak, and white oak stands in 1996. See Appendix II for means and standard errors of all species sampled. Asterisk (*) indicates alien species.

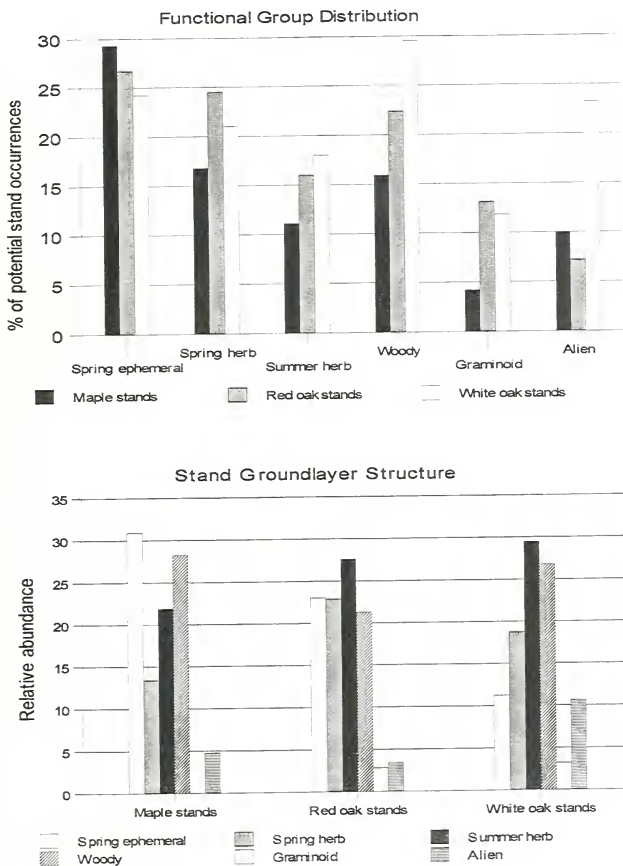


Fig. 7. Stand-type distribution of species functional groups as a percentage of potential occurrences (upper), and relative abundance of functional groups by percent species occurrence within stand types (lower). Distributions are significantly different ($p < 0.05$) for summer herb, graminoid, woody, and alien groups (upper graph).

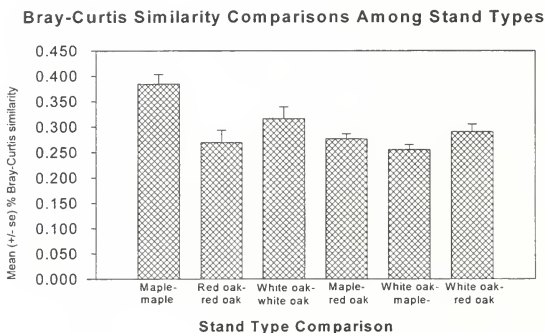


Fig. 8. Among vs. within stand comparisons of Bray-Curtis similarity indices using ground layer vegetation frequencies sampled in 1976

MRPP for maple = red oak = white oak: $t = -4.78$, $P < 0.001$.

ANOVA for all comparisons: $F = 9.245$, $P < 0.0001$; with Fisher's PLSD test at $P < 0.05$, maple-maple similarity is significantly higher than maple-white oak or maple-red oak similarity, and white oak-white oak similarity is significantly higher than white oak-maple similarity, but is not different from white oak-red oak similarity.

Table 3. Comparison of ground layer Species Richness and Floristic Quality indices among high quality maple, red oak, and white oak stands sampled in 1996 along original INAI woody vegetation transects

Maple-dominated site	S _N	S _A	$\bar{x}R$	$\bar{x}R_N$	SRI	NRI	NRI/SRI	$\bar{x}C$	FQI
Maple Grove	39.00	1.00	5.38	5.24	19.85	19.20	0.97	4.23	26.42
Pilcher Park	29.00	2.00	6.00	5.70	20.60	19.19	0.93	4.17	22.46
G. L. Lloyd Woods	29.00	1.00	5.65	5.60	19.22	18.86	0.98	4.34	23.37
Ryerson mesic	29.00	1.00	5.00	4.95	17.01	16.67	0.98	3.68	19.82
Johnson's Mound (mesic)	26.00	4.00	5.10	4.75	17.35	15.48	0.89	4.60	23.46
Bloomington Grove	23.00	4.00	5.60	4.85	18.46	15.21	0.82	3.54	16.98
Morton Arboretum	22.00	1.00	4.70	4.20	14.74	12.98	0.88	3.77	17.68
McCormick (mesic)	19.00	1.00	4.00	3.90	11.98	11.48	0.96	5.10	22.23
Busse Woods (mesic)	10.00	0.00	3.00	3.00	6.91	6.91	1.00	4.90	15.50
River Road	11.00	1.00	2.50	2.35	6.21	5.64	0.91	3.82	12.67
Average	23.70	1.60	4.69	4.45	15.23	14.16	0.93	4.22	20.06
Std. Error	2.64	0.40	0.35	0.33	1.57	1.47	0.02	0.16	1.28
Red oak-dominated site	S _N	S _A	$\bar{x}R$	$\bar{x}R_N$	SRI	NRI	NRI/SRI	$\bar{x}C$	FQI
Raccoon Grove	38.00	0.00	10.39	10.39	37.79	37.79	1.00	4.16	25.64
Messenger (dry-mesic)	41.00	0.00	9.50	9.50	35.28	35.28	1.00	4.49	28.75
Norris Woods	46.00	2.00	7.50	6.45	29.03	24.69	0.85	3.47	23.53
Crabtree	40.00	1.00	6.45	6.25	23.95	23.06	0.96	3.92	24.79
Messenger (mesic)	30.00	1.00	6.76	6.71	23.21	22.82	0.98	4.33	23.72
St. Francis Boys Camp	31.00	2.00	5.82	5.73	20.35	19.68	0.97	4.13	22.99
Busse Woods (dry-mesic)	38.00	1.00	4.15	4.10	15.20	14.91	0.98	3.86	23.79
Paw Paw Woods	10.00	1.00	1.23	1.04	2.95	2.39	0.81	3.60	11.38
Average	34.25	1.00	6.48	6.27	23.47	22.58	0.94	4.00	23.08
Std. Error	3.67	0.25	0.96	0.97	3.70	3.69	0.02	0.12	1.68
White oak-dominated site	S _N	S _A	$\bar{x}R$	$\bar{x}R_N$	SRI	NRI	NRI/SRI	$\bar{x}C$	FQI
Elburn	37.00	3.00	9.25	8.15	34.12	29.43	0.86	3.76	22.87
Johnson's Mound (dry-mesic)	39.00	3.00	7.70	7.25	28.78	26.56	0.92	4.06	25.35
McCormick (dry-mesic)	44.00	4.00	7.50	6.70	29.03	25.35	0.87	4.08	27.06
Thorn Creek Woods	43.00	0.00	6.45	6.45	24.26	24.26	1.00	3.77	24.72
MacArthur Woods	41.00	4.00	6.85	5.85	26.08	21.72	0.83	4.28	27.41
Mooseheart Ravine	29.00	4.00	7.25	6.20	25.35	20.88	0.82	3.82	20.57
Herrmann's Woods	30.00	1.00	6.00	5.80	20.60	19.73	0.96	3.73	20.43
Helms Woods	32.00	4.00	6.85	5.45	24.55	18.89	0.77	3.61	20.42
Average	36.88	2.88	7.23	6.48	26.60	23.35	0.88	3.89	23.60
Std. Error	1.95	0.51	0.33	0.29	1.34	1.21	0.03	0.07	0.97
ANOVA	F ratio		4.57	3.45	5.9	4.67	2.31	1.55	1.92
	P value		0.0214	0.0488	0.0085	0.0199	0.1219	0.296	0.357

S_N = total native richness, S_A = total alien richness, $\bar{x}R$ = plot species richness, $\bar{x}R_N$ = native plot species richness, SRI = species richness index, NRI = native richness index, $\bar{x}C$ = mean coefficient of conservatism, FQI = floristic quality index.

Notes: ANOVA tests hypotheses of no significant difference among stands for each column variable. Mean C and FQI calculations are based on native species, and their sample sizes may differ slightly from NRI values because species identified only to the genus level cannot be assigned C values.

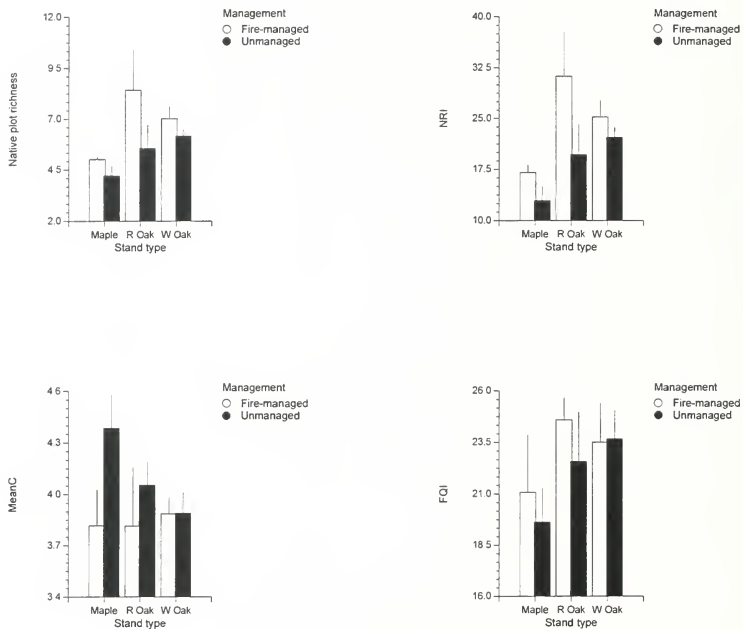


Fig. 9. Mean (\pm se) Native Plot Richness (upper left), Native Richness Index (upper right), Mean Coefficient of Conservatism (lower left), and Floristic Quality Index (lower right) of fire-managed and unmanaged maple, red oak, and white oak forest stands sampled in 1996

ANOVA:

<u>Response variable</u>	<u>Management</u>	<u>Stand type</u>	<u>Management \times Stand type</u>
Mean Native Plot Richness ($\bar{x}R_N$)	F = 3.98, P = 0.059	F = 4.00, P = 0.035	F = 0.74, P = 0.490
Native Richness Index (NRI)	F = 4.46, P = 0.048	F = 5.16, P = 0.016	F = 0.76, P = 0.481
Mean Coefficient of Conservatism	F = 2.66, P = 0.119	F = 0.67, P = 0.513	F = 1.08, P = 0.193
Floristic Quality Index	F = 0.33, P = 0.572	F = 1.38, P = 0.275	F = 0.11, P = 0.063

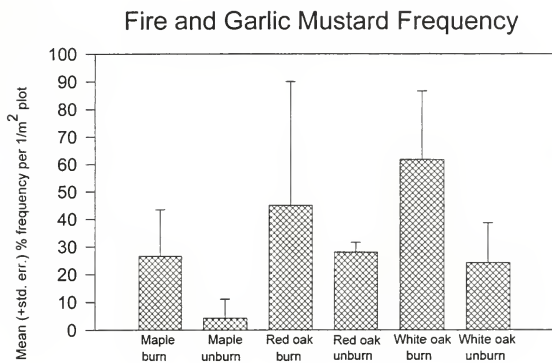


Fig. 10. *Alliaria petiolata* abundance in burned and unburned maple, red oak, and white oak stands sampled in 1996. ANOVA: fire ($F = 5.69$, $P = 0.026$), stands ($F = 1.22$, $P = 0.3134$), fire \times stands ($F = 0.46$, $P = 0.6375$).

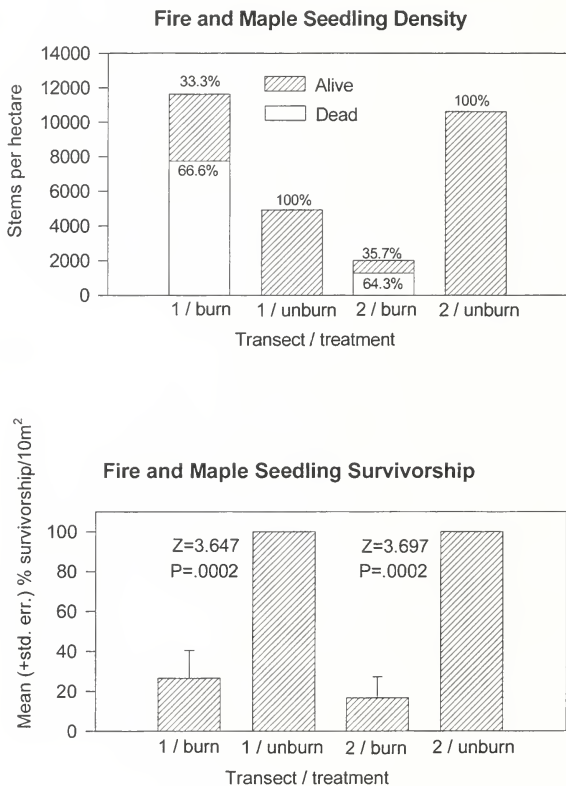


Fig. 11. Response of ground layer maples to prescribed fire in 2 transects in maple forest at Ryerson Conservation Area in 1996

Upper graph: stem density per ha and proportions of alive and dead maple stems in burned and unburned plots. Lower graph: transect Z statistics and probabilities that mean survivorship differs between burned and unburned plots. Transect 1 = 8 burned and 12 unburned 0.01 ha plots, Transect 2 = 7 burned and 13 unburned 0.01 ha plots.

Schnur 1976). We measured an extremely small but significant difference in percent canopy cover between maple (> 71%) and oak forests (70%). Whether or not > 71% represents a threshold for negatively affecting shrub layer (and ground layer) vegetation is not clear. However, Pubanz and Lorimer (1992) and Lorimer, Chapman, and Lambert (1994) found that a reduction from about 95% to 85% canopy cover, measured as a % of total Photosynthetically Active Radiation (PAR), enhanced oak seedling survivorship in oak forests. This indicates that change in a narrow range of canopy cover can significantly affect shade-intolerant understorey vegetation. Our measures used different instrumentation with a fixed calibration point, and may not be linear or directly comparable to measures of PAR.

Greater canopy cover and a large maple seed source are the most likely causes of higher maple sapling densities in maple stands. The lower densities of true shrub species in maple stands may result from low shade intolerance of most shrubs, and competition from maple seedlings and saplings (Bray 1956; Curtis 1959). Many shrubs decline with increasing canopy cover and thus prefer the more open canopy conditions of white oak stands (e.g., McIntosh 1957). The shade-intolerant shrub *Corylus americana* was the most frequent species of woody undergrowth recorded in presettlement DuPage County forests (Bowles, Hutchison, and McBride 1994; Bowles, McBride, and Bell 1999), but it now occurs at relatively low densities. The shade-tolerant shrub *Lindera benzoin* (Luken et al. 1997) is characteristic of mesic sites such as beech-maple forests (Davidson and Buell 1967; Rogers 1981; Foré, Vankat, and Schaefer 1997), but it is absent from most Chicago-region maple stands.

Deer browsing is an additional factor affecting shrub layer structure and composition, as deer winter-browse many shrubs and tree saplings, but tend to avoid maple (Strole and Anderson 1992). In 1996, we noted a browsing preference for *Carpinus caroliniana* var. *virginiana* at many sites, including the Ryerson Conservation Area and Busse Woods. At Thorn Creek Woods we also found higher frequencies of deer-browsed *Viburnum acerifolium* stems in ground layer plots than in shrub plots, whereas the INAI found higher shrub layer stem densities for this shrub in 1976. *Crataegus mollis* is also not preferred by deer (Strole and Anderson 1992), which may have enhanced its density in oak stands. However, the greater abundance of this and other *Crataegus* species in oak stands, as opposed to maple stands, may be related to former open canopy conditions and possibly a history of more pasturing in upland sites.

Ground layer vegetation distribution, composition, and structure

As with woody vegetation, the structure and composition of ground layer vegetation separates maple and oak stands, with red oak stands usually intermediate between maple and white oak stands. The primary differences are low species richness, greater relative abundance of spring ephemerals, and high abundance of maple seedlings in maple stands, and greater species richness and greater representation of different functional groups in oak stands. The alignment of these stands along a moisture gradient presumably has a strong effect on differences in species composition among stand types, and may result in differences in species richness. The correlation of these features with higher % canopy cover in maple stands also fits an expected model of reduced species richness associated with greater maple dominance and low available light (McIntosh 1957; Curtis 1959). As with shrubs, low diversity of ground layer species in some maple stands is also a direct effect of past overbrowsing by eastern white-tailed deer, which have eliminated many herbaceous species from the Ryerson Conservation Area (Anderson 1994) and Busse Woods (M. L. Bowles, pers. obs.), and are impacting ground layer vegetation at other sites (e.g., Bowles, Bell, and McBride 1995, 1996).

Chicago-region forests represent most of the ground layer vegetation expected for central hardwood mesophytic upland forest communities (Rogers 1981, 1982). It is possible that ground layer vegetation sampled in 1996 still represents the 1976 ground layer of most stands, as spring and summer herbs tend to have little temporal variability, except for differences in cover (Rogers 1983; Moore and Vankat 1986). Such spatially stable "light-flexible herbs" (Collins, Dunne, and Pickett 1985) tolerate shade, use light flecks, and flower and fruit more frequently in relation to their inherent size, or canopy gap and edge development (e.g., Zangerl and Bazzaz 1983; Lee et al. 1986; Dahlem and Boerner 1987; Piper 1989). However, these species require soil-disturbance gaps for regeneration (Thompson 1980), and some studies suggest that they may decline with increasing time since canopy disturbance (Brewer 1980; Olivero and Hix 1998).

