Buffalo National River

Final Project Report
Project No. CA7150-4-0001, SA #2

Inventory and Characterization of the Riparian Zone (Wetlands) at Buffalo National River

prepared by

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EXECUTIVE SUMMARY

The economic, ecological and recreational significance of the 220 km (132 mi) riparian corridor within the Buffalo National River (BNR) is of great interest to managers of this diverse resource. Recent interest in applying ecosystem management to forest systems has necessitated a fresh look at the tools and methods in use to assess existing patterns of plant community structure and diversity. The purpose and objective of the study described in this report was to initiate a series of vegetation studies that could be integrated with existing research and management information on the riparian vegetation in the BNR. Defining the compositional and spatial attributes of the riparian corridor were at the core of our research efforts. We used multivariate analysis and ordination techniques to characterize the composition and distribution of woody and herbaceous vegetation within the BNR.

- Between June 1994 and August 1995, we established transects at 36 sites along the Buffalo River. Study sites were chosen from among locations accessible by secondary roads or foot trails that were separated by approximately 5 km (3 mi). Transects ran perpendicular from the river channel uphill to a point where the forest was dominated by oak (*Quercus* spp.) and hickory (*Carya* spp.). Each transect site was categorized by landscape position. The vegetation sampling included 19 sites located in secondary forests and 16 located in campgrounds or fields.
- Geomorphic features were associated with some well-defined plant species assemblages. Identifying species associations on recognizable landscape features will facilitate restoration of disturbed or managed sites.
- There was limited evidence for discrete assemblages of woody and/or herbaceous species, with the exception of streamside vegetation. Mixing of woody and herbaceous species was observed across a broad transition zone or ecocline. The extreme variability in species turnover exhibited and the clustering observed in the agglomerative cluster analysis, suggests very heterogeneous substrate conditions along the ecocline.
- Woody and herbaceous vegetation was correlated with several important environmental gradients, including height above river and soil pH. Responses differed among the vegetation layer analyzed (overstory trees, woody shrubs, herbs). CCA biplots of overstory trees indicated that vegetation patterns were strongly correlated with pH and height above river, and secondarily by slope and soil organic matter content. CCA biplots of shrubs and herbs showed that CCA secondary axes were dominated by terms related to soil texture.
- Potential management of these forests may have to be approached from a broader landscape perspective rather than the more traditional approach of identifying and managing specific forest communities.

Given the spatial complexity of woody and herbaceous species distribution and composition within the BNR, the delineation of distinct vegetation boundaries (e.g., riparian versus mesic) remains problematic. The lack of any consistent delineation between plant assemblages limits the value of designating specific management zones based on any single landscape attribute (e.g., topography, soil type). Managing larger landscape units based on comprehensive vegetation analyses (e.g., functional types) rather than management zones based on limited vegetation analyses, may be a more effective management strategy in this spatially complex landscape. Stratifying sampling by vegetation layer in vegetation analyses can allay ecosystem management concerns by providing managers with a synoptic view of vegetation structure and

composition. Furthermore, because not all vegetation is responding in a homogeneous manner to underlying gradients, specific habitat conditions can be altered to favor specific species and also to maintain diversity across a changing mosaic. Functional type results can thus be integrated into management, protection, and restoration strategies. A landscape management approach based on integrated vegetation analyses is also more likely to buffer the impacts of successional processes (temporal complexity) that is altering, and will continue to alter, the composition of existing assemblages and the abundance and distribution of species.

THE STUDY AREA

The Buffalo National River (BNR) was authorized by an Act of Congress (Public Law 92-237) in 1972, insuring that the Buffalo would remain a free-flowing stream and creating a linear National Park along the lower 220 km (132 mi) of the river. The Park occupies some 38,600 ha along a narrow corridor that includes portions of Newton, Searcy and Marion Counties in Arkansas, USA. The BNR originates in the Boston Mountains Region of the Ozark Upland and flows eastward along a winding course to its confluence with the White River (Rafferty 1980).

The BNR flows through the Ozark Plateau, a region of considerable relief. Steep stream slopes characterize the upper reaches of the Buffalo River and narrow, elongate flood plains border the river on the inside of the bends throughout its course. The Buffalo flows through the three subdivisions of the Ozark Province: the Salem Plateau, the Springfield Plateau and the Boston Mountains. Approximately half (46.7%) of the Buffalo River watershed occurs in the Springfield Plateau, about one-third (34.2%) of the watershed occurs in the Boston Mountains, and the remainder (19.2%) occurs in the Salem Plateau (Scott and Hofer 1995). The drainage basin of the Buffalo River is underlain by Paleozoic strata ranging from Early Ordovician to Early Pennsylvanian in age. The Boston Mountains are erosional remnants of a plateau that has been dissected into rough terrain characterized by steep-sided valleys separated by high flats and ridges (Johnson and Schnell 1985). Some Pennsylvanian-age sandstone and shale outliers of the Boston Mountains occur near the upper reaches of the river westward. Exposed rocks in areas of the Springfield Plateau are primarily limestone and chert of Lower Mississippian-age, while on the lower stretches of the river and eastward into the Salem Plateau the surface rocks are mainly limestone and dolomite with some sandstone and shale largely Ordovician in age (Arkansas Department of Planning 1973). The Ozark Plateau has been a continuous land form since the end of the Paleozoic (Steyermark 1959, Vineyard 1969) and because the region has never been glaciated, it has been open for plant migration since the Tertiary. However, there have been extensive changes in vegetation cover over that period, especially in the past 12-14,000 years (Braun 1950).

The Buffalo River drains approximately 3,730 km^2, of which about 70% is forested (Scott and Hofer 1995), but only 11% of the watershed (386 km^2) is protected within the boundaries of the BNR. The Buffalo experiences periodic flooding, most frequently from January through May, as a result of intense local storms. The river has been characterized as a flashy system with river level in the upper reaches occasionally rising 8 m during a 24 h period. Much of the riparian landscape of the BNR has been highly disturbed following European settlement around the 1820's. The forests of the BNR experienced indiscriminate, and widespread clear cutting from 1890 to 1920, and the bottomland has been under cultivation since the first settlers arrived in 1822 (Johnson and Schnell 1985). Anthropogenic disturbances have altered vegetation cover, forest density, and fire regimes. Conversion of forest to pasture has continued over the last 27 years at a steady pace of approximately 0.5% per year (3,600 acres of the BNR watershed per year). The existing secondary forests have been broadly classified as oak-pine and oak-hickory (Braun 1950, Eyre 1980), but specific assemblages range from wet bottomland to mesic mid-slope to more xeric upland (Dale and Kuroda 1978).

STUDY OBJECTIVES

The present study was undertaken from the summer of 1994 into the fall of 1995. Field vegetation and site data were collected over this two-year period. During 1995-96, the data were summarized and analyzed at the University of Arkansas, Fayetteville. The goals of the study outlined by the National Park Service were divided into seven major objectives. This report does not provide complete analyses of all the study objectives. In some instances, only preliminary data were available. Nonetheless, the data collected and the results analyzed to date, provide a foundation for future research and investigations, and represent a starting point for future vegetation analysis, monitoring, and management.

The specific objectives of this study are presented below:

(1) To develop and utilize a standardized sampling strategy to collect descriptive data about the composition and structure of plant communities on a representative sample of the Park's riparian corridor.
(2) To used the inventory data to determine the most applicable and available native riparian species to be reestablished in previously cleared areas needing restoration.
(3) To assemble and integrate physical and ecological data that contribute to an understanding and characterization of riparian community structure, distribution and dynamics.
(4) To assess type, location, and intensity of disturbances, both natural and man-related, on site.
(5) To determine the presence of any rare or endangered plant species or communities.
(6) To determine the presence of exotic species, the extent of invasion and assess the potential effects on natural communities.
(7) Analyze information collected to develop plans for additional research, monitoring, restoration and management.

OVERVIEW

Riparian plant communities perform an array of important ecosystem functions including streambank stabilization (Osborne and Kovacic 1993), thermal regulation of streams (Gray and Eddington 1969), filtering and retention of nutrients (Vought et al. 1994), and maintenance of ecosystem stability (Wiens et al. 1985). Many riparian forests also support diverse flora (Gregory et al. 1991, Bratten et al. 1994) and provide important animal and wildlife habitat (Sparks 1995) and corridors for movement of animals (Simberloff and Cox 1987). However most riparian forests of North America have been substantially altered since European settlement in the 1800's potentially compromising essential ecosystem processes. Based on these attributes, there has been growing interest in characterizing the composition and spatial boundaries of riparian forests, as well as ascertaining the linkages between riparian vegetation assemblages and underlying environmental gradients (Hupp 1992, Bendix 1994, Nilsson et al 1994.) These approaches have provided effective information for the development of effective management strategies and restoration efforts in riparian forests (Bendix 1994, Nilsson et al. 1994).

Variation in bottomland vegetation patterns has previously been attributed to water and soil patterns generated by the fluvial environment, although the relation between bottomland plants and specific fluvial landforms and processes is largely unknown (Hupp and Osterkamp 1985). Flood frequency, flow duration and period of inundation are independent hydrologic factors that may be measured along stream reaches and have been related to vegetation patterns (Hack and Goodlett 1960, Sigafoos 1961, Bedinger 1972, Bell 1974, Johnson et al. 1976). This portion of the study is an analysis of the main channel of the BNR with the goal of documenting regular patterns in bottomland vegetation and determining whether these patterns can be correlated with hydrologically defined geomorphic surfaces. If vegetation patterns are indicative of particular hydrogeomorphic conditions, then vegetation can be used to identify specific hydrologic regimes. Alternatively, if geomorphic features support typal plant communities, then the composition and complexity of those communities may be restored on disturbed landforms.

Determining how best to describe plant communities has been a long-standing issue in community ecology (Clements 1920, Gleason 1926, 1939, Whittaker 1956, Daubenmire 1966). A substantial amount of plant ecology and forestry is practiced from the perspective that plant communities are largely influenced by the dominant species in an association, and that understanding the distributions of the largest, most abundant woody species will lead to an understanding of plant communities as a whole. This approach assumes a tight linkage among forest layers that a number of authors have questioned (Gams 1918, Gleason 1926, 1939, Cain 1936, Lippmaa 1939, Whittaker 1960, 1973, McIntosh and Hurley 1964, Daubenmire and Daubenmire 1968, Hoffman and Kazmierski 1969, Bratton 1975, del Moral and Watson 1978). Following this tradition, most characterizations of forests in the Ozarks derive from the phytosociology of canopy species (Read 1952, Redfearn et al. 1970, Zimmerman and Wagner 1979, Nigh et al. 1985, Pallardy et al. 1988, Ware et al. 1992, Cutter and Guyette 1994).

In the United States, the need for proper characterization is important in light of the mandates of the National Forest Management Act of 1976 (Federal Register 47(190), 219.26, 219,27 (g), 1982) and recent efforts to pursue ecosystem management, both which require the use of effective quantitative approaches to ensure that management practices maintain the integrity and biodiversity of forest systems (Thomas 1996).

The specific goals of this study are listed below. Most of the goals relate to the seven overall objectives of the study as described by the National Park Service (see Study Objectives section).

- characterize and classify the plant communities of the riparian landscape
- compare the composition of vegetation among forest groups
- ascertain patterns of woody and herbaceous species distributions along existing environmental gradients using a robust direct gradient analysis technique (canonical correspondence analysis)
- determine if different vegetation layers (trees, shrubs, herbs) exhibited differential responses to the same suite of environmental variables
- find if species richness is linked to landscape position in the BNR
- ascertain if the composition of the herbaceous layer is correlated or coupled with the composition of the tree or shrub layers.

We also discuss the management implications of the study and offer recommendations regarding the appropriateness and applicability of delineating specific vegetation assemblages for management purposes. Restoration and management efforts within the riparian zone have been hindered by a limited understanding of plant community structure and dynamics. Recommendations for managing this complex system must come from the quantitative study of natural populations.

OBJECTIVE 1

To develop and utilize a standardized sampling strategy to collect descriptive data about the composition and structure of the plant communities on a representative sample of the Park's riparian corridor.

Methods

Vegetation Sampling

Between June and August 1994, and in August 1995, sampling transects were established at 36 sites along the Buffalo National River. Study sites were chosen from among the locations that were accessible by secondary roads or foot trails, and separated by approximately 5 km (see Appendix I for study site location and classification). At each site we sampled vegetation and soil properties along a transect, the recommended method for sampling in areas where species assemblages are thought to be strongly influenced by an environmental gradient (Barbour et al. 1987). Transects began at the river's edge and continued upslope to a point where the forest canopy was dominated by oak (*Quercus* sp.) and hickory (*Carya* sp.). Each transect site was categorized by geomorphic landform: depositional bar, active channel shelf, floodplain, slope, upslope. Disturbed sites were identified as either hayfield or campsite to indicate present land use practices. This survey included 20 secondary forest transects, 10 campground transects and six hayfield transects.

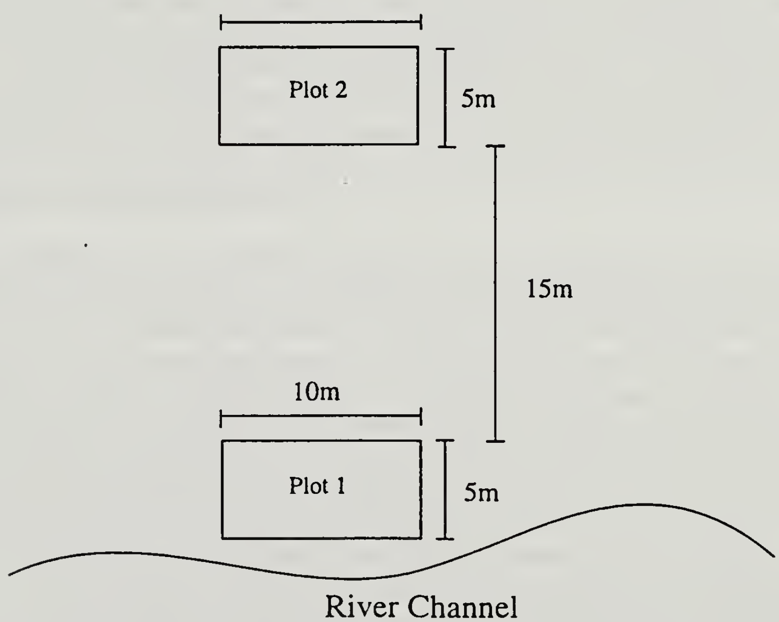

Fig. 1-1. Diagram of transect orientation and layout. 5 X 10 m plots were established at 15 m intervals . Transects began at the river's edge and continued to upland forest.

Five X 10m plots were spaced at 15m intervals along each transect (Fig. 1-1). The appropriate plot dimensions were determined from species area-curves of sampling plots within the BNR as the size at which sampling effort was most efficient (i.e., most species sampled per unit of sampling effort) (select species-area curves are shown Appendix I). Rectangular plots rather than square or circular plots were used because rectangular plots more adequately sample the existing diversity (Bormann 1953). Plots were named by the transect site and plot position along the transect away from the river. Plot name acronyms, plot names, USGS quad map locations, and forest type designations are given in Appendix II. Trees, shrubs and herbs were sampled in a total of 167 - 5 X 10m plots. Locations of secondary forest plots within the USGS quad map are indicated in Appendix III.

Sampling protocol for trees, shrubs, and herbs within each 5 X 10 m plot is given in Fig. 1-2. Plants were assigned to one of three forest layers based on stem diameter or height. Trees were defined as plants ≥1 cm in diameter at 1.3m in height (dbh). Trees were identified to species, their diameters recorded, and basal area ($m^2 ha^{-1}$) calculated for all species within each 5 X 10 m plot. Shrub cover was estimated in four - 3 m^2 circular subplots and herb cover was estimated in 10 - 0.1 m^2 rectangular subplots (Fig. 1-2). Plants <1 cm dbh, and ≥ 0.1 m in height were classified as shrubs. Herbs included all plants <0.1 m in height. Canopy coverage of shrub and herb species was recorded by the following cover classes (Daubenmire 1959): 0-5%, 5-25%, 25-50%, 50-75%, 75-95% and 95-100%.

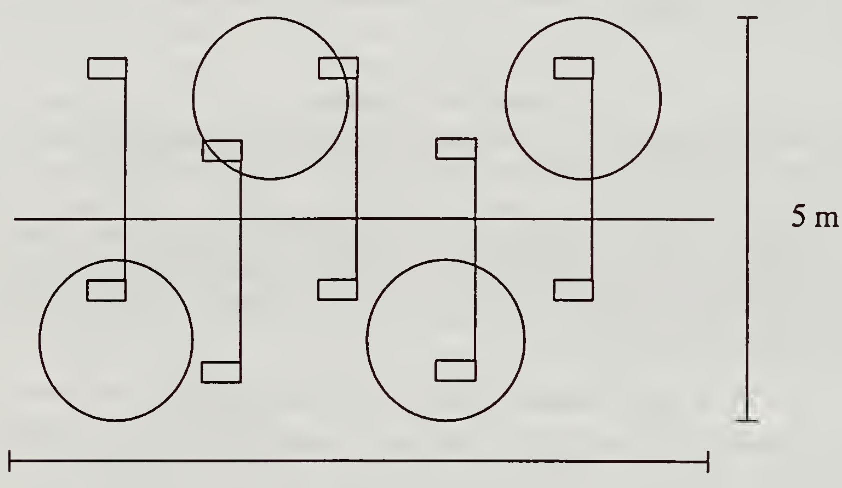

Fig. 1-2. Plot frame sampling design. All trees within the 5 X 10m plot were sampled. Shrubs were sampled within circular subplots, and herbs were sampled within rectangular subplots

Physical Attributes

The topographic position of each study plot was characterized by slope, aspect, and height above river. Slope and aspect were measured with a clinometer and compass, respectively. Height above river (HAR) was calculated from the angle (a) and distance (b) between one observer at the river's edge and another at the edge of the plot as: HAR = sin a(b). Height above river was measured from base flow river level.

Soils

Soils were collected at a depth of 10 cm from three locations chosen haphazardly within each 5 X 10 m plot. Samples were collected into polyvinyl bags and stored at 0°C until they could be processed. The bulk soil sample was air-dried and passed through a 2 mm sieve to separate fine and crude soil fractions. The weight of the smaller size fraction and the total sample weight were recorded to calculate the percentage of total sample <2 mm dia (fines). All subsequent analyses were performed on the fine fraction.

Soil pH

Soil pH was measured following McLean (1982). Eight grams of air-dried, fine soil was mixed with 8 ml of 0.01M $CaCl_2$, stirred thoroughly with a vortex mixer, and allowed to stand for 10 min. The pH of the resulting solution was measured with a High Performance Combination Probe read with a pH/ion 350 meter (Corning, Inc.).

Soil Texture: Hydrometer Method

Soil texture was quantified using the hydrometer method of Bouyoucos (1951). Eighteen grams of air-dried, fine soil was dissolved in a 0.1 M sodium hexametaphosphate solution by mixing and allowing to soak overnight. Twelve hours later the suspension was transferred to a 500 ml sedimentation cylinder and thoroughly mixed. Hydrometer readings were taken 40 s and 2 hr after mixing with a standard hydrometer (ASTM no. 152 H with Bouyoucos scale in g/L). The proportions in the soil of sand, clay and silt were calculated from these readings following Bouyoucos (1951). Hydrometer readings were corrected for deviations from normal room temperature.

Container Capacity

Container capacity (CC) is an estimate of the water holding capacity of disturbed soil and is the water content of soil after it has been saturated and then allowed to drain. Methods follow Cassel and Nielsen (1986). Soils were added to a container and weighed. Each container was inundated with water for 2 hr to saturation, allowed to drain freely for 12 hr, then re-weighed. Container capacity was calculated as the difference between the post-, and pre-wetting weights divided by the post-wetting weight of the sample.

Organic Matter Content : Loss on Ignition

Organic matter (OM) content was measured using the loss on ignition method described by Lim and Jackson (1982). Air-dried, fine soil was added to a porcelain crucible, weighed, and placed into a muffle furnace. The soil was ignited with a low flame to prevent any sudden or violent ignition of the organic matter, increased gradually to about 900°C , and held there for 15 min. The crucible was cooled, and the sample re-weighed. Loss on ignition, the change in weight after firing, includes water of constitution, organic matter, and some soluble, volatile salts.

OBJECTIVE 2

To use inventory data to determine the most applicable and available native riparian species to be reestablished in previously cleared areas needing restoration.

Methods

· Five bottomland landforms are displayed along most reaches of the Buffalo River: depositional bar (gravel bar), active channel shelf (active bank), floodplain, slope and upslope. These landforms are defined on hydrologic grounds. The independent parameters used to characterize landform are flow duration (amount of time during which a level is reached or exceeded by stream flow) for surfaces below the floodplain, and flood frequency (recurrence interval of flooding) for the floodplain, slope and upslope. Landforms described herein conform to those defined by Hupp and Osterkamp (1985). Gravel bars occur within the active channel bed and are raised features composed of relatively coarse sand, gravel and cobbles and often devoid of woody vegetation. The active bank is a sloping surface that normally extends the short distance between the break in the steep bank slope and the lower limit of persistent vegetation and corresponds to the stage of the average flow. The floodplain is a flat geomorphic surface that is inundated on average once every 1-3 yr. Slope extends above the floodplain to a height of 9 m, the approximate height of the 100 year flood stage at Ponca, AR. Downriver from Ponca, the elvebation of the 100 year flood plain increases significantly xceeding 20 meters at highway 65 USGS gauging station. Upslope is a zone above the slope forest that is likely to be a transitional zone between floodplain and upland forest vegetated with species of either forest type.

Vegetation sampling plots were classified to landform following the criteria established by Hupp and Osterkamp (1985). The most common fluvial landforms that were sampled in this survey were gravel bar, active bank, floodplain, slope and upslope. Environmental and soil variables were characterized for each sampling plot. To determine if either woody or herbaceous species were associated with landscape position, the composition and relative abundance of tree, shrub and herb species were compared among forest groups.

Results

Environmental Characteristics of forest groups

Table 2-1 provides a comparison of the 10 environmental variables measured in this study among the five categories of landforms. No significant differences in aspect or container capacity were noted among the five forest groups. However, slope, height above river, pH, fines, CC, sand, clay, silt and OM all showed incremental and significant increases moving from the bottomland to upslope forest group. Slope and height above river, not unexpectedly, were higher on slope and upslope plots than on the bottomland plots. A combination of these two variables gives an indication of the frequency and duration of flooding which are important criteria in landform designation (Hupp and Osterkamp 1985). These results indicated a high level of substrate and physical site heterogeneity within the forest groupings in the BNR landscape.

Table 2-1. Comparison of 10 environmental variables among the five forest groups in the BNR. Values listed are means ± 1 SE.

	Gravel bar	Active bank	Floodplain	Slope	Upslope
number of plots	*28*	*13*	*12*	*32*	*35*
Slope	3.3±1.0	24.9±4.6	7.4±2.6	21.2±2.1	18.9±1.9
Aspect	88.6±25.6	120.5±32.8	113.5±28.5	151.8±18.3	155.8±16.5
HAR	0.6±0.2	0.4±0.2	3.8±0.7	9.5±0.9	25.0±1.6
pH	7.1±0.1	6.8±0.1	6.3±0.2	6.2±0.2	5.6±0.1
Fines	41.3±5.1	77.0±8.0	92.0±2.3	84.3±2.9	72.8±3.4
CC	23.3±1.0	29.0±1.4	30.8±0.8	30.5±1.0	29.2±0.9
Sand	87.0±5.9	54.5±6.8	44.0±7.9	40.5±3.6	48.3±4.2
Clay	1.8±0.6	9.4±2.8	6.7±2.6	9.7±3.0	9.1±1.9
Silt	11.3±5.4	36.1±6.3	44.7±6.3	48.6±3.3	42.3±3.6
OM	3.1±0.7	4.3±0.1	5.8±0.7	7.6±1.0	6.2±1.1

Species composition of forest groups

Trees - Table 2-2 provides a summary of the mean basal areas for 35 tree species in five forest groups. Separation of species composition into five forest types is evident, but considerable overlap is also evident, particularly between the floodplain, slope and upslope groups. Five tree species (14% of the total) occurred in all five forest groups. Species overlap between floodplain and slope was 44%, between the slope and upslope was 50%, and between floodplain and upslope 36%. Sweet gum (*Liquidambar styraciflua* L.), sycamore, (*Plantanus occidentalis* L.), blue beech (*Carpinus caroliniana* Walt.), and American elm (*Ulmus americana* L.) were the most common trees on gravel bar plots, although, overall, gravel bars supported little woody vegetation. Sweet gum, boxelder (*Acer negundo* L.), sycamore, American elm, and river birch (*Betula nigra* L.) had the largest basal areas in the active bank. The floodplain group had no clear dominant species with sycamore, sweet gum, catalpa (*Catalpa speciosa* Warder), sugar maple (*Acer saccharum* Marsh), red maple (*A. rubrum* L.), bitternut hickory (*Carya cordiformis* (Wang.) K.Koch), green ash (*Fraxinus pennsylvanica* Marsh.), and river cane (*Arundinaria gigantea* (Walt.) Muhl.) having the greatest basal areas. (note: River cane is not a tree, it is a large monocot. River cane is included in the tree vegetation layer in order to evaluate its usefulness as an indicator species.)

