THE PRESETTLEMENT VEGETATION OF THE PLAIN OF GLACIAL LAKE CHICAGO IN COOK COUNTY, ILLINOIS

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This paper uses Government Land Office surveys to reconstruct the vegetation of the lake plain of glacial Lake Chicago, Cook County, Illinois, at the time of settlement. This area comprises most of what is now Chicago and many of its suburbs. Similar presettlement vegetation studies have been done in Wisconsin by Cottam (1949), Curtis (1959), Tans (1976), and Ward (1956); in Michigan by Bourdo (1956), Dick (1937), Huschen et al. (1966), Kapp (1978), Kenoyer (1929, 1933, 1939, 1942), and Meyer (1950); in Indiana by Finley and Potzger (1952), Meyer (1950), Potzger and Keller (1952), Potzger, Potzger, and McCormick (1954), and Rohr and Potzger (1950); and in Illinois by Anderson (1970), Anderson and Anderson (1975), Kilburn (1959), Moran (1978), and Rodgers and Anderson (1979).

The purpose of the early surveys was to establish township boundaries, and mark the section and quarter-section corners within the townships. At corners where no trees were near enough to mark, a post and two quarts of charcoal were placed in a mound or large stones were used. The numbers of trees used to mark corners varied with each survey because each surveyor operated under a different set of instructions (Dodds, McKean, Stewart, and Tigges, 1943). For example, the surveys done in 1821 and 1834 used two witness trees at each section corner; the 1839 survey used four witness trees, when available, at these points. All surveys marked quarter section points with two trees.

DESCRIPTION OF THE LAKE PLAIN OF LAKE CHICAGO

Lake Chicago was formed after the Wisconsinan glacier retreated from the Chicago area about 14,000 years ago. The Tinley and Valparaiso Moraine Systems, parallel to but 19.3 or 20.9 km (12 or 13 miles) west of the present shoreline, dammed up the meltwater from the retreating glacier. The impounded water level was 18.2 m higher than the present level of Lake Michigan and is known as the Glenwood Stage of glacial Lake Chicago. This glacial lake approached the present level of Lake Michigan in two steps, the first being 12.1 m above present level (Calumet Stage), and the second 6 m above present level (Toleston Stage). When the level fell to 182-176 m, its present height above sea level, the lake plain was covered by glacial lakes known as Lakes Algonquin, Nipissing, and Algoma.

The bottom of glacial Lake Chicago, is a flat surface that is approximately 72 km long and 24 km wide. The area was flattened by the action of waves in the glacial lake and is underlain by glacial till with thin deposits of silt, clay, and sand locally present (Willman, 1971). The plain is almost entirely uneroded by modern streams and because of the very shallow slope, runoff of water is very slow.

At each of the stages of Lake Chicago, near shore features such as beaches and spits that are predominantly medium-grained sand, were created by wave action. When the plain became completely exposed, these features appeared as low, long sandy ridges usually not more than 3 m high. Well-sorted sand and gravel occur in the north end of the Des Plaines River valley and in parts of the glacial sluiceway that drained the lake plain to the southwest. These beach ridges and sand spits have been mapped by Alden (1902), Bretz (1939), and Willman (1971).

METHODS

Microfilm copies of the original surveyors' field notes (Clark, 1834; Morrison, 1840; Walls, 1821) were examined at Northeastern Illinois University. The diameter, corner to tree distance, and species of all trees mentioned in their notes were recorded. The location and bearing of various plant communities the surveyors encountered were noted, such as 35 links from corner, enter timber, leave marsh, bears north and south. At the end of each mile, summaries of that mile were written by the surveyors, for example, "soil good, land level, timber burr oak, red oak, and white oak." The mile summaries, in conjunction with witness trees, were used to determine the type of forest communities that prevailed at that time. Forests and other communities that occurred adjacent to the lake plain on morainal slopes are not included in this study.

Information from the survey records were used to calculate relative dominance, relative frequency, and relative density of the species of trees. Importance values were computed for all species of trees by adding these three values. The forest structure for two areas was contrasted by comparing the importance values for the trees on sandy ridges (T36N, R14E, R15E and T37N, R14E, R15E) to the trees on the lake plain proper (T40N, R12E, R13E and T41N, R 12E, R13E; see my Fig. 1), which were usually on the east side of rivers.