A large array of summer herbs with high light requirements may be poorly represented in upland oak forests that lack fire disturbance (Wilhelm 1991), but few data document the former occurrence or composition of this species group in Illinois forests. Suites of species occupy a light gradient across savanna and woodland (Bowles et al. 1996; Bowles and McBride 1998), and many may have been more important in oak forests that had dynamic fire processes and more open canopies. The

measures of species richness and floristic quality in this paper apparently omit such species, and may under represent the potential species diversity of oak forests.

FOREST CONSERVATION AND MANAGEMENT ISSUES

Species distribution and conservation needs

Although our data represent stand samples rather than total species inventories, they indicate strong heterogeneity within and among stand types. These localized species distribution patterns have important implications for conservation of biodiversity within the Chicago region. The occurrence of most species in < 30% of all stands indicates that protection is needed for as many sites as possible to preserve landscape diversity, and that no single stand can completely represent a forest type. The low frequency of species within stands also suggests that larger sites are more likely to contain more individuals of most species, which should enhance population viability.

Management implications of forest structure

The size-class structure of northeastern Illinois forests is usually to other central hardwood oak forests. All species usually combine to produce size-class curves resembling a negative exponential distribution, but species groups have different distributions because they have different adaptations (Johnson and Bell 1975). In oak stands, workers have found that shade-tolerant maples are most abundant in small size classes, indicating recurring reproduction, while shade-intolerant oaks are usually restricted to larger size classes, indicating lack of reproduction under their own canopy shade. These observations have led to almost universal conclusions that in the absence of fire, formerly more open oak forests are shifting toward canopy closure and gap-phase reproduction processes, in which oaks will not reproduce in the face of increasing understory maple dominance (e.g., Bray 1956; Boggess 1964; Boggess and Bailey 1964; Boggess and Geis 1966; McClain and Ebinger 1968; Schlesinger 1976; Christensen 1977; Miceli et al. 1977; Anderson and Adams 1978; Adams and Anderson 1980; McGee 1986; Abrams and Downs 1990; Pallardy, Night, and Garrett 1991; Abrams 1992; Roovers and Shifley 1997). As indicated above, change or decline in ground layer vegetation should be expected in association with this change in canopy structure.

Stand histories are also important in structuring species size-class distributions and the overall condition of stands, and in understanding management or restoration needs. For example, the Ryerson Conservation Area had a large component of old growth *Ulmus americana* that was

destroyed by Dutch elm disease in the 1960s (Bowles et al. 1998). This disease reduced elms to small size classes in central Illinois (Johnson and Bell 1975), and allowed increased shrub growth in Wisconsin (Dunn 1986, 1987). At Ryerson, recent elm mortality may have been more important than absence of fire in promoting establishment of the large cohorts of 1–<2 dm size-class of maples that are now present. Thus the current structure of this stand is not necessarily directly related to fire history.

Postsettlement fire was replaced by human disturbances such as occasional burning, tree cutting, and pasturing in many forests through the early 1900s (e.g., Nowacki and Abrams 1997). When these disturbances were moderate, they may have been important in preserving ground layer diversity that would have been lost with total fire protection. More severe disturbances may have decoupled some forest stands from presettlement conditions, resulting in different successional trajectories that require different management goals (Mendelson 1998). However, such disturbances may have had less effect on the structure of old growth oak stands in this study. For example, excluding basswood, trees up to 50 cm dbh probably originated soon after settlement, trees > 60–70 cm dbh originated prior to settlement, and larger oaks appear to date back to the late 1700s (M. L. Bowles and M. Jones, unpublished tree ring data). Thus, these stands have direct linkage with presettlement conditions.

Given the evidence of former landscape-scale fire processes in northeastern Illinois forests, the lack of oak regeneration in most stands, and concerns for ground layer diversity, application of fire is a critically important management need. However, few experimental data are available to guide the implementation of this process, and there are many questions and concerns. For example, Luken and Shea (2000) found that burning an upland maple-forest stand did not significantly affect ground layer richness, and our lack of preburn data prevents a conclusion that fire management resulted in higher native species richness. However, the significant reduction of ground layer maples after one dormant-season fire suggests that fire management can reduce maple stem densities, as found by Luken and Shea (2000). Despite this reduction, the density of surviving maples in our burned plots remained in the 1000–4000 stems/ha range. Because maple seedling mortality is initially density dependent and decreases with age (Hett 1971), high levels of sapling recruitment might still occur. Repeated experimental burns are needed to determine if further maple recruitment can be controlled. Also, high maple seedling densities are natural in maple stands, and fire management to reduce

maples may be more important where they are invading oak forests.

Historic landscape-scale fire effects on forest canopy structure and ground layer composition may be difficult to replicate with modern management fires in forest fragments, and there are also potential damaging or conflicting effects of fire management. For example, although we lack controls and precise fire histories, our data suggest that garlic mustard may persist in fire-managed tracts, a conclusion supported by Luken and Shea (2000). This species is a disturbance-adapted biennial, and fires expose seed beds that enhance its establishment and spread (Anderson, Dhillon, and Kelley 1996). Although repeated annual burns may deplete seed banks and reduce its population sizes, they may negatively affect other plants or animals. Shrub layer management is of particular concern, because this forest structural component provides the nesting substrate for forest interior birds, and alien shrubs enhance nest predation (Whelan and Dilger 1992, 1995; Schmidt and Whelan 1999). However, the frequency and intensity of fires needed to maintain shrub layer diversity while managing for herbaceous ground layer vegetation is unknown and may vary among sites. For example, Luken and Shea (2000) found a 116% increase in shrub layer stems after 2 consecutive burns in lowland forest, but a 97% decline after 3 burns in upland habitat. Finally, almost no information is available on the status of forest invertebrate species and the potential effects of fire on their populations (although see Wolf [1992], and Newman and Wolf [1992]).

MONITORING ISSUES

Woody vegetation monitoring

The woody vegetation data in this paper represent a structural composition profile of high quality forests in the Chicago region of northeastern Illinois. These data also constitute a structural baseline against which temporal forest change can be compared. Important monitoring objectives should be to detect temporal and spatial changes in size-class distribution of different canopy species groups, especially in relation to management. For example, an increase in maple stem numbers in small size classes in oak stands would indicate maple invasion, while their decline in response to fire would indicate a positive management effect. Changes in smaller size classes of oaks could indicate whether reproduction is occurring, and loss of larger size-class trees would indicate that the oak canopy structure is deteriorating. Clearly, shrub layer monitoring is critical, as it examines an important component of structural diversity that may be vulnerable to changing

canopy conditions, deer browsing, or management fires. Measures of relative abundance of sapling, small tree, and true shrub species densities will reveal structural shifts, while species richness or diversity measures will help monitor changes in biodiversity.

Ground layer vegetation monitoring

Although using single indices to monitor vegetation and assess effects of management treatments is attractive, such metrics often fail to quantify complex vegetational features and may obscure important information (Magurran 1988; Kremen 1992). Indices intended to be useful for vegetation monitoring should be statistically sound and capable of detecting responses to factors that affect structural composition of vegetation. Our analysis and testing of the Native Richness Index (NRI) indicates that its components, mean plot species richness ($\bar{x}R_N$) and total native richness (S_N), are highly sensitive to differences among forest stand types and to differences among fire-managed and unmanaged stand sites. Plot species richness is also an unbiased measure that is amenable to statistical analysis. As a component of NRI, $\bar{x}R_N$ provides a useful small-scale measure that is sensitive to minor compositional changes in vegetation that may be linked to important causal factors. When coupled with measures of abundance of different species by functional group, this can be a highly effective monitoring tool.

The significant correlation ($r^2 = 0.645$, $P < 0.001$) between NRI and FQI occurred because total sample richness (S) is used in both formulations ($NRI = \ln S_N \times \bar{x}R_N$, and $FQI = \sqrt{S} \times \bar{x}C$). However, these indices differed because of the poor correlation ($r^2 = 0.003$, $P = 0.784$) between $\bar{x}R_N$ and $\bar{x}C$. The failure of FQI to find differences among stand types and management effects was thus due to the subjective assignments of C values to plant species. Likewise, Francis et al. (2000) found that FQI obscured patterns among its components because \sqrt{S} and $\bar{x}C$ are not similar measures. When using the FQI or $\bar{x}C$, one might conclude that there were no significant differences in quality among the stand types compared in this study. However, the NRI indicates that significant differences occur among stand types, and that these differences are due to factors affecting small- and large-scale measures of species richness. In this case, these factors may be related to differences in % canopy cover or in fire management.

More research is needed to determine how the NRI applies to other plant communities and to *a priori* assessments of their condition or quality. In an analysis of 1976 INAI graminoid plant community data, the NRI corroborated *a priori* A and B quality assignments with higher quality sites having higher species richness (Bowles

and Jones 1999). In savanna analysis, native and alien plot species richness was also highly sensitive to ground layer differences along a light gradient (Bowles et al. 1996; Bowles and McBride 1998). This suggests that fire-caused changes in forest structure that increase canopy light (an important management objective) should be detectable by the NRI.

CONCLUSIONS

Analysis of the structural composition of upland dry-mesic and mesic forests surveyed by the INAI in northeastern Illinois allowed classification of maple, red oak, and white oak forest types. Maple-dominated stands are structurally and compositionally less diverse than oak stands, with higher canopy cover, lower shrub layer diversity and stem densities, and lower ground layer species richness. Although ground layer richness was higher in oak stands, it was also highly heterogeneous within and among stands, with > 90% of all species sampled in < 30% of all stands. Thus, few, if any, single stands can represent stand types. Spring ephemerals and maple seedlings tended to be most important in maple stands, while other ground layer species functional groups tended to be more important in oak-stand types. These profiles provide a hierarchical baseline against which temporal change and management effects can be monitored. The Native Richness Index (NRI) appears to be a highly sensitive monitoring tool, as it was significantly higher for oak stands than for maple stands, and was higher in fire-managed than in unmanaged stands. Fire management also significantly reduced numbers of live maple stems. However, the invasive alien garlic mustard had higher frequencies in fire-managed stands.

Monitoring of canopy, shrub layer, and ground layer composition and structure can help identify important temporal changes or responses to management in forest systems. Monitoring of forest vegetation also should be kept in context with hypotheses that vegetation change is natural and expected (Pickett, Parker, and Fiedler 1992), and that data sets represent conditions at a point in time, and not necessarily important restoration or management goals. For example, the structural composition of oak forests in 1976 may or may not represent a more realistic restoration goal than conditions in 1820 or 1996. However, the earliest detailed record of vegetation structure and composition will be helpful in developing the profile of a reference system against which future change can be monitored (Aronson, Dhillon, and Le Floch 1995).

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APPENDIX I

Mean (\pm std. err.) stem density/ha of saplings, understory trees, and shrubs sampled by the INAI in maple, red oak, and white oak stand shrub layer plots in 1976. Simpson's diversity index ANOVA ($F = 8.54, P = .0017$). Asterisks (*) indicate alien species.

Saplings	Maple stands		Red oak stands		White oak stands	
	Mean	Std. err.	Mean	Std. err.	Mean	Std. err.
<i>Acer saccharum</i>	4080.00	623.21	1862.50	876.67	175.00	109.79
<i>Fraxinus americana</i>	70.00	39.58	387.50	187.50	337.50	175.19
<i>Prunus serotina</i>	100.00	80.28	562.50	239.74	237.50	159.17
<i>Ulmus rubra</i>	230.00	137.48	475.00	180.03	162.50	92.46
<i>Tilia americana</i>	90.00	37.86	150.00	100.00	50.00	32.73
<i>Carya ovata</i>			43.75	29.03	112.50	47.95
<i>Carya cordiformis</i>	10.00	10.00	18.75	13.15	137.50	84.38
<i>Fraxinus pennsylvanica</i>			112.50	112.50	162.50	162.50
<i>Quercus rubra</i>	30.00	30.00	62.50	41.99	112.50	87.50
<i>Fraxinus quadrangulata</i>	20.00	20.00			162.50	162.50
<i>Ulmus americana</i>	50.00	40.14			25.00	25.00
<i>Fraxinus nigra</i>	30.00	30.00			12.50	12.50
<i>Quercus alba</i>	10.00	10.00	12.50	12.50	12.50	12.50
<i>Quercus ellipsoidalis</i>					12.50	12.50
<i>Quercus macrocarpa</i>					12.50	12.50
Sapling density	4720.00		3687.50		1725.00	
Small trees	Mean	Std. err.	Mean	Std. err.	Mean	Std. err.
<i>Crataegus pruinosa</i>			56.25	56.25	537.50	386.81
<i>Ostrya virginiana</i>	80.00	15.49	212.50	87.50	312.50	174.68
<i>Carpinus caroliniana</i> v. <i>virginiana</i>	70.00	16.36	12.50	12.50	125.00	111.40
<i>Crataegus</i> sp.			18.75	13.15	87.50	51.54
<i>Crataegus mollis</i>			137.50	101.66	87.50	39.81
<i>Malus ioensis</i>	10.00	3.16	25.00	25.00	12.50	12.50
<i>Crataegus punctata</i>			12.50	12.50	12.50	12.50
<i>Crataegus succulenta</i>	10.00	3.16				
* <i>Rhamnus cathartica</i>	31.25	21.00	50	26.73		
* <i>Rhamnus frangula</i>	12.50	12.50				
Small tree density	213.75		525		1175	
Shrubs	Mean	Std. err.	Mean	Std. err.	Mean	Std. err.
<i>Viburnum prunifolium</i>			43.75	37.13	3775.00	3746.55
<i>Prunus virginiana</i>	90.00	11.00	787.50	345.60	450.00	153.53
<i>Viburnum rafinesquianum</i>			737.50	631.03	2187.50	1504.11
<i>Cornus racemosa</i>			693.75	549.71	1362.50	582.47
<i>Hamamelis virginiana</i>	510.00	124.76	62.50	62.50	250.00	236.04
<i>Viburnum acerifolium</i>	280.00	70.05	137.50	111.70	437.50	437.50
<i>Corylus americana</i>	10.00	3.16	375.00	153.24	137.50	82.24
<i>Rubus strigosus</i>			75.00	75.00	100.00	100.00
<i>Viburnum lentago</i>			87.50	74.25	25.00	16.37
<i>Cornus rugosa</i>	60.00	18.97				
<i>Rubus occidentalis</i>			50.00	50.00	12.50	12.50
* <i>Viburnum opulus</i>	10.00	3.16			37.50	37.50
<i>Cornus alternifolia</i>	30.00	9.49				
<i>Euonymus atropurpureus</i>			12.50	12.50		
<i>Rhus radicans</i>			12.50	12.50		
<i>Ribes americanum</i>					12.50	12.50
<i>Ribes</i> sp.	10.00	3.16				
<i>Rubus pensilvanicus</i>			12.50	12.50		
<i>Xanthoxylum americanum</i>			12.50	12.50		
* <i>Lonicera</i> sp.	62.5	62.50	87.50	74.25		
Shrub density	1062.5		3187.50		8787.5	
Total stand density	5996.25		7400.00		11687.50	
Simpsons Index (D)	0.3557		0.7187		0.6858	

APPENDIX II

Mean (\pm std. err.) stand frequencies for groundlayer species sampled in 1996 in maple, red oak, and white oak stands along transect lines established by the INAI. Species are ranked by overall stand means. Asterisks (*) indicate alien species.

Species	Maple stands		Red oak stands		White oak stands	
	Mean	std. err.	Mean	std. err.	Mean	std. err.
<i>Smilacina racemosa</i>	30.34	7.47	27.33	10.68	44.38	11.47
<i>Circaea lutehana</i> v. <i>canadensis</i>	29.92	7.11	28.13	10.05	40.63	10.41
<i>Erythronium albidum</i>	49.50	8.95	19.51	7.73	18.75	5.88
<i>Arisaema triphyllum</i>	19.03	5.32	40.12	9.99	27.50	5.26
<i>Dentaria laciniata</i>	39.24	10.19	29.21	12.11	10.63	10.63
<i>Acer saccharum</i>	50.73	8.99	14.10	9.68	5.63	2.74
* <i>Alitaria petiolata</i>	17.96	6.67	16.15	11.01	41.25	14.17
<i>Geranium maculatum</i>	7.56	4.97	23.28	10.53	37.50	9.21
<i>Parthenocissus</i> sp.	17.50	5.69	22.16	9.82	22.50	8.45
<i>Fragaria</i> sp.	20.11	7.16	7.67	2.41	17.50	5.09
<i>Claytonia virginica</i>	5.43	2.26	25.56	15.67	15.63	8.73
<i>Polygonum virginianum</i>	5.00	1.97	23.82	8.99	15.63	8.84
<i>Impatiens</i> sp.	6.48	2.35	17.64	8.96	13.75	5.73
<i>Geum canadense</i>	2.03	1.53	12.18	7.02	21.25	8.33
<i>Prunus virginiana</i>	6.00	4.40	8.52	3.89	14.38	4.86
<i>Prunus serotina</i>	5.08	2.69	6.63	2.43	15.00	6.88
<i>Podophyllum peltatum</i>	4.08	2.67	7.86	4.04	15.00	5.90
<i>Allium tricoccum</i> v. <i>burdickii</i>	21.26	11.08	--	--	0.63	0.63
<i>Geum</i> sp.	5.98	3.92	4.38	3.20	13.75	9.67
<i>Trillium recurvatum</i>	3.93	1.86	8.21	3.55	11.25	2.80
* <i>Rhamnus cathartica</i>	0.50	0.50	4.26	2.54	16.25	8.60
<i>Fiberka proserpinacoides</i>	5.36	2.90	8.75	8.75	5.63	5.63
<i>Rhus radicans</i>	0.50	0.50	4.18	1.75	13.75	4.89
<i>Trillium grandiflorum</i>	6.08	3.58	6.08	3.82	4.37	4.37
<i>Allium canadense</i>	1.03	0.68	5.49	4.81	11.25	3.87
<i>Galium aparine</i>	3.50	2.48	6.76	4.31	6.88	4.90
<i>Isopyrum biernatum</i>	13.06	6.16	--	--	0.63	0.63
<i>Cornus racemosa</i>	0.98	0.65	6.26	4.20	9.38	2.58
<i>Viola pubescens</i>	--	--	10.49	5.44	6.25	2.46
<i>Ribes missouriense</i>	4.58	2.08	2.50	2.50	6.25	2.46
<i>Hackelia virginiana</i>	2.00	2.00	4.38	2.90	5.63	3.59
<i>Viburnum rafinesquianum</i>	1.50	1.07	0.63	0.63	10.00	8.66
<i>Dicentra cucullaria</i>	1.00	0.67	5.56	5.56	5.63	3.33
<i>Viburnum prunifolium</i>	--	--	8.01	3.88	4.38	3.20
<i>Sanicle gregaria</i>	--	--	10.07	7.20	1.88	1.87
<i>Potentilla simplex</i>	--	--	3.75	1.83	8.13	4.81
<i>Rubus allegheniensis</i>	--	--	--	--	11.25	5.24
<i>Thalictrum dioicum</i>	4.50	3.98	3.64	1.78	1.88	1.32
<i>Anemone quinquefolia</i>	4.00	1.25	1.95	0.95	3.13	1.87
<i>Ulmus</i> sp.	4.56	2.08	1.88	1.32	2.50	1.89
<i>Vitis riparia</i>	6.00	2.56	1.25	1.25	1.25	1.25
<i>Carya cordiformis</i>	1.98	1.52	3.07	1.30	4.38	2.90
<i>Allium tricoccum</i>	3.93	2.30	3.40	2.76	1.25	1.25
<i>Carex pensylvanica</i>	--	--	0.63	0.63	8.75	5.73
<i>Carpinus caroliniana</i> v. <i>virginiana</i>	3.50	2.59	--	--	4.38	3.71
<i>Rubus pensilvanicus</i>	--	--	5.00	4.33	3.75	2.06
<i>Osmorhiza</i> sp.	--	--	8.06	5.76	0.63	0.63
<i>Hydrophyllum virginianum</i>	0.50	0.50	0.63	0.63	6.88	4.72
<i>Lonicera proliifera</i>	--	--	1.88	0.92	6.25	3.24
<i>Viburnum acerifolium</i>	1.00	1.00	4.38	3.20	2.50	1.89