The slope group had the highest tree species richness (29 species) which included chinkapin oak (*Quercus muhlenbergii* Engelm.), blackjack oak (*Q. marilandica* Muenchh.), sweet gum, sycamore, green ash, short-leaf pine (*Pinus echinata* Mill.), sugarberry (*Celtis laevigata* Willd.), green ash, red maple and river

Table 2-2. A comparison of basal areas (m^2 ha^{-1}) of 35 tree species organized by forest type. Values listed are means ± 1 SE.

	Gravel Bar	Active Channel	Floodplain	Slope	Upslope
number of plots	28	13	12	32	35
Platanus occidentalis	157.1±36.2	129.2±53.5	125.4±27.1	132.5±22.3	203.5±0.0
Liquidamber styraciflua	80.9 ±0.0	298.0 ±108.9	89.8±25.9	227.0±78.8	45.5±16.6
Carpinus caroliniana	31.8±7.8	22.9±10.7	7.9±1.7	7.6±1.9	9.2±0.0
Acer negundo	2.0±0.6	271.9±126.0	16.9±4.5	37.0±4.9	8.9±2.9
Ulmus americana	24.6±0.0	140.2±54.7	5.5±1.5	6.5±2.9	7.9±2.9
Ostrya virginiana	7.7 ±0.0	24.6±0.0		9.1±4.4	
Arundinaria gigantea	5.5±0.1		39.0±6.1	3.3±0.8	
Betula nigra		139.9±43.7		72.6±0.0	
Ulmus rubra		58.8±23.7		36.7±3.1	
Catalpa speciosa		46.7±0.0	59.5 ±0.0	8.0±0.1	
Asimina triloba		5.1±1.8	2.1±0.6	1.7±0.3	1.2±0.2
Celtis occidentalis		5.45±0.0		11.0±5.9	
Acer saccharum	8.8±0.00		115.5±0.0	3.9±1.2	
Fraxinus pennsylvanica			72.1±35.7	75.9±25.2	
Acer rubrum			49.8±19.7	61.1±5.7	2.3±0.4
Carya tomentosa			19.7±0.0	1.4±0.0	8.3±1.9
Fraxinus americana					5.8±0.0
Juniperus virginiana			18.9±0.0	5.8±1.6	3.2±1.2
Carya cordiformis			43.0±0.8	44.0±16.5	16.6±6.2
Morus rubra			10.0±0.0	1.1±0.1	1.6±0.6
Nyssa sylvatica			16.5±6.7	12.3±0.0	1.5±0.3
Aesculus glabra			7.1±0.0		2.0±0.0
Acer saccharinum			3.8±0.0		
Quercus muhlenbergii				144.4±40.2	7.0±1.7
Pinus echinata				268.6±0.0	
Quercus marilandica				64.9±2.6	23.5±6.3
Quercus stellata				26.8±0.0	
Quercus alba				15.6±2.4	26.6±4.2
Celtis laevigata				107.5±37.4	
Quercus prinoides				8.0±3.5	
Juglans nigra	5.9 ±0.0			2.2±0.0	109.8±0.0
Quercus rubra		1.6±0.0		3.1±0.4	10.8±2.1
Fagus gradifolia					3.0±0.3
Quercus falcata					43.2±5.1
Carya texana					21.5±0.0

birch. The upslope group had the highest diversity of oak *(Q. muhlenbergii*, and *Q. rubra*), and hickory species (*Carya cordiformis*, *C. tomentosa*, and *C. texana*), but the most dominant members of the upslope group were sycamore, and black walnut (*Juglans nigra* L.). Large basal areas of sycamore and black walnut in the upslope forest group were biased by rare, large individuals.

Despite the high level of species overlap between forest groups, the majority of species found in each subgroup had low fidelity values (i.e., occurred on few plots). Even the most dominant species in each group (gravel bar - sycamore; active channel - sweet gum; floodplain - sycamore; slope - short leaf pine; upslope - sycamore) were not found on all plots.

Tree saplings - Table 2-3 presents the mean cover classes for saplings of 18 tree species among five forest groups. Gravel bar and active bank groups had the most similar species composition between the overstory and understory (Table 2-2). Six of the most dominant species in the low elevation groups, sycamore, sweet gum, American elm, box elder, blue beech and ironwood (*Ostrya virginiana* (P.Mill.) K.

Table 2-3. A comparison of mean cover class of saplings of 18 tree species organized by forest type. Species with mean cover class < 0.01 are not shown. Values listed are means ± 1 SE.

	Gravel Bar	Active Channel	Floodplain	Slope	Upslope
number of plots	28	13	12	32	35
Platanus occidentalis	0.09±0.02				
Liquidamber styraciflua	0.08±0.02	0.06±0.02	0.02±0.01	0.06±0.01	0.04±0.01
Carpinus caroliniana	0.01±0.00	0.06±0.02	0.08±0.02	0.11±0.02	0.03±0.01
Acer negundo	0.14±0.03	0.33±0.09	0.23±0.01	0.10±0.02	0.13±0.02
Ulmus americana	0.05±0.01	0.25±0.07	0.21±0.06	0.40±0.07	0.71±0.12
Ostyra virginiana	0.02±0.00	0.02±0.01	0.06±0.02	0.07±0.01	0.15±0.03
Quercus rubra	0.02±0.00	0.12±0.03	0.02±0.01	0.15±0.03	0.08±0.01
Asimina triloba		0.04±0.01	0.17±0.05	0.31±0.06	0.38±0.06
Celtis occidentalis			0.15±0.04	0.08±0.01	0.10±0.02
Fraxinus pennsylvanica	0.06±0.01	0.19±0.05	0.13±0.04	0.19±0.03	0.17±0.03
Acer rubrum	0.01±0.00	0.02±0.01	0.02±0.01	0.06±0.01	0.11±0.02
Carya cordiformis		0.04±0.01	0.08±0.02	0.10±0.02	0.32±0.05
Juniperus virginiana		0.02±0.01		0.07±0.01	0.16±0.03
Ulmus alata			0.02±0.01	0.12±0.02	0.14±0.02
Quercus muhlenbergii		0.19±0.05		0.18±0.03	0.22±0.04
Nyssa sylvatica				0.05±0.01	0.13±0.03
Sassafras albidum				0.10±0.02	0.33±0.06
Quercus alba				0.09±0.02	0.18±0.03

Koch) also had the highest sapling cover classes. Pawpaw (*Asimina triloba* (L.) Dunal.) was present in the understory and overstory of the active bank group. Bitternut hickory, eastern red cedar, and chinkapin oak (*Quercus muhlenbergii* Engelm.) were present in the understory, but were absent in the overstory layer. No successful recruitment into the sapling layer was noted by any other species of the gravel or active bank groups.

Sapling cover in the floodplain, slope and upslope forest groups did not closely reflect the patterns observed with canopy trees. Three tree species were common in the overstory but absent from the low vegetation in the floodplain: catalpa, sugar maple, and river cane. Further, two species that appeared in the low vegetation of the floodplain are absent or not well-represented in the overstory: pawpaw *and* witch hazel (*Hamamalis viginiana* L.).

Sapling densities in the slope and upslope groups did not closely reflect the patterns observed in the canopy trees. Although chinkapin oak, green ash, bitternut hickory and red maple are common species in both the overstory and understory in the slope forest group, saplings of other species common in the slope forest overstory are absent: blackjack oak, shortleaf pine, sweet gum, sycamore and river birch. Further, five species common in the understory were absent or not well represented in the overstory: white oak, pawpaw, sassafras (*Sassafras albidum* (Nutt.) Nees.), black gum (*Nyssa sylvatica* Marsh.) and eastern redcedar (*Juniperus virginiana* L.).

Pawpaw, black gum, sassafras, and eastern redcedar saplings continued to increase in importance along an elevational gradient from floodplain into the upslope forest group. These trends run counter to those found in the overstory where pawpaw and black gum are most important in the flood plain decreasing in importance upslope. In contrast to their presence in the understory, sassafrass and eastern redcedar trees had small basal areas (<1.0 m^2 ha^{-1}) and are not a dominant component of any forest group.

Overall, species richness is lower in the sapling than the overstory tree layer. Diversity in saplings of overstory trees was especially reduced relative to overstory diversity in the floodplain, slope and upslope forest groups. These results suggest that recruitment in these forest groups is not representative of the overstory tree species indicating that all component groups of the riparian forest are in transition (Jeffers 1972).

<u>Woody shrubs and subcanopy trees</u> - A summary of mean cover classes among the five forest groups is given in Table 2-4. Only 14 of 377 species (4%) appear in Table 2-4 because most species were uncommon in our samples (fidelity 0-8%). Ward's willow (*Salix caroliniana* Michx.) is the most common shrub of gravel bars and is found only on low elevation plots. Witch hazel and flowering dogwood (*Cornus florida* L.) were abundant on gravel bars and also found in other groups. Buckbrush (*Andrachnye phyllanthoides* (Nutt.) Muell. Arg.)was most abundant on the active bank but was found in all forest groups. Spicebush (*Lindera benzoin* (L.) Blume) was most abundant in the flood plain group but was common in other groups. Gum bumelia (*Bumelia lanuginosa* (Michx.) Pers.), flowering dogwood, rusty black haw (*Viburnum rufidulum* Raf.) and buckthorn (*Rhamnus caroliniana* Walt.) were common only in the upslope. Species fidelity was very low across all bottomland groups (1-40%). Of all the species across all five groups, only flowering dogwood in the upslope group had a fidelity value exceeding 50% (29 of 35 plots or 83%).

Table 2-4. A comparison of mean cover class of woody shrubs and subcanopy trees organized by forest type. Species with mean cover class < 0.01 are not shown. Values listed are means ± 1 SE.

	Gravel Bar	Active Bank	Floodplain	Slope	Upslope
number of plots	28	13	12	32	35
Salix caroliniana	0.27±0.05	0.23±0.06			
Bumelia lanuginosa	0.01±0.00			0.02±0.00	0.15±0.03
Hamamalis virginiana	0.20±0.04	0.19±0.05	0.06±0.02		
Cornus drummondii		0.23±0.06		0.09±0.02	0.02±0.00
Hydrangea aborescens		0.15±0.04		0.07±0.01	0.16±0.03
Dirca palustris		0.04±0.01	0.17±0.05	0.09±0.02	0.06±0.01
Cornus florida	0.02±0.00	0.04±0.01	0.21±0.06	0.41±0.07	0.49±0.08
Lindera benzoin	0.02±0.00	0.25±0.07	0.52±0.15	0.43±0.08	0.16±0.03
Rubus sp.	0.07±0.01	0.14±0.04	0.04±0.01	0.04±0.01	0.01±0.00
Andrachyne phyllanthoides	0.03±0.01	0.40±0.11	0.27±0.08	0.31±0.06	0.33±0.06
Staphyla trifoliata	0.04±0.01	0.12±0.03	0.13±0.04	0.16±0.03	0.03±0.01
Cercis canadensis	0.03±0.01		0.02±0.01	0.02±0.00	0.11±0.02
Viburnum rufidulum			0.04±0.01	0.06±0.01	0.21±0.04
Rhamnus caroliniana				0.09±0.02	0.26±0.04

<u>Herbs</u> - Herb and vine densities among the five forest groups are given in Table 2-5. Only 20 of 323 (6%) of herb and vine species appear in Table 2-5 because most species were uncommon in our samples (fidelity 0-9%). The most abundant species across all forest types were poison ivy (*Toxicodendron radicans* (L.) Kuntze) and Virginia creeper (*Parthenocissus quinquefolia* (L.) Planchon). Water willow (*Justicia americana* (L.) Vahl.) was most abundant in the gravel bar and active bank groups. Inland sea oats (*Chasmanthium latifolium* (Michx.)Yates) was found in all five groups but had the highest density in the active bank group. River cane (*Arundinaria gigantea* (Walt.) Muhl.) was most common in the active bank and slope groups, but occurred in all forest groups. Touch-me-not (*Impatiens* sp.) was the most abundant species in the slope group. *Panicum boscii* Poir. was most abundant in the upslope group but was common in the other groups.

Table 2-5. A comparison of mean cover class of 20 herb and vine species in the low vegetation layer organized by forest type. Species with mean cover class < 0.01 are not shown. Values listed are means ± 1 SE.

Species	Gravel Bar	Active Bank	Floodplain	Slope	Upslope
number of plots	28	13	12	32	35
Justicia americana	0.49±0.10	0.56±0.16			
Festuca arundanaceae	0.03±0.01	0.02±0.01	0.08±0.02	0.06±0.01	
Ambrosia trifida	0.12±0.022	0.10±0.03	0.23±0.07	0.05±0.01	
Ambrosia artense	0.10±0.20	0.10±0.03	0.06±0.02	0.02±0.00	
Lespedeza virginica	0.05±0.01	0.19±0.05		0.04±0.01	
Elymus virginicus	0.02±0.00	0.19±0.05		0.06±0.01	0.01±0.00
Campsis radicans		0.17±0.05	0.08±0.02	0.02±0.00	0.05±0.01
Chasmantheum latifolium	0.15±0.03	0.79±0.22	0.25±0.07	0.16±0.03	0.06±0.01
Laportea canadensis	0.05±0.01	0.14±0.04	0.65±019	0.02±0.00	0.01±0.00
Impatiens sp	0.02±0.00	0.17±0.05	0.69±0.20	0.09±0.02	0.01±0.00
Verbesina helianthoides	0.03±0.01	0.08±0.02	0.31±0.09	0.05±0.01	0.05±0.01
Amphicarpa bracteata	0.09±0.00	0.04±0.01	0.17±0.05	0.02±0.00	0.08±0.01
Arundinaria gigantea	0.04±0.01	0.31±0.09	0.19±0.05	0.45±0.08	0.09±0.02
Panicum boscii	0.05±0.01	0.19±0.05	0.10±0.03	0.23±0.04	0.25±0.04
Parthenocissus quinquefolia	0.15±0.03	0.50±0.14	0.33±0.10	0.40±0.07	0.39±0.07
Rudbeckia lacinata	0.07±0.01	0.14±0.04	0.02±0.01	0.12±0.02	0.01±0.00
Toxicodendron radicans	0.25±0.05	0.31±0.09	0.19±0.05	0.34±0.06	0.48±0.08
Sanicula canadensis		0.02±0.01	0.10±0.01	0.05±0.01	0.03±0.01
Agrominia rostellata		0.02±0.01	0.06±0.02	0.07±0.01	0.13±0.02
Boehmeria cylindrica		0.21±0.06	0.08±0.02	0.09±0.02	0.08±0.01

Management implications

Criteria for restorative species are that they are common, they grow rapidly and they are easy to propagate. Results from this inventory will enable managers to select restorative species specific to the landform to be restored. Many bottomland species, such as *S. caroliniana* , *Acer negundo*, *P. occidentalis*, *U. americana*, and *Catalpa speciosa*, are common to the bottomland groups, fit these criteria of fast growth and ease in propagation, and are ideal candidates for restoration of bottomlands. Difficulties arise in selecting species for upland sites because the species that occur there are slow growing, are more difficult to propagate, and often have extremely limited distributions in upland forest. Results of this survey suggest that viable species are *U. americana*, *Acer* spp., and *Fraxinus* spp.

Although the desired end product of restoration is the reconstitution of native forest, it may be impossible to get there directly. Canopy species planted directly into an old field may have little chance of success since soil and light microenvironments have been altered. Previous restoration studies found that the first step in successful restoration of old fields was to eliminate exotic grasses by first creating shade with fast-growing shrubs or sub-canopy tress (Aide et al. 1995). Shading limited growth of grasses and enabled latter successional tree species to become established. A potential candidate for shrub level shade in the Arkansas Ozarks is red bud (*Cercis canadensis* L.) which tolerates extremes of light and poor soil and also fixes nitrogen improving soil quality. Once a low level canopy has become established, reconstruction can proceed. The results presented here will be useful in reconstituting a forested riparian landscape that resembles natural vegetation.

Restorative efforts are aimed at reestablishing fully functional ecosystems with all of the attributes of native vegetation. Central to ecosystem function is diversity and complexity (Tilman 1988), so that recreating a functional ecosystem requires recreating a complex forest. The results presented herein establish guidelines for restoration of biological complexity of all vegetation layers on common landforms within the BNR.

OBJECTIVE 3

To assemble and integrate physical and ecological data that contribute to an understanding and characterization of riparian community structure, distribution and dynamics.

Methods

Ordinations

Both canonical correspondence analysis (CCA) (ter Braak 1986) and detrended correspondence analysis (DCA) (Hill and Gauch 1980) ordinations were conducted on plant species-environmental variable matrices using the programs PC-ORD (McCune and Mefford 1995) and CANOCO 3.10 (ter Braak 1988). CCA is a direct gradient analysis technique in which species composition is directly related to measured environmental variables (ter Braak 1986). Direct gradient analysis is useful in identifying the relative importance of a particular environmental variable. The eigenvalue associated with each axis of the correspondence analysis is the correlation between environmental variables and ordination axes scores (Gauch 1982, Pielou 1984). The correlations between environmental variables and ordination axes are the "intraset" correlations of ter Braak (1986) which take into account the large colinearity in the matrix of environmental variables. The relative importance of environmental variables along each axis are shown graphically as vectors in a biplot of a CCA ordination diagram (Palmer 1993). DCA is an indirect gradient analysis technique whereby environmental gradients are not studied directly but are inferred from species composition data (Palmer 1993). Indirect gradient analysis is particularly useful when it is uncertain that the most important environmental variables have been measured.

Basal areas (m^2 ha^{-1})were calculated for all tree species for each sampling plot. Dominance of shrub and herb species for each sampling plot were evaluated using mean cover. The soil and environmental variables described in the Physical Attributes Section (Objective 1) were transformed when necessary to meet the assumptions of normality. Correlations among environmental variables were analyzed with Statistical Analysis Software, Proc CORR (SAS Institute 1985).

Classification of sampling plots was based on an agglomerative cluster analysis of Euclidean distances linked by the nearest neighbor method (McCune and Mefford 1995). Percent chaining indicates the degree to which the groups are the product of growth by accretion of early groups, a recognized shortcoming of this technique. Low values for percent chaining indicate a low probability of growth by accretion (Pielou 1984). The validity of the cluster analysis groupings was evaluated with Multi-response Permutation Procedures (MRPP) (McCune and Mefford 1995), non-parametric procedures for testing the concentration of samples into groups. The MRPP are permutation-based tests that utilize the average between-plot distance within a group as their primary unit of analysis (Berry et al. 1983). The null hypothesis states that correspondence among clusters is random versus the alternative hypothesis that the clusters correspond to a non-random allocation (Mielke 1984, Zimmerman et al. 1985).

We used Kappa statistics to evaluate the correspondence among classification schemes generated by tree, shrub and herb layers. Kappa statistics (Cohen 1960) were used in this study to evaluate whether the vegetation layers were in agreement in assigning sampling plots to classes. The Kappa statistic tests for agreement among classification schemes by evaluating whether a significant portion of the test units fall on the diagonal of a square matrix. The requirement of a square matrix is problematic when the number of clusters differs among vegetation layers. When this occurred, the critical distance in the cluster analysis for which the final grouping was established was increased until the number of groupings for the vegetation layers being compared were equal.

Results

Classification

Table 3-1 contains a correlation matrix and summary statistics of all the environmental variables measured in this study. The results in Table 3-1 show that soil pH, soil organic matter (OM), soil fines , and clay all exhibited wide ranges, indicating the presence of broad soil chemical and physical gradients. This variability, in part, reflects the diversity in soil parent materials and geomorphology within the BNR (Dollar et al. 1992). Thus, the sampling regime was effective in surveying

Table 3-1. Correlation coefficients between 10 environmental variables measured in the study. Means, medians, and ranges of variables are also listed at the bottom of the table.

Variable*	Slope	Aspect	HAR	pH	Fines	CC	Sand	Clay	Silt	Ol
Slope										
Aspect	0.55									
HAR	0.44	0.22								
pH	-0.32	-0.11	-0.63							
Fines	0.35	0.21	0.27	-0.21						
CC	0.38	0.24	0.36	-0.11	0.47					
Sand	-0.42	-0.22	-0.44	0.39	-0.43	-0.53				
Clay	0.21	0.05	0.31	-0.42	0.24	-.18	-0.59			
Silt	0.46	0.24	0.42	-0.32	0.42	0.55	-0.91	0.28		
OM	0.45	0.26	0.39	-0.03	0.21	0.86	-0.44	0.08	0.47	
units	deg	deg	m	pH	%	%	%	%	%	%L
Mean	13.1	-	7.9	6.45	69.7	26.2	59.6	6.5	33.2	4.
s.d.	12.6	-	10.4	0.8	28.1	6.0	29.8	10.8	25.8	4.
Range										
low	0.0	-	-0.4	4.11	3.8	16.5	0.0	0.0	0.0	0.
high	53.0	-	51.6	7.8	99.9	47.0	100.0	91.7	97.2	39

*Variables are defined as follows: slope = slope (˚) through the vegetation plot; aspect = aspect of the plot (˚); HAR = height above river of vegetation plot (m); pH = pH of soil sample from vegetation plot taken at 10 cm depth; Fines = % of total sample <2 mm dia; CC = container capacity of soil samples (%); Sand = (5%) sand in soil; Silt = silt in soil; Clay = % clay in soil; OM = organic matter content (%) in soil sample at 10 cm depth determined by LOI (loss on ignition).

across several environmental gradients and vegetation assemblages in the riparian landscape. The corresponding range in plot locations relative to river elevation (-0.04 m - 51.6 m) indicates that the vegetation sampling cut across a topographical gradient that included both flood prone and flood immune areas. The results presented in Table 3-1 also show that many of the environmental variables are correlated with one another. Such multicolinearity can negatively affect some ordination procedures (Palmer 1993). However, direct gradient analysis using canonical correspondence analysis (CCA) has been shown to be a robust technique that is not prone to these complications (ter Braak 1987, Palmer 1993.)

Species richness

A total of 337 plant species were recorded in this survey: 54 tree species on 98 plots, 337 shrub species on 142 plots, and 323 herb species on 147 plots. All species recorded from our samples can be found in the low vegetation of the shrub layer, making this the most rich vegetation layer in the riparian corridor. The tree layer represented only 14% of the total number of species.

CCA and DCA Ordinations

In all CCA ordinations performed the Monte Carlo permutation test indicated that the eigenvalues for the first and second axes were all significant ($P<0.05$). Eigenvalues of the first and second axes of the CCA ordinations were very similar among vegetation layers (Table 3-2). However, the environmental correlations with

Table 3-2. A comparison of CCA ordination results between three vegetation layers: trees, shrubs and herbs. Eigenvalues and environmental variable correlations with CCA ordination axes, are shown for comparison.

	TREES			SHRUBS			HERBS		
	AXIS			AXIS			AXIS		
	1	2	3	1	2	3	1	2	3
Eigenvalue	*0.42*	*0.27*	*0.23*	*0.49*	*0.30*	*0.27*	*0.49*	*0.30*	*0.27.*
Variables*									
HAR	-0.72	-0.15	0.19	0.86	-0.12	-0.13	-0.84	0.40	0.00
Clay	-0.32	0.36	0.26	-0.30	-0.04	-0.34	-0.34	0.20	-0.07
Sand	0.31	-0.05	-0.09	-0.47	0.38	-0.12	0.47	0.62	0.22
Silt	-0.27	-0.03	0.01	0.46	-0.37	0.25	-0.48	-0.30	0.04
Slope	-0.39	-0.64	-0.13	0.47	-0.09	0.14	-0.51	0.06	-0.03
Aspect	-0.31	-0.14	0.33	0.16	-0.19	0.02	-0.17	-0.03	0.07
Fine	0.32	0.34	-0.07	0.01	-0.87	-0.04	0.10	0.00	0.84
CC	-0.10	-0.37	0.44	0.37	-0.27	0.63	-0.55	-0.44	0.24
pH	0.81	-0.37	0.39	-0.68	-0.35	0.30	0.65	-0.18	0.06
OM	-0.04	-0.58	0.50	-0.47	-0.28	0.49	-0.59	-0.38	0.28

* Descriptions of environmental variables and how they were determined can be found in the Physical Attributes section (Objective 1) and at the bottom of Table 2-1.

the first three axes of the CCA ordinations differed among the vegetation layers, especially for the variables aspect, fines, CC and OM.

Trees - Fig. 3-1 is a biplot of the CCA ordination for tree species (N = 66). The eigenvalues for the first two axes (λ_1 = 0.41 and λ_2 =0.27, respectively) indicate separation along the measured gradients. Five of the 10 environmental variables are indicated by vectors on the biplot in Fig. 3-1. The dominant environmental variables correlated with the first axis were height above river (r = -0.72) and pH (r = 0.81). Slope and organic matter content showed the highest correlation (r = -0.64 and -0.58, respectively) with the second axis. Separation of vegetation plots located on gravel bar and directly adjacent to the river channel is represented by points in the right half of the ordination (low elevation , high pH). CCA ordination of species (Fig. 3-2) indicated that bottomland tree species such as *Platanus occidentalis* (PLOC), *Acer negundo* (ACNE), *Salix nigra* (SANI), *Acer saccharinum* (ACES), and *Catalpa speciosa* (CATS) were dominant in the right side of the figure. Some separation of plots supporting upland oak assemblages were also noted in the left half of the ordination (high elevation, low pH). Upland species such as *Quercus alba* (QUAL), *Q. falcata* (QUFA), *Q. marilandica* (QUMA) and *Carya texana* (CATE) were noted in CCA species ordinations in this half of the ordination diagram (Species acronyms listed in Appendix IV). Distinct separation and grouping of other plots and/or species were not as pronounced, indicating a continuum of woody vegetation moving left to right beneath the centroid of the ordination. Overall, the CCA biplot depicted in Fig. 3-1 indicates a transition in woody vegetation from bottomland to upland species that is influenced primarily by height above river and pH on the first axis and by the slope and organic matter content on the second axis.