The plat maps of the original surveys were copied and used as base maps. These maps show the location of forest, prairie, marsh, and open water, but they do not differentiate between types of forest or prairie. Information in the field notes and the mile summaries were used to separate prairie from wet prairie in the construction of Figure 1. Relative dominance, relative density, relative frequency, and comments in the field notes were used to subdivide forest into the forest types depicted in Figure 1.

To determine the forest density, the distance of each tree from a corner post was used to calculate the number of trees/ha, using the point-quarter method (Cottam and Curtis, 1956). By using the number of trees/ha, it was possible to differentiate between savanna and forest. Curtis (1959) defined savanna as at least 0.5 trees/ha, but not more than 50 percent canopy cover which would correspond to 46.9 trees/ha (Anderson, 1975). Anderson (1975) also differentiated between open forest and closed forest, open forest having between 46.9 and 98.8 trees/ha. In this study, locations where trees averaged between 93 m (or 0.5 trees/ha) and 9.6 m (or 46.9 trees/ha) from the corner were considered to be savanna. Where distances averaged shorter than 9.6 m, the location was simply designated as forest with no distinction being made between open and closed forest.

The determination of the extent of prairie, wet prairie, and marsh was made exclusively from field notes. The location of these communities was marked on the base map when mentioned by the surveyor. Nowhere in the field notes did the surveyors refer to specific plants from any of these communities. Moran (1978) reported that surveyors in Lake County mentioned redroot (*Ceanothus americanus*), rosin (*Silphium* sp.), and indigo (*Baptisia* sp.), all prairie plants, but none were mentioned in our area of study which is located just south of Lake County.

The area in the center of Figure 1, between the two Indian Boundary Lines, was surveyed in 1821. The surveyors (Walls, 1821) recorded 221 trees as "W. oak" and 137 trees as "B. oak." The "W. oak" was interpreted as white oak, *Quercus alba*, but it is not certain whether "B. oak" meant burr oak, black oak, or both. In all of the townships surveyed, no oak trees were designated as black or burr. This surveyor was operating under instructions issued in 1815 by E. Tiffin, Surveyor General of the United States (reproduced in Dodds et al., 1943), where the abbreviation "B. oak" is used as an example of proper recording techniques. In calculating importance values for the entire plain, those trees designated "W. oak" were added to those designated white oak. Since it is not possible to decipher further "B. oak," these trees were presented under that name.

The section south of the southern Indiana Boundary Line was surveyed in 1834 where the most common tree reported was "yellow oak" which was noted as occurring almost exclusively on the sandy ridges that are common in this area (Clark, 1834). By inspection of remnant sandy ridges in this area, it was determined that yellow oak