Species	Maple stands		Red oak stands		White oak stands	
	Mean	std. err.	Mean	std. err.	Mean	std. err.
<i>Tilia americana</i>	3.00	1.11	4.03	3.38	--	--
<i>Prenanthes altissima</i>	--	--	--	--	7.50	7.50
<i>Quercus alba</i>	--	--	--	--	7.50	4.12
<i>Rubus occidentalis</i>	0.50	0.50	0.63	0.63	6.25	2.46
<i>Solidago flexicanalis</i>	4.48	3.98	--	--	1.88	1.87
<i>Quercus rubra</i>	--	--	3.01	1.55	3.75	2.46
<i>Viola sororia</i>	0.50	0.50	2.08	2.08	3.75	1.83
<i>Sanguinaria canadensis</i>	1.00	0.67	2.44	1.32	1.88	1.32
<i>Carex</i> sp.	1.03	0.68	2.69	1.50	1.25	1.25
<i>Carex rosea</i>	0.50	0.50	1.32	0.87	3.13	1.62
<i>Phlox divaricata</i>	--	--	2.57	1.90	2.50	1.89
<i>Arisaema dracontium</i>	--	--	1.19	0.78	3.75	2.63
<i>Ostrya virginiana</i>	0.50	0.50	1.82	0.89	2.50	1.34
* <i>Rhamnus frangula</i>	1.00	1.00	0.57	0.57	3.13	2.49
<i>Ranunculus septentrionalis</i>	--	--	3.76	1.26	0.63	0.63
<i>Aster macrophyllus</i>	--	--	--	--	4.38	4.37
<i>Bidens</i> sp.	--	--	3.13	3.13	1.25	1.25
<i>Cardamine</i> sp.	1.00	1.00	0.63	0.63	2.50	1.64
<i>Glycyrrhiza striata</i>	--	--	1.88	1.32	2.50	1.34
* <i>Taraxacum officinale</i>	1.00	0.67	--	--	3.13	2.49
<i>Uvularia grandiflora</i>	2.50	2.01	--	--	1.25	1.25
<i>Maianthemum canadense</i>	--	--	--	--	4.38	4.38
<i>Smilacina stellata</i>	1.95	1.07	--	--	1.88	1.87
<i>Hepatica acutiloba</i>	2.50	1.71	--	--	0.63	0.63
* <i>Poa nemoralis</i>	--	--	--	--	3.75	3.75
<i>Aster lateriflorus</i>	0.48	0.48	--	--	3.13	3.13
<i>Solidago caesia</i>	--	--	3.47	3.47	--	--
<i>Laportea canadensis</i>	1.00	1.00	2.01	1.44	--	--
<i>Cinna arundinacea</i>	--	--	2.57	1.36	0.63	0.63
<i>Leersia virginica</i>	0.53	0.53	1.25	1.25	1.25	1.25
<i>Acer rubrum</i>	--	--	--	--	3.13	3.13
<i>Cardamine douglasii</i>	1.50	1.50	--	--	1.25	1.25
<i>Sambucus canadensis</i>	--	--	0.63	0.63	2.50	2.50
<i>Polygonatum canaliculatum</i>	0.98	0.65	0.63	0.63	1.25	1.25
<i>Prenanthes</i> sp.	1.48	1.06	1.25	1.25	--	--
<i>Prenanthes crepidinea</i>	0.56	0.56	--	--	1.88	0.63
<i>Agrimonia gryposepala</i>	--	--	--	--	2.50	1.89
<i>Anemone thalictroides</i>	0.50	0.50	--	--	1.88	0.92
<i>Aster</i> sp.	1.00	1.00	1.25	0.82	--	--
<i>Carex grayi</i>	--	--	--	--	2.50	1.64
<i>Elymus villosus</i>	--	--	1.25	1.25	1.25	1.25
<i>Polygonum hydropiperoides</i>	--	--	2.50	2.50	--	--
<i>Polygonum</i> sp.	--	--	--	--	2.50	2.50
* <i>Chelidonium majus</i>	1.50	1.50	--	--	0.63	0.63
<i>Potentilla</i> sp.	--	--	--	--	2.50	2.50
<i>Prunella vulgaris</i> v. <i>lanceolata</i>	--	--	1.88	1.32	0.63	0.63
<i>Smilax ecirrhata</i>	1.00	1.00	--	--	1.25	1.25
* <i>Viburnum opulus</i>	--	--	--	--	2.50	1.89
<i>Hystrix patula</i>	0.50	0.50	1.39	1.39	--	--
<i>Smilax</i> sp.	--	--	2.01	1.44	--	--
<i>Eupatorium purpureum</i>	--	--	1.95	1.34	--	--
<i>Urtica procera</i>	1.00	1.00	0.70	0.70	--	--
<i>Cirsium</i> sp.	1.05	1.05	--	--	0.63	0.63
<i>Calamagrostis canadensis</i>	--	--	1.88	1.87	--	--
<i>Carya ovata</i>	--	--	--	--	1.88	1.32

Species	Maple stands		Red oak stands		White oak stands	
	Mean	std. err.	Mean	std. err.	Mean	std. err.
<i>Caulophyllum thalictroides</i>	--	--	1.25	1.25	0.63	0.63
<i>Osmunda claytoniana</i>	--	--	--	--	1.88	1.32
<i>Ribes americanum</i>	--	--	1.25	1.25	0.63	0.63
<i>Smilax tamnoides</i> v. <i>hispida</i>	--	--	1.25	0.82	0.63	0.63
* <i>Solanum dulcamara</i>	--	--	--	--	1.88	1.87
<i>Trillium sessile</i>	1.50	1.07	--	--	--	--
<i>Oxalis</i> sp.	0.48	0.48	1.25	0.82	--	--
<i>Dioscorea villosa</i>	--	--	1.19	0.78	0.63	0.63
<i>Solidago ulmifolia</i>	0.95	0.95	--	--	0.63	0.63
<i>Menispermum canadense</i>	1.45	1.03	0.57	0.57	4.38	4.38
<i>Proserpinaca palustris</i>	--	--	1.39	1.39	--	--
<i>Acer negundo</i>	--	--	1.25	1.25	--	--
<i>Ampelicarpa bracteata</i>	--	--	1.25	1.25	--	--
<i>Carex hirsutella</i>	--	--	1.26	0.83	--	--
* <i>Arctium minus</i>	0.50	0.50	--	--	0.63	0.63
<i>Aster schreberi</i>	--	--	--	--	1.25	1.25
<i>Carex blanda</i>	0.50	0.50	0.63	0.63	--	--
<i>Corylus americana</i>	--	--	0.63	0.63	0.63	0.63
<i>Cystopteris fragilis</i> v. <i>protrusa</i>	--	--	1.25	1.25	--	--
<i>Equisetum arvense</i>	1.00	1.00	--	--	--	--
<i>Hamamelis virginiana</i>	--	--	--	--	1.25	1.25
<i>Lactuca</i> sp.	1.00	1.00	--	--	--	--
<i>Pilea pumila</i>	1.43	0.01	1.25	1.25	1.25	0.01
<i>Ranunculus abortivus</i>	--	--	0.63	0.63	0.63	0.63
<i>Smilax lasioneura</i>	--	--	1.25	1.25	--	--
<i>Solidago canadensis</i>	--	--	0.63	0.63	0.63	0.63
<i>Asarum canadense</i>	0.48	0.48	--	--	0.63	0.63
<i>Trillium flexipes</i>	0.48	0.48	0.63	0.63	--	--
<i>Cryptotaenia canadensis</i>	--	--	0.70	0.70	--	--
<i>Erigeron bulbosus</i>	--	--	0.70	0.70	--	--
<i>Actaea pachypoda</i>	--	--	--	--	0.63	0.63
<i>Aesculus</i> sp.	--	--	--	--	0.63	0.63
<i>Agrimonia pubescens</i>	--	--	--	--	0.63	0.63
<i>Agrostis perennans</i>	--	--	--	--	0.63	0.63
<i>Aster shortii</i>	0.50	0.50	--	--	--	--
<i>Althium filix-femina</i>	--	--	--	--	0.63	0.63
<i>Botrychium dissectum</i>	--	--	0.63	0.63	--	--
<i>Brachyelytrum erectum</i>	0.50	0.50	--	--	--	--
<i>Carex grisea</i>	0.50	0.50	--	--	--	--
<i>Carex scoparia</i>	--	--	0.63	0.63	--	--
<i>Carex tenera</i>	--	--	--	--	0.63	0.63
* <i>Cirsium arvense</i>	--	--	--	--	0.63	0.63
<i>Cirsium discolor</i>	--	--	0.63	0.63	--	--
<i>Cornus alternifolia</i>	--	--	--	--	0.63	0.63
<i>Crataegus</i> sp.	--	--	--	--	0.63	0.63
* <i>Daucus carota</i>	--	--	--	--	0.63	0.63
<i>Desmodium</i> sp.	--	--	--	--	0.63	0.63
<i>Dicentra canadensis</i>	0.50	0.50	--	--	--	--
<i>Dryopteris spinulosa</i>	--	--	--	--	0.63	0.63
* <i>Euzonymus</i> sp.	--	--	--	--	0.63	0.63
<i>Euzonymus atropurpureus</i>	0.50	0.50	--	--	--	--
<i>Eupatorium rigosum</i>	--	--	0.63	0.63	--	--
<i>Festuca obtusa</i>	--	--	--	--	0.63	0.63
<i>Fragaria virginiana</i>	--	--	--	--	0.63	0.63
<i>Fragaria quadrangulata</i>	--	--	--	--	0.63	0.63

Species	Maple stands		Red oak stands		White oak stands	
	Mean	std. err.	Mean	std. err.	Mean	std. err.
<i>Galium</i> sp.	--	--	0.63	0.63	--	--
<i>Galium triflorum</i>	--	--	--	--	0.63	0.63
<i>Hydrophyllum appendiculatum</i>	0.50	0.50	--	--	--	--
<i>Lonicera dioica</i>	--	--	--	--	0.63	0.63
<i>Mertensia virginiana</i>	0.50	0.50	--	--	--	--
<i>Morus alba</i>	0.50	0.50	--	--	--	--
<i>Oenoclea sensibilis</i>	--	--	--	--	0.63	0.63
<i>Osmunda cinnamomea</i>	0.50	0.50	--	--	--	--
<i>Penthorum sedoides</i>	--	--	0.63	0.63	--	--
<i>Phytolacca leptostachya</i>	--	--	--	--	0.63	0.63
<i>Poa</i> sp.	--	--	0.63	0.63	--	--
<i>Quercus macrocarpa</i>	--	--	0.63	0.63	--	--
<i>Ranunculus recurvatus</i>	--	--	--	--	0.63	0.63
<i>Rubus idaeus</i> v. <i>strigosus</i>	--	--	--	--	0.63	0.63
* <i>Rumex obtusifolius</i>	--	--	--	--	0.63	0.63
<i>Scrophularia marilandica</i>	--	--	--	--	0.63	0.63
<i>Symplocarpus foetidus</i>	0.50	0.50	--	--	--	--
* <i>Viburnum recognitum</i>	--	--	--	--	0.63	0.63
<i>Viburnum lentago</i>	--	--	0.63	0.63	--	--
<i>Viola affinis</i>	--	--	0.63	0.63	--	--
<i>Erythronium americanum</i>	--	--	0.48	0.48	--	--

NATIVE MIDWESTERN PLANTS FOR GOLF COURSE LANDSCAPES

Tom Voigt¹

ABSTRACT: Native prairie grasses, sedges, and forbs are frequently planted in out-of-play areas of Illinois golf courses. Compared with mowed out-of-play portions of courses, areas planted to native species require reduced management inputs, create wildlife habitat, and enhance the golfing experience. A study was designed to improve golf course superintendents' knowledge and understanding of more than 50 native species. Native grasses, sedges, and forbs were planted at three Chicago-area golf courses in full-sun and partial-shade settings. The objectives of this work were (1) to evaluate these plants to determine their aesthetic value in unmowed areas of Midwestern golf courses and (2) to explore the long-term performance of native plants following different planting-bed preparation options. In the full-sun plantings, *Allium cernuum*, *Helopsis helianthoides*, *Vernonia fasciculata*, *Veronicastrum virginicum*, *Andropogon hallii* cv. U. of I., *Eryngium yuccifolium*, *Ratibida pinnata*, *Penstemon digitalis*, *Pycnanthemum virginianum*, and *Solidago rigida* produced the highest aesthetic ratings. In the partial-shade settings, *Allium cernuum*, *Labelia siphilitica*, and *Uniola latifolia* were the most preferred. Applications of glyphosate prior to planting appeared to reduce competition from existing vegetation in both the full-sun and partial-shade settings.

INTRODUCTION

Using native plants in managed landscapes is not a new idea. Wilhelm Miller (1915) of the University of Illinois wrote that "every Illinois city should have in at least one park a 'prairie border'—with the grasses, composites, and other flowers labeled." Landscape designer Jens Jensen, a devotee of natural landscaping, planned the noted Lincoln Memorial Gardens in Springfield, Illinois, in 1934, and used only native Illinois trees, shrubs, flowers, and grasses (Ottesen 1989). As early as 1917, Texas recognized the wildflower as a roadside asset for controlling soil erosion (Shirley 1994).

Recently, this idea has received renewed attention. Blake (1990) stated that "... gardeners and landscape professionals ... more and more, ... are planting and cultivating the wildflowers, native grasses, native shrubs, and native trees of their specific region." Recommendations for cultivating natives in managed areas abound (Anderson 1988; Smith 1980; Favretti 1990).

The trend toward planting natives has even spread into the managed world of Illinois golf courses. Native plantings have been designed into recent golf course constructions in Galena, Libertyville, Bloomington, and many other areas in Illinois. Moreover, many long-established golf courses have taken previously mowed out-of-play areas and replaced them with native plantings (Voigt 1996; Voigt 1998b; Voigt 1999a; Voigt 1999b).

Superintendents at many Illinois golf courses have taken far-rough areas out of mowing. In a 1997 survey to which 110 Chicagoland golf course superintendents

responded, more than 8.5% of the 18,608 golf course acres represented in the survey were covered by unmowed grasslands, meadows, or prairies (Voigt 1998a). The superintendents recognized several benefits of native and naturalized areas; 89.8% of survey respondents agreed or strongly agreed with the statement, "Reducing golf course maintenance by not mowing out-of-play areas is a good idea." (Voigt 1998a).

Golf course managers are not routinely trained in the selection and management of native species. With the burgeoning interest in native plants, golf course superintendents have asked questions regarding the use of these species. Specifically, what native plants will perform well in unmowed rough areas, how should these plants be established, and how should these areas be maintained?

With these questions in mind, a study was designed to evaluate native grasses, sedges, and forbs at three Chicago-area golf courses. The research had two objectives: (1) to evaluate native grasses, sedges, and forbs to determine their aesthetic value in unmowed areas of Midwestern golf courses, and (2) to explore the effects of different planting-bed preparation options on native plant performance

METHODS

This project took place at three suburban golf courses in the Chicago area. The courses were Olympia Fields Country Club, in the south suburbs; Cantigny Golf Club, in the western suburbs; and Skokie Country Club, in the

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north suburbs. At each golf course, the superintendent enthusiastically cooperated with the project.

During the summer of 1997, full-sun and partial-shade test areas were planted and established at each golf course. Thirty species were planted in the full-sun areas (table 1) and 28 species were planted in the partial-shade areas (table 2). Plants for this study were selected to represent a wide range of native grasses, sedges, and forbs. In previous work, many common native grass species were evaluated (Voigt 1993; Voigt 1996).