Shrubs - A shrub vegetation layer was also analyzed (N = 337 species). The CCA biplot for shrubs is shown in Fig. 3-3. The eigenvalues of the first two axes (0.48, and 0.30) indicate acceptable levels of separation of plot scores along the measured environmental gradients. The three variables most strongly correlated with the first two axes are represented by vectors on the biplot in Fig. 3-3. The biplot shows that pH (r = -0.68) and HAR (r = 0.86) were the dominant environmental gradients influencing vegetation patterns on the first CCA axis and fines exhibited the strongest correlation (r = -0.87) with the second CCA axis. Secondary gradients of importance included clay, silt and container capacity. Segregation of species along the noted gradient was also observed, with species typically found in moist streamside environments located in the upper left quadrant, including Ward's willow, witchhazel and buttonbush (*Cephalanthus occidentalis* L.). Overall, shrub responses to environmental gradients were similar to the tree vegetation layer, with species on shrub plots more strongly correlated with fines than the other ordinations.

The shrub layer showed limited segregation among plant associations. In the CCA of shrub species, site scores fell out in a U-shaped distribution (Fig. 3-3). Plots in the upper left quadrant were almost exclusively gravel bar sites, plots in the upper right were upland sites, and plots in the lower quadrants were at mid-slope. Gravel bars hosted an assemblage of shrub species that were clearly distinct from other sites in the ordination. The repeated importance of pH and height above river suggests that these gradients, or other factors correlated with these gradients, hold major influence over the distribution and abundance of plant species in the riparian zone. Nonetheless, environmental variables correlated with the secondary CCA axes differ between tree

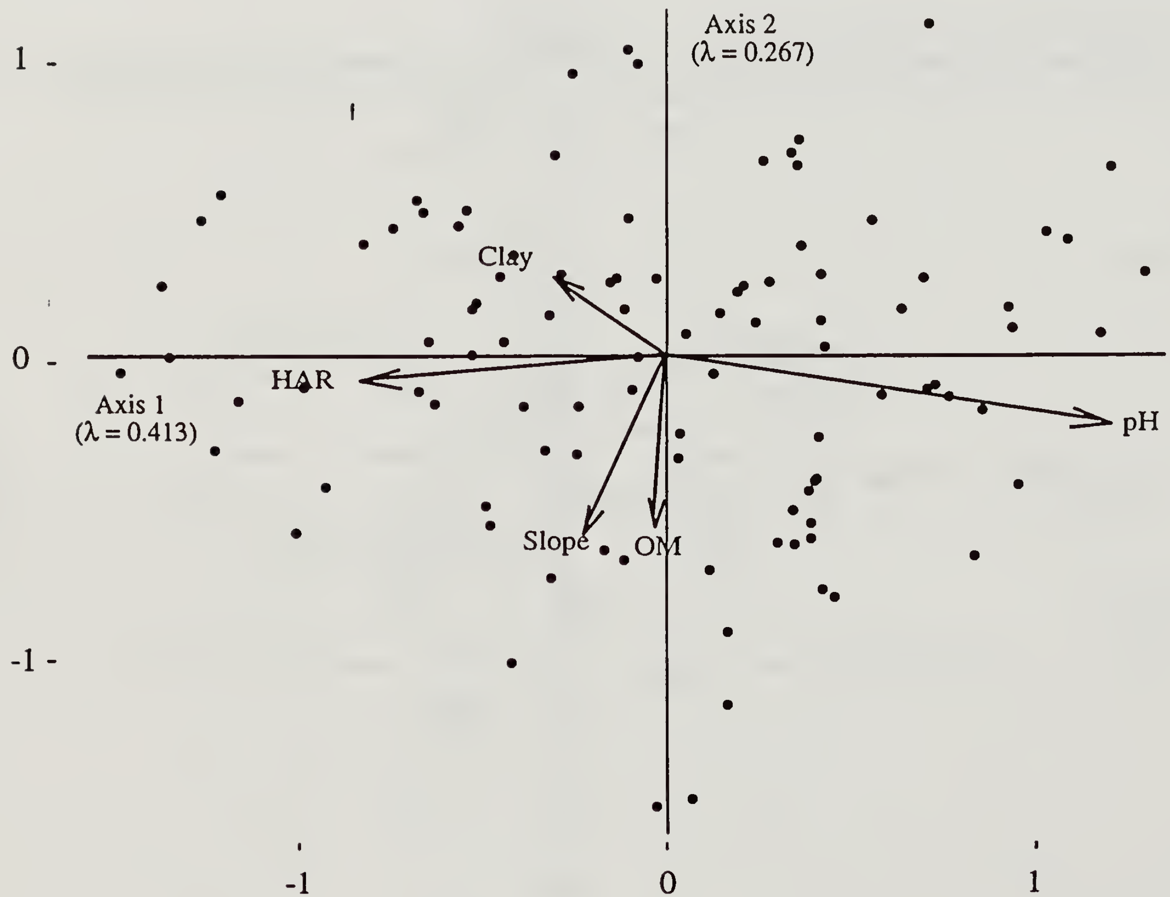

Fig. 3-1. CCA biplot of Buffalo River tree species ordination. Vectors represent environmental variables strongly correlated with the first two CCA axes. Each point represents a single plot (N = 100). A total of 66 species were found across all plots.

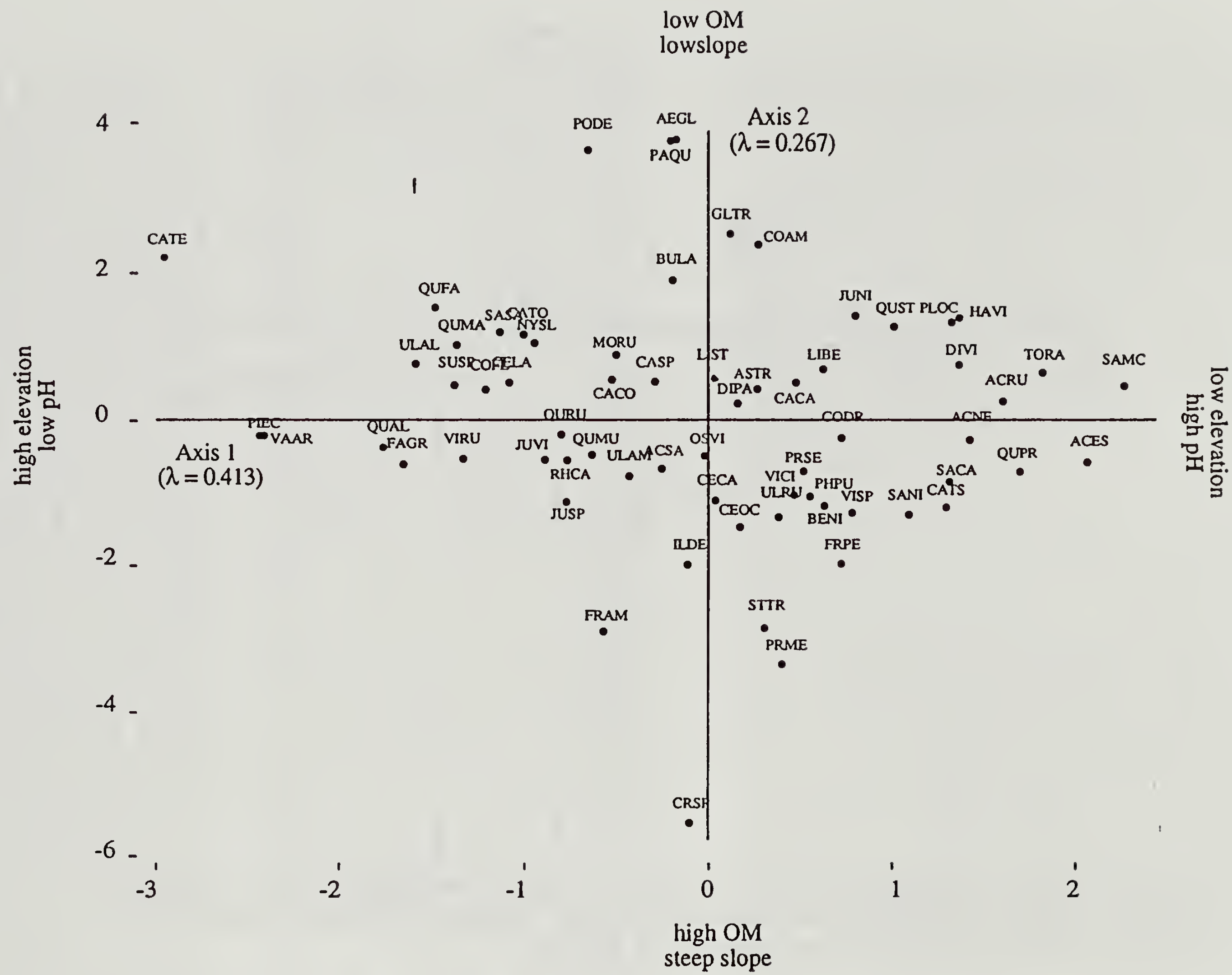

Fig. 3-2. CCA of Buffalo River tree species ordination. Each point represents a single species (N = 66) across 100 plots. Acronyms for species names are identified in Appendix IV.

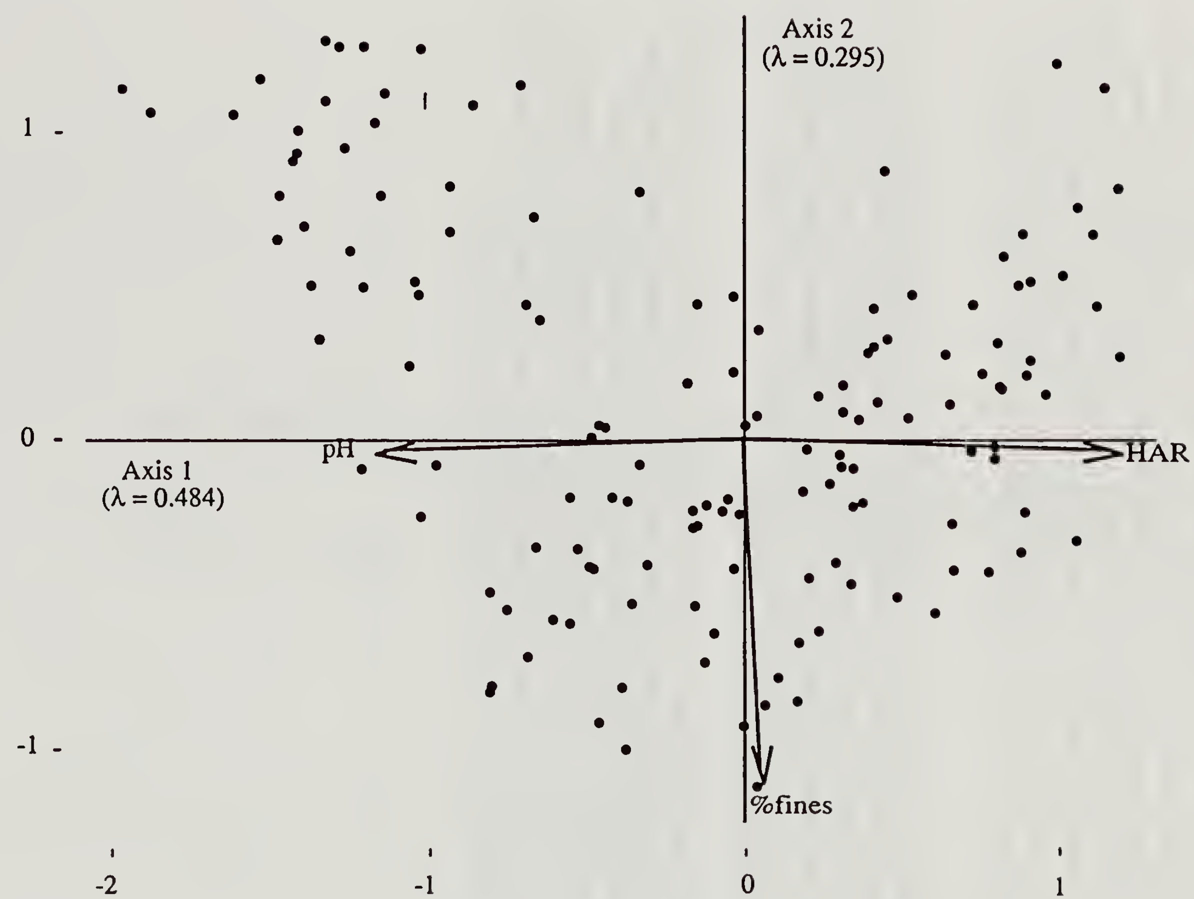

Fig. 3-3. CCA biplot of Buffalo River shrub species ordination. Arrows represent environmental variables strongly correlated with the first two CCA axes. Each point represents a single plot (N = 100). A total of 337 species were found across all plots.

and shrub layers which suggests that the relative importance of each variable differs among vegetation layers.

Herbs - Fig. 3-4 is a biplot of the canonical correspondence analysis (CCA) for all herbaceous species (N = 323). The eigenvalues for the first two axes (0.49 and 0.30, respectively) indicate acceptable levels of separation of plot scores along the measured environmental gradient. The four variables most strongly correlated with the first two CCA axes are represented by vectors on the biplot in Fig. 3-4. The biplot shows that pH (r = 0.65), HAR (r = -0.84), and organic matter content (-0.59) were the dominant environmental gradients influencing vegetation patterns on the first CCA axis and sand exhibited the strongest correlation with the second axis. (r = 0.62). Secondary gradients of importance included silt, slope and fines. Segregation of species along the noted gradients was also observed, with species typically found in moist, streamside environments located in the upper left quadrant, including water willow, false indigo (*Amorpha fruitcosa* L.) and dodder (*Cuscuta* spp.). Species adapted to drier and more acidic conditions were found on the far left of the first CCA axis, including agrimony (*Agrimonia rostellata* Wallr.) and black snakeroot (*Sanicula canadensis* L.).

Ordination of the herb layer suggests that herb distributions are influenced by some of the same environmental variables as trees and shrubs. Height above river and pH are again the dominant environmental factors correlated with axis 1 (Table 3-2). Like the tree ordination, organic matter content and container capacity are important in axis 2. In contrast, unlike either tree or shrub ordination, sand fraction has a strong correlation with axis 2 of the herb ordination.

These results provide evidence that woody and herbaceous vegetation in the BNR are responding differently to the existing suite of environmental variables. The existence of strong pH and HAR gradients, despite variability in CCA axes correlations with other variables, indicates that the three vegetation layers are not independent. However, the dramatic differences in intraset correlations and vector direction in the biplots confirms a differential response to underlying environmental gradients, particularly in the case of shrubs and herbaceous species.

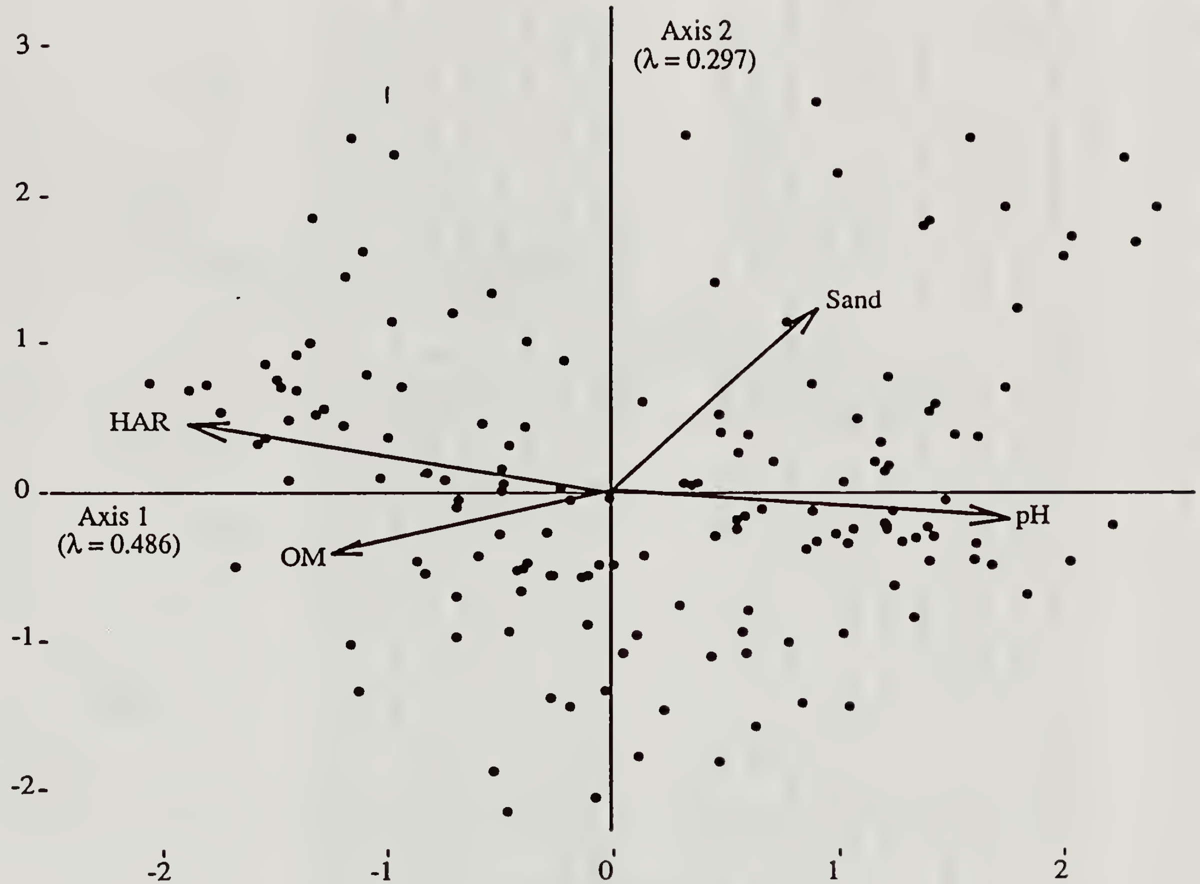

Fig. 3-4. CCA biplot of Buffalo River herb species ordination. Arrows represent environmental variables strongly correlated with the first two CCA axes. Each point represents a single plot (N = 155). A total of 303 species were found across all plots.

DCA - Indirect Gradient Analysis

Fig 3-5 is a plot of the detrended correspondence analysis (DCA) of BNR tree species. DCA differs from CCA in that DCA detects regular species associations independent of the environmental data (Palmer 1993). The distances among points in a DCA ordination indicate the degree of similarity in species composition among study plots. As a rule, a difference among plots of four standard deviation units indicates a complete turnover in species composition (Hill and Gauch 1980). BNR sampling plots within the riparian corridor varied substantially in species composition as shown by the large range of values along the first two DCA axes (4 to 6 standard deviation units) (Fig. 3-5).

Ordering along the first two axes accounted for approximately 35% of the variance among the 100 sites included in the DCA analysis. Dominance of a species in a plot is indicated by the correlation of the species score with each axis score. Axis 1 separates bottomland from upland sampling plots; study plots at the far left of DCA axis 1 are dominated by bottomland species: boxelder (r = 0.64), sycamore (r = 0.44), and catalpa (r = 0.34). Study plots at the far right of DCA axis 1 are dominated by upland species: white oak (r = -0.44), bitternut hickory (r = -0.34), and dogwood (r = -0.42). Axis 2 separates upland sampling plots into xeric and mesic sites. Study plots in the upper quadrants of the DCA ordination are dominated by xeric species: eastern redcedar (r = 0.36), shortleaf pine (r = 0.30), and blackjack oak (*Quercus marilandica* Meunchh. (r = 0.32). Study plots in the lower quadrants are dominated by more mesic species: white oak (r = -0.58), flowering dogwood (r = -0.50), and southern red oak (*Q. falcata* Michx.) (r = -0.33).

The relationships between DCA axis scores and the measured environmental variables are similar to the results of the CCA ordination. DCA axis 1 was strongly correlated with height above river (r= 0.55), pH (r = -0.42), and container capacity (r=-0.42). Axis 2 showed the strongest correlations with slope (r = 0.32) and organic matter content (r = 0.43). The similarity in environmental correlations on the first axis of both the DCA (unconstrained) and CCA (constrained) ordinations, indicates that the environmental/soil variables measured were likely good indicators (either directly or as covariates) of key underlying environmental gradients that exist within the study area (Jongman et al. 1995). Sampling plots are distributed continuously along the DCA axes with no abrupt transitions or ecotones to indicate community boundaries, just as in the CCA.

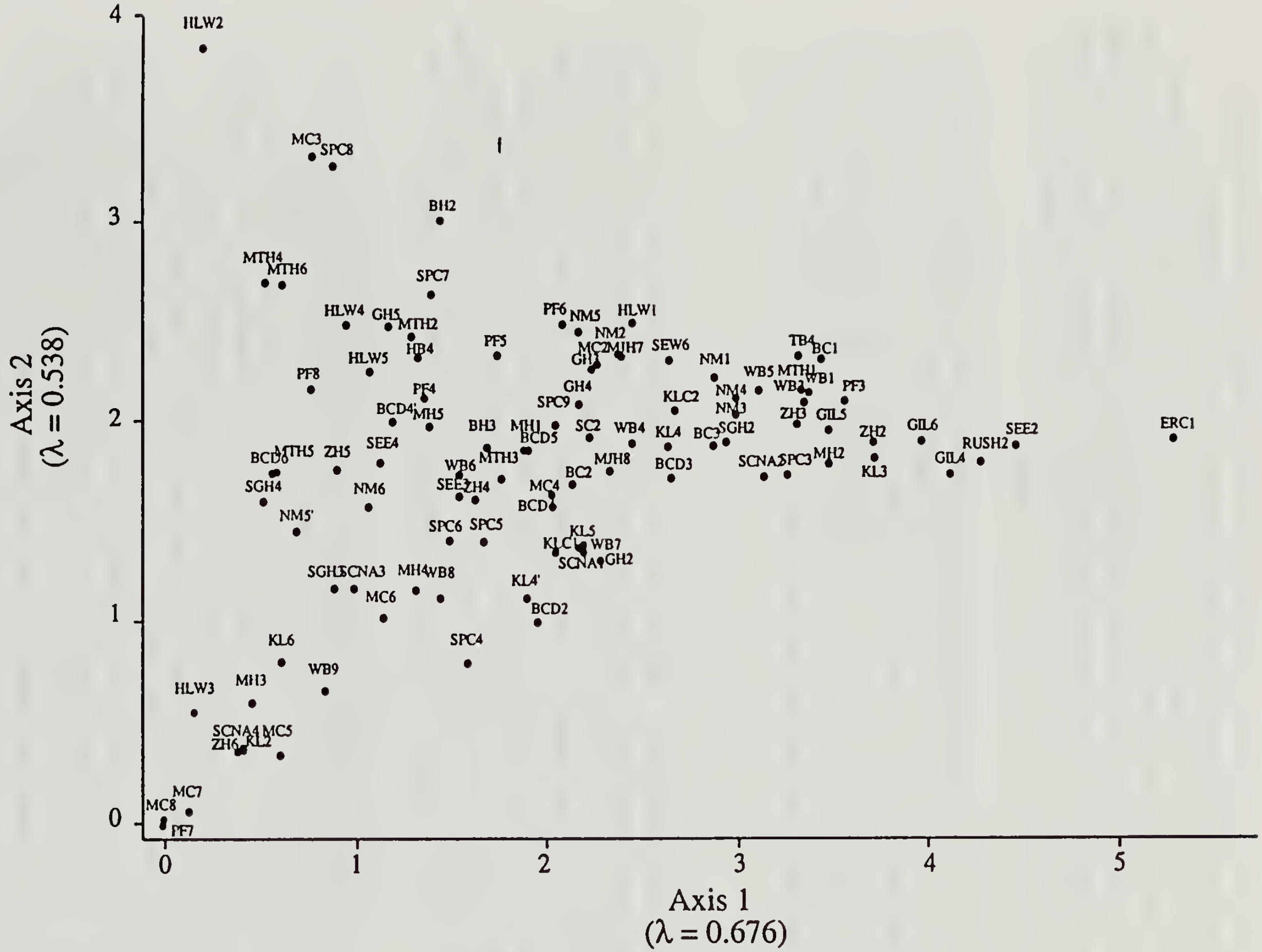

Fig. 3-5. DCA of Buffalo River tree (>1 cm dbh) species. Each point represents a site (N = 100). Study site acronyms are identified in Appendix II. A total of 66 species were found across all sites.

Cluster analyses

Cluster analysis of DCA Euclidean distances used to classify tree, shrub and herb data resulted in different classifications for the three vegetation layers (Fig 3-6). Sampling plots clustered in to six distinct groups in the tree layer (percent chaining = 5.16%), four groups in the shrub layer (percent chaining = 4.27%), and six groups in the herb layer (percent chaining = 7.31%) (Fig. 3-6). MRPP results support the groupings for all layers (trees: $T = -23.42$, $P<.0001$, shrubs: $T = -5.43$, $P<0.0001$, herbs: $T = -15.21$, $P<0.0001$).

