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Impacts of Settlement on Floodplain Vegetation at the Confluence of the Illinois and Mississippi Rivers

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ABSTRACT

Government Land Office (GLO) survey records were used to reconstruct the presettlement floodplain landscape at the confluence of the Illinois and Mississippi rivers. Presettlement prairie and forest land covers were determined by digitizing GLO plat maps using a computerized geographic information system (GIS). A case history of land cover change was determined by comparing this presettlement map to GIS land cover maps for 1903, 1935, and 1975. Data from witness trees and current forest samples were used to compare presettlement and present forest composition and structure. Results indicate that approximately 56% of the presettlement floodplain was forested, while 41% was prairie. The presettlement forests were generally open (86.8 stems/ha) and consisted of several dominant tree species. In contrast, the present forest is more dense (489 stems/ha) and is dominated by silver maple (*Acer saccharinum*). Early settlement had little affect on the spatial distribution of forest cover, but river impoundment in 1938 reduced forests to approximately 35% of the floodplain. Prairies were converted to agriculture during the middle 1800s and now occupy only 6% of the floodplain. Overall, the floodplain landscape and vegetation patterns present today are very different from their presettlement conditions. The major activities responsible for these changes were timber harvesting, agriculture, and river impoundment.

INTRODUCTION

The Illinois and Upper Mississippi River valleys have been so extensively modified that it is difficult to imagine natural landscapes as they appeared before Euro-American settlement. Examples of human alterations to the Upper Mississippi River (UMR) valley include deforestation, agricultural land development, draining of wetlands, levee construction, urban expansion, and river impoundments (U.S. Army Corps of Engineers [COE], 1980; Fremling et al., 1989; Bhowmik, 1993). Despite these impacts, the UMR retains a high degree of biological integrity because it provides a diversity of habitats that are essential to a variety of plants and animals (Upper Mississippi River Basin Commission, 1982; COE, 1991; National Research Council, 1992; Sparks, 1992). However, natural floodplain landscapes were so quickly modified following settlement that baseline data regarding pristine conditions are lacking. Therefore, information concerning natural conditions, as well as the impacts that have led to present conditions, should be valuable to those involved in the management, preservation, and restoration of the UMR.

The Mississippi and Illinois River floodplains in west-central Illinois consisted of prairie and forest communities before Euro-American settlement (Finiels, 1797; Allen, 1870). Early settlers were attracted to this western frontier by the high fertility of the land, its vast resources, and the transportation network provided by the Mississippi River and its tributaries. As a result, most of the natural floodplain prairies were converted to agricultural fields. In contrast, many floodplain forests remain because they were more flood prone and thus less suitable for agriculture. Nonetheless, these forests were often intensively logged for lumber and for fueling steamboats (Havighurst, 1964; Donovan, 1966; Ward, 1973; Williams, 1980).

While floodplain landscapes of the UMR valley were being altered by early settlement, the mainstem rivers were also being modified to improve navigation. In the mid-1800s, river projects were limited to dredging and snag removal. Later, demands for a more reliable commercial navigation system prompted large-scale river control projects (O'Brien et al., 1992). The most notable project was the construction of our present-day navigation system. During the 1930s, a series of 27 locks and dams were built between St. Louis, Missouri and St. Paul-Minneapolis, Minnesota (except for the Keokuk, Iowa, dam built in 1913). Another series of 8 locks and dams were built along the Illinois River to Chicago, Illinois. The dams impound water to maintain a minimum 2.7 m (9 foot) deep navigation channel.

An immediate result of each impoundment was the permanent inundation of low-lying floodplain habitats bordering the river, especially those areas just upstream from each dam. Inundation replaced some floodplain forests and prairies with aquatic habitats (Yeager, 1949; COE, 1980).