For all but 2 species, plugs measuring 2.25 in. by 2.25 in. were purchased and planted. In the full-sun installations at each course, plots 2 ft. by 3 ft. were planted with 3 plants each of the 30 species of native plants. The exceptions were *Andropogon hallii* cv. U. of I., in which case only one plant was planted per plot, and *Hierochloa odorata*, in which case 2 plants were planted per plot. The plots were replicated 3 times. In the partial shade, 3 to 5 plugs of each species were grouped and planted. The partial-shade plots were not replicated. Plantings at each site were irrigated as necessary to ensure establishment. Each site was visited in August, September, and October.

At each site, plantings were handled differently. At Cantigny Golf Club, the full-sun area was planted into the far rough on July 2 and 3. Site preparations included removal of the existing vegetation (mostly cool-season grasses) to 1 in. using a string trimmer. In the partial shade, an area was treated with glyphosate, and 3 plugs of each species were planted on July 18.

At Olympia Fields Country Club, both the full-sun and partial-shade test areas were planted on July 11. The full-sun site was mowed to 2 inches, rotary tilled to an approximate depth of 5 in., and planted. Following planting, the site was broadcast with Preen at the labeled rate to deter invasion of annual grasses and broad-leaved weeds. In the partial shade, 5 plugs of each species were grouped and planted into the existing vegetation.

At Skokie Country Club, both the full-sun and partial-shade sites were planted on July 23. Both the full-sun and partial-shade settings were treated with glyphosate and mowed to less than 2 in. prior to planting.

During the 1998 growing season, each location was visited monthly from May through September. During the 1999 growing season, Skokie Country Club was visited monthly from May through September, and Cantigny Golf Club and Olympia Fields Country Club were visited in May, June, July, and September. At each site visit, plant information was recorded (flowering period, aesthetic value, height, and shape).

At the conclusion of the 1998 growing season, the collected data were compiled, and a rating scale was

developed. This rating scale is based on the collected data and the horticultural judgment of the principal investigator. Here, aesthetic value (AV) was ranked using a 3-point scale in which 3 = an extremely attractive plant, 2 = a plant with desirable, but less showy, aesthetic characteristics, and 1 = a plant not worth establishing, based on its appearance. The rating scale developed in 1998 was similarly applied to the collected evaluations in 1999. The 1998 and 1999 ratings were averaged to produce a list of desirable native plants. A mean AV of 2 or 3 indicates that a plant may have great enough aesthetic value for recommendation for use at other Chicago-area sites.

It is important to note that the aesthetic values assigned to these species are both plant- and context-related. Plant performance is certainly related to the specific growing conditions at each golf course, as well as management, deer browse, exotic weed competition, or other episodic factors. Some of these plants that were assigned an AV of 1 in this study may receive an AV of 2 or 3 when grown elsewhere. Thus, the aesthetic values in tables 1 and 2 should be regarded as provisional and circumstance specific.

Plants of the Chicago Region by Swink and Wilhelm (1994) was used as the taxonomic guide for this article.

RESULTS AND DISCUSSION

Aesthetic value was recorded during visits to each site during the second and third years of this study. Observations and results from the full-sun and partial-shade areas are presented in tables 1 and 2. Each table lists the scientific and common names of the planted species, plant heights, comments about each plant, 1998 and 1999 ratings of aesthetic appeal, and a mean aesthetic value (AV) rating. A differential trend in plant aesthetic value and establishment and management methods became obvious during 1998 and continued into 1999.

First, differences in AV among plants were identified. Generally, plants receiving a 3 performed well in both years at all three sites. In the full-sun plots, *Allium cernuum*, *Heliopsis belanthoides*, *Vernonia fasciculata*, and *Veronicastrum virginicum* were highly rated because of their colorful, long-lasting flowers.

Those plants receiving a mean AV of 2.5 in the full-sun plots also performed well. This group included *Andropogon hallii* cv. U. of I., *Eryngium yuccifolium*, *Ratibida pinnata*, *Penstemon digitalis*, *Pycnanthemum virginianum*, and *Solidago rigida*. Most of these plants also were found to produce colorful, long-lasting flowers. The fall color of *Andropogon hallii* cv. U. of I. and *Penstemon digitalis* enabled them to be rated highly.

Finally, several additional plants received a mean AV of 2 in the full-sun plots. *Asclepias incarnata*, *Deschampsia caespitosa*, *Lythrum aspera*, *Lythrum alatum*, and *Monarda fistulosa* all produced attractive flowers and/or foliage, but were less uniformly reliable at all sites than those rated more highly.

Plants receiving an AV rating of 1.5 or 1 presented little aesthetic value for flowers or foliage. While these plants may lack aesthetic appeal, they may provide useful growth in difficult sites: *Hierochloa odorata* and *Carex atherodes* are both very competitive in damp or wet settings.

In the partial-shade plots, *Allium cernuum* and *Lobelia siphilitica* were the only plants that had an average AV of 3. These plants produced attractive flowers at all three sites in both years. The only plant receiving a mean AV rating of 2.5 in the partial shade was *Urtica latifolia*.

Plants receiving an aesthetic value of 2 in the partial-shade were *Aster novae-angliae*, *Carex pennsylvanica*, *C. radiata*, *Deschampsia caespitosa*, *Hystrix patula*, *Iris virginica* var. *shrevei*, *Phlox divaricata*, *Rudbeckia triloba*, *Solidago flexicaulis*, *S. ulmifolia*, and *Zizia aurea*. An average AV rating of 2 indicates attractive flowers or foliage. Plants in this group may not have performed equally well at each site.

As in the full-sun plots, plants receiving an average AV rating of 1.5 or 1 presented little aesthetic value for flowers or foliage. Some of these plants, particularly the sedges (*Carex* spp.), survived the shaded settings acceptably. Unfortunately, these plants were generally viewed as unattractive.

Establishment methods appeared to be related to plant performance, as was regrowth of existing species and invasion of weeds. In the full-sun plantings, plant performance was superior at Olympia Fields when compared with the plots at Cantigny or Skokie, and there was less weed invasion into the plots. Because the existing vegetation was only trimmed to 1 in. prior to the planting of the natives in the full-sun plots at Cantigny, competition resulting from regrowth of the existing plants was expected. Natives at Olympia Fields were generally larger and more robust than those at Cantigny, where competition from existing plants was greater. In 1999, for example, *Andropogon hallii* cv. U. of I. at Olympia Fields reached nearly 7 ft. in height and was many-stemmed. The same species at Cantigny was shorter (approximately 5 ft.) and developed a much smaller clump diameter. By the end of the 1999 growing season, many of the full-sun plots at Cantigny were taken over by the European field thistle *Cirsium arvense*.

The herbicide-treated cool-season grasses appeared as though they were only damaged to the ground in 1997; regrowth occurred from underground portions of the

grasses in 1998 and 1999 at Skokie. Following treatment with glyphosate in 1997, the full-sun natives at Skokie performed similarly to those planted at Olympia Fields, where the site was rotary tilled and treated with Preen after planting. Regrowth of many cool-season perennial grasses (particularly *Agrostis* spp.) at Skokie occurred during 1998 and continued during 1999, and it can be speculated that competition reduced the size and attractiveness of the plants in the evaluation.

These site differences may point to differences in soil or weather conditions, or to differences in preexisting vegetation. It appears that soils at Olympia Fields and Skokie were disturbed less recently than those at Cantigny. Also, precipitation and temperature differences over the Chicago region can vary greatly. These differences may also account for some of the variation that prevailed among locations. The existing vegetation at both Cantigny and Skokie appears to be composed primarily of cool-season turfgrasses (*Festuca* spp. and *Agrostis* spp.). At Olympia Fields, the existing vegetation is a combination of *Phleum pratense*, *Agrostis alba*, and several natives. The plants growing in this area appear to be more easily controlled.

During 1998 and 1999 at Skokie, it was apparent that another form of pest was invading the full-sun and partial-shade settings. In both years, in the sun plots, it appeared as though deer had "bedded down" in the center of the experimental area. Plants in this area were broken and matted in a large, nestlike fashion. In the partial shade, the tops of several plants, particularly *Eupatorium purpureum* and *Lobelia siphilitica*, had been eaten, most likely by deer.

In both years, the partial-shade plantings at Cantigny and Skokie performed better than those at Olympia Fields. Again, this is not surprising given the establishment methods. Competition from existing vegetation at Olympia Fields reduced the aesthetic value and size of the study plants. Even at Olympia Fields, however, *Lobelia siphilitica* and *Rudbeckia triloba* performed well in 1998. Cantigny and Skokie plantings performed similarly. The wood-chip mulch used at Cantigny did not seem to provide conditions superior to the unmulched plots at Skokie. The effects of the mulch, however, may have been offset by the thick layer of tree leaves (primarily *Quercus* spp.) that covered the Skokie site during winter and early spring. The shaded planting area at Cantigny was expanded in late 1999. Native species that performed well in this trial will be established in the newly prepared, enlarged setting.

Invasion of exotic weed species into the full-sun test sites continues to be the greatest threat to success with unmowed native plantings on golf courses. Broadleaf weeds, including *Cichorium intybus*, *Cirsium arvense*, and *Daucus carota*, and grassy weeds such as *Setaria* spp., *Agrostis*

alba var. *palustris*, *Festuca elatior*, *Agropyron repens*, and *Phalaris arundinacea* have appeared in unmowed areas at these courses and at others in the Chicago area. Future studies should be designed to evaluate chemical, mechanical, and other weed control methods in native plantings (for example, fallow and plowing treatments prior to planting, or annual burns).

CONCLUSIONS

Golf course managers have identified several benefits that accrue from planting and cultivating unmowed naturalized areas. First, replacing maintained areas with unmowed native vegetation can reduce golf course fertilizer and pesticide use and require less labor. While the costs of preparing and planting areas with native plants can be substantial initially, management savings are often realized once the areas are established. The costs of fertilizers, insect- and disease-control chemicals, labor, and equipment are often far less for out-of-play native plantings than when the same areas are planted to turfgrasses and mowed regularly. At one Chicago-area golf course, for example, management expenses for native and naturalized areas were approximately \$400 per acre per year less than the cost of routinely mowing similar areas (O. Miles, pers. comm.). Most of the management costs in the native areas were for weed control.

Another benefit from planting natives in unmowed areas is the creation of biologically diverse areas, which are necessary for attracting wildlife. Many Illinois golf courses are involved in the Audubon Cooperative Sanctuary Program sponsored by Audubon International, Inc., of Selkirk, New York. The Audubon Cooperative Sanctuary Program for Golf Courses promotes ecologically sound land management and conservation of natural resources. For full certification, golf courses must complete and manage tasks in six "Achievement Categories." These include Environmental Planning, Wildlife and Habitat Management, Integrated Pest Management, Water Conservation, Water Quality Management, and Outreach and Education. In 1999, 11 Chicago-area golf courses and 130 courses in the U.S. were fully certified sanctuaries. In

addition, of the 110 superintendents who responded to the previously mentioned survey, 99 are currently participating in, or plan future involvement in, the program (Voigt 1998a).

An enhanced golfing experience is a final benefit from having native plants in unmowed areas. Many golfers enjoy playing in an environmentally diverse setting where native plants provide a natural experience. Again, in the survey of Chicago-area superintendents, 104 of 108 respondents agreed or strongly agreed with the statement, "The presence of wildlife enhances the golfing experience." (Voigt 1998a). When appropriately placed, natural areas can certainly benefit a golf course.

Native plantings, however, are not without some drawbacks. Some golfers, for example, have complained that unmowed areas appear unkempt and wild (Voigt 1996). Another concern is that of nuisance insect and exotic weed invasions. These pests can proliferate in natural areas and result in management concerns. A final problem often occurs when planted native areas are located too close to in-play areas. In these settings, golfers may slow the play on the course as they search for errant shots in unmowed plantings.

While the initial field trial is now complete, work with golf course native plant revegetation and naturalization will continue. A list of natives suited for golf course planting is being compiled for distribution starting in 2000. In addition, weed-control studies are scheduled for the year 2000.

Planting information and management data derived from this study are already being used. Several Chicago-area golf courses planted areas with native grasses and forbs during 1999. These courses have been provided with guidelines for plant selection and establishment. Many of these guidelines originated from information garnered while conducting this study.

Future studies should evaluate additional plant species, and more importantly, establishment and management options, so that tools and methods to ensure success can be identified.

Table 1. 1998 and 1999 aesthetic values (AV) of native plants established in full sun at three Chicago-area golf courses

Entry (height in feet)	Comments	1998 AV	1999 AV	Mean AV
<i>Allium cernuum</i> (2-3) nodding wild onion	drooping white-pink flowers on upright stems in mid- to late summer; spreading habit	3	3	3
<i>Andropogon hallii</i> cv. U. I. (2-3) sand bluestem	upright warm-season grass with rusty bronze fall color; late summer turkey-foot shaped inflorescences	2	3	2.5
<i>Asclepias incarnata</i> (4) swamp milkweed	attractive pink flowers in mid-summer; upright, shrublike growth	3	1	2
<i>Aster azureus</i> (2) sky-blue aster	inconspicuous small pale blue flowers in late summer to early autumn	1	1	1
<i>Bouteloua curtipendula</i> (3) side-oats grama	bunch-type, warm-season grass; blue-green medium-textured foliage; did not compete well with taller plants	2	1	1.5
<i>Bromus kalmii</i> (2)	cool-season grass; drooping seed heads; pale blue-green foliage; not competitive with other plants in study	1	1	1
<i>Carex atherodes</i> (1-3) hairy-leaved lake sedge	spreading coarse-textured sedge; yellow-green flowers in late spring; yellow-green foliage; invasive in moist areas by rhizomes; not showy, but can cover a great deal of ground	1	1	1
<i>Carex bicknellii</i> (1-2) copper-shouldered oval sedge	subtly attractive yellow-gold inflorescences in early summer; medium-green foliage; sprawling habit	1	1	1
<i>Carex crux-corvi</i> (1) crowfoot fox sedge	yellowish golden brown inflorescences in early summer; generally unattractive	1	1	1
<i>Coreopsis palmata</i> (2) prairie coreopsis	moderately showy yellow flowers in early to mid-summer; bright green fine-textured foliage	1	1	1
<i>Coreopsis tripteris</i> (4-6) tall coreopsis	small yellow flowers in late summer of modest appeal; upright growth habit; dull medium-green foliage	1	2	1.5
<i>Deschampsia caespitosa</i> (1.5-4) tufted hair grass	cool-season grass; attractive dark green tufted foliage; silver-green panicles fade to golden brown and persist through summer	2	2	2
<i>Desmodium canadense</i> (1-3) showy tick trefoil	showy, pale pink-purple pea-shaped flowers in mid-summer; upright growth habit	2	1	1.5
<i>Elymus canadensis</i> (4) Canada wild rye	cool-season grass with large, nodding, foxtail-like seedheads; turns brown in mid-summer; can be invasive because of self-seeding into open areas; a pioneer species suitable for use in prairie restoration	1	1	1
<i>Eryngium yuccifolium</i> (4-6) rattlesnake master	interesting silvery greenish white ball-shaped inflorescences in mid-summer; foliage gray-green and yuccalike; upright growth habit	2	3	2.5
<i>Heliopsis helianthoides</i> (3-4) false sunflower	showy butter yellow disk and ray flowers in early to mid-summer; upright habit; reliable performer	3	3	3
<i>Hierochloa odorata</i> (0.5-1.5) vanilla grass	unattractive, spreading cool-season grass; panicles formed in early to mid-spring; suited to cool, moist to wet sites	1	1	1
<i>Iris virginica</i> var. <i>shrevei</i> (2-3) blue flag	pale blue flowers in spring; spreading upright fans of dull gray-green foliage; not competitive	2	1	1.5

Entry (height in feet)	Comments	1998 AV	1999 AV	Mean AV
<i>Koeleria cristata</i> (1–2.5) June grass	cool-season upright-growing grass; spikes emerge silver-green in late spring, becoming golden and then dirty brown; disappeared from most plots	1	1	1
<i>Liatris aspera</i> (2–4) rough blazing star	purple flowers on upright stems in late summer; plants are upright, but may topple over	3	1	2
<i>Lythrum alatum</i> (1–2) winged loosestrife	small purple flowers in mid-summer; upright grower, fine-textured foliage; too short to be showy	2	2	2
<i>Monarda fistulosa</i> (3–4) wild bergamot	pale purple flowers in early to mid-summer; upright growing; bright green hairy foliage	2	2	2
<i>Penstemon digitalis</i> (3) foxglove beard tongue	attractive white flowers in late spring and early summer; spreading plant; glossy green foliage sometimes becomes reddish in autumn	2	3	2.5
<i>Pycnanthemum virginianum</i> (3) common mountain mint	masses of dense white inflorescences in early to mid-summer; upright bushy plant with fine-textured medium-green foliage	2	3	2.5
<i>Ratibida pinnata</i> (3–5) yellow coneflower	yellow ray flowers with green-gold cone in mid-summer; medium-green foliage	3	2	2.5
<i>Sanguisorba canadensis</i> (2) American burnet	interesting white spikes in late summer on low-growing, spreading plants; inconspicuous	2	1	1.5
<i>Siphium terrebinthinaceum</i> (1–6) prairie dock	yellow disk and ray flowers sit atop long stems above large, oval foliage rosettes; foliage is unattractive	1	1	1
<i>Solidago rigida</i> (3–6) stiff goldenrod	upright growth habit; bright yellow inflorescences in late summer	3	2	2.5
<i>Vernonia fasciculata</i> (3–4) common ironweed	dark purple inflorescences; shrublike upright growth habit	3	3	3
<i>Veronicastrum virginicum</i> (3) Culver's root	spirelike white inflorescences in early to mid-summer; upright growth habit	3	3	3

Table 2. 1998 and 1999 aesthetic value (AV) of native plants established in partial shade at three Chicago-area golf courses