Despite strong support for the classification in each layer, there were few similarities among forest layers in dendrogram structure or in cluster group composition. The tree ordination fit roughly with typical classification of riparian forests, but instead of three forest types (gravel bar, floodplain and upland), there are six (Fig. 3-6). Clusters in the tree layer can be roughly identified as gravel bar (group 1), floodplain (groups 2, 6) and upland (groups 3,4,5). Nonetheless, classification of the tree layer yields a unique dendrogram that cannot easily be made congruent to the other dendrograms by collapsing or splitting clusters.

Plots fell into distinct clusters in all vegetation layers, but the composition of each cluster differed significantly between the overstory and understory. There was little symmetry in the matrix of tree by shrub groups ($K = 19.62$, $df = 15$, $P = 0.19$) or tree by herb clusters ($K = 17.19$, $df = 15$, $P = 0.31$) but the shrub by herb matrix was symmetrical ($K = 48.86$, $df = 15$, $P = 0.001$), indicating that the classification schemes of the shrub and herb vegetation layers were similar.

Discussion

Much of the complexity and diversity of the riparian forest is not accounted for by classification schemes based on canopy dominants. The groupings defined in the cluster analyses do not correspond well between overstory and understory vegetation layers, a recurring phenomenon in forest vegetation studies (Bratton 1975, del Moral and Watson 1978, Rogers 1980, 1981, McCune and Antos 1981). Three possible explanations for these inconsistencies are: 1) forest layers respond differentially to environmental gradients, 2) the rate of recovery from disturbance differs among forest layers, and 3) differences are artifacts of the analysis and arise from unequal sample sizes.

Forest layers may respond to different environmental gradients, or to similar gradients at different spatial scales. Species associations in the overstory and understory shift along key environmental gradients, the influence of these gradients is indicated by significant correlations between layers in ordination scores. However, species associations in the overstory and understory may not shift in concert. CCA identified pH and elevation gradients as correlates of species composition in all vegetation layers, but correlations with secondary factors, such as soil particle size or organic matter content, varied among forest layers in sign and magnitude. Vegetation layers may be tracking different gradients at the landscape scale thereby uncoupling overstory from understory in transitions between plant associations. Further, the same gradient may not be perceived equally by all vegetation layers (McCune and Antos 1981). For example, canopy plants experience a much broader range of light availabilities from low-light on north-facing slopes in steep valleys, to full-light on upland, south-facing slopes, whereas understory plants may experience a much more

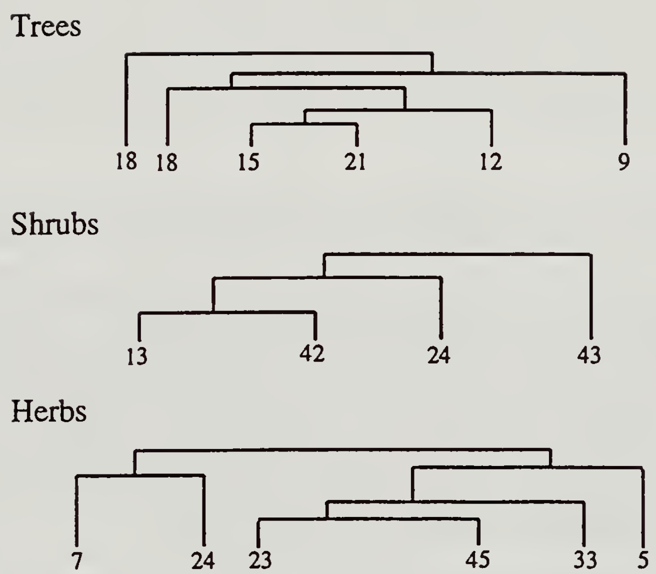

Fig. 3-6. Cluster analysis of Euclidean distances for the tree, shrub and herb layers. Bar lengths are drawn in proportion to the dendrograms generated by the DCA ordinations. Values below bars represent the number of sampling plots in each cluster.

limited range of light conditions. The same may be true of water availability where streamside canopy plants are rooted at the capillary column and upland plants are tapping ground water sources, whereas understory herbs are generally more reliant on ephemeral rainfall events.

A factor that may further promote uncoupling between understory and overstory associations is that gradients presumed to be continuous at the landscape scale may be discontinuous on a more localized scale. Species associations in the herb layer respond to major gradients, such as moisture or elevation (Bratton 1976), but also segregate along microgradients of microtopography (Struick and Curtis 1962, Bratton 1976), light and water availability (Moir 1966, Anderson et al. 1969) and temperature (Bazzaz and Bliss 1971) leading to shifts in composition at a spatial scale different from shifts in tree associations (Bendix 1994). Herbs and shrubs may respond to microsite heterogeneity because of their relatively small canopies, rooting volume and rooting depth, whereas trees more easily integrate microsite heterogeneity (Körner 1994). On a large scale, this may break the link between species associations in the overstory and understory, and contribute to the incongruencies in classification among vegetation layers.

Incongruence may also result from a differential response among forest layers to disturbance (McCune and Antos 1981, Gilliam et al. 1995). A natural gradient in a riparian zone is the frequency, duration, and intensity of flooding (Dale and Kuroda 1978, Bell 1974, Bell and del Moral 1977, Sharitz and Mitsch 1993). Flooding has a well-documented impact on the composition and structure of bottomland forests (Huffman 1979, White 1979, Larson et al. 1981, Hupp and Osterkamp 1985), but whether its influence differs among forest layers is not fully understood. Response to disturbance is influenced by a number of life history traits (Grime 1979), with shrubs and herbs likely to respond more quickly due to shorter life cycles (Achuff and La Roi 1977), differential colonization rates (McCune and Antos 1981), and the propensity of shrubs and herbs to propagate vegetatively (Sagers 1993).

Finally, inconsistencies may result from attempting to classify groups of vastly unequal sizes. Classification schemes of canopy plants are based on a relatively small number of species, typically less than 50 for temperate forests (Bell 1974, Bell and del Moral 1977, Dollar et al. 1992), whereas classification of the shrub and herb incorporate often more than 300 species. The relatively small number of species in a tree ordination may result in community segregation that is deceptively simple. Sampling plots in the ordination of the tree layer often appear to have discrete boundaries (Daubenmire 1966, Nigh et al. 1985, Pallardy 1988), whereas in the understory the distinctions are not as clear, and groupings show considerable overlap. The overstory layer may have too few species to adequately describe the behavior of diverse understory communities.

The Buffalo River system is a flashy system dominated by erosion rather than deposition, and characterized by steep valleys and rapid changes in water level. The strong gradient correlated with pH is likely the product of weathering of parent material, soil erosion, and removal of soil nutrients by vegetation (Dollar et al. 1992). Further, the Ozarks are very old, having been continuously covered with vegetation since the end of the Paleozoic (Steyermark 1959). The resulting environmental gradients across this riparian landscape are steep and may accentuate the discordance between vegetation layers. A number of other studies in less disturbed areas have reported a similar lack of correspondence among vegetation layers (Bratton 1975, del Moral and Watson 1978, Rogers 1980, 1981, McCune and Antos 1981), so it is not surprising to see these patterns in an extremely old, topographically diverse, highly disturbed site.

Management Implications

Our findings indicate that changes in both understory and overstory composition along a floristic gradient approximate a continuum (Gleason 1926), rather than an abrupt change in community composition (Daubenmire 1966). Among the vegetation groups identified by the cluster analysis there is considerable overlap in species composition and abundance. These results indicate that it will be difficult in the riparian zone to identify distinct forest types in order to prioritize for management purposes. Criteria for the recognition of forest types include the condition that dominant cover must be of trees (at least 25% canopy cover) and that the forest type be named by the species that comprise 20% of the total basal area of the forest type (Eyre 1980). Forest groups identified by cluster analysis cannot be recognized or named according to these criteria since canopy cover is often <25% and rarely does a single species reach a dominance of 20%. The riparian zone is a complex mix of species distributed throughout the riparian corridor as a product of environmental tolerances, historical events and extremely heterogeneous soils and light environments. Rather than attempt to dissect the riparian forest into recognizable forest types, management efforts should focus on the landscape scale and treat the riparian forest as a single forest type.

The tradition of describing plant communities by the dominance of large, woody species is based on a number of logistic considerations. Often the purpose of plant community classification is to evaluate the value of a stand is based on the quantity of extractable timber products. Therefore, it profitable to quickly assess the presence and abundance of the largest, most valuable species. Secondly, quantitative sampling in the understory is labor-intensive because low vegetation is dense and species-rich. Nonetheless, to attempt to characterize forest structure based solely on canopy tree species ignores the most diverse and complex plant groups in the forest. In addition to housing the vast majority of plant species, recent studies suggest that the understory vegetation may have a critical role in forest regeneration (Abrams 1992, Lorimer et al. 1994) and will likely provide stability and promote recovery during disturbance (Tilman et al. 1996).

The National Forest Management Act of 1976 (16 U.S.C. § 1600 et. seq. [1988]) directs the USDA Forest Service to provide for diversity of plant and animal communities. This suggests to us that the goal of forest management should be to maintain natural diversity and species composition, as well as to enhance diversity in areas where it has declined due to human activity. We agree with Roberts and Gilliam (1995) that management strategies should be based on natural patterns of diversity and on the ecological processes that influence these patterns. Therefore, classification schemes should incorporate an understory component and should rely not only on the overstory dominant tree species.

OBJECTIVE 4

To assess type, location, and intensity of disturbances, both natural and man-related, on site.

Methods

Vegetation sampling plots were classified as campsite or hayfield based on present land use and were sampled in the same manner as all other vegetation plots in this study (See Objective 2: Vegetation Sampling). Environmental and soil variables were also characterized for hayfields and campsites.

Results

A comparison of environmental variables in the disturbed and forested areas is given in Table 4-1. Campsites are most like floodplain in position (slope and height), most similar to gravel bars in pH, CC, and organic matter, but different from all other forest groups in fines, clay, silt. Hayfields are like floodplain and campsites in position (slope and height), but differ from campsites in that pH is lower, soil texture more coarse (more sand, less silt,) and organic mater content is lower than gravel bars. The lowest measure of organic matter content in the study (1.7%) was measured in the hayfield at South Maumee. Overall, soil texture and nutrient availability (OM) are significantly reduced in campsite and hayfield soils relative to floodplain.

Table 4-1. Comparison of 10 environmental variables among the seven forest groups in the BNR. Values listed are means ± 1 SE.

	Campsite	**Hayfield**	Gravel Bar	Active Bank	Flood-plain	Slope	Upslope
number of plots	35	11	28	13	12	32	35
Slope	**7.7±1.4**	**7.3±3.4**	3.3±1.0	24.9±4.6	7.4±2.6	21.2±2.1	18.9±1.9
Aspect	**97.7±17.6**	**77.3±0.0**	88.6±25.6	120.5±32.8	113.5±28.5	151.8±18.3	155.8±16.5
HAR	**2.4±0.5**	**2.9±0.8**	0.6±0.2	0.4±0.2	3.8±0.7	9.5±0.9	25.0±1.6
pH	**7.0±0.1**	**6.3±0.2**	7.1±0.1	6.8±0.1	6.3±0.2	6.2±0.2	5.6±0.1
Fines	**63.7±5.2**	**76.2±9.0**	41.3±5.1	77.0±8.0	92.0±2.3	84.3±2.9	72.8±3.4
CC	**23.5±0.9**	**21.7±0.7**	23.3±1.0	29.0±1.4	30.8±0.8	30.5±1.0	29.2±0.9
Sand	**70.5±5.4**	**74.0±5.6**	87.0±5.9	54.5±6.8	44.0±7.9	40.5±3.6	48.3±4.2
Clay	**3.0±0.7**	**8.3±3.7**	1.8±0.6	9.4±2.8	6.7±2.6	9.7±3.0	9.1±1.9
Silt	**27.2±5.2**	**17.7±3.4**	11.3±5.4	36.1±6.3	44.7±6.3	48.6±3.3	42.3±3.6
OM	**2.8±0.5**	**2.3±0.3**	3.1±0.7	4.3±0.1	5.8±0.7	7.6±1.0	6.2±1.1

<u>Trees</u> - Comparisons of the overall basal area and species richness of BNR tree species are given in Table 4-2. Not surprisingly, the overall structure of campsites and hayfields differs from other forest groups. Total basal area was reduced 80-100% in hayfields, and species richness was reduced by 94% in hayfields and 22% in campsites, respectively. Of the five most important tree species of the floodplain forest group, sycamore, sugar maple, sweet gum , catalpa, and green ash, only sycamore was present in hayfields, and sugar maple and green ash were missing from campsites.

Table 4-2. A comparison of basal areas (m^2 ha^{-1}) of tree species organized by forest type. Values listed are means ± 1 SE.

	Campsite	Hayfield	Gravel Bar	Active Channel	Flood-plain	Slope
number of plots	35	11	28	13	12	32
Platanus occidentalis	208.2±37.6	141.8±0.0	157.1±36.2	129.2±53.5	125.4±27.1	132.5±22.3
Liquidamber styraciflua	13.4±2.4		80.9 ±0.0	298.0 ±108.9	89.8±25.9	227.0±78.8
Carpinus caroliniana			31.8±7.8	22.9±10.7	7.9±1.7	7.6±1.9
Acer negundo	94.2±13.8		2.0±0.6	271.9±126.0	16.9±4.5	37.0±4.9
Ulmus americana	5.1±1.0		24.6±0.0	140.2±54.7	5.5±1.5	6.5±2.9
Ostrya virginiana	12.7±0.0		7.7 ±0.0	24.6±0.0		9.1±4.4
Cornus florida	2.4±0.0		6.6 ±0.0	20.3 ±0.0		5.3±1.4
Arundinaria gigantea	4.0±0.7		5.5±0.1		39.0±6.1	3.3±0.8
Betula nigra				139.9±43.7		72.6±0.0
Ulmus rubra				58.8±23.7		36.7±3.1
Catalpa speciosa	85.3±23.1			46.7±0.0	59.5 ±0.0	8.0±0.1
Asimina triloba				5.1±1.8	2.1±0.6	1.7±0.3
Celtis occidentalis	49.9±2.3			5.45±0.0		11.0±5.9
Acer saccharum			8.8±0.00		115.5±0.0	3.9±1.2
Fraxinus pennsylvanica					72.1±35.7	75.9±25.2
Acer rubrum	39.1±8.4				49.8±19.7	61.1±5.7
Carya tomentosa					19.7±0.0	1.4±0.0
Juniperus virginiana					18.9±0.0	5.8±1.6
Carya cordiformis					43.0±0.8	44.0±16.5
Morus rubra					10.0±0.0	1.1±0.1
Nyssa sylvatica					16.5±6.7	12.3±0.0
Acer saccharinum	4.8±0.0				3.8±0.0	
Quercus muhlenbergii	1.4±0.0					144.4±40.2
Pinus echinata						268.6±0.0
Quercus marilandica						64.9±2.6
Quercus stellata						26.8±0.0
Quercus alba						15.6±2.4
Celtis laevigata						107.5±37.4
Quercus prinoides						8.0±3.5
Juglans nigra	5.0±0.0		5.9 ±0.0			2.2±0.0
Quercus rubra	769.3±0.0			1.6±0.0		3.1±0.4

Saplings of overstory trees - The mean cover of saplings of overstory tree species are summarized in Table 4-3. In campsites, the understory resembles the overstory indicating that these species are successfully replacing themselves. Hayfields are more diverse in the sapling layer than the overstory layer where in addition to the sycamore, seedlings of sweet gum, American elm, green ash, and winged elm were present. The utility of these species lies in their importance as components of floodplain forest, and because the seedlings are able to establish in the altered soils of heavily managed landscapes, they may be good candidates for early stages of old field restoration.

Table 4-3. A comparison of mean cover class of saplings of overstory tree species organized by forest type. Species with mean cover class <0.01 are not shown. Values listed are means ± 1 SE.

	Campsite	**Hayfield**	Gravel Bar	Active Channel	Floodplain	Slope
number of plots	35	11	28	13	12	32
Platanus occidentalis		**0.11±0.03**	0.09±0.02			
Liquidamber styraciflua	**0.01±0.00**	**0.02±0.01**	0.08±0.02	0.06±0.02	0.02±0.01	0.06±0.01
Carpinus caroliniana	**0.03±0.01**		0.01±0.00	0.06±0.02	0.08±0.02	0.11±0.02
Acer negundo	**0.17±0.03**		0.14±0.03	0.33±0.09	0.23±0.01	0.10±0.02
Ulmus americana	**0.05±0.01**	**0.05±0.01**	0.05±0.01	0.25±0.07	0.21±0.06	0.40±0.07
Ostyra virginiana	**0.04±0.01**		0.02±0.00	0.02±0.01	0.06±0.02	0.07±0.01
Quercus rubra			0.02±0.00	0.12±0.03	0.02±0.01	0.15±0.03
Hamamalis virginiana	**0.05±0.01**		0.20±0.04	0.19±0.05	0.06±0.02	
Asimina triloba	**0.01±0.00**			0.04±0.01	0.17±0.05	0.31±0.06
Celtis occidentalis					0.15±0.04	0.08±0.01
Fraxinus pennsylvanica	**0.04±0.01**	**0.02±0.01**	0.06±0.01	0.19±0.05	0.13±0.04	0.19±0.03
Acer rubrum			0.01±0.00	0.02±0.01	0.02±0.01	0.06±0.01
Carya cordiformis				0.04±0.01	0.08±0.02	0.10±0.02
Juniperus virginiana	**0.01±0.00**			0.02±0.01		0.07±0.01
Ulmus alata		**0.02±0.01**			0.02±0.01	0.12±0.02
Quercus muhlenbergii	**0.02±0.00**			0.19±0.05		0.18±0.03
Nyssa sylvatica						0.05±0.01
Sassafras albidum						0.10±0.02
Quercus alba						0.09±0.02

Shrubs and subcanopy trees - Table 4-4 provides a comparison of understory species among forest types. The composition and relative abundance of shrub species is completely altered in the campsite and hayfield sites relative to the floodplain forest group. Three of the four most abundant species in the floodplain forest, spicebush, flowering dogwood and leatherwood (*Dirca palustris* L.), are absent in campsites and hayfields. Overall, species richness of shrubs is reduced in campsites (50% decrease) and hayfields (75%). Of the species that occur at these sites, pest species such as *Rubus* sp., are found in much higher abundance that in any other forest types. Further, the distribution of Ward's willow, the only shrub species common in hayfields, is limited to low elevation sites and is likely to persist at these sites despite upper floodplain disturbance.

Table 4-4. A comparison of mean cover class of woody shrubs and subcanopy trees organized by forest type. Values shown are means ± 1 SE.

	Campsite	**Hayfield**	Gravel Bar	Active Bank	Flood-plain	Slope
number of plots	35	11	28	13	12	32
Salix caroliniana	**0.01±0.00**	**0.21±0.07**	0.27±0.05	0.23±0.06		
Bumelia lanuginosa			0.01±0.00			0.02±0.00
Hydrangea aborescens				0.15±0.04		0.07±0.01
Cornus drummondii	**0.01±0.00**			0.23±0.06		0.09±0.02
Dirca palustris				0.04±0.01	0.17±0.05	0.09±0.02
Cornus florida			0.02±0.00	0.04±0.01	0.21±0.06	0.41±0.07
Lindera benzoin			0.02±0.00	0.25±0.07	0.52±0.15	0.43±0.08
Rubus sp	**0.11±0.02**	**0.11±0.03**	0.07±0.01	0.14±0.04	0.04±0.01	0.04±0.01
Andrachyne phyllanthoides	**0.03±0.01**		0.03±0.01	0.40±0.11	0.27±0.08	0.31±0.06
Staphyla trifoliata			0.04±0.01	0.12±0.03	0.13±0.04	0.16±0.03
Cercis canadensis			0.03±0.01		0.02±0.01	0.02±0.00
Viburnum rufidulum					0.04±0.01	0.06±0.01
Rhamnus caroliniana						0.09±0.02

Herbs - The mean cover classes of herb and vine species are summarized in Table 4-5. Overall, the species richness of the herb vegetation layer is greater than other vegetation layers in campsites and hayfields. Campsites retain many of the species common to floodplain forest group (19 of 23 (83%) floodplain species occur in the campsite group), and hayfields retain 10 of 23 (43%) floodplain herb species. However, the relative importance of these species in campsites and hayfields does not reflect their importance in floodplain forest group.

Table 4-5. A comparison of mean cover class of herbs and vines in the low vegetation layer organized by forest type. Values shown are means ± 1 SE.

Species	**Campsite**	**Hayfield**	Gravel Bar	Active Bank	Flood-plain	Slope
number of plots	35	11	28	13	12	32
Justicia americana	**0.08±0.01**	**0.23±0.07**	0.49±0.10	0.56±0.16		
Xanthium strumarium	**0.13±0.02**	**0.02±0.01**	0.01±0.00	0.02±0.01		
Saponaria officinalis	**0.10±0.02**	**0.48±0.14**	0.02±0.00		0.02±0.01	
Festuca arundanaceae	**0.06±0.01**	**0.47±0.08**	0.03±0.01	0.02±0.01	0.08±0.02	0.06±0.0
Ambrosia trifida	**0.21±0.04**	**0.05±0.01**	0.12±0.02 2	0.10±0.03	0.23±0.07	0.05±0.0
Ambrosia artense	**0.16±0.16**	**0.18±0.06**	0.10±0.20	0.10±0.03	0.06±0.02	0.02±0.0
Lespedeza virginica		**0.05±0.01**	0.05±0.01	0.19±0.05		0.04±0.0
Elymus virginicus	**0.04±0.01**	**0.21±0.06**	0.02±0.00	0.19±0.05		0.06±0.0
Cynodon dactylon	**0.01±0.00**	**0.43±0.13**		0.02±0.01		
Campsis radicans	**0.14±0.02**	**0.39±0.12**		0.17±0.05	0.08±0.02	0.02±0.0
Chasmantheum latifolium	**0.19±0.03**	**0.16±0.05**	0.15±0.03	0.79±0.22	0.25±0.07	0.16±0.0
Laportea canadensis	**0.14±0.02**	**0.02±0.01**	0.05±0.01	0.14±0.04	0.65±019	0.02±0.0
Impatiens sp	**0.04±0.01**		0.02±0.00	0.17±0.05	0.69±0.20	0.09±0.0
Verbesina helianthoides	**0.08±0.01**		0.03±0.01	0.08±0.02	0.31±0.09	0.05±0.0
Amphicarpa bracteata	**0.06±0.01**		0.09±0.00	0.04±0.01	0.17±0.05	0.02±0.0
Arundinaria gigantea	**0.24±0.04**	**0.09±0.03**	0.04±0.01	0.31±0.09	0.19±0.05	0.45±0.0
Panicum boscii	**0.13±0.02**		0.05±0.01	0.19±0.05	0.10±0.03	0.23±0.0
Parthenocissus quinquefolia	**0.08±0.01**		0.15±0.03	0.50±0.14	0.33±0.10	0.40±0.0
Rudbeckia lacinata	**0.10±0.02**		0.07±0.01	0.14±0.04	0.02±0.01	0.12±0.0
Sorghum halepense	**0.04±0.01**	**0.27±0.08**	0.02±0.00	0.02±0.01	0.04±0.01	0.05±0.0
Toxicodendron radicans	**0.26±0.05**	**0.25±0.08**	0.25±0.05	0.31±0.09	0.19±0.05	0.34±0.0
Sanicula canadensis				0.02±0.01	0.10±0.01	0.05±0.0
Agrominia rostellata				0.02±0.01	0.06±0.02	0.07±0.0
Boehmeria cylindrica				0.21±0.06	0.08±0.02	0.09±0.0
Trifolium campestre		**0.16±0.05**				0.09±0.0

The diversity of herb species in managed sites was dominated by pest species. In campsites cocklebur (*Xanthium strumarium* L.), poison ivy (*Toxicodendron radicans* (L.) Kuntze), field clover (*Trifolium campestre* Schreb.) were common while native components, nettle (*Laportea canadensis* (L.) Wedd.), *Impatiens* spp., *Verbesina* spp., hogpeanut (*Amphicarpaea bracteata* (L.), Virginia creeper (*Parthenocissus quinquefolia* (L.) Planchon), and black snakeroot (*Sanicula canadensis* L.) were absent. In hayfields, cocklebur, fescue (*Festuca* spp.), Bermuda grass (*Cynodon dactylon* (L.) Pers.), trumpet creeper (*Campsis radicans* (L.) Seem) and sorghum (*Sorghum halapense* (L.) Pers.) are common, while native ragweed (*Ambrosia trifida* L.), nettle, *Impatiens* spp., crown-beard (*Verbesina helianthoides* Michx.), hogpeanut, Virginia creeper and river cane were absent.

Shifts in species composition from floodplain to campsite and hayfield are predominantly from forbs to grasses which represent transition from shade-tolerant, native species to sun tolerant, exotic herbs that tolerate browsing. The recovery of native vegetation will likely be closely linked to the recovery of native soils. Re-establishment into the artificial grassland of woody perennials is likely to accelerate the accumulation of soil nutrients in old filed sites (Vinton and Burke 1995).

Management implications

Assuming that campsites and hayfields are situated on former floodplains, our study demonstrates reductions in soil organic matter content of 52% (campsite) and 60% (hayfields). Further, high sand and low silt in disturbed sites relative to floodplain indicates that soil erosion may be responsible for a portion of the total soil losses resulting from altered land use (Burke et al. 1995). The trend of highest sand content and lowest silt content on cultivated and managed soils suggests that erosion may have preferentially removed fine material from cultivated fields and campgrounds. Such reductions in silt content could have a significant influence on recovery dynamics. Lauenroth et al. (1994) recently demonstrated that silt content significantly influences the rate of recovery, with a 10% reduction in silt content reducing seedling establishment rates by as much as 90%.