Another important consequence of the navigation system was its alteration of the rivers' natural water level fluctuations. Hydrology is considered one of the dominant environment factors influencing tree species distributions and productivity in bottomland forests (Briscoe, 1961; Bedinger, 1978; Brown and Peterson, 1983). Navigation dams reduce mean annual river water level fluctuations (Grubaugh and Anderson, 1988), thus altering the conditions to which most floodplain tree species are adapted. While permanent inundation kills most trees species (Yeager, 1949), the long-term effects of impoundments and reduced annual flooding on the remaining forests are unclear. Recently, biologists working along the UMR have observed poor natural regeneration of native hardwoods such as pecan, hickories, oaks, and other important mast producing trees (Schnick et al., 1982).

Forest ecologists have long recognized the important information contained in GLO survey records for many regions of the United States (e.g., Cottam and Curtis, 1956; Anderson, 1970; Anderson and Anderson, 1975; Delcourt, 1976; Rogers and Anderson, 1979; Leitner and Jackson, 1981; Barnes, 1989; Iverson et al., 1989; Thomas and Anderson 1990; and others). The records have proven to be one of the best sources of information regarding natural presettlement vegetation patterns for two primary reasons. First, most GLO surveys were conducted before Euro-American settlement had significantly altered the landscape. Second, the survey methods employed by the GLO represents a systematic form of sampling that provides quantifiable data.

In this study, GLO survey records were used to reconstruct the presettlement floodplain vegetation patterns at the confluence of the Illinois and Mississippi rivers. Forest data and GIS maps are used to present a 170 year case history of landscape and vegetation changes within the study area. Our intention is to provide a better understanding of the presettlement floodplain conditions within the UMR, as well as the effects of human activities upon the natural floodplain landscape.

STUDY AREA

The study area is located on the floodplain at the confluence of the Illinois and Mississippi rivers at the southern tip of Calhoun County, Illinois. The area is 3388 ha (8371 acres) and includes areas known locally as Calhoun Point and Swan Lake (Fig. 1). Its location is mid-reach between Mississippi River Locks and Dams 25 and 26. Here, river water level fluctuations are minimized because dam operating procedures maintain target water levels at a river gage at Grafton (Fig. 1).

Topography is nearly level, with scattered ridges and flats ranging in elevation between 127.7 m (419 ft) and 131.0 m (430 ft) above mean sea level. The predominant soil type on the lowest elevations is Beaucoup silty clay loam, characterized as poorly drained silty soil formed in alluvium. At slightly higher elevations, soils are either Tice silt loam or Wakeland silt loam, characterized as somewhat poorly drained soils. Although much less extensive, the Sharpy sand series, characterized as rapidly drained sandy soils, occur on some shorelines, sandbars, and natural levees (U.S. Department of Agriculture, 1989).

Calhoun Point is subject to occasional flooding by both the Illinois and Mississippi rivers. The area consists of several backwater lakes, sloughs, and ephemeral ponds with much of the land cover in bottomland hardwoods. Swan Lake is subject to occasional flooding by the Illinois River. Although 1060 ha (2619 acres) of the historical floodplain has been permanently inundated (since closure of Lock and Dam 26 in 1938), 527 ha (1302 acres) of the surrounding floodplain remains in bottomland hardwoods.

METHODS

GLO Survey Records and Current Forest Sampling

The township lines of Calhoun County were surveyed in 1815 and the interior section lines were completed in 1817. A post was set and two witness trees were blazed at section corners, quarter section corners, and on river banks in timbered lands. Species names, distances, diameters and bearings were recorded in field notes. If trees were not present or near a corner, the surveyors erected a mound and noted "prairie" in their field notes. In addition to witness trees, trees encountered on section lines were similarly recorded in the field notes. At the end of each section line, the deputy surveyor recorded a brief description of the vegetation, terrain, any unusual features, and agricultural suitability. Presettlement forest composition and structure were determined by compiling witness tree data from these GLO survey records, which resulted in a sample of 97 trees.

Instructions given to GLO surveyors was that the first witness tree be nearest the post, and the second be the next nearest tree in an opposite direction (Tiffin, 1815). However, in the case of our study area, there was no consistent pattern in the location of the second witness tree after the first witness tree was recorded. This was probably due to the many river banks sites at which the second tree could not occur in an opposite direction because of the presence of the Illinois or Mississippi rivers. We therefore used the shortest witness tree distance as the Q_1 distance of the quarter point method for computing the square root of the mean area (Cottam and Curtis, 1956).