Entry (height in feet)	Comments	1998 AV	1999 AV	Mean AV
<i>Allium cernuum</i> (1.5–2.5) nodding wild onion	drooping white-pink flowers on upright stems in mid- to late summer, spreading habit; flowered acceptably in both sun and shade	3	3	3
<i>Aster macrophyllus</i> (1–2) big-leaved aster	medium-green foliage; upright growth habit; inconspicuous white ray flowers with yellow disk flowers; clump enlarging	1	1	1
<i>Aster novae-angliae</i> (1–4) New England aster	purple ray flowers with golden disk flowers; generally more attractive in full sun than in filtered shade; clump enlarging	2	2	2
<i>Carex crinita</i> (1–2) fringed sedge	yellow-green branched foliage; unattractive	1	1	1
<i>Carex frankii</i> (1–2) bristly cattail sedge	vase-shaped habit; medium-textured, dull yellow-green foliage; yellow-green flowers	1	1	1
<i>Carex grayi</i> (1–2.5) common bur sedge	tufted habit; coarse yellow-green foliage; burlike inflorescence; unattractive	1	1	1

Entry (height in feet)	Comments	1998 AV	1999 AV	Mean AV
<i>Carex muskingumensis</i> (1–2) swamp oval sedge	medium-textured, yellow-green foliage of little appeal; uninteresting flowers in early summer; unattractive overall	1	1	1
<i>Carex pensylvanica</i> (0.5–1) common oak sedge	low-growing, fine-textured sedge; may be useful when massed as ground cover in light shade; copper brown flowers	2	2	2
<i>Carex radiata</i> (0.5–1) straight-styled wood sedge	tufted; fine-textured; inconspicuous yellow-green flowers in early summer; can be used in masses as attractive ground cover	2	2	2
<i>Deschampsia caespitosa</i> (1.5–3) tufted hair grass	cool-season grass; dark green tufted foliage; silver-green panicles fade to golden brown	2	2	2
<i>Diarrhena americana</i> (1.5–3) beak grass	coarse-textured, dark yellow-green foliage; interesting beak-shaped flowers in late summer; has leaf spot early in season	1	1	1
<i>Dodecatheon meadia</i> (1–1.5) shooting star	attractive, drooping white flowers in mid-spring; rosette-shaped foliage disappears in early summer	2	1	1.5
<i>Elymus riparius</i> (2–4) riverbank wild rye	upright growing; foxtail-like green flowers in mid-summer becoming tan-brown by early autumn; spreading growth; tolerates shade well	1	1	1
<i>Elymus villosus</i> (2–3) silky wild rye	upright growing; foxtail-like green flowers in mid-summer that become tan-brown by early autumn; spreading growth	1	1	1
<i>Elymus virginicus</i> (2–3) Virginia wild rye	upright growth habit; foxtail-like green flowers in mid-summer that become brown by early autumn	1	1	1
<i>Eupatorium purpureum</i> (1–4) purple Joe Pye weed	pale, dirty purple flowers in late summer; upright growth habit; yellow-green foliage	1	2	1.5
<i>Festuca obtusa</i> (1–1.5) nodding fescue	ephemeral grass flowering in spring and disappearing by early summer; disappeared from all sites after first growing season	1	1	1
<i>Hystrix patula</i> (2–3) bottlebrush grass	long-awned florets clustered at culm apex in mid-summer becoming tan at maturity; upright growth habit; tolerates shade well	2	2	2
<i>Iris virginica</i> var. <i>shrevei</i> (2–3) blue flag	pale blue flowers in spring; spreading upright fans of dull gray-green foliage	2	2	2
<i>Juncus tenuis</i> (0.5–1) path rush	fine-textured upright tufts of yellow-green leaves; yellow-green flowers in early summer; declined by late summer	1	2	1.5
<i>Lobelia siphilitica</i> (2–3) great blue lobelia	attractive medium-blue flowers on spikes; yellow-green foliage; upright grower; self-seeded into other plot areas	3	3	3
<i>Phlox divaricata</i> (0.5–1) blue phlox	spring-blooming blue-purple flowers; foliage disappears during summer, reappears as temperatures cool in autumn; most attractive when viewed from a short distance	2	2	2
<i>Rudbeckia triloba</i> (3) brown-eyed Susan	vigorous late summer blooms of golden ray flowers and brown disk flowers; upright growth habit, biennial life cycle; seedlings present in 1999	3	1	2

Entry (height in feet)	Comments	1998 AV	1999 AV	Mean AV
<i>Solidago flexicaulis</i> (1.5–3) broad-leaved goldenrod	small yellow flowers in late summer and early autumn; upright growing; attractive foliage	2	2	2
<i>Solidago ulmifolia</i> (2) elm-leaved goldenrod	interesting small yellow flowers on arching spikes in late summer and early autumn; short, upright grower; seeded itself into adjacent plot areas	2	2	2
<i>Thalictrum dioicum</i> (0.5–2) early meadowrue	attractive foliage; low growing; flowers inconspicuous and of little aesthetic value	1	1	1
<i>Urtica latifolia</i> (2–3) spike grass	flattened oatlike seed clusters turning copper brown in late summer; medium-green foliage; upright growth habit	2	3	2.5
<i>Zizia aurea</i> (2–3) golden alexanders	small yellow spring flowers; yellow-green foliage	2	2	2

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THE ILLINOIS POPULATIONS OF *PHAEOPHYSCIA LEANA*, ONE OF THE WORLD'S RAREST LICHENS

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ABSTRACT: New discoveries of several populations of the lichenized fungus *Phaeophyscia leana* in Illinois, Kentucky, Indiana, and Tennessee are reported, and its habitat and floristic status in Illinois are described. The Tower Rock, Illinois, population and habitat of *P. leana* are described in detail. At Tower Rock, 380 individual trees on a bottomland terrace along the Ohio River were sampled for *P. leana*, and 1,540 thalli were noted on 109 individual trees (29% of those sampled) of 11 different species. The habitat is in an area where the spring flood crests average 8 m above the normal pool level. As distance from the river increases, thalli are progressively fewer up an elevation gradient, displaying preferences for certain tree species and forming a discrete elevation band below the level of the spring flood crest. Other lichen associates were scant in this band, but were progressively more frequent immediately above the lower spring flood crest elevations. In an intensive survey of the populations in Illinois along the Ohio River, 5 additional populations that can be described as large and 11 smaller populations were discovered, all of which are vulnerable to the threat of changes in contemporary river hydrology.

INTRODUCTION

Worldwide, *Phaeophyscia leana* (Tuck.) Essl. is about as limited in its known distribution as any rare lichen. Until recently, it was known only from its type locality and believed to be extinct (Thomson 1963; Taylor 1967), until it was discovered 400 km farther west along the Ohio River at Tower Rock, Hardin County, Illinois, in 1978 (Skorepa 1984). Since Skorepa's discovery, several new locations have been determined, mostly in the lower Ohio River valley near the confluences of the Wabash and Cumberland rivers.

In 1994, appreciating the rareness of this species, the Illinois Department of Natural Resources commissioned the authors to research the status of populations in Illinois and to report on any and all known sites, which included a regionwide survey. We already had been doing demographic and habitat research on the species under the sponsorship of the U.S. Forest Service, Harrisburg, Illinois, which was also interested in the extent to which the Shawnee National Forest provided habitat (Wilhelm and Wetstein 1991).

The purpose of this paper is severalfold. *Phaeophyscia leana* is fairly specific in its habitat requirements, and it is highly unusual among lichenized fungi in that its substrate is in a zone of regular inundation by vernal freshwater flooding. Given the changing nature of Midwestern river hydrology today (Patchett and Wilhelm 1999), the population demography is recorded in great detail. This will allow future studies to easily track population changes.

Also, given the unique and limited geographic range of the species, the current extent of the known inhabitancy of *Phaeophyscia leana* is provided so that comparisons may be made in the future.

TAXONOMY

The genus *Phaeophyscia*, an ascocarpous lichenized fungus with a lobed foliose thallus, resembles *Physcia* in that it has a lower cortex, a lecanorine exciple, and 1-septate spores with *Physcia*-type lumina. It is distinguished from *Physcia* and other allied genera, however, by the lack of atranorin in the cortex, a generally dark gray to brownish upper cortex, and a usually paraplectenchymatous and black lower cortex (Esslinger 1978). As currently delineated, the genus has 20 species in North America (Esslinger and Egan 1995). *Phaeophyscia leana* is characterized by an adnate, corticolous thallus with a white paraplectenchymatous lower cortex, a white medulla, elongate lobes mostly less than 2 mm wide, and an absence of specialized diaspores. The thalli have a mean diameter of 3.1 ± 1.9 cm ($n = 1,530$), ranging from 1 to 13 cm across. When dry, the thalli are a light gray-green (Royal Horticultural Society #196A) with a tinge of brown. With wetting, the thalli turn a bright apple green (R.H.S. #143C), which is easily visible on tree trunks from 25 m or more. *Phaeophyscia leana* was first described from the Thomas Lea collections that were made near Cincinnati, Ohio, from 1834 to 1844.

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DISTRIBUTION

Skorepa (1984) reported that at the Tower Rock site, *Phaeophyscia leana* was restricted to trees within 70 m of the Ohio River, and occurred from the tree base to about 2.5 m up the trunk. He also noted that it tended to grow almost without other lichen associates on bark flooded by the spring high water, and that several other lichens grew on bark above the spring crest level. Skorepa described the Tower Rock site as parklike and estimated that the population was confined to an area of about 0.4 ha.

Since then, eight large populations have been identified, as well as seventeen additional locations at which one to several thalli have been noted. One of the larger populations is the Skorepa study site at Tower Rock in Hardin County. Five other large populations are known in Illinois, one along Bell Island north of Old Shawneetown, one north of Old Shawneetown at Round Pond, and three south of New Haven, all in Gallatin County. Another large population is 10.5 km north of Birdsville, Livingston County, Kentucky, and one other was discovered recently by Loy R. Phillippe, of the Illinois Natural History Survey, along the Caney Fork River, a tributary of the Cumberland River near Carthage, Smith County, Tennessee.

The largest known Illinois populations, those comprising thousands of thalli, are principally on *Quercus palustris*, *Q. pagodaefolia*, and associated trees that grow in the bottomland areas of old backwaters of the Wabash and Little Wabash rivers. The other large populations are along the Ohio River, one at Tower Rock, where it grows on a variety of trees along the river bank, mostly on *Populus deltoides* and *Carya illinoensis*. In all cases, this lichen grows below the more recent high-water marks, where other lichen species are essentially absent.

Of the Kentucky populations, the largest was found north of Birdsville in a bottomland swamp off of the Ohio River, where thousands of thalli were noted, mostly on the numerous trees of *Taxodium distichum*. Many of these trees have groups of coalesced thalli covering large portions of their trunks in what appears to be the zone just below the high-water mark. Just above the high-water mark, where *P. leana* is not found, several other species of lichens were evident. As the swamp changes to higher ground, numerous *P. leana* thalli are on several tree species, including *Acer negundo* and *Carya laciniata*, which grow along the border of the swamp.

According to Phillippe (pers. comm.), the Tennessee population includes "thousands" of thalli on many different tree species along the Caney Fork River, just north of Bluff Creek. It was his impression that thallus occurrence was proportional to the number of individuals of trees rather than to a particular tree species. The only

exception was a perceived rareness on *Platanus occidentalis*. He noted it from *Acer negundo*, *A. saccharinum*, *Celtis occidentalis*, *Fraxinus pennsylvanica* var. *subintegerrima*, *Populus deltoides*, *Ulmus americana*, and even on the vine *Aristolochia tomentosa*.

Eleven other locations in Illinois, mostly in Gallatin County, are known to support smaller populations of *Phaeophyscia leana*. In Gallatin County, there are 2 thalli at the base of a *Fraxinus pennsylvanica* var. *subintegerrima*, near the high-water mark at the Department of Natural Resources boat launch in New Haven, along the Little Wabash River; notwithstanding the type location in Cincinnati, Ohio, this location marks the northernmost known population. Just southeast of New Haven, southwest of Horseshoe Pond and Clark Pond, in old oxbows of the Little Wabash River, there is at each *Phaeophyscia leana* location at least one tree of *Quercus pagodaefolia* that contains numerous thalli at or near the base. In Hardin County, the cottonwood trees (*Populus deltoides*) in the park east of the ferry landing at Cave-in-Rock support a small population, and another very small population was noted on *Carya cordiformis* and *Populus deltoides* at a defunct ferry landing near Elizabethtown, just west of the mouth of Big Creek. It is also scattered locally on trees along the Ohio River north of Sturgeon Island, near Finneyville. In Pope County, there are a few thalli on only one of several cottonwood trees at the south end of the fishing village just south of Golconda. Only a few thalli were seen in 1990 in the whole of Fort Massac State Park, Massac County, but none were seen after extensive surveys of the park bottomlands in 1994.

ADDITIONAL POPULATION SURVEYS

In 1994, an extensive survey of the Ohio and lower Wabash rivers included seventeen days of field work. Given the frequency of *Phaeophyscia leana* thalli encountered in Gallatin County, south of New Haven, it was postulated that they might be found in White County, north of New Haven. The Wabash River and its backwaters, where access was possible, were surveyed by automobile from Wabash to White counties. Extensive searches, however, including the large bottomland complex at Beall Woods, yielded neither populations nor individual thalli.

During a five-day reconnaissance by boat along the lower Ohio River, from New Haven to Cairo and its confluences with the Wabash, Tennessee, and Cumberland rivers, the portions of the river inaccessible by automobile were explored for *Phaeophyscia leana*. The survey was conducted in August, when the water levels were a little above the "normal pool level." Including the population at

Tower Rock, 7 populations, mostly small, were detected from the confluence of the Wabash River to the mouth of the Ohio River. The following notes summarize the course taken and observations made.

At the boat landing and parking lot at Cave-In-Rock, Illinois, there were a few thalli noted on large trees of *Populus deltoides* (Sighting 1). A search east of the village, where *Populus deltoides* populations were present, yielded no thalli; then we proceeded eastward from Grove Pits to Battery Rock, where there were mostly trees of *Acer saccharinum* and *Salix nigra*. The shores of Battery Rock are bedrock, and there was no *P. leana*. From Battery Rock to Sturgeon Island the trees were mostly *Acer saccharinum* and *Salix nigra*, no thalli were found.

From there, we explored the Saline River for about 2 km but found no thalli or suitable substrate. From the Saline River to Old Shawneetown, the land is nearly all in corn and soybeans up to the bank, which is slumping into the river. All along Bell Island, however, there were trees of *Populus deltoides* thinly inhabited by steadily occurring thalli of *P. leana*, mostly at elevations 3 to 5 m above the water line (Sighting 2); thalli were not noted on *Salix nigra* or *Acer saccharinum*.

We then turned up into the Wabash River for about 3 km, where there was mostly *Salix nigra* on the Illinois side and very little forest on the Indiana side. We returned to the Ohio River and encountered along the Kentucky side a few thalli among several trees of *Populus deltoides* in Union County, just opposite a creek that enters on the Illinois side, at the northeast corner of Section 12 T10S R9E (Sighting 3). We then followed the Kentucky shore to just south of Battery Rock, and returned to Cave-in-Rock along the Illinois side, noting scattered habitat throughout, but no *P. leana*.

We then put in at Elizabethtown, Illinois, heading upstream, but encountered no thalli of *P. leana* until Tower Rock (Sighting 4—studied population); although scattered potential habitat occurred, much of it was shaded by undergrowth. From Tower Rock to Cave-In-Rock there are mostly high bluffs to the water's edge. We crossed the river and searched along the Kentucky shore down to Elizabethtown; we encountered a few thalli on *Ulmus americana* at the southeast end of Hurricane Island, but none on *Populus deltoides*, which were present (Sighting 5).

From Elizabethtown to Rosiclare there are mostly high bluffs and rock to the water's edge, and mostly *Acer saccharinum* and *Salix nigra* from Rosiclare to Pierre Creek on larger sandbars. We noted no *Phaeophyscia leana* thalli. We diverted to the Kentucky side and explored Buck Creek for about 1 km, then back across the river to Grand Pierre Creek, where we explored up into Little Grand Pierre. There was very little cottonwood and some

bald cypress, but no *P. leana*. There are high bluffs from Grand Pierre to Golconda; we noted a few thalli on one tree of *Populus deltoides* at south end of a fishing camp in Section 31 T13S R7E (Sighting 6).

The river banks from the fishing camp to the Bay Creek area are mostly in agriculture. We explored Bay Creek for about ½ km, but not much potential habitat was discovered. The landscape was mostly agriculture and young trees from Bay City to the Smithland Lock and Dam. We explored extensively the area at Fort Massac State Park, where *P. leana* had been recorded in a survey in 1990. There was good potential habitat along Massac Creek, insofar as we could discern, but no thalli were found. There was fairly plentiful potential habitat from Fort Massac State Park to Brookport, but no thalli were seen. From east of Brookport to Smithland Lock and Dam there are mostly young trees of *Acer saccharinum* and *Salix nigra*, but no thalli were seen. We headed upstream along the Kentucky shore and noted 3 thalli along the right bank of the Cumberland River about 3 km from its mouth, but many suitable cottonwoods were devoid of this lichen (Sighting 7).

There are large cottonwoods on Cumberland Island, but no thalli of *P. leana*. Cottonwoods are scattered along the Kentucky shore to the mouth of the Tennessee River, but *P. leana* was absent. There is also suitable habitat, it would seem, across from Brookport, but no thalli. There are frequent lines of old cottonwoods from Metropolis to Joppa, which we searched intensively, but to no avail. We went a short way up Post Creek Cutoff, but discovered no potential habitat. From Post Creek Cutoff to Lock and Dam 53, we noted little suitable habitat, and several intensive searches revealed no thalli.³ We then searched the area up and downstream from Mound City, but the riverbanks from Olmsted to Cairo are increasingly dominated by industrial land uses. No thalli were seen.