Long-term losses of soil organic matter from cultivated fields represent a significant decline in soil fertility due to decreased nutrient availability. Losses of fine soil particles and total soil organic matter are not likely to be recovered over human time scales, since they represent pools that are accumulated over pedogenic periods (Schlesinger 1990). These slow fractions are lost with cultivation due to enhanced mixing and decomposition rates far beyond those that occur in natural systems (Parton et al. 1983). However, it appears that in some systems (Burke et al. 1994), that total soil organic matter can increase to some extent after several decades, and active soil organic matter and nutrient supply capacity can recover to initial levels. Changing substrate quality may alter the regular pattern of succession (D'Antonio and Vitousek 1992), and further influence the successful reintroduction and re-establishment of native species.

OBJECTIVE 5

To determine the presence of any rare or endangered plant species or communities.

Methods

Woody and herbaceous species lists of all species encountered in the 1994 and 1995 sampling in the BNR were compared with lists of rare and endangered species that were 1) known to exist within the BNR, 2) were listed as rare or threatened for the State of Arkansas, and or federal listings, or 3) were recognized by the Arkansas Natural Heritage Commission as rare or threatened.

Results

Three hundred and seventy-seven plant species were identified in our survey. Names and family associations of all species encountered in the survey are listed in Appendix IV. Included in the sample were 12 species listed as rare and threatened. Their names, state and federal listings, and the study sites at which they were found are listed in Table 5-1.

Rare plant species are found throughout mid-slope to upland forest groups, but threatened and endangered species are seldom encountered in the lowlands (Fig. 5-1). The relative abundance of rare species upslope may reflect an increasing heterogeneity of habitats at higher elevations.

Although most rare species are confined to the mid-, and upper elevation sites, rare herbs were found in two campsites (GIL6, RU3) and one old field (WF2). Gilbert has long been recognized among local botanists for a series of rare species including rock cress (*Arabis shortii* var. *shortii*), yellow monkeyflower (*Mimulus floribundus*), and tassel flower (*Brickellia grandiflora*). These populations persist despite the proximity of an abandoned railway grade, a horse trail and a canoe launch. We recommend that the status of these populations be monitored regularly, and suggest further that the populations of rare species at Rush and White Ford be verified and monitored.

Upper elevation sites are biologically more diverse than lowland sites (Fig. 5-2). The correlation between biological diversity and elevation is likely the product of the frequency of rare species, limited disturbance, increasing soil quality, and increasing heterogeneity of microenvironments. Intermediate sites are as diverse as the upland sites, but sites at the river's edge are less predictable.

Because both mid-slope and upland forest harbor rare species, and because we cannot distinguish the two forest types, we recommend that mid-, and upper slopes of the forest receive special protection. To establish an edge to the riparian zone at some arbitrary point would be ungrounded, and may compromise the goals of maintaining biological diversity within the park.

Table 5-1. Threatened and endangered species encountered in survey. Listing are from Arkansas Natural Heritage Commission (1993).

Family	Species	Common name	Fed Status	State Status	Global Ra
Brassicaceae	*Arabis shortii* (Fern.) Gl. var. *shortii*	Rock cress	-	-	G5T5
Cyperaceae	*Carex laxiflora* Lam.	Bristly stalk sedge	-	-	G5
Commelinaceae	*Tradescantia ozarkana* Anderson and Woodson	Ozark spiderwort	C2		G2G3
Compositae	*Brickellia grandiflora* (Hook.) Nutt.	Tassel flower	-	-	G5
Compositae	*Hieracium scabrum* Michx.	Rough hawkweed	-	-	G5
Compositae	*Solidago ulmifolia* (var. unknown)	Goldenrod	-	-	G?
Fabaceae	*Desmodium cuspidatum* (var. unknown)	Tree tuck-foil	-	-	G5T?
Fagaceae	*Castanea pumila* (L.) Mill. var. *ozarkensis* (Ashe) Tucker	Ozark chinquapin	C2	-	G5T3
Lamiaceae	*Stachys eplingii* J. Nelson	Stachys	-	-	G5
Papaveraceae	*Stylophorum diphyllum* (Michx.) Nutt.	Celadine poppy	-	-	G5
Rubiaceae	*Galium texense* Gray	Texas bedstraw	-	-	G4
Smilaceaeae	*Smilax tamnoides* (var. unknown)	Smilax	-	-	G5?

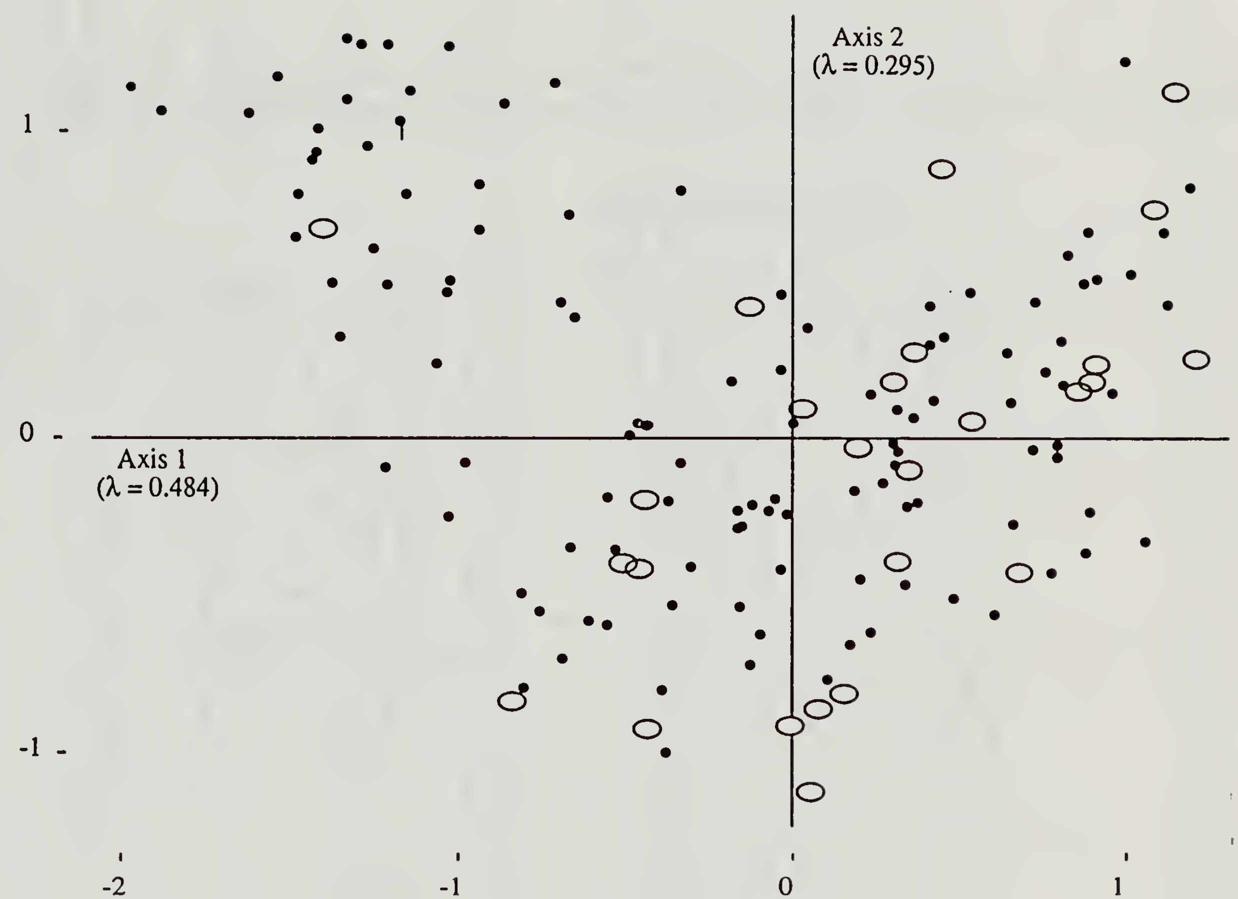

Fig. 5-1. CCA of Buffalo River shrub species ordination. Each point represents a single plot (N=142). A total of 377 species were found across all plots. O = rare species encountered.

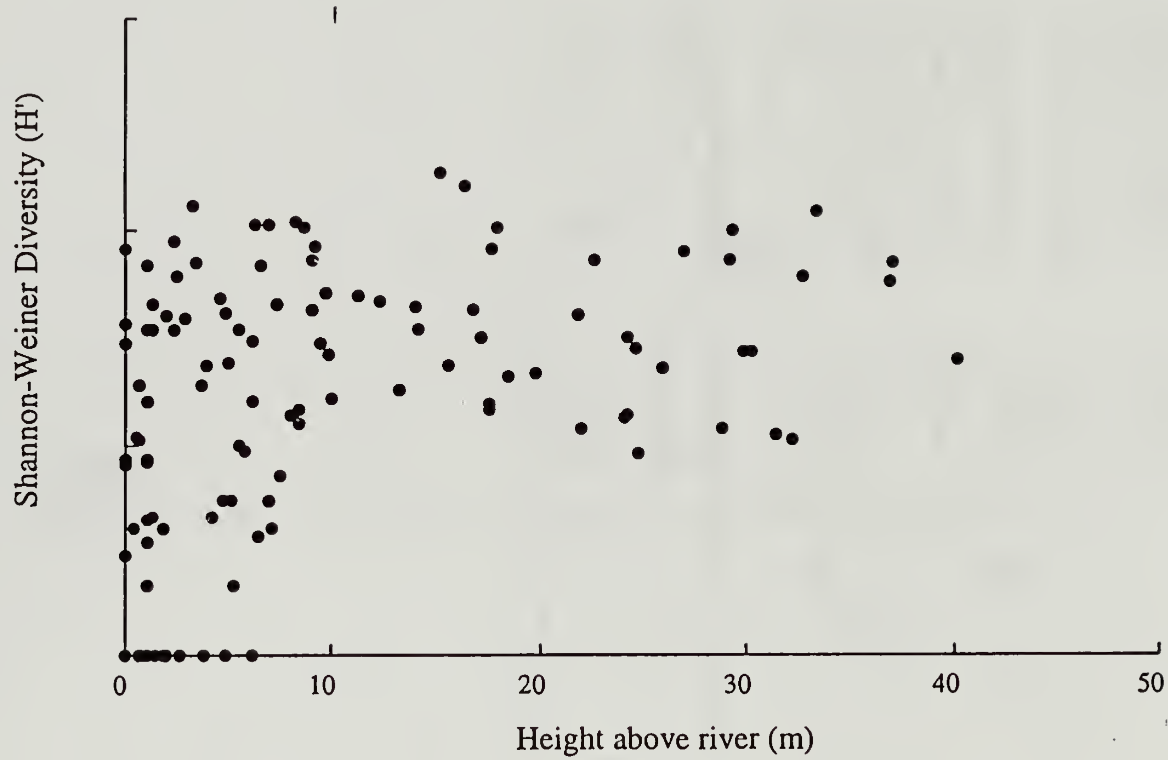

Fig. 5-2. Relationship between the Shannon-Weiner Diversity Index (Barbour et al. 1987) and elevation. A total of 66 tree species were found across 100 plots.

OBJECTIVE 6

To determine the presence of any exotic species, the extent of invasion and assess the potential effects on natural communities.

Methods

Woody and herbaceous species lists of all species encountered in the 1994 and 1995 sampling in the BNR were compared with lists of pest species in five different habitat types in the BNR

Discussion

Disturbed sites are known to be prime sites for invasions of exotic and pest plant species (Elton 1958). Pest species were uncommon in upland, secondary forest but were found more frequently in disturbed areas such as gravel bars, old fields, campsites and old cemeteries (Table 6-1). The distributions of these species among forest types is statistically different from random ($P<0.001$, $\chi^2=197.03$, df = 24) with exotics encountered significantly more frequently in disturbed sites. Although the samples in this survey were dominated by secondary forest sites, old fields, campsites and old cemeteries were the primary source of exotic plant species. The absence of a closed canopy is likely to promote invasions into disturbed sites such as gravel bars, old fields and campsites (Cavers and Harper 1967, Rejmanek 1989). Old cemeteries host a few exotic species that probably persist from ornamental or horticultural plantings (e.g., persimmon, Japanese honeysuckle), and their ability to invade secondary forest is unknown.

Table 6-1. Proportion of sampling plots of five land used types in which the pest or exotic species occur. Distributions differ significantly from random (P<0.001).

	Common name	Secondary forest	Gravel bar	Old field	Camp-site	Old cemetery
number of plots		81	28	11	35	11
Diospyros virginiana L.	Persimmon	1	25	8	0	27
Festuca arundinaceae Schreb.	Fescue	4	5	23	8	0
Gleditsia triacanthos L.	Honey locust	1	15	23	0	0
Lespedeza cuneata (Dumont) G. Don.	Bush clover	0	10	0	0	9
Lonicera japonica Thunb.	Japanese honey-suckle	1	0	0	0	18
Robinia pseudo-acacia L.	Black locust	2	30	0	3	18
Rosa multiflora Thunb.	Multiflora rose	1	5	0	0	0
Proportion of plots with pest species		9.5%	45.0%	30.8%	5.3%	18.2%

The secondary forest of the BNR appears to be resistant to invasion by pest species. Only 9.5% of the secondary forest sample plots contained pest species compared to 45% and 30.8% for gravel bars and old fields, respectively (Table 6-1). Restoration of secondary forest in old fields will facilitate the elimination of exotics from the BNR, but there is little that can be done to slow the colonization of gravel bars by pests. We suggest that restoration efforts in old fields be doubled, and that that large gravel bars be monitored for the growth of pest species populations.

OBJECTIVE 7

Analyze information collected to develop plans for additional research, monitoring, restoration and management.

Discussion

We used standard plot frame sampling protocols to characterize plant species assemblages within the BNR riparian corridor. A standard sampling strategy should incorporate traditional sampling methods, such as sampling along transects, to provide quantitative data that can be statistically analyzed. We strongly recommend that in a project designed to characterize the natural vegetation, that sample sites be chosen randomly or haphazardly, and that data are collected that can be evaluated statistically. Multivariate methods, such as DCA and CCA, are commonly used and are robust to many shortcomings of ecological data sets (Palmer 1993). We also argue that all species rather than a select group of species must be included in the analysis or else the interpretation must be restricted to the species included in the analysis. Further, we recommend that all vegetation layers be included because the species-rich vegetation layers (shrubs, herbs) hold more information about microgradients and substrate heterogeneity than the species-poor tree vegetation layer.

Restoration efforts should be aimed at reestablishing fully functional ecosystems with all of the attributes of native vegetation. Central to ecosystem function is diversity and complexity (Tilman 1988). The results presented herein establish guidelines for restoration of biological complexity on common landforms within the BNR. Restorative species were identified for five geomorphic landforms common in the BNR. Criteria for restorative species are that they are common, they grow rapidly and they are easy to propagate. Many bottomland species, such as Ward's willow, boxelder, sycamore and American elm are common in the bottomland groups, fit the remaining criteria of fast growth and ease in propagation, and are ideal candidates for restoration of bottomlands. Candidate species for upland sites are American elm, maple species and green ash.

Although species and species groups were shown to be associated with geomorphic landforms, riparian species fail to form unique or characteristic assemblages within the riparian corridor. Correspondence analysis demonstrated that tree, shrub and herb species were distributed along gradients of soil pH and elevation. Despite large correlations with environmental variables, species do not to form cohesive or distinct communities. Rather, successive species replacements occur as a function of variation in the environment (Pickett 1980). Plant species occur in a characteristic, limited range of habitats and within their range they tend to be most abundant around their particular environmental optima (Ter Braak and Prentice 1988). Soil pH and elevation (i.e., height above river) are well-defined gradients strongly correlated with plant species distributions in the BNR. In the riparian zone of the BNR, plant associations grade continuously from a unique gravel bar assemblage to an equally unique upland forest of oaks and hickories, and between the extremes fail to sort into distinguishable or unique associations along the gradients.

Trees, shrubs and herbs may be tracking different environmental variables. All ordinations identified pH and elevation as important environmental variables, but the relative importance of the remaining variables differed among vegetation layers. For example, slope and organic matter content were highly correlated with tree, but not shrub distributions on the second axis. Stoniness (i.e., fines) was correlated with the second axis of the shrub, but not tree ordination. Percent sand was correlated with the second axis of the herb, but not the tree nor the shrub ordinations. Since trees, shrubs and herbs differ in their morphologies, physiologies and life histories (Körner 1994), it is not surprising that they respond differently to environmental gradients. Nonetheless, it is important to recognize vegetation layers may behave as different functional groups that respond differentially to variability in the environment.

Species assemblages in heavily managed areas are distinct from natural species assemblages. These heavily used areas are highly correlated with sandy soils, low organic matter content, and high soil pH. The effects of removing canopy cover combined with the action of exotic species are likely modifying soil quality. Changing substrate quality may alter the regular pattern of succession (D'Antonio and Vitousek 1992), and further influence the successful reintroduction and re-establishment of native species.

Our sampling strategy was designed to characterize the vegetation by sampling the most common species, yet a number of rare and threatened species were found, predominantly in mid-, to upper elevation sites. Although most rare and endangered species were encountered in upper elevation sites, rare herbs were found in two campsites and one old field. These populations persist despite heavy and intense use by park visitors. We recommend that the status of these populations be monitored regularly.

Exotic and pest species were uncommon in secondary forest, but were abundant in all disturbed sites. Disturbed sites, such as gravel bars and old fields are points of entry for invasive species. Hayfield sites should be managed to hasten recovery to less invasible secondary forest. Gravel bar sites should be monitored for the incidence and growth of threatening populations.

Most studies designed to characterize the vegetation of the Ozarks have included only tree species, and often trees >10 cm dbh (Read 1952, Nigh et al. 1985, Ware et al. 1992). Sampling the lower vegetation is tedious, time-consuming and difficult (C. Sagers, personal observation) and it is argued that the tree layer is biologically more important because its biomass dominates the landscape. However, the usefulness of sampling the lower vegetation was apparent in attempting to distinguish riparian communities. Patterns in plant community structure that were masked in the tree layer were clearly discernible in the shrub and herb layers. Gravel bar sites were an emergent group in the shrub and herb ordinations but were indistinct in the tree layer. The species richness of the lower vegetation layer is 5.7 greater than the tree layer, and is probably more responsive to microenvironmental heterogeneity and to disturbance. We suggest that if the goal of management is to monitor and remediate plant communities, then research efforts should focus on the lower, more diverse vegetation of the shrub and herb layers, or alternatively, that studies of the tree layer be conducted over longer periods to accommodate the slow response of this layer to environmental perturbation.

The overriding objective of this study was to identify and characterize plant communities in the riparian zone of the Buffalo National River. Although the gravel bar sites are somewhat distinct, the remaining plots form a continuum and fail to fall within identifiable bounds. Therefore, it is difficult to recommend where the boundaries of the riparian zone should be drawn since no clear zonation between mid-, and upper elevation sites exists. Because the riparian zone represents an ecocline, it is unlikely that communities within the riparian zone can be clearly defined, nor that the boundary of the riparian zone can be established. Further, because landscape position showed little relationship with species richness or diversity, we recommend that preservation efforts be directed at the ecosystem/watershed level to conserve the diversity and complexity of the forested mid-slope.

The corridor of forest that meanders with the BNR is surrounded by old fields, a large component of bottomland vegetation. Hayfields are major disruptions of natural plant communities since they are sources of exotics, serve as nurseries for invasive species, and promote soil degradation and nutrient loss. We recommend that future research efforts be invested in restoring old fields to their native composition and diversity.

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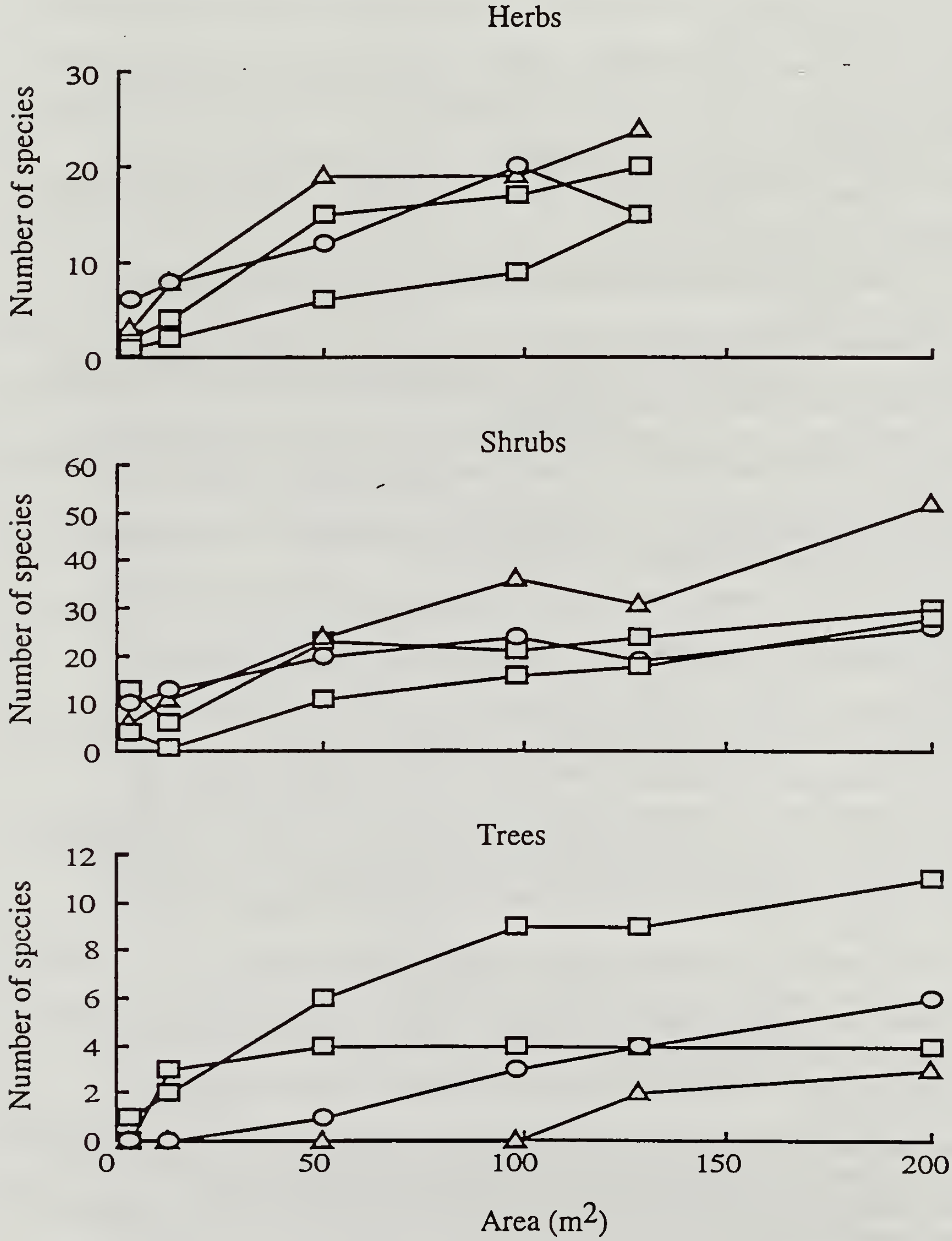
Appendix I.

Species-area curves of plots of varying size at four riparian sites - Species area curves were constructed from nested sampling plots at four transect sites within the BNR riparian corridor. Herbs, shrubs and trees were sampled following the protocols given in Objective 1 (Methods: Vegetation sampling). Optimal sampling area is the decided as the average inflection point for each vegeation layer at each site (i.e., $50m^2$).



Appendix II.

Acronyms of sites, site names, quad location and forest group classification.

Sites	Site Name	Quad location	Forest group
BC1	Brown's Cemetary	Jasper	Gravel bar
BC2			Active bank
BC3			Floodplain
BCD1	Brown's Cemetary Downstream	Jasper	Gravel bar
BCD2			Active bank
BCD3			Active bank
BCD4			Slope
BCD4'			Upslope
BCD5			Upslope
BCD6			Upslope
BH1	Blue Hole	Mt. Judea	Active bank
BH2			Slope
BH3			Slope
BP1	Buffalo Point	Cozahome	Campsite
BP2			Campsite
ERC1	Erbie Campground	Jasper	Campsite
ERC2			Campsite
GF1	Grinder's Ferry	Snowball	Campsite
GF2			Campsite
GF3			Campsite
GH1	Gaddy House	Jasper	Gravel bar
GH2			Slope
GH3			Slope
GH4			Slope
GH5			Upslope
GIL1	Gilbert	Marshall	Campsite
GIL2			Campsite
GIL3			Campsite
GIL4			Campsite
GIL5			Campsite
GIL6			Campsite
HLW1	Hasty Low Water Bridge	Hasty	Active bank
HLW2			Slope
HLW3			Slope
HLW4			Upslope
HLW5			Upslope
HBR1	Hellbender	Cozahome	Gravel bar
HBR2			Gravel bar
HB3			Floodplain
HB4			Floodplain
HWB1	Hayfield at Wilderness Boundary	Boxley	Old field
HWB2			Old field
KL1	Kyle's Landing	Ponca	Gravel bar
KL2			Active bank
KL3			Floodplain
KL4			Slope
KL4'			Slope
KL5			Slope

Appedix II cont.