Using the Q_1 distance to estimate tree density at each surveyed corner, forest, savannah, and prairie communities were determined by criteria established by Anderson and Anderson (1975). Corners with more than 46.9 trees/ha were considered forest. Corners with 46.9 trees/ha or less, but more than 0.5 trees/ha were considered savannah. Corners with 0.5 trees/ha or less, or where surveyors erected a mound, were considered prairie. The percent frequency of corners established in each vegetation type was then calculated.

Since the study area lies between two major rivers, there were many points surveyed along the river banks. These points were not considered in computing the overall percent frequencies of vegetation types because more timbered land naturally occurred along the river banks. Including these points would skew results because they were surveyed as a function of river locality rather than a distance measurement. Rather, we evaluated the river bank corners separate from the corners surveyed within the interior of the study area.

Additional GLO surveys were conducted in 1826 and 1842 to measure the meanders of the Illinois and Mississippi rivers, respectively. The witness tree data in these survey records were not suitable for analysis because they did not cover the entire study area. However, the deputy surveyor's line descriptions helped determine historic human impacts on the floodplain environment in the decades immediately following the original surveys of 1815 and 1817.

A current forest survey of the study area was conducted during the spring of 1992 using the quarter point method (Wenger 1984), which closely approximates the GLO survey methods. Tree measurements were obtained from samples sites at 156 random locations throughout the forested floodplain, resulting in a sample of 628 trees.

Mean diameter breast height (dbh), relative density, relative dominance, and importance value were calculated for each taxa to compare presettlement and present forest composition.

Mapping
A geographic information system (GIS) map of the presettlement floodplain was prepared from GLO survey data and plat maps. Because the GLO surveyors recorded distances on each section line when vegetation patterns changed (e.g., forest to prairie), we were able to locate these points on modern U.S. Geological Survey quadrangle maps. Plat maps were then used to determine the boundaries (connections between points) of three land cover types mapped at the time of the original surveys; forest, prairie, and water. These land cover types were digitized after registering the map to a digitizing tablet using universal transverse mercater (UTM) coordinates at the intersection of several section corners. Enough known UTM coordinates were used to insure that standard deviations were within acceptable limits of the GIS application.

The GLO survey plat maps of the study area contained sufficient detail to map the land covers described above except the outline of presettlement Swan Lake. In their notes however, surveyors did describe the presence of a lake and mapped a portion of its southern boundary. In order to complete our presettlement map, we incorporated a 1935 outline of Swan Lake as the presettlement condition. We believe this to be the best representation of the presettlement floodplain despite this small discrepancy.

Spatial changes in land cover over time were determined by comparing the presettlement map to GIS land cover maps for 1903 (Woermann, 1903), 1935, and 1975 (U.S. Fish and Wildlife Service, 1991). Land covers are presented as percent of total area.

Hydrology
Historic river water level data, obtained from the Grafton gage (Fig. 1), were used to evaluate hydrologic changes at the study site resulting from the completion of Lock and Dam 26 in 1938. The U.S. Army Corps of Engineers has maintained a daily record of water levels at this gage station since 1879. Predam and postdam mean annual hydrographs were made by averaging water levels by day of year.

RESULTS AND DISCUSSION

Presettlement Vegetation (1817)
Our presettlement GIS map shows that forests covered approximately 56% of the floodplain (Fig. 2A). This result compares closely with 56.2% of corners established in both forest and savannah categories. The GLO surveyors clearly did not distinguish between forest and savannah communities when constructing their plat maps in this area.

Nineteen tree taxa were recorded by the GLO surveyors (Table 1). The taxa with the highest importance values (IV > 20) were hackberry (*Celtis occidentalis*), pecan (*Carya illinoensis*), elm (*Ulmus* spp.), willow (*salix* spp.), and cottonwood (*Populus deltoides*).