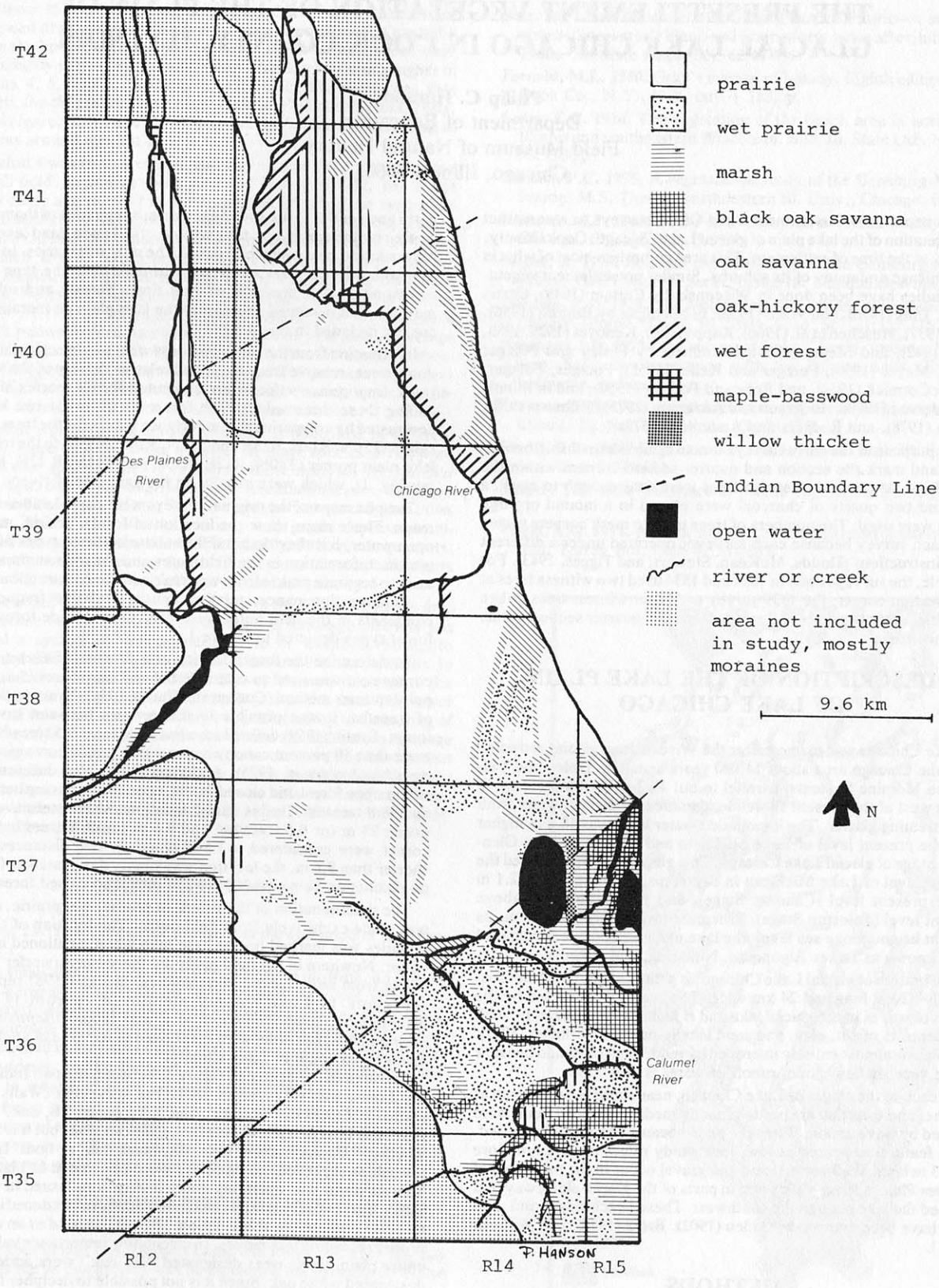

Figure 1. Presettlement vegetation of the lake plain of glacial Lake Chicago.

was black oak, *Quercus velutina*. Little (1953) listed yellow oak as a common name for *Q. muehlenbergii, Q. stellata v. mississipiensis,* and *Q. velutina*. *Quercus stellata* is not in Cook County (Swink, 1974) and *Q. muehlenbergii* is in more calcareous situations.

RESULTS AND DISCUSSION

Nine plant communities were distinguished: prairie, wet prairie, marsh, black oak savanna and oak savanna, oak—hickory forest, wet forest, sugar maple—basswood, willow thicket, and Lake Michigan beach. Prairie accounted for more than half of the total area, while black oak savanna was a forest type restricted mainly to the sandy beaches and spits deposited on the lake plain at the various levels of Lake Chicago. This community was almost the only forest type in the southern end of the lake plain known as the Calumet area. In the four townships comprising this area where most of the sandy ridges occur (T36N, R14E, R15E and T37N, R14E, R15E), the average tree to corner distance was 16.7 m which corresponds to an average density of 15.6 trees/ha.

Oak—hickory forests occurred mainly east of the Des Plaines River and the North Branch of the Chicago River. A similar forest occurrence was noted along the Des Plaines River in Lake County, Illinois, by Moran (1978). In the four townships sampled as representing forests on the silt and clay deposited on the bottom of the lake plain (T40N, R12E, R13E and T41N, R12E, R13E), the average post to tree distance was 8.4 m which corresponds to about 62.2 trees/ha.

The importance values for most species in these two samples are compared in Table 1, so that a comparison can be made between trees growing on predominantly sandy beach ridges in the southern portion of the plain with the trees growing on the silt and clay of the glacial lake bottom at the north end of the plain. Twenty-four species of trees were used as witness trees and the size-class distribution of these trees is in Table 2. Importance values for all trees encountered in the entire study area are given in Table 3.

When Figure 1 is superimposed on a map of the surficial geology of the lake plain, the strips of oak savanna on the section of the lake plain south of the mouth of the Chicago River nearly coincide with sandy

Table 1. Comparison of relative frequency, relative dominance, relative density, and importance values for tree species occurring in four townships (T36N, R14E, R15E and T37N, R14E, R15E) where trees occur predominantly on sand or gravel ridges (R) and four townships (T40N, R12E, R13E and T41N, R12E, R13E) where trees occur on silt and clay deposited on the plain of glacial Lake Chicago (P).