Sites	Site Name	Quad location	Forest group
KL6			
KLC1	Kyle's Landing Campground	Ponca	Campsite
KLC2			Campsite
KLC3			Campsite
MJ1	Marni and John's House	Hasty	Gravel bar
MJ2			Gravel bar
MJ3			Gravel bar
MJ4			Gravel bar
MJ5			Gravel bar
MJ6			Gravel bar
MJ7			Slope
MJ8			Upslope
MH1	Mike's House	Jasper	Active bank
MH2			Slope
MH3			Slope
MH4			Upslope
MH5			Upslope
MHI1	Mike's House Island	Jasper	Gravel bar
MHI2			Gravel bar
MHI3			Gravel bar
MC1	Morris Cemetary	Eula	Active bank
MC2			Slope
MC3			Slope
MC4			Slope
MC5			Upslope
MC6			Upslope
MC7			Upslope
MC8			Upslope
MTH1	Mt. Hershey	Western Grove	Active bank
MTH2			Slope
MTH3			Slope
MTH4			Upslope
MTH5			Upslope
MTH6			Upslope
NM1	North Maumee	Maumee	Active bank
NM2			Slope
NM3			Slope
NM4			Upslope
NM5			Upslope
NM5'			Upslope
NM6			Upslope
OZC1	Ozark Campground	Jasper	Campsite
OZC2			Campsite
OZC3			Campsite
PF1	Plum Field	Maumee	Gravel bar
PF2			Gravel bar
PF3			Slope
PF4			Slope
PF5			Upslope
PF6			Upslope

Appendix II cont.

Sites	Site Name	Quad location	Forest group
PF7			Upslope
PF8			Upslope
PRC1	Pruitt Campground	Jasper	Campsite
PRC2			Campsite
PRC3			Campsite
RU1	Rush	Cozahome	Campsite
RU2			Campsite
RU3			Campsite
SEE1	Shine Eye East	Snowball	Active bank
SEE2			Floodplain
SEE3			Slope
SEE4			Upslope
SEW1	Shine Eye West	Snowball	Campsite
SEW2			Campsite
SEW3			Campsite
SEW4			Campsite
SEW5			Campsite
SEW6			Campsite
SM1	South Maumee	Maumee	Old field
SM2			Old field
SM3			Old field
SPC1	Spring Creek	Cozahome	Gravel bar
SPC2			Gravel bar
SPC3			Gravel bar
SPC4			Gravel bar
SPC5			Slope
SPC6			Upslope
SPC7			Upslope
SPC8			Upslope
SPC9			Upslope
SC1	Steel Creek	Ponca	Old field
SC2			Old field
SC3			Old field
SCNA1	Steel Creek Natural Area	Ponca	Active bank
SCNA2			Slope
SCNA3			Upslope
SCNA4			Upslope
SGH1	Sweet Gum Hollow	Eula	Active bank
SGH2			Slope
SGH3			Slope
SGH4			Upslope
TB1	Tyler Bend	Snowball	Campsite
TB2			Campsite
TB3			Campsite
TB4			Campsite
WB1	Wilderness Boundary	Boxley	Gravel bar
WB2			Gravel bar
WB3			Gravel bar
WB4			Floodplain
WB5			Floodplain

Appendix II cont.

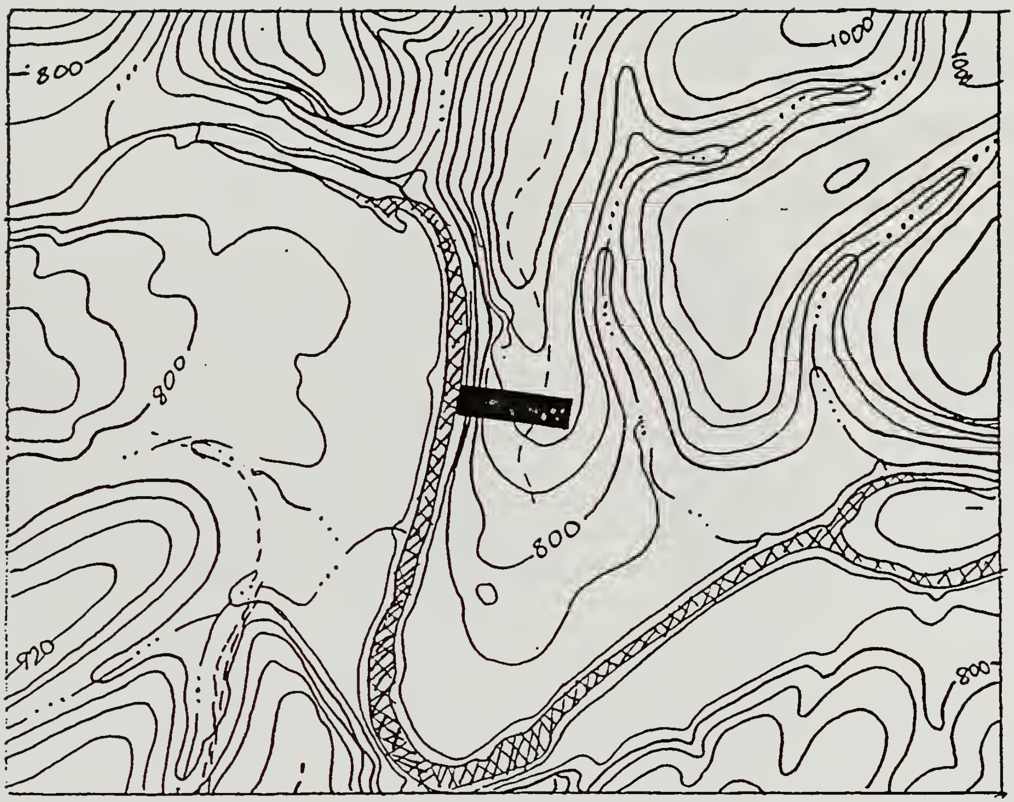
Sites	Site Name	Quad location	Forest group
WB6			Floodplain
WB7			Floodplain
WB8			Upslope
WB9			Upslope
WF1	White Ford	Snowball	Gravel bar
WF2			Gravel bar
WF3			Gravel bar
WF4			Slope
WF5			Slope
WOL1	Woolum	Eula	Old field
WOL2			Old field
WOL3			Old field
ZH1	Zen House	Hasty	Gravel bar
ZH2			Floodplain
ZH3			Floodplain
ZH4			Floodplain
ZH5			Slope
ZH6			Slope

Appendix III.

Location of secondary forest transects by USGS 7.5' quadrangle maps. Approximate transect location and direction indicated by dark bar. All maps oriented with the top of the page as due north.

Scale for all figures:

1" = 1000 ft	1 cm = 0.12 km
5.25" = 1 mile	8.4 cm = 1.0 km



Site name: Blue hole

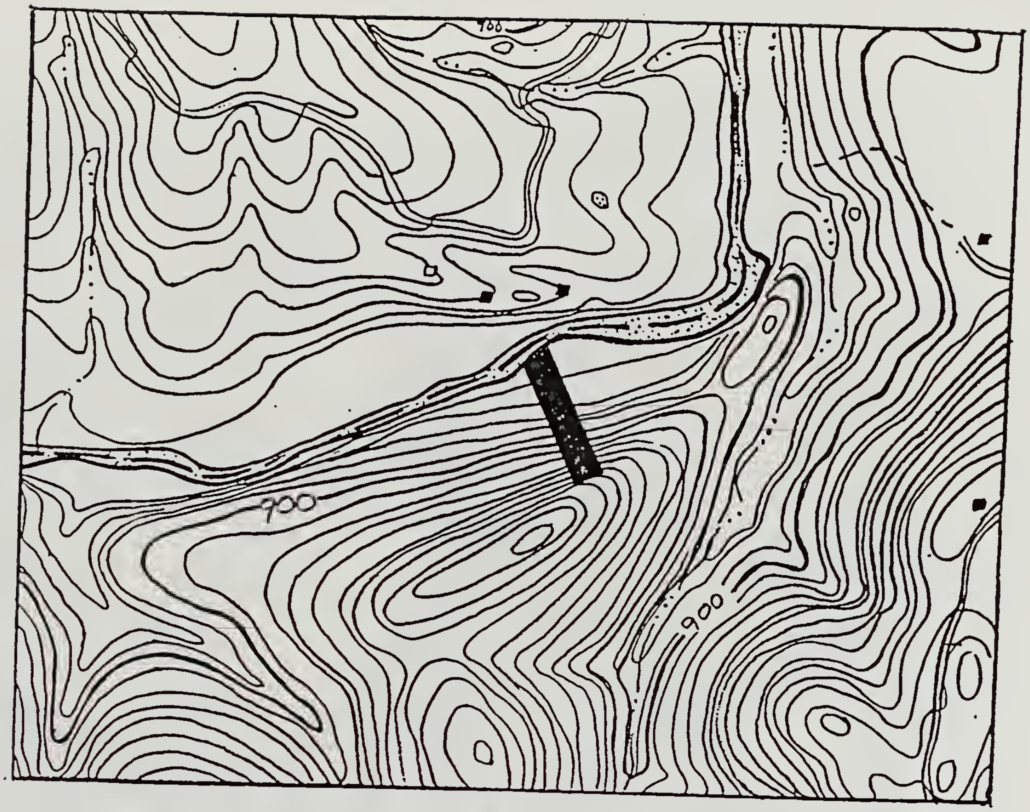
USGS quad: Mt. Judea

Number of plots: 3

Site name: Brown’s Cemetery

USGS quad: Jasper

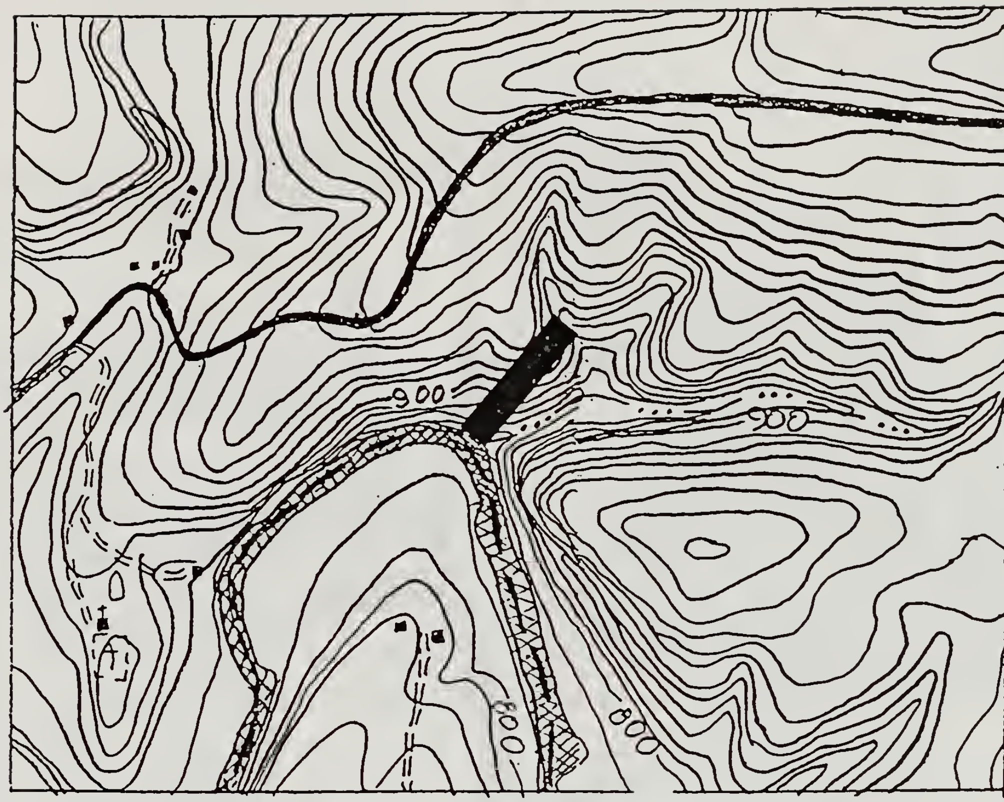
Number of plots: 3



Site name: Brown's Cemetery Downstream

USGS quad: Jasper

Number of plots: 6



Site name: Gaddy House

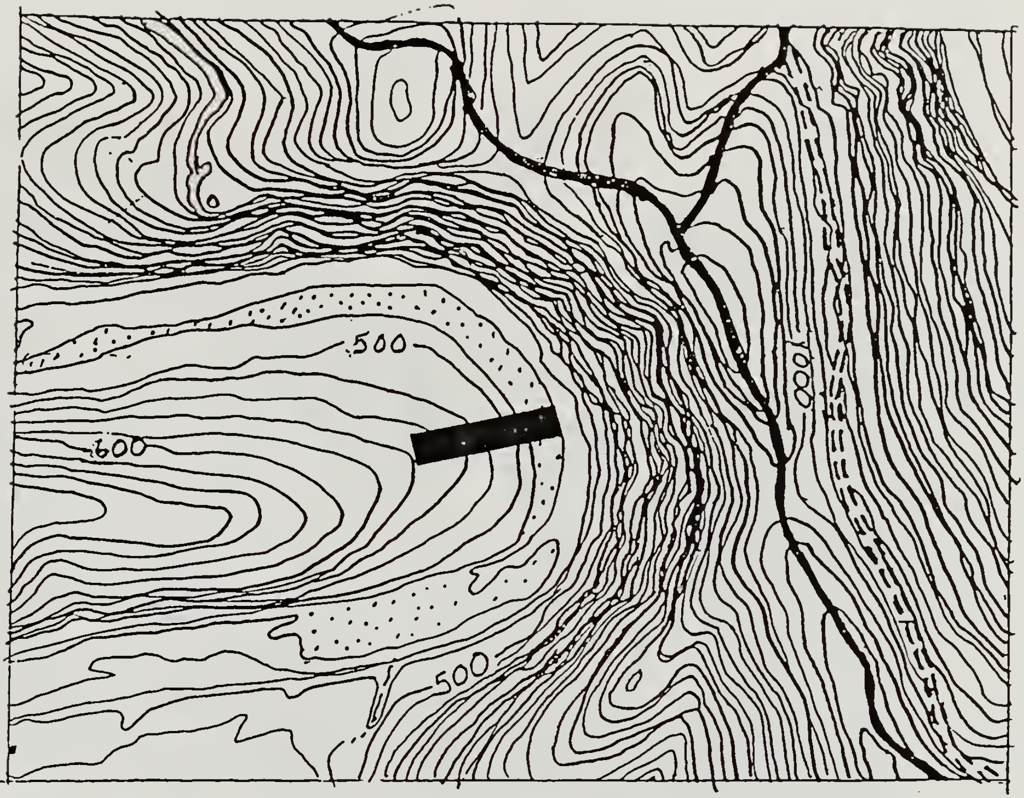
USGS quad: Jasper

Number of plots: 5

Site name: Hasty Low Water Bridge

USGS quad: Hasty

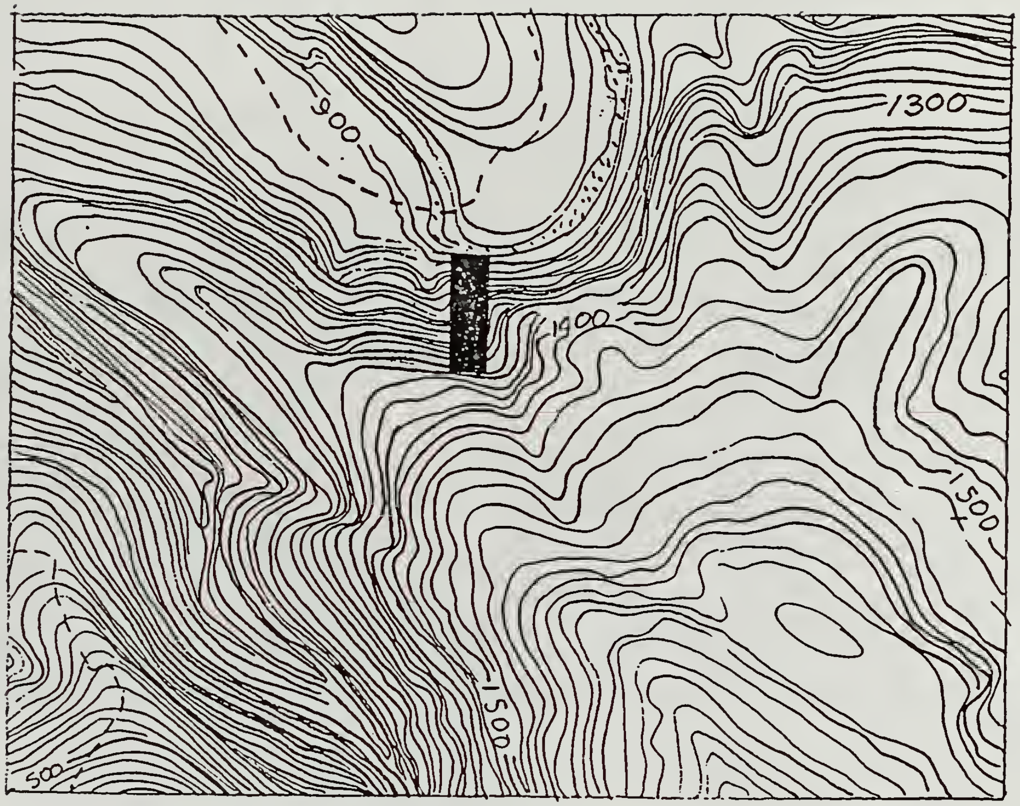
Number of plots: 5



Site name: Hellbender

USGS quad: Cozahome

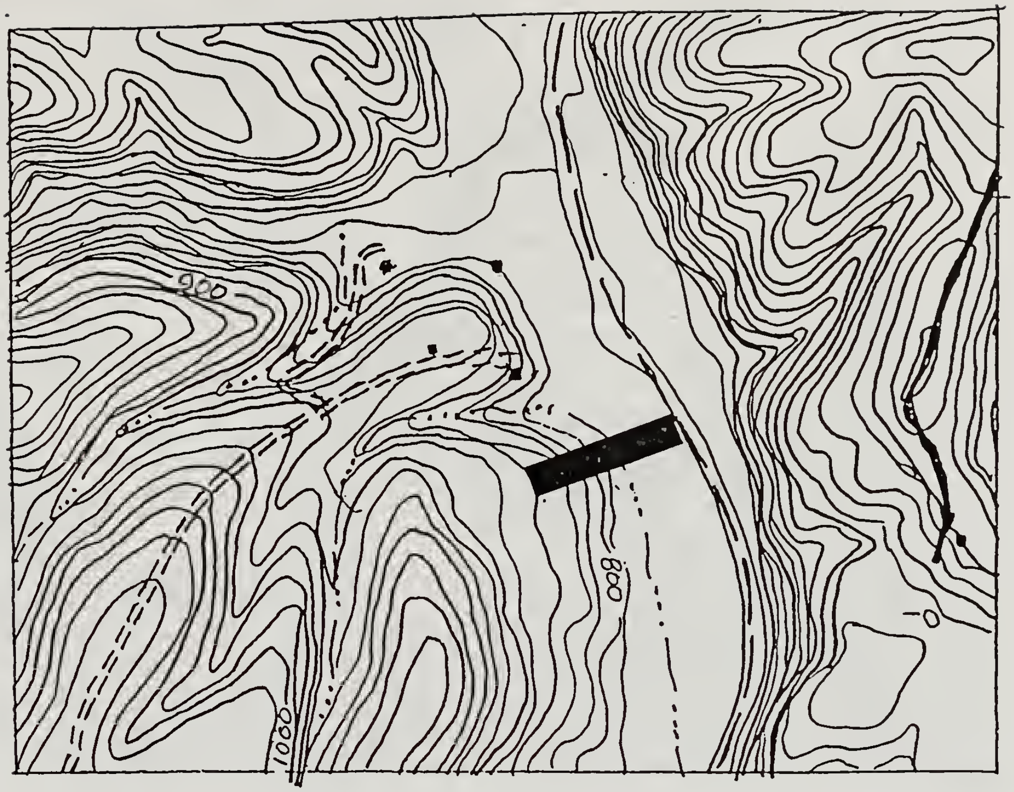
Number of plots: 4



Site name: Kyle's Landing

USGS quad: Ponca

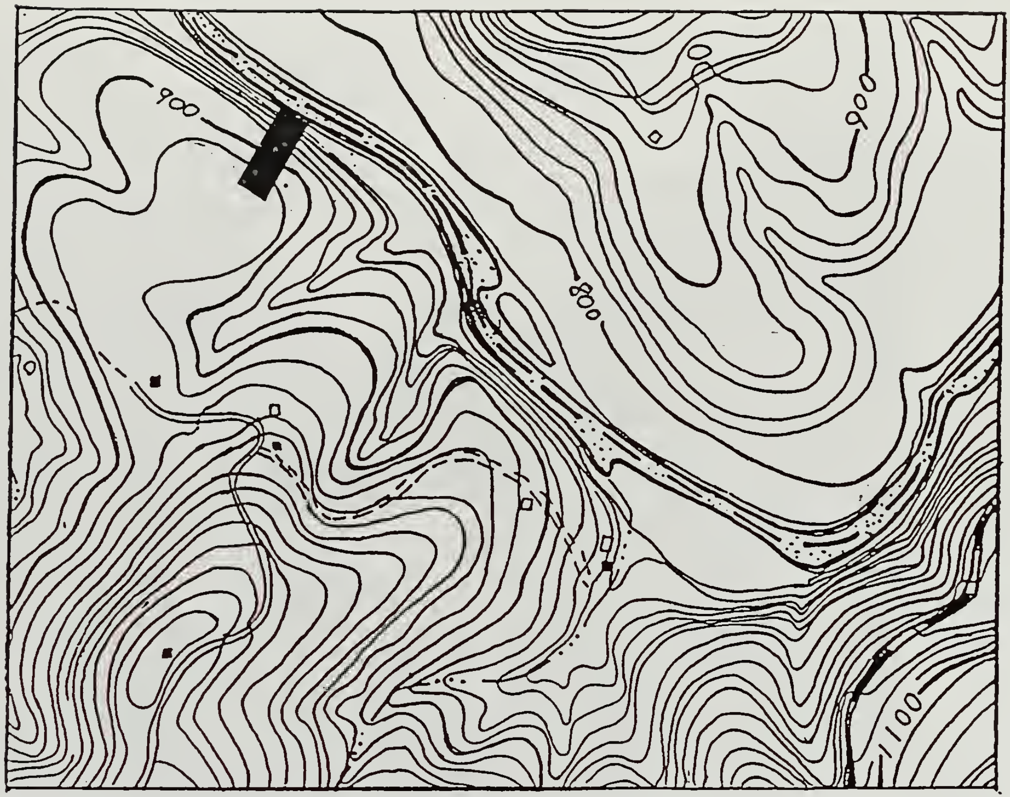
Number of plots: 6



Site name: Marni and John's House

USGS quad: Hasty

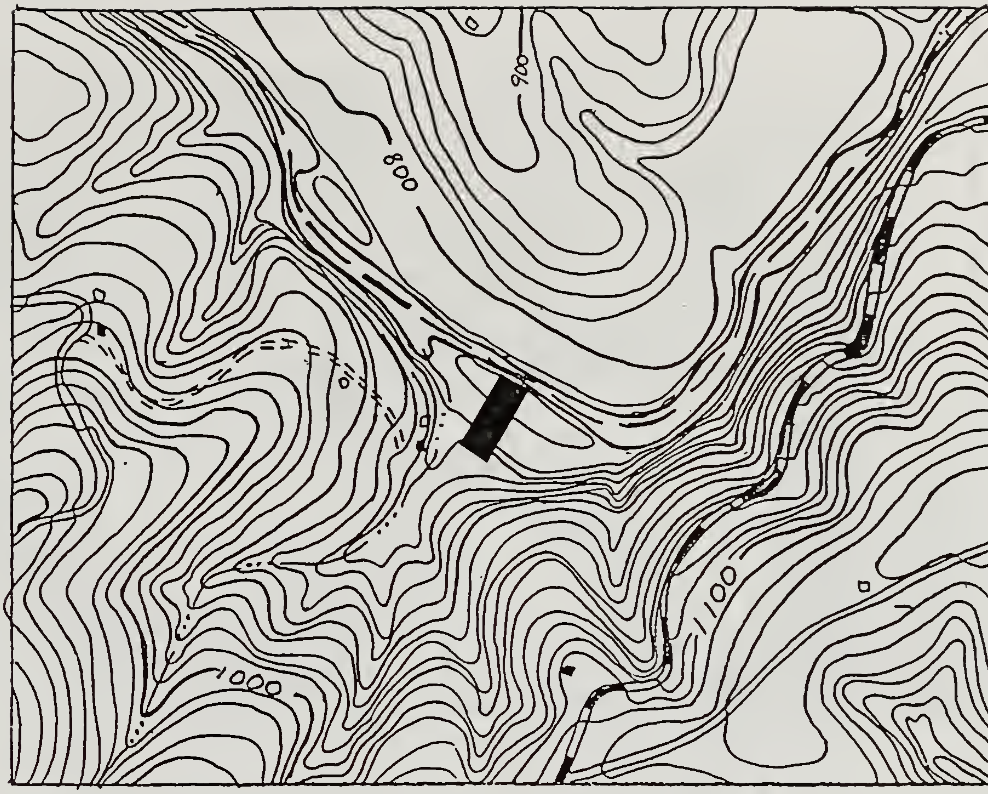
Number of plots: 8



Site name: Mike's House

USGS quad: Jasper

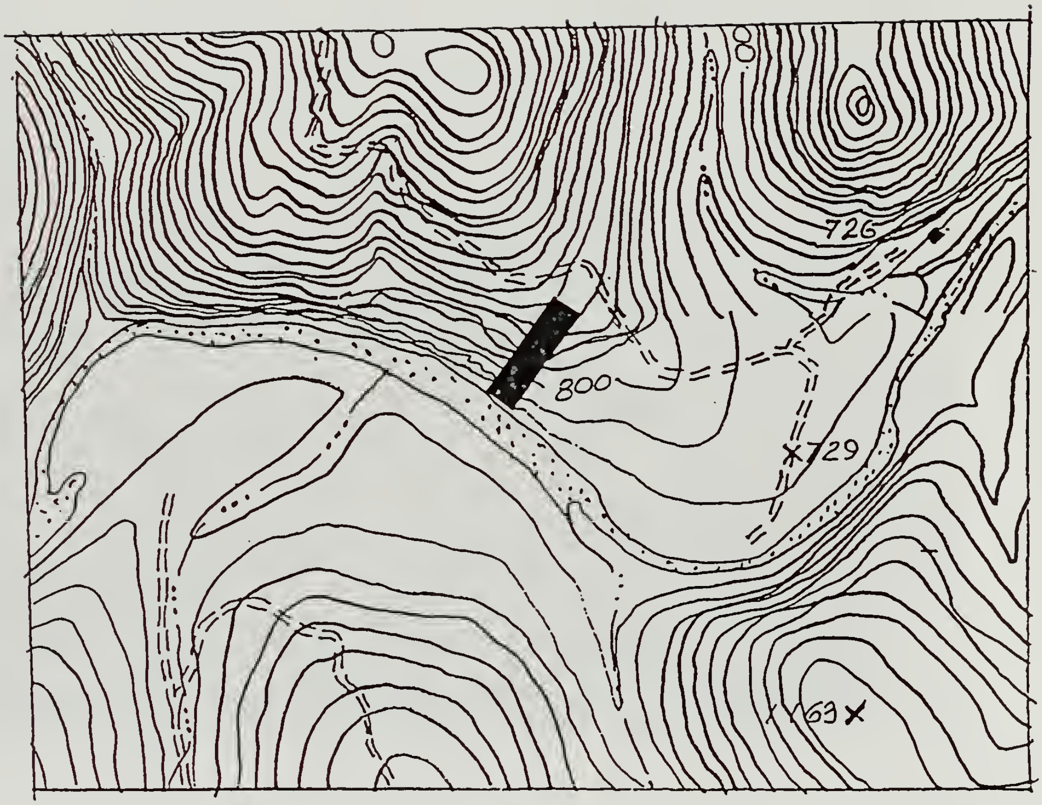
Number of plots: 5



Site name: Mike's House Island

USGS quad: Jasper

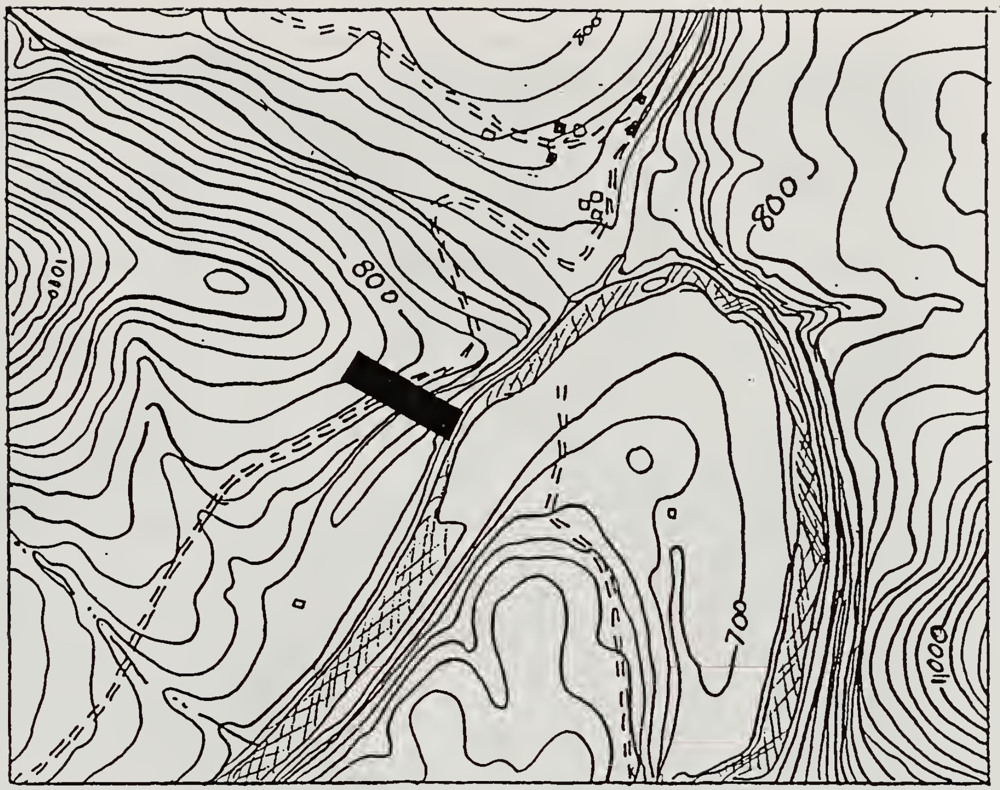
Number of plots: 3



Site name: Morris Cemetery

USGS quad: Eula

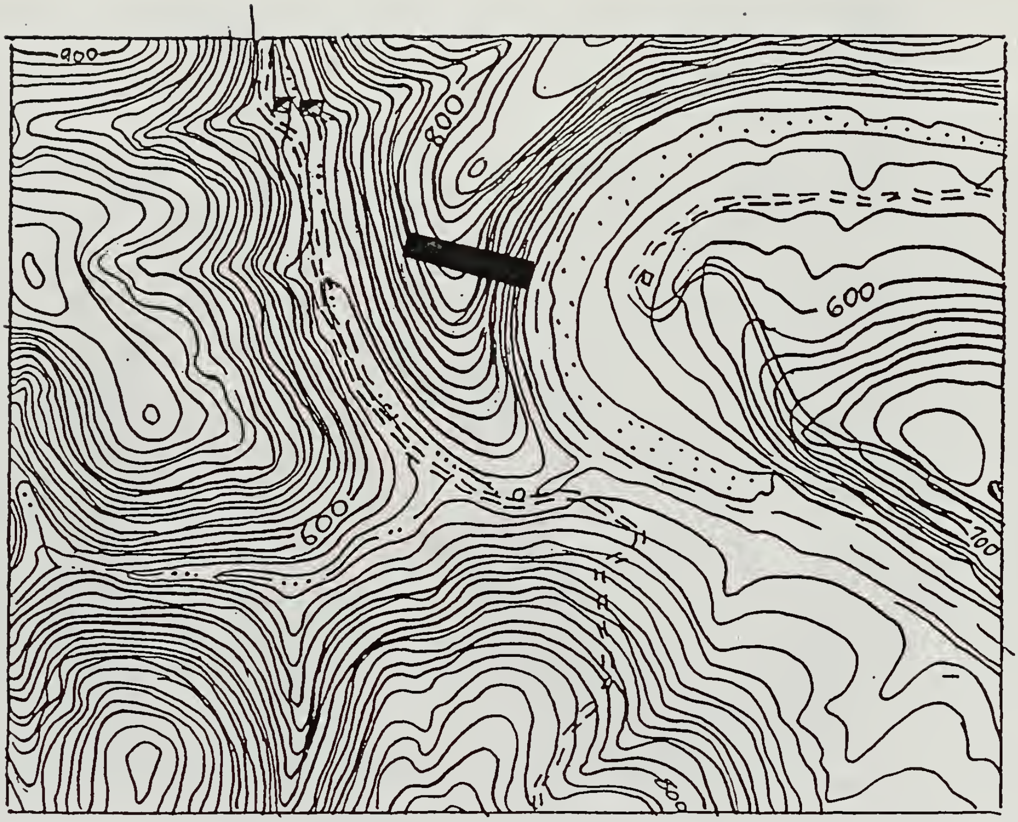
Number of plots: 8



Site name: Mt. Hershey

USGS quad: Western Grove

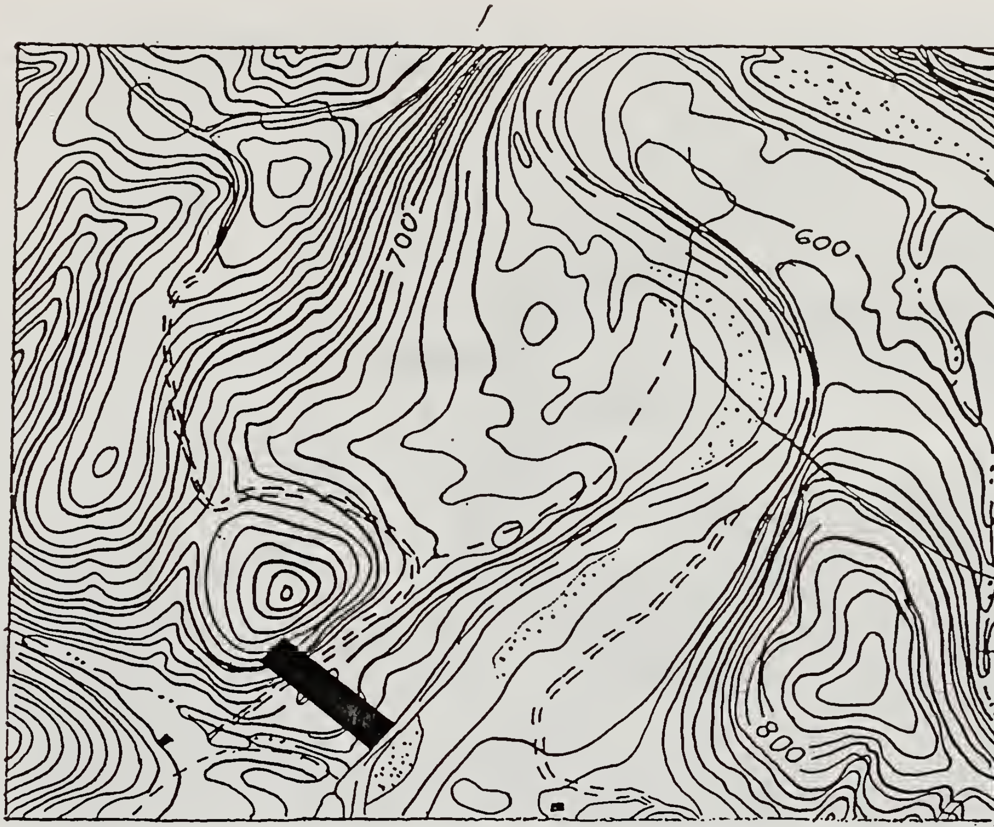
Number of plots: 6



Site name: N. Maumee

USGS quad: Maumee

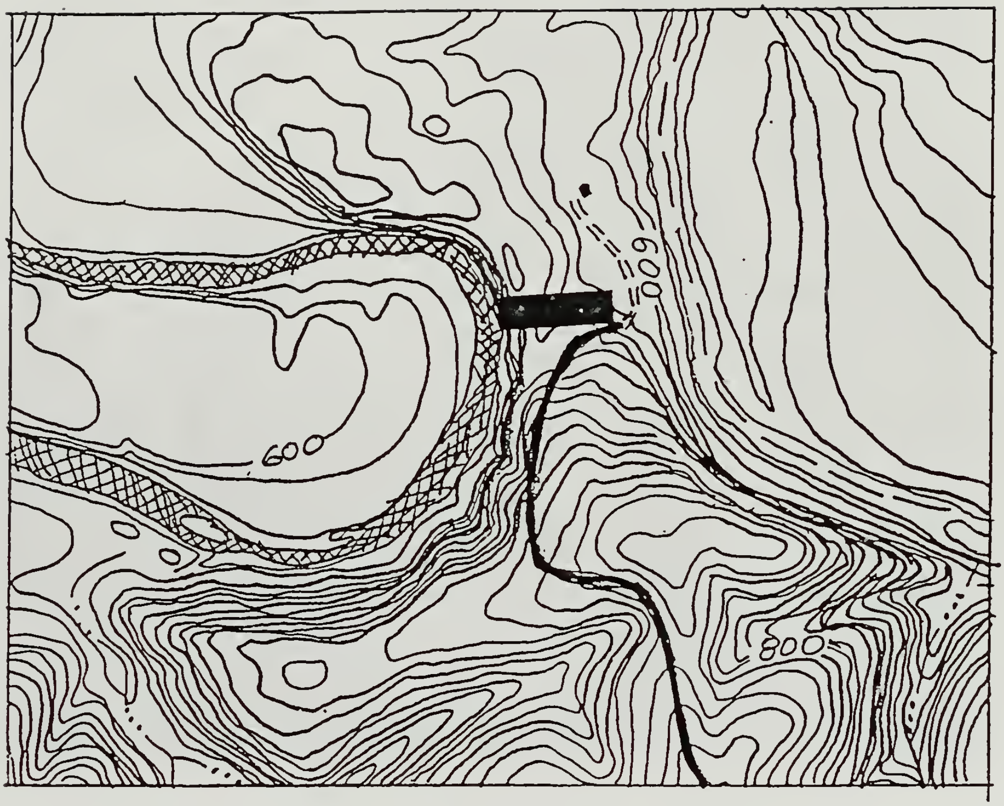
Number of plots: 6



Site name: Plum Field

USGS quad: Maumee

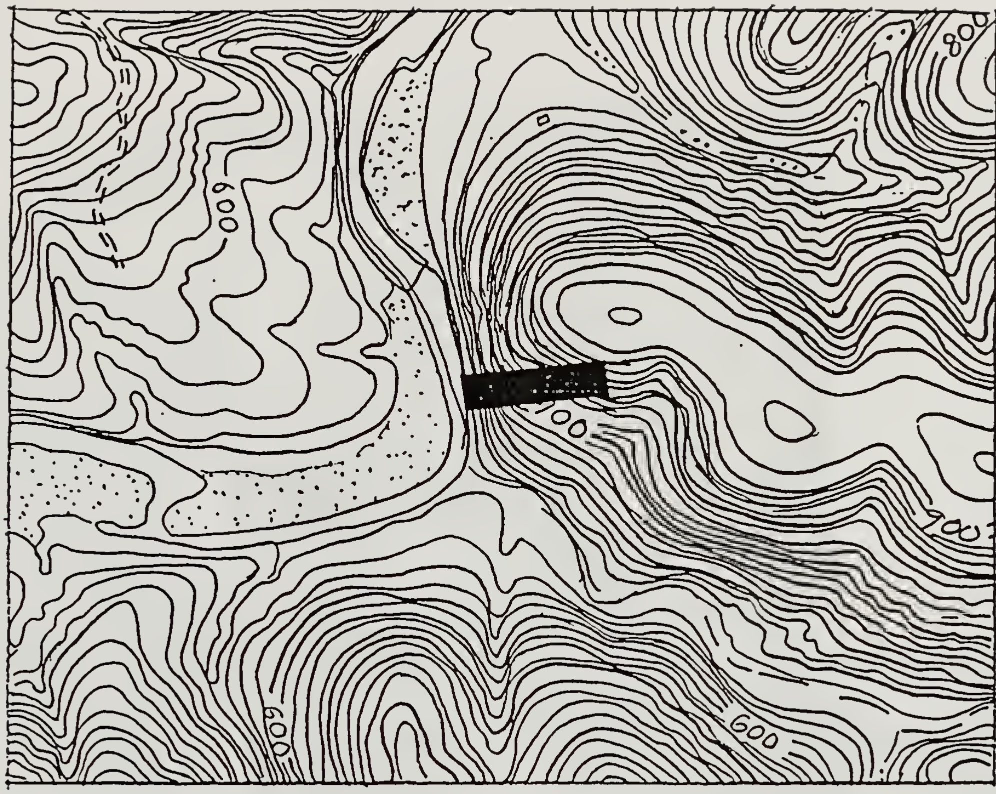
Number of plots: 8



Site name: Shine Eye East

USGS quad: Marshall

Number of plots: 4



Site name: Spring Creek

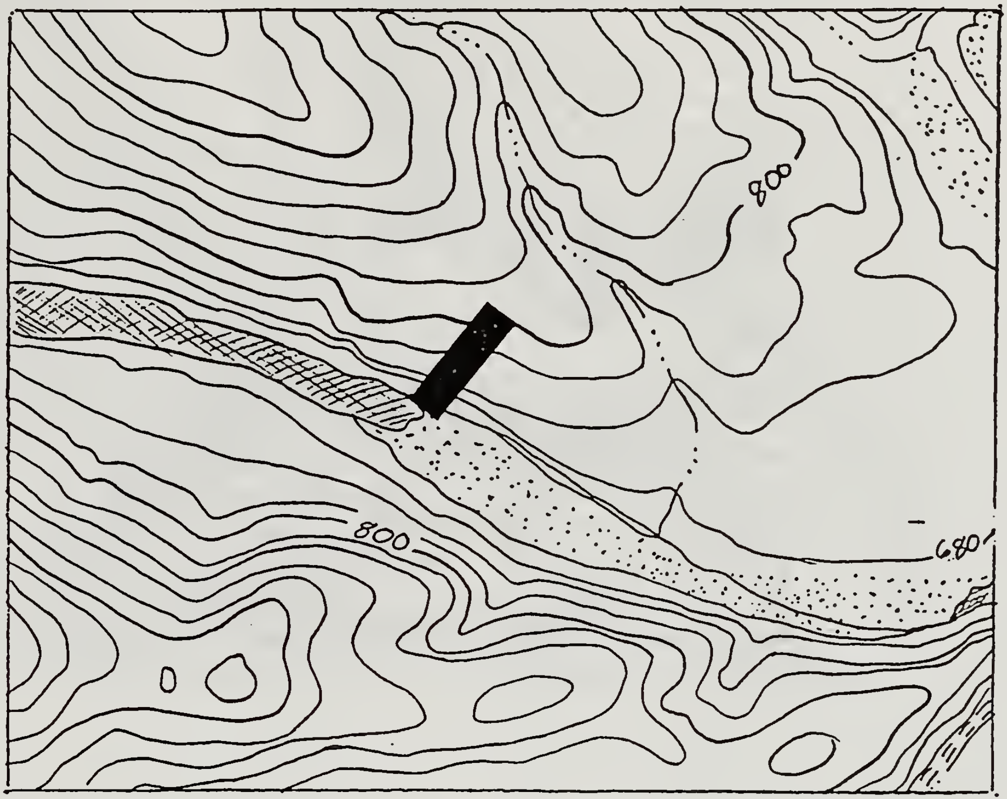
USGS quad: Cozahome

Number of plots: 9

Site name: Steel Creek Natural Area

USGS quad: Ponca

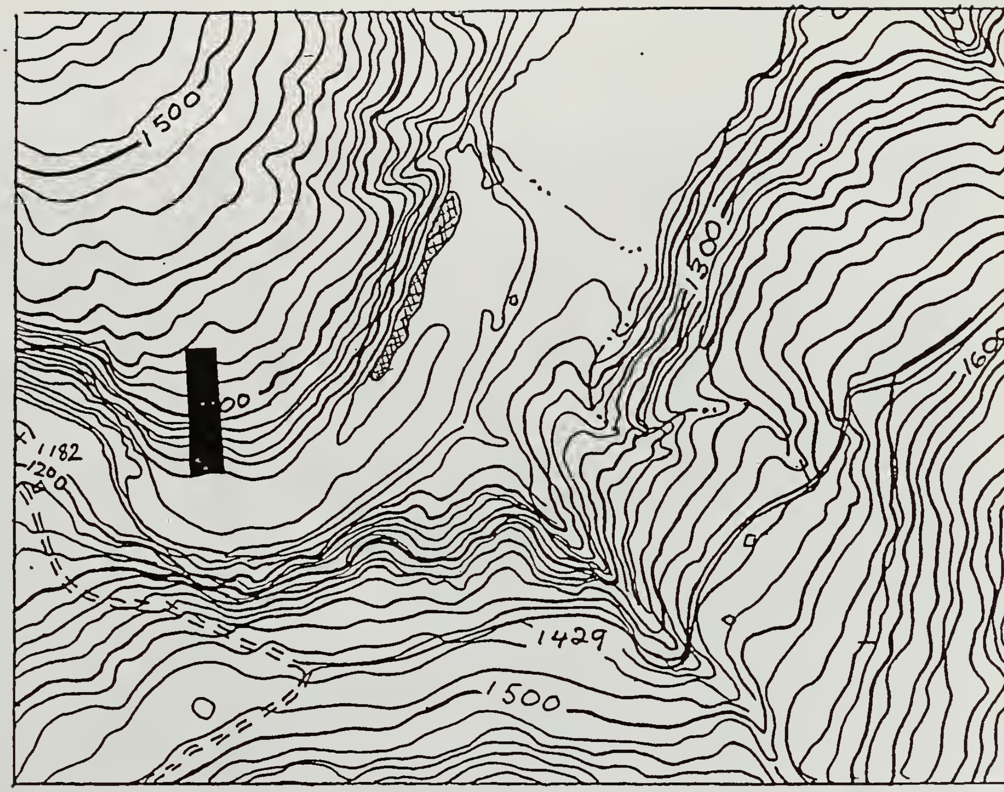
Number of plots: 4



Site name: Sweet Gum Hollow

USGS quad: Eula

Number of plots: 4



Site name: Wilderness Boundary

USGS quad: Boxley

Number of plots: 9

Site name: Zen House

USGS quad: Hasty

Number of plots: 6

Appendix IV.