Average tree density was estimated to be 86.8 trees per hectare. This low density is one indication that the presettlement forest was a somewhat open landscape with widely spaced trees. Another indication is that 66.6% of corners surveyed with witness trees were determined to be in savannah. GLO surveyors recorded savannah conditions as "scattering timber" and "thinnly timbered" in their line descriptions. Savannah communities were most often encountered in transitions zones between prairie and forest communities. For example, a typical line description reports: "Leave scattering timber and enter prairie." However, these conditions were not limited to the floodplain interior. Of the corners established along the river banks, 47.8% were determined to be in savannah.

More recent evidence of the open nature of the presettlement forest was also alluded to by Yeager (1949) in 1937. In his predam study of Calhoun Point, he noted the presence of some old growth stands that contained over mature and large multi-branched maples, elms, oaks, and sycamores. These trees were probably remnants of the presettlement forest because their old age and branching habit are indicative of former open forest conditions.

Prairie communities covered approximately 41% of the presettlement floodplain (Fig. 2A) and this estimate compares closely with the percent frequency of corners established in prairie (37.8%). Although GLO surveyors did not identify any of the plant species they observed, they did apply the terms "wet" and "dry" to the various line descriptions of the floodplain prairies. One surveyor noted, for example: "Land level and rather wet-bottom prairie too wet for cultivation....Land gently rolling, good dry prairie fit for cultivation." Today, similar soil moisture modifiers are still used to delineate prairie communities (i.e., wet prairie, dry sand prairie, wet meadow, etc.). Based on the inferred moisture gradient, topography, and soils, at least three distinct prairie communities existed within the presettlement floodplain: wet, wet-mesic, and mesic prairies. Studies of relic floodplain prairies are good sources of information about the composition and species associations of natural prairie communities (see Zawacki and Hausfater, 1969; Nelson, 1987). The following description by Turner (1934) of a relic prairie along the lower Illinois River is important to note because it agrees closely with the GLO prairie descriptions: "This forest type merges into a grass association, at first on the hydric side of mesophytism, but giving way in turn, as the elevation of the floodplain increases, to a mesic grass association."

The maintenance of natural floodplain prairie communities in the Midwest has been attributed to disturbances by fire, flooding, sedimentation, and erosion (Nelson, 1987). Fire has long been considered a principal component of mid-western prairie ecosystems (Englemann, 1863; Allen, 1870; Anderson, 1970), and most fires are considered to have been intentionally set by Native Americans (Gleason, 1913; Ladd 1991). The open nature of the presettlement forest (86.8 trees/ha) might indicate that fire was also an important component of UMR floodplain ecosystems.

Impacts during Early Settlement (1817-1903)

The field notes of the original GLO surveys (1815-1817) contained no references to settlers within the study, but later surveys contained some information about settlement and timber harvesting. During the river meander survey of 1826, the deputy surveyor noted on the Mississippi River bank: "Timber mostly all cut down near the river bank by the settlers living here, but find a black oak stump said to be former lone bearing tree by the present settlers." At another nearby corner he noted: "re-establish (corner) in its former position from the remains of the former witness trees. The bur oak is fallen by decay and the black oak cut down." These comments indicate that settlement began soon after the original land surveys and that settlers were actively harvesting timber.

After 1830, steamboat traffic on the UMR system increased steadily, and the demand for fuelwood became enormous. Because abundant timber lined the river banks, steamboat commerce was not limited by any lack of fuel (Havighurst, 1964). Woodyards became a booming bussiness and many river bank farmers supplemented their incomes by harvesting and selling cordwood from bottomland forests (Havighurst, 1964; Donovan, 1966; Ward, 1973).