	Relative Frequency (%)		Relative Dominance (%)		Relative Dominance (%)		Importance Values	
	R	P	R	P	R	P	R	P
Bur oak	22.8	20.7	28.0	25.0	21.7	23.4	72.5	69.1
White oak	17.7	17.5	10.9	21.7	15.9	20.6	44.5	59.8
Red oak	4.7	7.4	5.6	16.9	4.1	10.9	14.4	35.2
Hickory	2.7	11.7	2.4	5.7	2.9	10.3	8.0	27.7
Elm	3.6	9.0	2.6	8.0	2.9	8.4	9.1	25.4
Ash	8.3	11.7	7.4	5.2	7.3	7.6	23.0	24.5
Black oak	28.5	5.3	35.1	4.7	33.4	3.5	97.0	13.5
Basswood	1.6	4.8	1.1	2.6	1.3	4.0	4.0	11.4
Silver maple		4.3		3.2		2.7		10.2
Aspen	1.0	2.1	0.5	2.9	0.6	2.7	2.1	7.7
Sugar maple		1.0		0.6		1.1		2.7
Walnut		1.0		0.3		0.3		1.6
Cottonwood		0.5		0.5		0.5		1.5

Table 2. Diameter class distribution of tree species encountered in all townships of the entire lake plain of glacial Lake Chicago in Cook County, Illinois. All measurements are in centimeters.

	0-10	11-15	16-20	21-25	26-30	31-35	36-41	42-46	47-51	52-56	57-61	62-66	67-71	72-76	77-81	82-86	87-91	92-96	97-101	>101	Totals
White oak		1	1	15	25	48	27	15	34	16	6	22	1		2			2	1	3	219
Bur oak		4	13	11	55	64	72	14	47	23	4	27	1		8			4		11	358
"B. oak"	1	6	4	21	23	23	24	4	11	7		6	1		2					2	135
Black oak				7	14	17	23	30	24	3	6	3	3	4						1	135
Ash		1		12	20	25	1	7	6	3		4	1							1	81
Red oak			1	2	6	17	13	2	19	2	4	9					1				76
Hickory	1	1	2	10	16	26	3	6	4	1										1	71
Elm		3	4	4	16	6	4	6	1	5		2	1		1					3	56
Basswood			1	1	6	10	2	1	1	1										1	24
Aspen			2	1	2	10	3		1	1		1			1						22
Willow	2	2	6	7	1		1														19
Cottonwood		1	2	3	3	2		1	1			1								3	17
Silver maple						4	4	1	6						1						16
Pine			2		2															1	5
Sugar maple					1	3															4
Black walnut			1		3																4
Birch					1			1													2
"Pin oak"				2																	2
Swamp white oak				1											1						2
Cedar					1																1
Cherry				1																	1
Hackberry								1													1
Ironwood				1																	1
"Thorn"				1																	1
Totals	4	19	39	100	195	255	177	89	155	62	20	75	8	4	16	0	1	6	1	27	1253

Table 3. Relative frequency, relative density, relative dominance, and importance values for tree species occurring in all townships on the lake plain of glacial Lake Chicago in Cook County, Illinois.

	Relative Frequency (%)	Relative Density (%)	Relative Dominance (%)	Importance Value
White oak	28.0	29.1	27.4	84.5
Bur oak	17.8	17.2	22.6	57.6
Black oak	9.9	10.5	12.7	33.1
"B. oak"	10.6	10.6	8.2	29.4
Red oak	5.2	5.9	9.4	20.5
Ash	6.9	6.4	5.0	18.3
Hickory	5.8	5.6	3.7	15.1
Elm	4.7	4.6	3.8	13.1
Aspen	2.2	1.7	1.6	5.5
Basswood	2.1	1.9	1.4	5.4
Cottonwood	1.2	1.5	1.4	4.1
Silver maple	1.2	1.2	1.3	3.7
Willow	1.5	1.4	0.4	3.3
Walnut	0.5	0.3	1.2	2.0
Birch	0.3	0.1	0.9	1.3
Pine	0.5	0.5	0.1	1.1
Sugar maple	0.3	0.3	0.2	0.8

beach ridges and spits. In the western portion of the plain are apparent extensions of oak savanna pointing northeast as well as other scattered groups; these areas are actually beach ridges and the groves are intermittent wooded areas along those ridges. The nine plant communities are described below.