DEMOGRAPHY OF *PHAEOPHYSCLIA LEANA* AT TOWER ROCK

In a study of the population at Tower Rock, which was done over the winter of 1989–1990, we studied certain aspects of the demography of *Phaeophyscia leana*, the findings from which have been useful in locating other populations. Tower Rock is a 10 ha recreation area located on a bottomland terrace along the north side of the Ohio

³ Ron Hall, U. S. Army Corps of Engineers Lock and Dam 53 director, informed us that water levels below Smithland Lock and Dam are much more erratic than above the dam, in part because of the confluences of the Cumberland and Tennessee rivers with the Ohio at Paducah. He noted also that the water levels are higher and laden with coarse sediments.

River, 6.5 km east of Elizabethtown, Illinois. The north side of the river is characterized by high, dissected bluffs that rise abruptly to nearly 40 m. The river is about 1 km wide in this area and is bordered by extensive bottomland along the south bank. The north bank of the Ohio River is eroding, and most of the trees that now are at the edge of the bank have exposed root systems, many of which support large colonies of *P. leana*. There are stumps along the water's edge from trees that had been drowned by a rise in normal (low-water) pool levels several years ago. Most of the *P. leana* population is confined to a 1.2 ha area on the terrace, mostly along the riverbank and around the mouth of an unnamed creek.

METHODS

A reconnaissance of the Tower Rock population of *P. leana* was conducted to determine its limits. Within those limits, all trees were identified and their positions relative to each other and the river were mapped. The trunks of coppiced trees were counted as individuals if the trunks started at or near the base. The diameter at breast height of each tree was also recorded.

We investigated the location of the thalli relative to the spring flood crest levels and the extent to which the recent raising of the normal pool level altered annual flood crests. In addition, we evaluated corticolous substrate preferences, noted distances from the river; and measured thallus diameter, aspect on the tree, elevation above the normal pool level, and elevation above the tree base. A general survey of corticolous lichens in the immediate area was conducted to determine lichen associates. Nomenclature follows Esslinger and Egan (1995); vascular plant nomenclature follows Mohlenbrock (1986).

The diameter of each thallus was measured to the nearest centimeter. When the thallus was oblong in shape, a visual estimate was made as to its average diameter. When a thallus was eroded at the center and only portions of the perimeter remained, the perimeter became the default diameter. Where tree girth had expanded sufficiently to separate an original thallus into 2 isolated portions, each portion was counted as a thallus. In some instances, small thalli appeared to be next to or commingled with eroded older thalli; these were measured as separate thalli. Thallus color for both wet and dry states was compared with the shades on the Royal Horticultural Society (1986) color chart. Information on annual flood crest data from 1937 to 1990 was obtained from the U.S. Army Corps of Engineers, Louisville, Kentucky, which also provided information on dam removal and replacement, as well as distances from the dam — to gauge locations along the river.

The available corticolous surface area, that is, potential substrate for *Phaeophyscia leana*, was calculated for each tree species sampled. Because no thallus was observed to grow higher than 3.7 m up the trunk, the height limit for each tree was either 3.7 m or the difference between the base elevation of the tree and the elevation of the spring crest in 1989, whichever was shorter. The height datum was combined with the DBH datum to arrive at the available surface area for each tree.

The base elevation of the normal pool stage was determined to be 98.8 m above mean sea level (MSL). The elevation of each tree above normal pool stage was then calculated at the base of its northern aspect. For many trees along the interface with the river, the southern aspect was so eroded as to render the ground elevation as much as 2 m below the northern aspect. Where trees grew on natural slopes, the southern aspect was as much as several centimeters below the northern aspect.

Thallus elevation was measured using the base of the northern aspect of the tree as the starting point. The elevation of each thallus was measured from the base of the tree to the thallus center. The elevation of the thallus was then added to the elevation of the tree base to determine the position of the thallus above the normal pool level. In some instances, elevation measurements were difficult to determine and have some degree of error, probably ± 5 cm, primarily due to the position of the tree either on a slope or on the eroded river bank.

RESULTS AND DISCUSSION

From 1937 to 1981, the normal pool level at Tower Rock, about 94.5 m above mean sea level (MSL), was controlled by the Golconda Dam, which was located 29 km downriver. During the first 6 months of each year, however, meltwaters and spring rains brought floodwaters as high as 14.5 m above the normal pool level at Golconda. The river, under such conditions, was sloped, and the head loss from Tower Rock to Golconda was 2.7 m. Peak annual flood waters had averaged 106.1 ± 2.0 m above MSL since 1937. The month before Skorepa made his observations on the *P. leana* population in April of 1978, the river at Tower Rock had risen to 106.7 m above MSL.

In 1981, the Golconda Dam was replaced by a higher dam at Smithland, 53 km downriver from Tower Rock. Since then, the normal pool level has been 98.8 m above MSL, an increase of 4.3 m. For much of the year, the head loss from dam to dam is negligible, rendering the pool slope virtually flat. Because of the increase in the normal pool level, trees were inundated and killed, and presumably the *P. leana* population has had to adjust. The

flood crest in February 1989 was 106.9 m above MSL, and the average over the decade prior to our observations had been 105.5 ± 1.3 m. Interestingly, because of the immense storage volume of the floodplain and negligible volume of the main channel, annual water level fluctuations along the Ohio River have dampened, and mean annual crest elevations seem not to have been much affected.

Of the 17 species of trees sampled at Tower Rock, including 380 individuals within the general population limits of *P. leana*, 11 supported nearly all of the 1,530 thalli of *P. leana* that were noted during the study. Potential available substrate area below the average spring flood crest elevation (106 m) was 452.6 m²; lichen thalli covered a total of 1.6 m² (0.35%).

There was an obvious avoidance of the northern quadrant of the trees, regardless of tree species or individual tree location. Although aspect preferences varied substantially with individual tree species, 41% of the thalli occurred on the south aspect of the trunk, facing the river, and 35% were on the east. Sixteen percent of the thalli were on the west side, and only 8% were on the north. Thalli were progressively fewer on trees as distance increased from the river's edge and up the elevation gradient.

Thallus position on the trees ranged from ground level, where *P. leana* sometimes grew on the upper surfaces of exposed roots, to as high as 3.7 m up the trunk. The average elevation of thalli above the base of the tree diminished progressively up the elevation gradient. Ninety-five percent of all the thalli were within a vertical zone 4.3–8.4 m above the normal pool level. Ninety-eight percent were found below the level of the 1989 spring crest (106.9 m above MSL) and within the standard deviation range of the average annual crest over the last 9 years. Eighty-four percent of all thalli were on 3 tree species, and 60% of

those thalli were on 9 individual trees: 5 individuals of *Populus deltoides* and 2 each of *Carya illinoensis* and *Liquidambar styraciflua* (table 1).

The tree most remote from the river within the population limit was 126 m from the bank; base elevations of trees ranged from 0.4 to 8.5 m above the normal pool level. Six taxa of trees were represented by only one or 2 individuals: *Cercis canadensis*, *Crataegus* sp., *Gleditsia triacanthos*, *Juglans nigra*, *Quercus prinoides* var. *acuminata*, and *Robinia pseudoacacia*. None of these 6 trees had thalli of *P. leana*. The 11 other tree species, totaling 109 individuals (29% of those sampled), had from 2 to 649 thalli.

The most common of the tree species was *Acer saccharinum*, which had a relative abundance of 30%. Other species, in order of their relative abundance, were *Celtis occidentalis* (14), *Carya illinoensis* (11), *Ulmus americana* (9), *Platanus occidentalis* (8), *Populus deltoides* (8), *Acer negundo* (5), *Liquidambar styraciflua* (5), *Diospyros virginiana* (4), *Maclura pomifera* (3), and *Fraxinus pennsylvanica* var. *subintegerrima* (1). Two individuals of *Maclura pomifera* had only one thallus each of *P. leana*, which are not included in the following analyses. The other 10 tree species and their inhabitation by *P. leana* are shown in table 2. The average distance of lichen-inhabited trees from the river was 44 ± 24 m, though nearly half of all thalli were on trees 24 ± 18 m from the river.

The 10 tree species (107 individuals) that provided suitable substrate for *P. leana* formed 4 population cohorts, which are describable generally in accordance with trunk diameter, elevation above the normal pool level, and distance from the river's edge (table 2).

Cohort 1. *Populus deltoides*, *Platanus occidentalis*, and *Acer saccharinum* made up a group of large-diameter trees (49 ± 20 cm DBH) that grew 35 ± 26 m from the river, in a zone that has been inundated annually since 1937. These

Table 1. Measurements and lichen data from 9 trees along the Ohio River at Tower Rock, each with 48 or more thalli of *Phaeophyscia leana*, arranged by distance from the river

Tree species	Distance from river (m)	DBH (cm)	Tree base elevation above river (m)	Range thalli elevation (m)	Thalli by aspect				Thalli per tree
					S	W	N	E	
<i>Populus deltoides</i>	10	67	2.8	3.1–6.0	51	3	7	25	86
<i>Populus deltoides</i>	10	91	3.6	4.0–7.2	7	20	7	78	112
<i>Populus deltoides</i>	12	90	3.6	3.8–6.6	87	1	3	64	155
<i>Populus deltoides</i>	18	103	4.1	4.3–6.4	44	5	1	21	71
<i>Populus deltoides</i>	25	81	4.6	4.7–6.3	5	29	2	17	53
<i>Carya illinoensis</i>	48	39	5.4	5.5–7.3	108	73	8	29	218
<i>Liquidambar styraciflua</i>	48	24	5.5	5.9–7.0	46	19	13	35	113
<i>Liquidambar styraciflua</i>	54	18	5.9	6.1–6.4	19	10	7	12	48
<i>Carya illinoensis</i>	87	30	7.7	7.8–8.8	40	0	1	19	60

trees constituted 46% of all measured trunks and had an average base elevation of 4.4 ± 1.1 m above the normal pool level. Eighty percent of the thalli were on 12 out of 13 trees that were within 20 m of the river. Only 9 out of 17 more remote trees had the lichen. Forty-eight percent of all *P. leana* thalli were on these trees; all of them were below the level of the spring crest elevation of 1989.

Cohort 2. *Carya illinoensis* and *Ulmus americana* formed a group of small to medium-sized trees (31.4 ± 10.7 cm DBH) on the bottomland terrace, a zone that has received floodwaters 7 to 8 years out of 10 since 1937. These tree species accounted for 20% of all the trees in the study area. Their average base elevation was 5.1 ± 1.7 m above the normal pool level, and they averaged 48.8 ± 32.6 m from the river. Thirty-one percent of all thalli were on these trees. Ninety-two percent of the thalli were below the level of the spring crest of 1989.

Cohort 3. *Acer negundo*, *Diospyros virginiana*, and *Liquidambar styraciflua* formed a group of small trees (27.9 ± 10.1 cm DBH) situated a little higher on the terrace, about 50 m from the river's edge. This area of the floodplain has received floodwaters 6 out of 10 years. These trees constituted 14% of all trees sampled, with an average base elevation of 5.5 m above the level of the normal pool. Nineteen percent of all thalli were in this cohort, and all of these were below the level of the spring crest of 1989.

Cohort 4. *Celtis occidentalis* and *Fraxinus pennsylvanica* var. *subintegrifolia* constituted a group of small trees (21.9 ± 9.0 cm DBH) that were high on the terrace and relatively

remote from the river, 75 ± 23 m. The bases of these trees have been inundated 2 to 3 out of 10 years since 1937. They had average base elevations 6.9 ± 1.3 m above the normal pool level. Only 3% of all thalli were on these trees. No more than 10% of these thalli grew above the level of the spring crest of 1989. In this cohort, *Phaeophyscia leana* grew in a narrow elevation range averaging 7.2 ± 0.5 m above the normal pool level.

Phaeophyscia leana appeared to exhibit a preference for individual tree species (table 2), but variations in tree diameters and relative abundance in the study area complicate a preference analysis. *Populus deltoides* had 14 times more thalli than *Acer negundo*, but only slightly more of its potential available bark surface was covered. *Liquidambar styraciflua* had one-third the number of thalli that *Populus deltoides* had, but nearly two-thirds more of its potential available surface was covered. *Carya illinoensis* was the next most inhabited, but 90% of its thalli were on trees outside of the zone occupied by *P. deltoides* (Cohort 1), even though half of the individuals of *C. illinoensis* grew within Cohort 1.

It would appear that at Tower Rock *Phaeophyscia leana* exhibits predilections for certain tree species and individuals within the floodplain community, depending upon the tree's context. There was, however, an inexplicable absence or paucity of thalli in apparently similar habitat at Tower Rock and at numerous other locations along the river. The largest populations of *P. leana* in Illinois are on *Quercus palustris* in the backwater oxbows of the Little Wabash River; in Kentucky, the largest population is on *Taxodium distichum* in an old oxbow of the Ohio River. The

Table 2. Demography and size of *Phaeophyscia leana* thalli on 107 trees along the Ohio River at Tower Rock, arranged by total thallus area within each of 4 cohorts

Tree species	% trees w/thalli	% of all thalli	Total thallus area (cm ²)	% of bark area	Average thallus diameter (cm)	Distance above tree base (m)	Average thallus elevation	
							Low	High
Cohort 1								
<i>Populus deltoides</i>	70	42	6677	0.37	3.1 ± 1.9	1.9 ± 0.9	4.8 ± 0.9	6.1 ± 0.7
<i>Acer saccharinum</i>	18	5	921	0.10	3.3 ± 2.3	0.8 ± 0.6	5.4 ± 0.7	5.8 ± 0.4
<i>Platanus occidentalis</i>	20	1	101	0.03	3.0 ± 2.3	0.8 ± 0.7	5.8 ± 0.5	6.0 ± 0.4
Cohort 2								
<i>Carya illinoensis</i>	43	27	4032	0.79	3.0 ± 1.8	0.9 ± 0.8	5.8 ± 1.0	6.5 ± 1.1
<i>Ulmus americana</i>	24	4	663	0.28	3.4 ± 1.9	0.6 ± 0.6	5.7 ± 1.3	6.1 ± 1.4
Cohort 3								
<i>Liquidambar styraciflua</i>	63	15	2370	0.95	3.1 ± 1.8	0.3 ± 0.6	6.5 ± 0.3	6.8 ± 0.5
<i>Acer negundo</i>	37	3	726	0.33	3.8 ± 2.5	0.6 ± 0.6	6.5 ± 0.3	6.8 ± 0.2
<i>Diospyros virginiana</i>	40	1	111	0.12	2.7 ± 1.4	0.6 ± 0.5	6.2 ± 0.5	6.6 ± 0.5
Cohort 4								
<i>Celtis occidentalis</i>	11	1	185	0.23	3.3 ± 1.3	0.0 ± 0.0	7.0 ± 1.0	7.8 ± 0.7
<i>Fraxinus pennsylvanica</i>	60	2	121	0.30	2.2 ± 1.1	0.1 ± 0.1	7.1 ± 0.4	7.2 ± 0.4

parameters and statistics noted for the Tower Rock location are site specific, but the study does show that the inhabitancy of *P. leana* in the Ohio bottoms is complex and evidently responding to factors beyond our ability to discern. There have been no demographic studies on any of the other populations, but each of them demonstrates a site-specific character that enlarges our understanding of the contemporary floristics of this globally rare lichen.

Generally, all of the known Illinois populations of *Phaeophyscia leana* are along or near the floodplain of the Ohio River, above the lock and dam at Smithland, Kentucky, and below the dam at Uniontown, Kentucky. The lichen grows in an elevation zone where the spring flood crests average 8 m above the "normal" pool level of the Smithland dam. As distance from the river increases, thalli become progressively fewer in number up the elevation gradient, displaying preferences for certain tree species and forming a discrete elevation band below the level of the spring flood crest. Other lichen associates are scant in this band, but are progressively more frequent at higher elevations.

LICHEN ASSOCIATES

In a survey of other corticolous lichens in the Tower Rock area, 48 additional species of lichenized fungi were noted (table 3). One of these was the unknown *Rinodina* species mentioned by Skorepa (1984), which still remains without an epithet as far as we know. The *Rinodina* thalli are well developed; their spores are about 16 microns long with globose lumina. This lichen appears to be a regular associate of *Phaeophyscia leana*, particularly along the Ohio River.

In addition to the *Rinodina*, 13 other lichen species were noted at the Tower Rock location as associates of *P. leana* below the spring high-water level (table 4). In most cases, the thalli were small and present at scattered locations. Of the 107 trees that bore thalli of *P. leana*, 29 supported one or more associate lichen species. Nineteen of these trees (66%) had thalli of *Physcia millegrana*, and 18 had *Candelaria concolor*; together, these lichens constituted 47% of all lichen associate occurrences. *Punctelia rudecta* occurred on 12 of the trees and accounted for 15% of all the occurrences. Lichen associate frequency increased up the elevation gradient. At the level of the 1989 spring crest, about 8.1 m above the level of the normal pool, other species of lichens became important and covered some of the tree trunks in the prolific manner characteristic of southern Illinois.