While measuring the meanders of the Illinois River in 1842, GLO surveyors noted "cut-off timber" in 50% of the line descriptions that ended at the river bank. For example, a typical record reports: "Timber pecan, maple, ash, elm, willows has been mostly cut-off." It is reasonable to assume that these cuttings were the result of steamboat fuelwood harvesting because they bordered the river bank and because no mention was made of nearby settlers or agricultural fields. Supporting evidence is provided by Williams (1980), who used the census of 1840 to map products from the eastern U.S. forests. He found that sales of cordwood were concentrated along major waterways due to demands from settlers and the hundreds of steamboats plying the rivers. Calhoun County ranked nationally among the highest in cordwood sales in 1840 (Williams, 1980).

Between 1817 and 1903, agriculture was the major impact that changed the presettlement floodplain landscape (Fig. 2A and 2B). During this time period, all of the higher elevation mesic prairie communities were converted to agriculture. The floodplain forests were exploited during this same time period but did not change much in their spatial distribution. Harvested areas were presumably quickly revegetated. Settlers were probably reluctant to clear forests for agriculture because these lands were more susceptible to flooding than the higher elevation mesic prairies. Surveyors in 1817 applied the term "overflows" to 76% of the line descriptions of the presettlement forest.

Impacts due to Impoundment (1935-1975)

GIS maps from 1935 and 1975 (Fig. 2C and 2D) show another period of dramatic land cover change, but the year of significance is 1938. During June of that year, the gates of Lock and Dam 26, located 32 km (20 miles) downstream, were closed for the first time. An immediate impact to the study area was a 2.6 m rise in water surface elevation (Fig. 3). This rise permanently inundated the lowest lying floodplain habitats and caused extensive timber mortality (Yeager, 1949). Consequently, forest cover was reduced from a predam distribution of 59% to a postdam distribution of 35%, while prairies were reduced from 8% to 6%.

Yeager (1949) studied impoundment effects on standing timber in the Calhoun Point area and found that nearly all trees subject to permanent inundation died within six years. At slightly higher elevations, where the effects of a perched water table were still evident, timber mortality ranged between 50 and 100% for all species except ash, river birch (*Betula nigra*), and cottonwood. Yeager (1949) also reported the rapid colonization of exposed mud flats by silver maple reproduction at four stems/ft^2. The ability of silver maple to exploit the new site conditions created following impoundment, along with its fast growth and intermediate shade tolerance, may explain its dominance in the present forest.

While river impoundment eliminated portions of forest and prairie within the study area, other hydrologic changes are important when considering the status of the remaining floodplain vegetation. Prior to impoundment, annual river water level fluctuations were much more dynamic than after impoundment. The predam mean annual hydrograph exhibits a pronounced spring and autumn rise in water levels, with periods of very low flow occurring in summer and winter (Fig. 3). Presently, the degree of annual flooding and drying has been reduced due to dam operating procedures that maintain high target water levels (Fig. 3). This hydrologic change has eliminated the period of very low flow during the growing season to which many floodplain tree species are adapted. Consequently, soil moisture content throughout the year may be higher in some areas and could be a limiting factor in the growth and establishment of some species.

Present Vegetation (1992)

Eighteen taxa were recorded in 1992 from a sample of 628 trees (Table 1). The importance value of silver maple (86.3) is over four times higher than that of the next most important species, hackberry (19.7). Average forest density was estimated at 489 trees per hectare. Changes in species importance values and forest densities between the presettlement and present suggest a forest in recovery following one or more major disturbances.

Forest sampling conducted in 1990 at pools 8 and 13 of the Mississippi River and the LaGrange Pool of the Illinois River also show silver maple to be the most abundant floodplain species (Langrehr, 1990; Shay and Gent, 1990; Peitzmeier-Ramano et al., 1990). This dominance of silver maple in the present floodplain forests of the UMR system may be one of the most important indicators of forest change due to human activities. For example, the shallow rooting habit, intermediate shade tolerance, and prolific seed production of silver maple (Burns and Honkala, 1990) should favor its growth and establishment on sites that were affected by river impoundments. Saturated soil conditions caused by perched water tables, though not as harmful as inundation, can adversely affect the growth of many species. However, silver maple seedlings are very tolerant of saturated soils, and height growth is even enhanced (Hosner and Boyce, 1962). The increased importance, high relative density, frequency, and dominance of silver maple (Table 1) imply that this species will continue to be the most abundant species occupying the floodplain for some time.