Prairie

Although the most common community in presettlement times, occupying about 60 percent of the area, the prairie is also the community with the least descriptive survey field notes and plats. Many mile field-note summaries simply state "prairie rich level," or, less descriptive, "land similar to last mile" (Walls, 1821). Occasionally the notes mentioned "sandy soil." Once, in a prairie along the path of the Lake Chicago outlet to the southwest the phrase "stony prairie" was recorded. This prairie may have been a boulder field similar to those described by Bretz (1939). This community is assumed to include dry prairie which is usually dominated by little bluestem (*Andropogon scoparius*) and mesic prairie which is dominated by big bluestem (*A. gerardii*), Indian grass (*Sorghastrum nutans*), and panic grass (*Panicum virgatum*).

Wet Prairie

Again, no plant species are mentioned as being characteristic of this community. However, the surveyors clearly demonstrated an intuitive feeling for this community. Since their criteria for designating wet prairie are not explained, the definition must be inferred. In all cases where wet prairie is indicated in Figure 1, the area was described as such in the notes. Entries often read, "leave dry prairie, enter wet prairie" or "leave wet prairie enter marsh" (Clark, 1834; Morrison, 1840; Walls, 1821). These entries indicate that they had some criteria for separating these three communities. Possibly what they referred to as "wet prairie" would be classified today as sedge meadow or fen depending on soil and groundwater conditions. These communities are often very wet, but visually quite distinct from cattail and rush marshes. The areas where the wet prairies were located in the Chicago area have been so drastically disturbed by construction and changes in surface water springs and seeps that these communities may never be fully defined.

Marsh

As before, no plant species are recorded for the marshes. Little doubt, however, exists that the locations of marshes described in the surveys are accurate. One surveyor defined what he meant by "marsh" at the beginning of each of his books, "a low wet piece of land, utterly destitute of timber and generally covered with a growth of strong, coarse grass" (Morrison, 1840). This information is a useful and practical working definition, and appears to be the only instance where a surveyor presented a definition. On 22 May 1834 one surveyor gave a qualitative description of the marshes in the Calumet region: "Land all marsh, grass is so high that it is impossible for me to see my flag more than 3.00 chains when the flag is elevated 14 feet [4.2 m] above ground" (Clark, 1834).

A description appearing in Brown (1884:184) of the Kankakee marshes in northwestern Indiana, probably very similar to the marsh described above, gave an indication of the species encountered. "The balance of these wetlands running west to the state line, is open marsh, covered with a luxuriant growth of wild grasses, wild rice, and flags [*Typha* sp.?]."

The surveyor (Clark, 1834) was careful about recording the depth of water in these marshes. Water depths ranged from 0.1 to 1.06 m with most depths between 0.3 and 0.9 m. The deepest water encountered was east of Lake Calumet where most depths were over 0.6 m.

Black Oak Savanna and Oak Savanna

This community is almost entirely on the sandy beaches and ridges that cross the lake plain. Black oak and burr oak were the dominant species of trees; they accounted for more than 50 percent of trees in a sample. These trees predominated because of their ability to resist fire. Clark (1834) also noted that common understory plants were oak, hazel, and occasionally wortleberry (*Vaccinium* sp.). The surveyor's use of "B. oak" in the area between the two Indian Boundary Lines, makes it impossible to determine the burr oak to black oak ratio. The composition of these ridges was probably similar to the beach ridges south of the lower boundary line (Cowles, 1901). However, on Figure 1, these ridges are designated as "Oak Savanna."

Curtis (1959) stated that in the sand plains of central Wisconsin the oak savanna was dominated by Hill's oak (*Quercus ellipsoidalis*) with black oak (*Q. velutina*) also occurring. At the time of this survey, Hill's oak had not been defined as a separate species (Hill, 1899); consequently, the abundance of this species at the time of settlement is unknown. From observations of present remnants, it seems that black oak was the dominant tree. A few remnants of this community are in Calumet City, Illinois, at the Sand Ridge Nature Preserve where sandy ridges with black oak and dry prairie understory are separated by long, narrow marsh areas.