HABITAT THREATS AND POPULATION VULNERABILITY

Virtually all of the populations discovered along the shores of the Ohio River itself appear to have little possibility of persisting indefinitely. The irregular, high-volume floods, combined with the large wakes of river traffic, are eroding the shorelines at a rate much faster

Table 3. Additional lichenized fungus species at the Tower Rock study site that grow on corticolous substrates

<i>Amanidinea punctata</i> (Hoffm.) Coppins & Scheid.
<i>Anisomeridium bifforme</i> (Borrer) R. C. Harris
<i>Buellia stillingiana</i> J. Steiner
<i>Caloplaca cerina</i> (Hedwig) Th. Fr.
<i>Candelaria concolor</i> (Dickson) Stein
<i>Candelariella reflexa</i> (Nyl.) Lettau
<i>Candelariella xanthostigma</i> (Ach.) Lettau
<i>Canoparmelia crozalsiana</i> (B. de Lesd. ex Harm.) Elix & Hale
<i>Cladonia</i> sp. [squamales with fumarprotocetraric acid]
<i>Flavoparmelia caperata</i> (L.) Hale
<i>Graphis scripta</i> (L.) Ach.
<i>Heterodermia alliciana</i> (Pers.) Swinscow & Krog
<i>Heterodermia granulifera</i> (Ach.) Culb.
<i>Heterodermia speciosa</i> (Wulfen) Trev.
<i>Hyperphyscia syncolla</i> (Tuck. ex Nyl.) Kalb
<i>Hypotrachyna livida</i> (Taylor) Hale
<i>Lecanora hybocarpa</i> (Tuck.) Brodo
<i>Lecanora sribohlina</i> (Sprengel) Kieffer
<i>Lepraria lobiflora</i> Nyl.
<i>Lepraria</i> sp. #1 (sensu Wilhelm 1998)
<i>Loxospora pustulata</i> (Brodo & Culb.) R. C. Harris
<i>Myelochroa aurulenta</i> (Tuck.) Elix & Hale
<i>Myelochroa galbina</i> (Ach.) Elix & Hale
<i>Opoglyphis vulgata</i> Ach.
<i>Parmotrema hypotropum</i> (Nyl.) Hale
<i>Phaeophyscia cernoborskyi</i> (Nádv.) Essl.
<i>Phaeophyscia ciliata</i> (Hoffm.) Moberg
<i>Phaeophyscia hirtella</i> Essl.
<i>Phaeophyscia pusilloides</i> (Zahlbr.) Essl.
<i>Phaeophyscia rubropulchra</i> (Degel.) Moberg
<i>Physcia americana</i> G. K. Merr.
<i>Physcia millegrana</i> Degel.
<i>Physicella chloantha</i> (Ach.) Essl.
<i>Physconia detersa</i> (Nyl.) Poelt
<i>Physconia kurokawae</i> Kashiw.
" <i>Porina pulla</i> (Ach.) Müll. Arg."
<i>Punctelia missouriensis</i> Wilhelm & Ladd
<i>Punctelia rudecta</i> (Ach.) Krog
<i>Pyxine soredata</i> (Ach.) Mont.
<i>Pyxine subcinerea</i> Sturton
<i>Ramalina unifolia</i> J. W. Thompson
<i>Rimelia reticulata</i> (Taylor) Hale & Fletcher
<i>Rinodina ascoiscana</i> Tuck.
<i>Rinodina subminuta</i> Magn.
<i>Rinodina</i> sp.
<i>Sclotzioporum chlorocorum</i> (Stenh.) Vězda
<i>Uzma mutabilis</i> Sturton
<i>Xanthoria</i> sp. #1 (sensu Wilhelm 1998)

than trees of suitable size are being replaced. Another critical aspect of the habitat of *P. leana* is the fact that it grows on the lower trunks and bases of trees that are not shaded by understory or heavy growth of ground-cover vegetation. All the major Illinois populations are in areas such as boat landings or parklike areas where a maximum amount of light coincides with old-growth trees. Such areas are maintained by mowing or regular brush removal. If such activity were to cease, there is a likelihood that those large populations would disappear. One *P. leana* site, situated in a large tract of bottomland forest, is confined to the well-lit margins, which at the time of the study were free of significant edge shrubbery.

Given the rareness of this lichen in Illinois, and the tenuous ecological contexts in which its populations persist, it would seem that the long-term existence of *P. leana* is endangered. At the federal level, further study is needed to determine its range and habitat parameters outside of the lower Ohio River region.

Table 4. Lichen associates of *Phaeophyscia leana* at Tower Rock at elevations below spring flood crests, in descending order of importance

Occurrences	%	Species
19	24	<i>Physcia millegrana</i>
18	23	<i>Candelaria concolor</i>
12	15	<i>Punctelia rudecta</i>
6	8	<i>Candelariella xanthostigma</i>
6	8	<i>Phaeophyscia rubropulchra</i>
4	5	<i>Physcia americana</i>
4	5	<i>Rinodina</i> sp.
3	4	<i>Physciella chloantha</i>
1	1	<i>Heterodermia speciosa</i>
1	1	<i>Lepraria lobificans</i>
1	1	<i>Lepraria</i> sp. #1
1	1	<i>Phaeophyscia cernohorskyi</i>
1	1	<i>Physconia detersa</i>
1	1	<i>Pyxine subcinerea</i>

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REPRESENTATIVE HERBARIUM SPECIMENS

The following specimens are provided to document the known locations of populations of *Phaeophyscia leana*. They all have been examined by the authors and include the complete label data. All specimens are at the Morton Arboretum herbarium (MOR) unless otherwise indicated as housed in the following herbaria:

- BALT Towson State University, Baltimore, Md.
 ILLS Illinois Natural History Survey, Champaign, Ill.
 US The United States National Herbarium, Washington, D.C.
 WIS University of Wisconsin, Madison, Wis.

ILLINOIS

Gallatin County

- Wilhelm & J. Shimp* 22326, 22 AUG 1994; about 3 miles north of Old Shawneetown, along edge of Bell Island, mostly 3-5 m above water, which is not at normal pool elev.; thin but steady population on *Populus deltoides* for more than a mile.
- Wilhelm & Masters* 22336, 30 AUG 1994; 10 miles east of Ridgway, 10 miles south-southeast of New Haven, at the south end of Hulda Lake, an old oxbow of the Little Wabash River.
- Wilhelm & Masters* 22339, 30 AUG 1994; 10 miles east of Ridgway, 9 miles south-southeast of New Haven, east of Hulda Lake, an old oxbow of the Little Wabash River, off east side of county road, along south edge of woodland; on *Quercus palustris*.
- Wilhelm & Masters* 22343, 30 AUG 1994; about 3 miles southeast of New Haven, at the north end of Beaver Pond, an old oxbow lake of the Little Wabash River, east of county road; on *Quercus palustris*.
- Wilhelm & Masters* 22346, 30 AUG 1994; in New Haven, at the Department of Conservation boat launch into the Little Wabash River, at base of *Fraxinus pennsylvanica* var. *subintegerrima* near high-water mark.
- Shimp* 5269, 5 SEP 1994; south end of Big Lake, 2.5 miles northeast of Old Shawneetown, SW SW Sec. 21 T9S R10E; on *Carya illinoensis* in seasonally flooded bottomland hardwood forest.

Shimp 5270, 5 SEP 1994; west side of Long Pond 5 miles northeast of Old Shawneetown, SE SE Sec. 9 T9S R10E; on *Populus deltoides* in hardwood forest dominated by *Acer saccharinum*, *Fraxinus pennsylvanica subintegerrima*, and *Populus deltoides*.

Shimp 5271, 5 SEP 1994; southwest of Cow Pond slough, 5.25 miles north of Old Shawneetown, growing on *Acer rubrum* in bottomland forest dominated by *Acer rubrum*.

Shimp 5272, 5 SEP 1994; south of Hulda Lake, 9 miles east of Ridgway, growing on *Quercus pagodaefolia*, at an old home site with other open-grown bottomland species; *Quercus palustris*, *Q. macrocarpa*, *Carya laciniata*, and *Fraxinus tomentosa*.

Shimp 5273, 5 SEP 1994; southwest of Horseshoe Pond, 2.5 miles southeast of New Haven, growing along the road on *Quercus pagodaefolia* in disturbed floodplain forest.

Shimp 5274, 5 SEP 1994; southwest of Clark Pond, 1.75 miles southeast of New Haven, growing along road on *Quercus pagodaefolia* in disturbed bottomland hardwood forest.

Hardin County

Skorepa 11975, APR 1978; near Elizabethtown, at Tower Rock, on *Populus deltoides*. (BALT, US, WIS)

Wilhelm & Masters 17802, 16 OCT 1989; about 5 miles east of Elizabethtown, at Tower Rock Recreation Area, at picnic area; SE Sec. 20 T12S R9E; on *Liquidambar styraciflua*.

Wilhelm & Masters 18770, 16 DEC 1990; at Elizabethtown, west of the mouth of Big Creek, at old ferry landing; in SW Sec. 27 T12S R8E; on *Carya cordiformis*.

Wilhelm & Masters 18802, 17 DEC 1990; in Cave In Rock, in park area just east of the ferry landing, occasional on cottonwoods near the river.

Shimp & Basinger 5386, 18 SEP 1994; R10E T11S Sec. 21, NE, SE, NE, Dekoven 7.5' topo, growing on *Liquidambar styraciflua* in flood plain forest adjacent to the Ohio River; also growing on *Quercus palustris*, *Carya laciniata*, and *Populus deltoides*.

Shimp & Basinger 5387, 18 SEP 1994; R10E T11S Sec. 21, SE, NE, Dekoven 7.5' topo, growing on a isolated tree of *Populus deltoides* on sandy bank of Ohio River.

Massac County

Wilhelm & Masters 18772, 17 DEC 1990; near Metropolis, at Fort Massac State Park; rare on *Populus deltoides* near the river, west of where Massac Creek empties into the Ohio River.

Pope County

Wilhelm & J. Shimp 22332, 23 AUG 1994; about 1 mile south of Golconda, along Ohio River, at south end of fishing village, on one of several trees of *Populus deltoides*; SW Sec. 31 T13S R7E.

INDIANA

Posey County

Shimp & Shimp 5391, 18 SEP 1994; 5.5 miles southeast of New Haven, Illinois, growing on *Populus deltoides* in floodplain forest along the Wabash River.

KENTUCKY

Crिटtenden County

Wilhelm & Masters 18801, 17 DEC 1990; at Tolu, west of the mouth of Hurricane Creek, west of the boat landing; rare on *Populus deltoides*.

Wilhelm & J. Shimp 22331, 23 AUG 1994; north of Tolu, at SE end of Hurricane Island, on *Ulmus americana*; not on several neighboring trees of *Populus deltoides*.

Livingston County

Wilhelm & Masters 18800, 17 DEC 1990; about 4 miles west of Joy, at the west end of Rte. 133, east of the boat landing opposite Golconda, Illinois; rare on *Populus deltoides*.

Wilhelm & Masters 18797, 17 DEC 1990; about 6.3 miles north of Birdsville, west of Rte. 137 in Cypress swamp; frequent on *Carya laciniata* near the swamp.

Wilhelm & J. Shimp 22333, 24 AUG 1994; northeast of Smithland, along west bank of Cumberland River, about 2.5 miles above its mouth; only 3 thalli noted on about 100 trees.

Wilhelm & J. Shimp 22334, 24 AUG 1994; about 1 mile north of Bayou, west of Rte. 137, along east edge of long slough; on *Taxodium distichum*.

Union County

Wilhelm & J. Shimp 22329, 22 AUG 1994; along Ohio River, on *Populus deltoides*, about 1.5 miles downstream from bridge to Old Shawneetown, Illinois.

OHIO

Hamilton County

Lea s.n., 14 MAY 1839; on the bark of a large tree in Ridley's Bog toward Barner's. (PH)

Lea s.n., 19 JUL 1849; growing among moss on trunk of a large tree. (US)

Lea s.n., 1839; near Cincinnati. (MICH)

Lea s.n., 1839; Burnet Woods, Cincinnati. (MICH)

Lea s.n., 1839; Ohio. (MINN)

TENNESSEE

Smith County

Phillippe LA0, 19 NOV 1990; south of Carthage, 2-3 miles up the Caney Fork River from the Cumberland River, along the south bank; on *Acer negundo*. The lichen grows below the level of highwater on *Acer saccharinum*, *Fraxinus pennsylvanica* var. *subintegerrima*, *Acer negundo*, *Celtis occidentalis*, *Populus deltoides*, *Ulmus americana*, *Aristolochia serpentaria*, and *Salix nigra*.

SOME NOTABLE PLANT RECORDS FROM EAST-CENTRAL AND SOUTHERN ILLINOIS

Gordon C. Tucker¹

INTRODUCTION

The purpose of this paper is to document the occurrence of several species new to the Illinois state flora. Also included are county records for some species new to east-central and southern Illinois (roughly, but not exclusively, the area from Vermilion, Champaign, and Piatt counties southward). In general, specimens were collected by the author or some of his students at Eastern Illinois University. Subsequent searches of collections at EIU, ILL, ILLS, and ISM turned up several additional collections of these same species noted below as new state, regional, or county records.

Nomenclature generally follows Gleason and Cronquist (1991) or other recent works individually noted. Distribution information within Illinois follows Mohlenbrock and Ladd (1978) or Swink and Wilhelm (1994). Distribution information for other states comes from Gleason and Cronquist (1991) or USDA, NRCS (1999).

FERN ALLIES

LYCOPODIUM DIGITATUM A. Braun [*Diphasiastrum digitatum* (A. Br.) Holub] (Lycopodiaceae)

Clark Co., Westfield, Clarksville Rd., SE S27 T12N R14W, ash and sugar maple woods, 11 June 1999, *Tucker 11706* (EIU, GH, ILLS, NYS); N of Martinsville, first terrace W of N Fork of Embarras River, SE S24 T11N R14W, 19 May 1988, *Phillippe 13180* (EIU, ILLS).

This clubmoss has not previously been reported from Clark County.

GYMNOSPERMS

TAXODIUM DISTICHUM (L.) Rich. (Cupressaceae)

Vermilion Co., Kickapoo State Park, Clear Lake near boat launch, 6 September 1997, *Tucker 11436* (EIU) and Inland Sea boat launch near Emerald Pond, *Tucker 11440* (EIU, ILLS).

Coles Co., EIU Campus, near Tarble Art Center, volunteers in flower beds near planted trees, 14 October 1996, *Tucker 11253* (EIU).

Bald cypress has not previously been reported north of Lawrence County. The collections from Kickapoo State Park were made about 1 mile apart. The collection from Clear Lake represents saplings up to 2 m tall, located about

100 m from several planted mature trees. The collection from Inland Sea, however, had no planted trees anywhere in the vicinity.

DICOTYLEDONS

CELOSIA ARGENTEA L. (Amaranthaceae)

Coles Co., Charleston, EIU Campus, S of softball field, abundant in area where compost and topsoil are dumped, 13 September 1998, *Tucker 11583* (BKL, EIU, GH, ILLS). Also observed as weed at electric substation on west edge of campus.

Celosia argentea (cockscorn) is a new state record. It has been reported from the adjacent states of Kentucky and Indiana (USDA, NRCS 1999). Several specimens at ILL and ILLS represent cultivated plants.

APIUM LEPTOPHYLLUM (Pers.) F. Muell. (Apiaceae)

Effingham Co., Effingham, Rte. 32 N of I-70, weed in landscape planting, 27 September 1997, *Tucker 11456* (EIU).

Apium leptophyllum is a new state record. This tropical and warm temperate species is widely distributed in the mid-Atlantic, southeastern, and southwestern U.S. It was mentioned in passing by Gleason and Cronquist (1991) without attribution to any states in their manual's range. It was not attributed to any Midwestern state by USDA, NRCS (1999).

CARDAMINE FLEXUOSA Withering (Brassicaceae)

Coles Co., Charleston, Madison Ave. and 9th St., St. Charles Borromeo Roman Catholic Church, weed in planters, 24 June 1999, *Tucker 11783A* (EIU); Lerna, CR 1200E, SE S24 T12N R8E, weed in garden, 19 March 2000, *Tucker 12002* (EIU).

Cardamine flexuosa is a new state record. A native of Eurasia, this species is widely distributed in the southeastern and mid-Atlantic states, ranging from Florida and North Carolina (Al-Shehbaz 1988) as far north as New York (Mitchell and Tucker 1997). In the Midwest, it has been reported from Indiana, Michigan, and Ohio (USDA, NRCS 1999). This species is easily confused with the common *C. hirsuta* L. Both have ciliate petioles and the lowermost leaves with suborbicular lobes, which distinguishes them from other biennial or annual species of *Cardamine* (Al-Shehbaz 1988). They can be distinguished as follows (key based on Fernald, 1950):

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1. Stem flexuous, hirsute especially above; cauline and basal leaves similar; leaflets 4–20 mm wide; stamens 6.
..... *C. flexuosa*
1. Stem stiffly erect, glabrous; cauline and basal leaves dissimilar; leaflets 0.5–4 mm wide; stamens usually 4.
..... *C. hirsuta*

LOBULARIA MARITIMA (L.) Desv. (Brassicaceae)

Coles Co., Charleston, EIU Campus, weed in gravelly edge of parking lot near 7th St., 4 November 1996, *Tucker 11257A* (EIU).

Sweet alyssum has been reported previously from the Chicago area, Champaign County, Hancock County, and McDonough County (Mohlenbrock and Ladd 1978; Swink and Wilhelm 1994; Mohlenbrock 1985).

CASSIA TORA L. [*Senna tora* (L.) Roxb.] (Caesalpinaceae)

Coles Co., Charleston, Reasor Ave. near Rte. 130 on N edge of city, NW S2 T12N R9E, railroad cinders, 9 September 1996, *Tucker 11237* (EIU).

There are few records of this legume in Illinois: Mohlenbrock and Ladd (1978) listed Wabash, Jackson, Pulaski, and Lake counties; Swink and Wilhelm (1994) also listed Cook County; Mohlenbrock (1985) added Clinton County.

SAGINA JAPONICA (Sw.) Ohwi (Caryophyllaceae)

Coles Co., Charleston, 1049 11th St., 28 May 1997, *Tucker 11273* (EIU); 1400 Block of 7th St., 14 June 1997, *Tucker 11275* (EIU, ILLS, ISM); 7th St. and Buchanan Ave., 24 June 1999, *Tucker 11731* (EIU).

A new record for the state, Japanese pearlwort is widely distributed in the Northeast (Mitchell and Tucker 1991). This east Asian species has also been reported from northwestern Ohio (Rabaler 1996). Japanese pearlwort can be distinguished from the other Illinois species of *Sagina* as follows (key derived from Mitchell and Tucker, 1992):

1. Flower parts in 4s (rarely 5s on the same plant); sepals reflexed in fruit; matted wiry perennials, spreading by offshoots. *S. procumbens*
1. Flower parts primarily in 5s (rarely 4s on the same plant); sepals erect or appressed in fruit; annuals with erect-ascending (or decumbent), often capillary stems and slender taproots, not strongly tufted, not spreading by offshoots.
2. Leaves with cilia at base. *S. apetala*
2. Leaves glabrous at base.
3. Seeds pale brown, triangular, with a dorsal groove; capsules longer than broad; pedicels and sepals glabrous (occasionally sparsely glandular); leaves not succulent. *S. decumbens*
3. Seeds dark brown to black, plump, ellipsoid-ovoid, lacking a dorsal groove; capsules globose; pedicels and sepals glandular; leaves succulent.
..... *S. japonica*

CELASTRUS ORBICULATA Thunb. (Celastraceae)

Effingham Co., Summit Township, S23 T8N R5E, *Matthew E. Brooks 85* (EIU).