Plant species acronyms

ACRH	*Acalypha rhomboidea*
ACNE	*Acer negundo*
ACRU	*Acer rubrum*
ACSA	*Acer saccharum*
ACES	*Acer saccharinum*
AEGL	*Aesculus glabra*
AGRO	*Agrimonia rostellata*
ALJU	*Albizia julibrissia*
ALVI	*Allium vineale*
AMSP	*Amarantha spinosus*
AMHY	*Amaranthus hybridus*
AMAR	*Ambrosia artemesiafolia*
AMBA	*Ambrosia artense*
AMTR	*Ambrosia trifida*
AMFR	*Amorpha fruticosa*
AMPA	*Ampelopsis arborea*
AMBR	*Amphicarpa bracteata*
AMIL	*Amsonia illustris*
ANPH	*Andrachyne phyllanthoides*
ANVI	*Anemone virginiana*
ANPL	*Antennaria plantaginifolia*
APAM	*Apios americana*
APCA	*Apocynum cannabinum*
ARSH	*Arabis shortii*
ARAT	*Arisaema atrorubens*
ARDR	*Arisaema dracontium*
ARTO	*Aristolochia tomentosa*
ARSE	*Aristolochia serpentaria*
ARGI	*Arundinaria gigantea*
ASCA	*Asarum canadense*
ASTR	*Asimina triloba*
ASPL	*Asplenium platyneuron*
ASDR	*Aster drummondii*
ASSP	*Aster* sp.
BAVU	*Barbarea vulgaris*
BESC	*Berchemia scandens*
BENI	*Betula nigra*
BESP	*Betula* sp.
BIFR	*Bidens frondosa*
BOCY	*Boehmeria cylindrica*
BOVI	*Botrychium virginianum*
BRJA	*Bromus japonicus*
BRPU	*Bromus pubescens*
BRTE	*Bromus tectorum*
BULA	*Bumelia lanuginosa*
CALY	*Calycocarpum lyonii*
CARA	*Campsis radicans*
CAPA	*Cardimine parviflora*
CAGR	*Carex grisea*
CALA	*Carex laxiflora*
CAOL	*Carex oligocarpa*
CAOX	*Carex oxylepsis*
CAPH	*Carex physorhyncha*
CARO	*Carex rosea*
CARS	*Carex* sp.
CACA	*Carpinus caroliniana*
CACO	*Carya cordiformis*
CASP	*Carya* sp.
CATS	*Catalpa speciosa*
CELA	*Celtis laevigata*
CEOC	*Celtis occidentalis*
CEPO	*Cercis canadensis*
CHSP	*Chaemaechrista* sp.
CHLA	*Chasmantheum latifolium*
CHAM	*Chenopodiium ambrosioidea*
CHAL	*Chenopodium album*
CHPU	*Chenopodium pumilo*
CHLE	*Chrysanthemum leucanthemum*
CIRA	*Cimicifuga racemosa*
CILY	*Cincerea lyonii*
CISP	*Cirsium* sp.
CLVE	*Clematis versicolor*
CLVI	*Clematis virginica*
CLMA	*Clitoria mariana*
COAM	*Cornus ammomum*
COCC	*Cocculus carolinus*
COER	*Commelina erecta*
COSE	*Convolvulus sepium*
CODR	*Cornus drummondii*
COFL	*Cornus florida*
COSP	*Corydalis* sp.
CRGL	*Croton glandulosus*
CRCA	*Cryptotaenia canadensis*
CUOR	*Cunila organoides*
CUSP	*Cuscuta* sp.
CYDA	*Cynodon dactylon*
CYRE	*Cyperus retroflexus*
CYPR	*Cystopteris protrusa*
DASP	*Danthonia spicata*
DACA	*Daucus carota*
DETR	*Delphinium tricorne*
DECA	*Desmodium canescens*
DEMA	*Desmodium marilandicum*
DEPA	*Desmodium paniculatum*
DENU	*Desmodium nudiflorum*
DERO	*Desmodium rotundifolium*
DESP	*Desmodium* sp.
DIAM	*Diarrhena americana*
DIPA	*Dirca palustris*
DISP	*Dicentra* sp.
DIBR	*Dicliptera brachiata*
DISA	*Digitaria sanguinalis*

DIGS	*Digitaria* sp.	ILDE	*Ilex decidua*
DITE	*Diodia teres*	IMSP	*Impatiens* sp.
DIVI	*Diodia virginiana*	IPCO	*Ipomoea coccinea*
DIOP	*Dioscorea oppositifolia*	IPLA	*Ipomoea lacunosa*
DIQU	*Diocsorea quaternata*	IPPA	*Ipomoea pandurata*
DIVI	*Diospyros virginiana*	ISBI	*Isopyron biternatum*
ECCR	*Echinochloa crusgalli*	JUNI	*Juglans nigra*
ELTE	*Eleocharis tenuis*	JUVI	*Juniperus virginiana*
ELCA	*Elephantopus carolinianus*	JUAM	*Justicia americana*
ELVI	*Elymus virginicus*	LAFL	*Lactuca floridana*
EQFE	*Equisetum x ferrissii*	LACA	*Laportea canadensis*
ERHI	*Erechtites hieraciifolia*	LEVI	*Leersia virginica*
ERAN	*Erigeron annuus*	LEPV	*Lepidium virginicum*
EUAT	*Euonymus atropurpureus*	LECU	*Lespedeza cuneata*
EUIN	*Eupatorium incarnatum*	LERE	*Lespedeza repens*
EUSE	*Eupatorium serotinum*	LEST	*Lespedeza stipulacea*
EUCO	*Euphorbia corollata*	LESS	*Lespedeza striata*
EUDE	*Euphorbia dentata*	LESV	*Lespedeza virginica*
EUNU	*Euphorbia nutans*	LICA	*Ligusticum canadense*
FAGR	*Fagus grandifolia*	LIBE	*Lindera benzoin*
FERN	Fern	LIST	*Liquidamber styraciflua*
FEAR	*Festuca arundinacea*	LIVR	Liverwort
FESP	*Festuca* sp.	LOJA	*Lonicera japonica*
FRAM	Fraxinus americana	LYSP	*Lythrum* sp.
FRPE	*Fraxinus pennsylvanica*	LUAL	*Ludwegia alternifolia*
FRQU	*Fraxinus quadrangulata*	MADI	*Matelea dicipiens*
GAAP	*Galium aparine*	MAGO	*Matelea gonocarpos*
GACI	*Galium circaezans*	MEOF	*Melilotus officinalis*
GACO	*Galium concinnum*	MECA	*Menispermum canadensis*
GAOB	*Galium obtusum*	MESP	*Mentha* sp.
GAPE	*Galium pedemontanum*	MIVI	*Microstegium vimineum*
GAPI	*Galium pilosum*	MISC	*Mikania scandens*
GASP	*Galium* sp.	MICL	Misc. clover
GATE	*Galium texense*	MIFO	Misc. forb
GATR	*Galium triflorum*	MIGR	Misc. grass
GULO	*Gaura longiflora*	MISE	Misc. seedling
GECA	*Geranium carolinianum*	MIUM	Misc. umbel
GEUC	*Geum canadense*	MISV	Misc. violet
GEVE	*Geum vernum*	MOCA	*Modiola caroliniana*
GLHE	*Glechoma hederacea*	MORU	*Morus rubra*
GLTR	*Gleditsia triacanthos*	MOSP	*Morus* sp.
GLST	*Glyeria striata*	MOSS	Moss
HAVI	*Hamamelis virginiana*	MUSP	*Muhlenbergia* sp.
HEPU	*Hedyotis purpurea*	MUTE	*Muhlenbergia tenuiflora*
HEAN	*Helianthus annuus*	MUSC	*Muhlenbergii schreberi*
HEDI	*Helianthus divaricatus*	MUSY	*Muhlenbergii sylvatica*
HEHI	*Helianthus hirsutus*	NYSL	*Nyssa sylvatica*
HETU	*Helianthus tuberosus*	OSLO	*Osmorhiza longistylis*
HEHE	*Heliopsis helianthoides*	OSVI	*Ostyra virginiana*
HEIN	*Heliotropum indicum*	OXSP	*Oxalis* sp.
HISC	*Hieracium scabrum*	PAQU	*Panax quinquefolia*
HYAB	*Hydrangea aborescens*	PAAC	*Panicum acuminatum*
HYAP	*Hydrophyllum appendiculatum*	PAAN	*Panicum anceps*
HYVI	*Hydrophyllum virginianum*	PABO	*Panicum boscii*

PACL	*Panicum clandestinum*	RUDS	*Rudbeckia* sp.
PACO	*Panicum commulatum*	RUPE	*Ruellia pedunculata*
PASP	*Panicum* sp.	SACA	*Salix caroliniana*
PAPE	*Parietaria pennsylvanica*	SANI	*Salix nigra*
PAQU	*Parthenocissus quinquefolia*	SALY	*Salvia lyrata*
PASE	*Paspalum setaceum*	SAMC	*Sambucus canadensis*
PALU	*Passiflora lutea*	SANC	*Sanicula canadensis*
PECA	*Pedicularis canadensis*	SAOF	*Saponaria officinalis*
PEFR	*Perilla frutescens*	SAAL	*Sasafras albidum*
PHAN	*Physalis angulata*	SCPU	*Scirpus pungens*
PHPU	*Philadelphus pubescens*	SCOL	*Scleria oligantha*
PHGL	*Phlox glaberrima*	SCSP	*Scleria* sp.
PHIN	*Phyla incisa*	SCEL	*Scutellaria eliptica*
PHLA	*Phyla lanceolata*	SCOV	*Scutellaria ovata*
PHNO	*Phyla nodiflora*	SEAU	*Senecio aureus*
PHPA	*Phlox paniculata*	SEOB	*Senecio obovatus*
PIEC	*Pinus echinata*	SEPL	*Senecio platensis*
PIPU	*Pilea pumila*	SESP	*Senecio* sp.
PLLA	*Plantago lanceolata*	SEVI	*Setaria viridis*
PLRU	*Plantago rugellii*	SIAN	*Sicyos angulatus*
PLSP	*Plantago* sp.	SIVI	*Silene virginica*
PLOC	*Platanus occidentalis*	SMRA	*Smilacina racemosa*
PODE	*Populus deltoides*	SMBO	*Smilax bona-nox*
POPE	*Podophyllum peltatum*	SMSP	*Smilax* sp.
POSE	*Polygala senega*	SMTA	*Smilax tamnoides*
POBI	*Polygonatum biflorum*	SOCA	*Solanum carolinense*
POLP	*Polygonum pennsylvanica*	SOSP	*Solanum* sp.
POLY	*Polygonum persicaria*	SOAR	*Solidago arguta*
POPU	*Polygonum punctatum*	SOCA	*Solidago caesea*
POSC	*Polygonum scandens*	SOLC	*Solidago canadensis*
POSP	*Polygonum* sp.	SOGI	*Solidago gigantea*
POVI	*Polygonum virginianum*	SOLS	*Solidago* sp.
POCA	*Polymnia canadensis*	SOHA	*Sorghum halepense*
PORE	*Polymnia reptens*	STEP	*Stachys eplingii*
POUV	*Polymnia uvedalia*	STTR	*Staphyla trifoliata*
PRVU	*Prunella vulgaris*	STME	*Stellaria media*
PRSE	*Prunus serotina*	STHE	*Strophostyles helvula*
PRSP	*Prunus* sp.	STDI	*Stylophorum diphyllum*
QUAL	*Quercus alba*	SYOR	*Symphoricarpus orbicularis*
QUFA	*Quercus falcata*	TAOF	*Taraxacum officinale*
QUMA	*Quercus marilandica*	THTH	*Thalictrum thalictroides*
QUMU	*Quercus muhlenbergii*	THTR	*Thaspium trifoliatum*
QUPR	*Quercus prinoides*	TIAM	*Tilia americana*
QURU	*Quercus rubra*	TORA	*Toxicodendron radicans*
QUST	Quercus stellata	TRCA	*Trifolium campestre*
RAHI	*Ranunculus hispitus*	TRRE	*Trifolium repens*
RASP	*Ranunculus* sp.	TRSP	*Trifolium* sp.
RHCA	*Rhamnus caroliniana*	TRIS	*Trillium* sp.
RHAR	*Rhus aromatica*	ULAL	*Ulmus alata*
RHGL	*Rhynchosia latifolia*	ULAM	*Ulmus americana*
ROPS	*Robinia pseudo-acacia*	ULSP	*Ulmus* sp.
ROMU	*Rosa multiflora*	VAAR	*Vaccinium arboreum*
RUSP	*Rubus* sp.	VAPO	*Vaccinium pollidum*
RULA	*Rudbeckia lacinata*	VESP	*Verbesina* sp.

VEAR	*Vernonia arkansana*
VERA	*Veronica arvensis*
VIMO	*Viburnum molle*
VIRU	*Viburnum rufidulum*
VISA	*Vicia sativa*
VIPU	*Viola pubsecens*
VISO	*Viola sororia*
VIOS	*Viola* sp.
VIAE	*Vitis aestivalis*
VICI	*Vitis cinerea*
VILA	*Vitis lambrusca*
VIRI	*Vitis riparia*
VIRO	*Vitis rotundifolia*
VISP	*Vitis* sp.
XAST	*Xanthium strumarium*

Appendix V.

Plant species list.

Acanthaceae
- *Dicliptera brachiata* (Pursh) Spreng.
- *Justicia americana* (L.) Vahl
- *Ruellia pedunculata* Torr. ex Gray

Aceraceae
- *Acer negundo* L.
- *Acer rubrum* L.
- *Acer saccharinum* L.
- *Acer saccharum* Marsh.

Amaranthaceae
- *Amaranthus spinosus* L.
- *Amaranthus hybridus* L.

Anacardiaceae
- *Rhus aromatica* Ait.
- *Rhus glabra* L.
- *Toxicodendron radicans* (L.) Kuntze

Annonaceae
- *Asimina triloba* (L.) Dunal

Apocynaceae
- *Amsonia illustris* Woodson
- *Apocynum cannabinum* L.

Aquifoliaceae
- *Ilex decidua* Walt.

Araceae
- *Arisaema dracontium* (L.) Schott
- *Arisaema triphyllum* (L.) Schott

Araliaceae
- *Panax quinquefolium* L.

Aristolochiaceae
- *Aristolochia serpentaria* L.
- *Aristolochia tomentosa* Sims
- *Asarum canadense* L.

Asclepiadaceae
- *Gonolobus gonocarpos* (Walt.) Perry
- *Matelea decipiens* (Alex.) Woodson

Balsaminaceae
- *Impatiens* sp.

Berberidaceae
- *Podophyllum peltatum* L.

Betulaceae
- *Betula nigra* L.
- *Carpinus caroliniana* Walt.
- *Ostyra virginiana* (P. Mill.) K. Koch

Bignoniaceae
- *Campsis radicans* (L.) Seem.
- *Catalpa speciosa* Warder

Boraginaceae
- *Heliotropium indicum* L.

Campanulaceae
- *Campanula americana* L.

Capparaceae
- *Polanisia dodecandra* (L.) DC.

Caprifoliaceae
- *Lonicera japonica* Thunb.
- *Sambucus canadensis* L.
- *Symphoricarpos orbiculatus* Moench
- *Triosteum perfoliatum* L.
- *Viburnum molle* Michx.
- *Viburnum prunifolium* L.
- *Viburnum rafinesquianum* Schultes
- *Viburnum rufidulum* Raf.

Caryophyllaceae
- *Saponaria officinalis* L.
- *Silene stellata* (L.) Ait. f.
- *Stellaria media* (L.) Villars

Celastraceae
- *Euonymus atropurpureus* Jacq.

Chenopodiacaeae
- *Chenopodium ambrosioides* L.
- *Chenopodium album* L.
- *Chenopodium pumilio* R. Br.

Commelinaceae
- *Commelina erecta* L.
- *Tradescantia ozarkana* Anderson and Woodson

Compositae
- *Ambrosia artemisiifolia* L.
- *Ambrosia trifida* L.
- *Antennaria plantaginifolia* (L.) Richards
- *Aster anomalus* Engelm.
- *Aster drummondii* Lindl.
- *Bidens frondosa* L.
- *Brickellia grandiflora* (Hook.) Nutt.
- *Cacalia atriplicifolia* L.
- *Chrysanthemum leucanthemum* L.
- *Cirsium altissimum* (L.) Spreng.
- *Elephantopus carolinianus* Raeusch.
- *Erechtites hieraciifolia* (L.) Raf. ex DC.
- *Erigeron annuus* (L.) Pers.
- *Erigeron strigosus* Muhl. ex Willd.
- *Eupatorium fistulosum* Barratt
- *Eupatorium incarnatum* Walt.
- *Eupatorium purpureum* L.
- *Eupatorium rugosum* Houtt.
- *Eupatorium serotinum* Michx.
- *Grindelia lanceolata* Nutt.
- *Helianthus annuus* L.
- *Helianthus divaricatus* L.
- *Helianthus hirsutus* Raf.
- *Helianthus tuberosus* L.
- *Heliopsis helianthoides* (L.) Sweet
- *Heterotheca pilosa* Nutt.
- *Hieracium scabrum* Michx.

Lactuca floridana (L.) Gaertn.
Mikania scandens Willd.
Polymnia canadensis L.
Polymnia uvedalia (L.) L.
Ratibida pinnata (Vent.) Barnh.
Rudbeckia laciniata L.
Senecio aureus L.
Senecio obovatus Muhl. ex Willd.
Senecio plattensis Nutt.
Silphium asteriscus L.
Silphium terebinthinaceum Jacq.
Solidago arguta Ait.
Solidago caesia L.
Solidago canadensis L.
Solidago flexicaulis L.
Solidago gigantea Ait.
Solidago nemoralis Ait.
Solidago petiolaris Ait.
Solidago ulmifolia Muhl.
Taraxacum officinale Wiggers
Verbesina alternifolia (L.) Britt.
Verbesina helianthoides Michx.
Verbesina virginica L.
Vernonia arkansana DC.
Xanthium strumarium L.

Convolvulaceae
Convolvulus sepium L.
Cuscuta sp.
Ipomoea coccinea L.
Ipomoea lacunosa L.
Ipomoea pandurata (L.) Mey.

Cornaceae
Cornus amomum P. Mill.
Cornus drummondii Meyer
Cornus florida L.

Cruciferae
Arabis canadensis L.
Arabis shortii (Fern.) Gl.
Barbarea vulgaris R. Br.
Cardamine parviflora L.
Lepidium virginicum L.

Cucurbitaceae
Sicyos angulatus L.

Cupressaceae
Juniperus virginiana L.

Cyperaceae
Carex grisea Wahl.
Carex jamesii Schwein.
Carex laxiflora Lam.
Carex oligocarpa Schkuhr
Carex oxylepsis Nees ex Steud.
Carex physorhyncha Lieb. ex Steudel
Carex rosea Schkuhr
Cyperus retroflexus Buckley
Eleocharis tenuis (Willd.) Schultes
Scirpus pungens Vahl
Scleria oligantha Michx.

Ebenaceae
Diospyros virginiana L.

Equisetaceae
Equisetum x ferrissii Clute

Ericaceae
Rhododendron prinophyllum (Small) Millais
Vaccinium arboreum Marsh.
Vaccinium pallidum Ait.

Euphorbiaceae
Acalypha rhomboidea Raf.
Andrachyne phyllanthoides (Nutt.) Muell. Arg.
Croton glandulosus L.
Euphorbia commutata Engelm.
Euphorbia corollata L.
Euphorbia cyathophora Murr.
Euphorbia dentata Michx.
Euphorbia nutans Lag.

Fagaceae
Castanea pumila (L.) Mill. var. *ozarkensis* (Ashe) Tucker
Fagus grandifolia Ehrh.
Quercus alba L.
Quercus falcata Michx.
Quercus macrocarpa Michx.
Quercus marilandica Muench.
Quercus muehlenbergii Engelm.
Quercus prinoides Willd.
Quercus rubra L.
Quercus stellata Wang.

Fumariaceae
Corydalis sp.
Dicentra sp.

Geraniaceae
Geranium carolinianum L.

Gramineae
Brachyelytrum erectum (Schreb.) Beauv.
Bromus japonicus Thunb. ex Murr.
Bromus pubescens Muhl. ex Willd.
Bromus tectorum L.
Andropogen virginicus L.
Arundinaria gigantea (Walt.) Muhl.
Chasmanthium latifolium (Michx.) Yates
Cynodon dactylon (L.) Pers.
Dactylis glomerata L.
Danthonia spicata (L.) Beauv. ex Roem. & Schult.
Diarhenna americana Beauv.
Digitaria sanguinalis (L.) Scop.

Echinochloa crusgalli (L.) Beauv.
Elymus virginicus L.
Festuca arundinacea Schreb.
Festuca obtusa Biehler
Glyceria striata (Lam.) Hitchc.
Hordeum pusillum Nutt.
Leersia virginica Willd.
Microstegium vimineum (Trin.) A. Camus
Muhlenbergia tenuiflora (Willd.) B.S.P.
Muhlenbergia schreberi Gmel.
Muhlenbergia sylvatica (Torr.) Torr. in Gray
Panicum acuminatum Swartz
Panicum anceps Michx.
Panicum boscii Poir.
Panicum clandestinum L.
Panicum commutatum Schult.
Panicum polyanthes Schult.
Paspalum setaceum Michx.
Poa pratensis L.
Poa sylvestris Gray
Setaria viridis (L.) Beauv.
Sorghum halepense (L.) Pers.
Spenopholis obtusata (Michx.) Scribn.
Tridens flavus (L.) Hitchc.

Hamamelidaceae
Hamamelis virginiana L
Liquidambar styraciflua L.

Hippocastanaceae
Aesculus glabra Willd.

Hydrophyllaceae
Hydrophyllum appendiculatum Michx.
Hydrophyllum virginianum L.

Iridaceae
Belamcanda chinensis (L.) DC.
Dioscorea oppositifolia L.
Dioscorea quaternata J. F. Gmelin

Juglandaceae
Carya cordiformis (Wang.) K. Koch
Carya texana Buckl.
Carya tomentosa (Poir.) Nutt.
Juglans nigra L.
Juglans sp.

Labiatae
Cunila organiodes (L.) Britt.
Glechoma hederacea L.
Perilla frutescens (L.) Britt.
Prunella vulgaris L.
Salvia lyrata L.
Scutellaria elliptica Muhl.
Scutellaria ovata Hill
Stachys eplingii J. Nelson
Stachys tenuifolia Willd.
Teucrium canadense L.
Mentha sp.

Lauraceae
Lindera benzoin (L.) Blume
Sassafras albidum (Nutt.) Nees

Leguminosae
Albizia julibrissin Durazz.
Amorpha fruticosa L.
Amphicarpaea bracteata (L.) Fern.
Apios americana Medic.
Cercis canadensis L.
Clitoria mariana L.
Desmodium canescens (L.) DC.
Desmodium cuspidatum (Muhl. ex Willd.) DC.
Desmodium glutinosum (Muhl. ex Willd.) Wood
Desmodium laevigatum (Nutt.) DC.
Desmodium marilandicum (L.) DC.
Desmodium nudiflorum (L.) DC.
Desmodium nuttallii (Schindl.) Schub.
Desmodium paniculatum (L.) DC.
Desmodium rotundifolium DC.
Gleditsia triacanthos L.
Lathyrus pusillus Ell.
Lespedeza cuneata (Dumont) G. Don.
Lespedeza repens (L.) Bart.
Lespedeza stipulacea Maxim.
Lespedeza striata (Thunb.) H. & A.
Lespedeza virginica (L.) Britt.
Melilotus officinalis (L.) Pall.
Phaseolus polystachios (L.) B.S.P.
Rhynchosia latifolia Nutt. ex T. & G.
Robinia pseudo-acacia L.
Senna marilandica (L.) Link
Strophostyles helvula (L.) Ell.
Trifolium campestre Schreb.
Trifolium pratense L.
Trifolium repens L.
Vicia sativa L.
Chamaecrista sp.

Liliacaeae
Allium vineale L.
Maianthemum racemosum (L.) Link
Polygonatum biflorum (Walt.) Ell.
Smilax bona-nox L.
Smilax glauca Walt.
Smilax herbacea L.
Smilax tamnoides L.
Trillium sp.

Lythraceae
Lythrum sp.

Magnoliaceae
Magnolia tripetala L.

Malvaceae
Modiola caroliniana (L.) G. Don
Menispermaceae
Calycocarpum lyonii (Pursh) Nutt.
Cocculus carolinus (L.) DC.
Menispermum canadense L.
Moraceae
Morus rubra L.
Nyssaceae
Nyssa sylvatica Marsh.
Oleaceae
Fraxinus americana L.
Fraxinus pennsylvanica Marsh.
Fraxinus quadrangulata Michx.
Onagraceae
Circaea lutetiana L.
Gaura longiflora Spach
Ludwigia alternifolia L.
Oenothera laciniata Hill
Ophioglossaceae
Botrychium virginianum (L.) Sw.
Oxalidaceae
Oxalis sp.
Papaveraceae
Sanguinaria canadensis L.
Stylophorum diphyllum (Michx.) Nutt.
Passifloraceae
Passiflora lutea L.
Phrymaceae
Phryma leptostachya L.
Phytolaccaceae
Phytolacca americana L.
Pinaceae
Pinus echinata Miller
Plantaginaceae
Plantago lanceolata L.
Plantago rugelii Dcne.
Platanus occidentalis L.
Polemoniaceae
Phlox glaberrima L.
Phlox paniculata L.
Polemonium reptans L.
Polygalaceae
Polygala senega L.
Polygonaceae
Polygonum pensylvanicum L.
Polygonum persicaria L.
Polygonum punctatum Ell.
Polygonum scandens L.
Polygonum virginianum L.
Rumex crispus L.
Polypodiaceae
Asplenium platyneuron (L.) B.S.P.
Cystopteris protrusa (Weatherby) Blasdell
Polystichum acrostichoides (Michx.) Schott
Ranunculaceae
Anemone virginiana L.
Cimicifuga racemosa (L.) Nutt.
Clematis versicolor Small
Clematis virginiana L.
Delphinium tricorne Michx.
Isopyrum biternatum (Raf.) T. & G.
Ranunculus hispidus Michx.
Thalictrum thalictroides Eames & Boivin
Rhamnaceae
Berchemia scandens (Hill) K. Koch
Rhamnus caroliniana Walt.
Rosaceae
Agrimonia rostellata Wallr.
Amelanchier arborea (Michx. f.) Fern.
Crataegus sp.
Geum canadense Jacq.
Geum vernum (Raf.) T. & G.
Prunus mexicana S. Wats.
Prunus serotina Ehrh.
Rosa multiflora Thunb.
Rubus phoenicolasius Maxim.
Rubus sp.
Rubiaceae
Cephalanthus occidentalis L.
Diodia teres Walt.
Diodia virginiana L.
Galium aparine L.
Galium circaezans Michx.
Galium concinnum T. & G.
Galium obtusum Bigel.
Galium pedemontanum (Bell.) All.
Galium pilosum Ait.
Galium texense Gray
Galium triflorum Michx.
Hedyotis purpurea (L.) T. & G.
Rutaceae
Ptelea trifoliata L.
Salicaceae
Populus deltoides Marsh.
Salix caroliniana Michx.
Salix humilis Marsh.
Salix nigra Marsh.
Sapotaceae
Bumelia lanuginosa (Michx.) Pers.
Saxifragaceae
Hydrangea aborescens L.
Philadelphus pubescens Loisel.
Ribes sp.
Scrophulariaceae

Pedicularis canadensis L.
Veronica arvensis L.
Solanaceae
Physalis angulata L.
Solanum carolinense L.
Staphyleaceae
Staphylea trifolia L.
Thymeleaceae
Dirca palustris L.
Tiliaceae
Tilia americana L.
Ulmus
Celtis laevigata Willd.
Celtis occidentalis L.
Ulmus alata Michx.
Ulmus americana L.
Ulmus rubra Muhl.
Umbelliferae
Conium maculatum L.
Cryptotaenia canadensis (L.) DC.
Daucus carota L.
Ligusticum canadense (L.) Britt.
Osmorhiza longistylis (Torr.) DC.
Sanicula canadensis L.
Sanicula odorata (Raf.) Phillippe
Taenidia integerrima (L.) Drude
Thaspium trifoliatum (L.) Gray
Urticaceae
Boehmeria cylindrica (L.) Sw.
Laportea canadensis (L.) Wedd.
Parietaria pennsylvanica Muhl.
Pilea pumila (L.) Gray
Verbenaceae
Phyla lanceolata (Michx.) Greene
Phyla nodiflora (L.) Greene var. *incisa* (Small) Moldenke
Phyla nodiflora (L.) Greene var. *nodiflora*
Verbena urticifolia L.
Violaceae
Hybanthus concolor (T.F. Forst.) Spreng.
Viola pubescens Ait.
Viola sororia Willd.
Viola viarum Pollard
Vitaceae
Ampelopsis arborea (L.) Koehne
Parthenocissus quinquefolia (L.) Planchon
Vitis aestivalis Michx.
Vitis cinerea (Engelm. in Gray) Engelm. ex Millard
Vitis labrusca L.
Vitis riparia Michx.
Vitis rotundifolia Michx.