Many species, such as hackberry, pecan, elm, willow, cottonwood and others (Table 1), have decreased in importance values since the presettlement. This indicates that reproduction and/or establishment of these species is poor. This is probably due to the lack of suitable site conditions, due to impoundment effects, as well as to a lack of an abundant seed source, due to past logging activities. Therefore, these species should continue to decline as a component of this floodplain forest.

Prairie communities currently occupy only 6% of the floodplain (Fig. 2D). Wet prairie communities that survived the agricultural boom in the mid-1800s were less affected than the forests by river impoundment in 1938. Although inundation destroyed some prairies, it created new prairie wetlands in other areas (Fig. 2C and 2D). Presently, high sedimentation in backwaters created by impoundment are reducing water depths at a tremendous rate (approx. 1.3 cm/yr)(Cahill and Steel, 1986; Grubaugh and Anderson, 1989; Roseboom et al., 1992; Bhowmik and Demissie, 1993). New sediments can promote the growth and establishment of early successional emergent species such as river bulrush (*Scirpus fluviatilis*) (Sampson, 1921; COE, 1980).

CONCLUSIONS

The evidence presented in this paper should not be interpreted to mean that if left alone, the floodplain landscape today would resemble its presettlement state. There are many natural disturbances, such as flooding, sedimentation, erosion, etc., that can bring about drastic changes in floodplain environments. The conversion of prairies to agriculture and the permanent inundation of floodplain habitats are obviously the result of human activities. Although less obvious, it seems reasonable to infer that the trend away from a more diverse forest toward a forest dominated by silver maple is also directly related to human influences. It should further be noted that results presented here may not agree with conditions found in some other areas of the UMR system. This is because the effects of settlement on floodplain ecosystems vary, especially when considering the effects of river impoundments. For example, the degree of forest disturbance due to impoundment is probably greatest just upstream of each impounding dam, where river water levels are most severely raised. Impoundment effects decrease upstream of each dam, and the degree of forest disturbance accordingly decreases upstream of each dam. Because the floodplain area under consideration here is located at mid-reach (Fig. 1), the effects of impoundment on the floodplain forests may be moderate.

Presently, there is much attention on enhancing or restoring the ecological integrity of the UMR system. Habitat rehabilitation and enhancement projects now being conducted by the U.S. Army Corps of Engineers are aimed at combating habitat degradation caused by alterations within the river and its drainage basin. These projects may represent the next generation of river-floodplain modifications. GLO survey records should be used in the planning and implementation of some of these projects because they provide worthwhile data about the natural conditions of the UMR system. Furthermore, GLO survey records can help focus attention on preserving habitats least affected by settlement and on restoring those habitats most severely affected by settlement. In the case of our study area, the mesic prairie and savannah communities have been eliminated and the forests are lacking diversity. If the presence of natural conditions of floodplains and their inherent biodiversity are considered worthwhile, then steps should be taken to reintroduce or promote the establishment of the natural plant communities that existed prior to settlement.

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Fig 1. Map of study area at the confluence of the Illinois and Mississippi rivers and its location within Navigation Pool 26.

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Table 1. Presettlement and present floodplain forest composition at the confluence of the Illinois and Mississippi rivers. Mean diameter breast height (dbh), relative density, relative dominance, and importance value (Rel. Dens. + Rel. Dom.) and importance value of all stems 10.0 cm or greater dbh in 1817 and 1992. Species ranked by imporatnce value in 1817.

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Fig 2. Geographic information system maps showing the percent distribution of several land cover types in 1817, 1903, 1935, and 1975.

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Fig 3. Mean annual hydrographs from predam (n=23 yr) and postdam (n=50 yr) periods at the Grafton, Illinois, gage. Solid horizontal lines indicate overall means; dashed lines directly above and below each indicate ± 1 SD.

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