Hardin Co., 1/8 mi. N of Elizabethtown on Watson Lane, S27 T12S R8E, 29 September 1997, *Garrison Gross 84* (EIU). An earlier collection was apparently not seen by Mohlenbrock and Ladd (1978): Hardin Co., Peters Creek Fire Tower, 19 June 1962, *Evers 74244* (ILLS), originally identified as *C. scandens*, reidentified by Evers in 1973.

Asiatic bittersweet has been reported previously from Piatt County in eastern and east-central Illinois and from Jackson and Union counties in southern Illinois. It is cited from several counties in northeastern Illinois (Swink and Wilhelm 1994).

EUONYMUS FORTUNEI (Turcz.) Hand.-Mazz. var. *radicans* (Sieb. ex Miq.) Rehd. (Celastraceae)

Coles Co., EIU Campus near football stadium, 10 July 1996, *Tucker 11192* (EIU); Charleston, Eastgate Dr., weed in vegetable garden, 1 January 2000, *Tucker 11997* (EIU).

Lawrence Co., Red Hills State Park, 19 July 1998, *B. Edgin 984* (EIU); Chauncey Marsh, 15 June 1995, *L. R. Philippe et al. 26406* (ILLS).

Richland Co., W of Olney, 30 July 1998, *M. A. Feist 100* (ILLS).

There are relatively few collections of *Euonymus fortunei* (winter-creeper) from Illinois, aside from several county records provided by Swink and Wilhelm (1994). Vegetative plants have been seen by the author at the Rocky Branch Nature Preserve in Clark County in November of 1999.

SEDUM SARMENTOSUM Bunge (Crassulaceae)

Coles Co., Charleston, Lincoln Ave. and 10th St., on lower trunk of sugar maple at corner of parking lot, no garden or plantings nearby, 1 July 1998, *Tucker 11477* (EIU).

This commonly cultivated stoneweed has been reported previously only from northeastern Illinois (Swink and Wilhelm 1994) and western and southwestern Illinois (Mohlenbrock and Ladd 1978).

CUCURBITA PEPO L. (Cucurbitaceae)

Coles Co., Charleston, Edgar Dr. on EIU Campus, growing on heaps of soil, 3 October 1996, *Tucker 11242* (EIU); Walnut Grove, weed in cornfield, 21 September 1997, *Tucker 11452* (EIU).

In eastern and central Illinois, pumpkin has been recorded as a noncultivated plant from Piatt, Douglas, and Lawrence counties (Mohlenbrock and Ladd 1978; Mohlenbrock 1985).

RICINUS COMMUNIS L. (Euphorbiaceae)

Coles Co., Charleston, EIU Campus, S of baseball field, disturbed area where soil, compost, and clippings are stored, 28 August 1997, *Beth Storm 1* (EIU).

Lawrence Co., NE of St. Francisville, refuse heap, 24 August 1956, *Evers 51966* (ILLS).

Castor bean plant has been recorded only from Jackson County (Mohlenbrock and Ladd 1978) and Union County (Mohlenbrock 1985). The population on the EIU campus has maintained itself since first documented in 1997.

Buddleia davidii Franchet (Loganiaceae)

Coles Co., Charleston, EIU Campus, around loading dock and steps of university Union, weed in cracks and crevices, 14 October 1998, *Tucker 11593* (EIU, ILLS).

Butterfly-bush is not recorded for Illinois by Mohlenbrock and Ladd (1978). This species is widely naturalized in the southeastern states and potentially a problem exotic there (Reichard 1996). In the Midwest, butterfly-bush is attributed to Kentucky, Michigan, and Ohio (USDA, NRCS 1999). The name of this genus is sometimes spelled "Buddleja," and it is sometimes placed in a segregate family, Buddleiaceae.

Lliamna remota Greene (Malvaceae)

Coles Co., Charleston, EIU Campus, near Life Science Bldg., weeds among irises and spirea, planted in flower bed nearby, 12 July 1999, *Tucker 11783* (EIU, ILLS).

Well known as Illinois's only surviving endemic, *Lliamna remota* is often cultivated for its attractive purple flowers. The lack of collections from other areas of the state suggests this Kankakee Mallow has a limited ability to colonize, even in the region where it is native.

Duchesnea indica (Andrews) Focke (Rosaceae)

Coles Co., Charleston, Wesley Whiteside's Garden, CR 1820E and SR 16, 2 July 1997, *Tucker s.n.* (EIU); Charleston, EIU Campus, near Science Bldg., 14 May 1995, *Ebinger 26522* (EIU).

Edgar Co., Paris, Carnegie Library, shaded lawn, 13 June 1997, *Tucker 11274* (EIU).

Macon Co., Decatur, Scovill Zoo, S19 T16N R3E, 19 June 1999, *Tucker 11729* (EIU).

The preceding are new county records. In central and eastern Illinois, it has been recorded from only Sangamon and Christian counties. Swink and Wilhelm (1994) mapped four counties in northeastern Illinois.

Fragaria × Ananassa Dcne. (Rosaceae)

Coles Co., NE of Loxa, S30 T13N R9E, gravelly roadside bordering fields, hundreds of plants, 13 June 1999, *Tucker 11724* (EIU, ILLS).

The cultivated strawberry is recorded from only Lawrence and Jackson counties by Mohlenbrock and Ladd (1978).

Salix matsudana Koidz. "Tortuosa" [*S. babylonica* L. Tortuosa] (Salicaceae)

Coles Co., Charleston, Elmira Street just N of Eastgate Dr., two shrubs 2–3 m tall, in ditch at edge of field, 8 May 1999, *Tucker 11641* (CAN, EIU, ILLS); dupl. det. G. Argus, Canadian Museum of Nature, Ottawa.

Not previously recorded from Illinois, this distinctive cultivated willow with contorted yellow twigs has been recorded from Ohio, New York, and Virginia (USDA, NRCS 1999; Mitchell and Tucker 1997).

Tilia cordata Mill. (Tiliaceae)

Coles Co., Charleston, EIU Campus, near Life Science Bldg., weed in hedge and flower bed, 8 May 1997, *Tucker 11269* (EIU).

Little-leaf linden has not previously been recorded from Illinois, or any Midwestern state. This European native has been reported from Maine to New York and Maryland (USDA, NRCS 1999). In the collections at EIU and ILL are several cultivated specimens from eastern Illinois, but no specimens of escaped plants.

Verbena bonariensis L. (Verbenaceae)

Coles Co., Charleston, EIU Campus, Carman Pond, weeds among cattails, 26 August 1999, *Tucker 11873* (EIU).

This tropical species of vervain is occasionally cultivated, but has not previously been recorded as an escape in Illinois or any other Midwestern state. It is known from several states in the mid-Atlantic, Southeast, and Pacific regions (USDA, NRCS 1999), where it is often weedy.

Parthenocissus vitacea (Kner) A. Hitchc. [*P. inserta* of authors] (Vitaceae)

Coles Co., Charleston, near Charleston High School, along fence with *Toxicodendron radicans* and *Lonicera japonica*, 23 June 1999, *Tucker 11730* (BKL, EIU, ILLS, MOR).

There are few records of this native vine in eastern and central Illinois: Mohlenbrock and Ladd (1978) have only Champaign and Ford counties marked. Mohlenbrock (1986) used the name *P. inserta* for this species.

MONOCOTYLEDONS

Scirpus atrovirens Willd. × **S. georgianus** Harper (Cyperaceae)

Effingham Co., Fremington Cemetery, between Keptown and Altamont, S7 T7N R5E, 12 September 1978, *Shildneck C-10366* (ILLS), originally identified as *S. atrovirens*.

Both of the parental species of this hybrid are widespread in Illinois, but the hybrid is scarce, as it is throughout much of the overlapping ranges of the two parental species. *Scirpus atrovirens* (common throughout Illinois) has perianth bristles about as long as the achenes; *S. georgianus* (common in central and southern Illinois) generally lacks bristles (Tucker 1987). The hybrid, apparently unnamed, has bristles about half as long as the achenes, which are generally undeveloped and lack endosperm. Also, the hybrid is often proliferous, with viviparous plantlets developing in the inflorescence (Tucker 1992); this is the case with the specimen cited here. This hybrid could be described as a leafy-stemmed bulrush found late in summer with scales falling from the spikelets, empty or shriveled achenes, and perianth bristles about half as long as the achenes and proliferous plantlets in the inflorescence. The following key its immediate means to distinguish the hybrid from its immediate relatives.

1. Perianth bristles absent (or rudimentary, at most 1/3 as long as mature achene); in damp shaded or sunny wet places; statewide, but scarce in the north.

..... *S. georgianus* Harper

1. Perianth bristles 5–6 (about $\frac{1}{2}$ as long as to equaling the mature achene).
2. Scales \pm persistent, brown; bristles as long as to slightly longer than achenes; plants of marshes, streambanks, pools; usually in standing water well into summer; statewide. *S. atrovirens* S. Muhl.
2. Scales \pm deciduous, gray, black, or brown; bristles about $\frac{1}{2}$ – $\frac{2}{3}$ as long as achene.
3. Scales brownish; bristles about $\frac{1}{2}$ as long as achene; achenes empty or shriveled; spikelets often proliferous; plants of ditches in full sun; to be expected anywhere in the state.
. *S. atrovirens* \times *S. georgianus*
3. Scales gray to black; bristles about $\frac{2}{3}$ as long as achene; achenes well developed, with endosperm; spikelets seldom proliferous; plants of damp upland soils, typically in light shade; rare; northeastern Illinois. *S. hatterianus* Makino

SCIRPUS MUCRONATUS L. [*Schoenoplectus mucronatus* (L.) Palla] (Cyperaceae)

Jasper Co., Prairie Ridge State Natural Area, artificial wetland W of IDNR office, S27 T6N R9E, 14 September 1999, M. Boyer s.n. (EIU, GH).

Alexander Co., Horseshoe Lake, S10 R2W T16 N, 6 June 1993, M. A. Basinger 5363 (ILLS), S22 R2W T16 N, 3 July 1993, M. A. Basinger 6016 (ILLS), and S20 R2W T16 N, 8 July 1996, M. A. Basinger 10890 (ILLS).

The 1993 collections were identified by S. Galen Smith in 1998. *Scirpus mucronatus* was first reported from Illinois in 1984 (Schwegman 1984) from Mason County. This annual European bulrush has begun to spread, albeit slowly. Although superficially similar to the native *S. pungens* Vahl, *S. mucronatus* is an annual, with fibrous roots and tufted stems. Numerous recent taxonomic works place *S. mucronatus* in the segregate genus *Schoenoplectus*, e.g., Yatskievich (1999). He provides a key to *Schoenoplectus mucronatus* and related species that will work well for Illinois as well as Missouri specimens.

LIPOCARPHA DRUMMONDII (Nees) G. Tucker [*Hemicarpha drummondii* Nees in Mart., *H. micrantha* var. *drummondii* (Nees) Friedland] (Cyperaceae)

Iroquois Co., Iroquois County Conservation Area, S24 T29N R11W, edge of road, 5 July 1983, Ebinger 22309 (EIU).

This minute native sedge was recorded from only Lake and Cook counties by Swink and Wilhelm (1994), and by Mohlenbrock (1986), as *Scirpus micranthus* Vahl var. *drummondii* (Nees) Mohlenbrock. Although this taxon has been treated as a synonym or variety of *L. micrantha*, recent studies have demonstrated its distinctness at the species level (Goetghebeur and Van den Borre 1989; Tucker 1987). In *L. drummondii*, each achene is subtended by an acuminate outer scale, as well as an inner hyaline scale; in *L. micrantha*, only the outer scale is present, which is subacute.

Because of its rarity, I believe *L. drummondii* is an appropriate candidate for state listing as an endangered

species. I have examined all Illinois collections of *Lipocarpha* at ILL, ILLS, ISM, and EIU. Ebinger's collection from Vermilion County, originally identified as *Scirpus micranthus*, is only the third report from the state. Swink and Wilhelm reported it from Lake and Cook counties, based on collections made in 1967 and 1867, respectively.

ALLIUM CEPAL. (Liliaceae)

Coles Co., Charleston, EIU Campus, W of stadium on fitness trail in thickets with *Sanicula gregaria*, 28 May 1997, Tucker 11271 (EIU); Charleston, alley between 1st and 2nd streets N of Grant Ave., abundantly escaped, hundreds of plants, 15 June 1998, Tucker 11469 (EIU, ILL).

Cumberland Co., 10 mi. W of Toledo, S33 T10N R7E, 14 June 1972, Ebinger 11455 (EIU).

Allium cepa, the common garden onion, has been reported previously only from Union County (Mohlenbrock and Ladd 1978), and from DuPage, Grundy, Kankakee, and Will counties by Swink and Wilhelm (1994).

CHIONODOXA FORBESII Baker [*C. luciliae* of authors] (Liliaceae)

Coles Co., Charleston, EIU Campus, lawn near H. F. Thut Greenhouse, naturalized in lawn and around hedges, 10 April 1998, Tucker 11478 (EIU).

Glory-of-the-snow has not been recorded from Illinois (Mohlenbrock and Ladd 1978) or from any Midwestern state. It has been reported only from Massachusetts, Michigan, and Utah (USDA, NRCS 1999).

SCILLA SIBIRICA Haw. ex Andr. (Liliaceae)

Coles Co., Charleston, EIU Campus, lawn near H. F. Thut Greenhouse, naturalized in lawn and around hedges, 10 April 1998, Tucker 11479 (EIU).

Piatt Co., near Allerton House, disturbed roadside, now multiplying, 25 March 1995, S. R. Hill 26244 (ILLS).

Scilla sibirica has been noted from only DuPage, Moultrie, and McDonough counties by Mohlenbrock and Ladd (1978), and from Cook, DuPage, and Kane counties by Swink and Wilhelm (1994).

BRIZA MINOR L. (Poaceae)

Coles Co., E of Charleston, Stone Quarry, 28 September 1996, Matthew E. Brooks 69 (EIU).

In Illinois, quake-grass has been reported previously only from St. Clair County (Mohlenbrock 1986). This attractive annual, a native of Europe, is sometimes included in packets of "ornamental grass" seeds and might be expected to turn up more often than records indicate.

CHLORIS VERTICILLATA Nutt. (Poaceae)

Coles Co., Charleston, 18th Street near Circle Dr., 1 September 1996, Tucker 11232 (EIU, ILLS, ISM).

Wingmill grass was noted previously from Crawford and Douglas counties (Mohlenbrock and Ladd 1978); the above is a new county record. Swink and Wilhelm (1994) report it from Cook and Will counties.

ELYMUS × EBINGERI G. Tucker (Poaceae)

Cumberland Co., Greenup, fall 1997, *Cris Thomas 88* (EIU).
 Douglas Co., Walnut Point State Park, Twin Points Picnic
 Area, 6 October 1996, *Tucker 11244* (EIU, ILLS).
 Vermilion Co., Horseshoe Bottom Nature Preserve, SE S36
 T21N R13W, edge of swamp, 9 December 1998, *Ebinger
 27702* (ILLS).

The hybrid of *Elymus hystrix* L. and *Elymus virginicus* L. was originally studied and characterized by Ebinger (1987), based on populations in Shelby and Coles counties. Recently, the formal name, *Elymus × ebingeri*, was provided (Tucker 1996).

POA BULBOSA L. (Poaceae)

Coles Co., Charleston, EIU Campus, S side of Doudna Bldg.
 on 7th St., 24 March 1997, *Tucker 11258* (EIU, GH);
 Charleston, 10th St. and Van Buren Ave., 20 April 1997,
Tucker 11260 (EIU, ILLS).
 Shelby Co., Wolf Creek State Park, S6 T12N R5E, 11 May
 1989, *Ebinger 24274* (EIU). Vermilion Co., 3 mi. N of
 Fairmount, Larimore Farm, 16 May 1997, *Richard Larimore
 s.n.* (EIU).

Bulbous bluegrass, a native of the Mediterranean region, was noted from Champaign and DuPage counties by Mohlenbrock and Ladd (1978); from Kane, DuPage, Cook, Will, and Grundy counties by Swink and Wilhelm (1994); and from Hardin County by Mohlenbrock (1985).

SCLEROCHLOA DURA (L.) Beauv. (Poaceae)

Coles Co., Mattoon, Patterson Park, 26 April 1997, *Tucker
 11260* (EIU, ILLS); Charleston, EIU Campus, near soccer
 field, common weed on fitness trail, 28 April 1997, *Tucker
 11262* (EIU).
 Douglas Co., Arthur, high school baseball field, 18 May 1997,
Tucker 11270 (EIU).

Hardgrass, a native of Europe, was not reported from Illinois by Mohlenbrock and Ladd (1978), although it was recently documented from the Chicago region by Swink and Wilhelm (1994).

EICHHORNIA CRASSIPES (Mart.) Solms (Pontederiaceae)

Hardin Co., Cave in Rock, in the Ohio River, aquatic,
 persisting here for 2 years, 1 October 1997, *Les Frankland
 s.n.* (EIU).

Water-hyacinth has not been previously recorded from Illinois. This tropical species is widely distributed and a notorious pest in the Gulf Coast states (Rosatti 1987), but it has not been previously reported farther north than Missouri and Kentucky (USDA, NRCS 1999). Yatskiyevich (1999) noted that the few populations in Missouri had not persisted for more than a few years.

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