Oak—Hickory Forest

This type of forest was most extensively developed in the northern half of the lake plain, mainly to the east of the Des Plaines and Chicago Rivers. The main difference between this community and the black oak savanna was that black oak is relatively unimportant in these oak—hickory forests. Burr oak, white oak, red oak, hickory, elm, and ash represented more than 80 percent of the importance values in the oak—hickory forest. Surveyor's notes sometimes mentioned an undergrowth of vines and briars in these areas. One can only guess what plants, vines and briars actually were. In the black oak savanna, black oak, burr oak, white oak, and red oak comprised approximately the same percentage (Table 1).

In much of this forest type east of the Chicago River, the surveyor's summaries read, "level and wet" (Morrison, 1840). It is possible that swamp white oak was present here but not distinguished by the surveyor. When forests occurred adjacent to but west of the river, this area was open oak savanna. Trees mentioned west of the Chicago River in R41N, R13E are burr oak and black oak. Summaries of miles through these areas referred to "Scattering timber" (Morrison, 1840). Since these areas are small little quantitative data is available to describe them accurately.

Wet Forest

This type of forest is encountered along rivers and their floodplains, where there was periodic flooding or flooded backwaters. Silver maple, elm, basswood, and ash were the most frequently mentioned trees. The relative densities of basswood, ash, elm, silver maple, and

burr oak accounted for almost 70 percent of the trees with the remaining 30 percent shared by 11 other species. This community is quite common along the north branch of the Chicago River. The riparian forest along the Calumet River and its main tributary Thorn Creek was more complex. In most places the surveyor (Clark, 1834) mentioned that the timber adjacent to the river and creek on the uplands was "very scattering," "thinly timbered," or "very poor and scrubby." Most of the trees mentioned were black oak and burr oak with an understory of oak. In a few sheltered places more mesic oak—hickory forests developed. Occasionally along the flood plain white ash, elm, or swamp white oak were noted. Many times these trees were used as witness trees to mark the places where section lines intersected the Calumet River and Thorn Creek. Also at several places along these watercourses the surveyors noted that the floodplains, or bottoms as they were called, were "destitute" of timber. In the southeast corner of T36N, R14E an area of oak—hickory forest existed as indicated in Figure 1. Within this area was an unusual swamp flatwoods dominated by pin oak and black tupelo. The area is too small to be shown on Figure 1.

Sugar Maple—Basswood

The survey field notes give slight indication of the presence of this community. Two locations for sugar maple, one on the Des Plaines River and the other on the Chicago River, were noted for the area. In the surveyor's notes, silver maple was referred to as maple while sugar maple is called sugar tree.

Willow Swamp

This vegetational type was a very small community and was only mentioned at the south end of the plain in the Calumet marsh. The surveyor referred to it as "willow thicket" (Clark, 1834). It is difficult to know which willow or willows comprised this community.

Lake Michigan Beach

By examining the bearing trees used to locate the Lake Michigan beach, some insight can be gained about the trees that prevailed. The beach was composed entirely of sand with low dunes extending a short distance back from the beach. Forty-eight individual trees were used as bearing trees on Lake Michigan: black oak, 29 percent; white oak, 23 percent; cottonwood, 19 percent; pine, 10 percent; and aspen, 8 percent. Other trees recorded were cedar, red oak, burr oak, and willow. The vegetation was probably similar to that currently along the Lake Michigan Beach at Waukegan in the Illinois Beach State Park. Here, black oak savanna was on low sand dunes extending back from the beach. Pratt (1935:13) described the area north and south of the Chicago River as follows:

> . . . there were along where Michigan Avenue now is walled with palatial mansions innumerable sand hills rising to a considerable height, overrun by the wild juniper loaded with its fragrant berries at the feet of which stretched away to the southeast the soft smooth beach of firm glistening sand . . . along the beach north of the river where also the drifting sand has been piled by the shifting winds into a thousand hills stretching farther back from the waters than on the south, but here the juniper bush was replaced by a stunted growth of scraggy pines often hilled up by the drifting sand . . . Further back was a broad ramble among stately oaks sparsely scattered over the even plain among which a horseman could be seen at a great distance, and if one sought a deeper solitude it might be found still further west in the densely tangled mass of bushes among which one could not see a deer at a distance of twenty feet [6m].

CONCLUSIONS

1. The lake plain of glacial Lake Chicago consists of about 3370 ha. According to Government Land Office Survey field notes, about 60 percent of the miles walked were considered dry or mesic prairie; 30 percent, tree covered, either forest or savanna; 6 percent, wet prairie; and 4 percent, marsh.
2. Tree cover occurred mostly under two conditions. First, trees were usually on sandy and gravelly beach ridges or spits on the lake plain. These areas were dry and were dominated by black oak, burr oak, and white oak. Most of these locations had corner to tree distances greater than 9.6 m and were considered savanna. Secondly, forests developed on the east side of the Chicago and Des Plaines Rivers where they were sheltered from prairie fires blown by westerly winds. Surveyors' notes indicated the most common trees here were burr oak, white oak, hickory, ash, and elm. While investigating the lake plain forests in Evanston, Waterman (1920) mentioned that swamp white oak was very common in these forests. The surveyors, however, did not list swamp white oak for this area. At corners where bearing trees were used, 62 percent were classified as savanna, and 38 percent as forest.
3. Because the criteria used by the surveyors to separate prairie from wet prairie and wet prairie from marsh were not clearly defined, the boundaries for these areas are approximations. As a result of the mild slope of the lake plain and the lack of a developed drainage pattern, moderate rains could have flooded large areas. So, if the presence or absence of water was used as a criterion to separate these communities, the proportion of prairie, wet prairie, and marsh could have varied considerably with the amount of rain or the season of the year.

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PRAIRIE FENS IN NORTHEASTERN ILLINOIS: FLORISTIC COMPOSITION AND DISTURBANCE

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Prairie fens, as delimited in this study, are areas of firm sapric peat soils constantly saturated with cold, calcareous, artesian groundwater, and supporting a distinctive calciphilous herbaceous flora. Prairie fens are usually dominated by typical prairie grasses and/or sedges and contain a large prairie element in their flora. The term "prairie fen" is used here in a strict sense to distinguish fens within the Prairie Peninsula from a variety of wetland communities that are also termed "fens." Prairie fens, hereafter shortened to "fens," were probably once a common floristic community in northeastern Illinois during presettlement times, because the topography and hydrologic conditions favoring them occur frequently. In this paper, the flora of 12 fens in northeastern Illinois is analyzed. No previous work has been done on Illinois fens.

METHODS

Data were collected by the Illinois Natural Areas Inventory personnel during the months of July and August, 1976 and 1977, and from the author's studies during 1978. At each site the species were listed and the natural boundaries of the plant communities were mapped on aerial photographic overlays. Frequency values of the species in each fen were determined by recording species presence in a series of circular 0.25 m^2 plots randomly placed along an arbitrary transect through the undisturbed portions of the fen. The sampling results and locations for individual sites are obtainable from the Natural Areas Section, Illinois Department of Conservation, 605 State Office Building, Springfield, Illinois 62706. Nomenclature throughout this paper follows Mohlenbrock (1975).

Presence among the ten prairie grass dominated fens was calculated as the number of stands a species occurred in divided by the total number of stands, and expressed as a percentage. Frequency presence indices (FPI) were calculated as the percentage multiplied by the mean percentage frequency. This index has a maximum value of 10,000 where a species occurs in all stands with a sampling frequency of 100 percent and a minimum value approaching zero for rare plants (Curtis, 1959).

The prevalent species (Curtis, 1959) were determined by arranging the species in decreasing order according to their FPI, and listing the top group of species equal in number to the average species density among the ten stands included in the calculation. The index of homogeneity (Curtis, 1959) was calculated as the ratio of the sum of the percentage presence of the prevalent species to the total sum of the percentage presence of all species, and expressed as a percentage.

MINFO (acronym for "minimal information") was the computer program used for the cluster analysis shown in Fig. 2 (Goldstein and Grigal, 1972). MINFO clusters on a mutual information theory measure by linking pairs or groups with minimum increase in mutual information.

Dominance-diversity structure was analyzed by plotting relative frequency on the ordinate against species sequence from most to least important on the abscissa. Such curves are useful in comparing structural differences among communities or sample sets. To quantify these relationships, diversity indices including species richness, S; the number of species in the set; the Shannon index, H′, which is a dual concept diversity or heterogeneity index (Peet, 1974); and J′ which is an equitability index (Pielou, 1966) were calculated. H′ is an information theory measure and is given by Shannon and Weaver (1949), as:

$$H' = -\sum_{i=1}^{s} p_i \ln p_i$$

where S is the number of species and p_i is the decimal fraction of the Importance Value which in this case is relative frequency. J′ is a measure of the dominance-diversity curve evenness (Peet, 1974) and is calculated by:

$$J' = H'/\ln S$$

where H′is the value calculated above and S is the number of species. As the measure of importance becomes more evenly distributed among the species, J′ approaches 1.

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