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Inventory and Characterization of the Riparian Zone of the Current and Jacks Fork Rivers

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Ozark National Scenic Riverways

Final Project Report

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Inventory and Characterization of the Riparian Zone of the Current and Jacks Fork Rivers

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EXECUTIVE SUMMARY

The ecological, recreational, and economic value of the 134 mile (216 km) riparian corridor within the Ozark National Scenic Riverways (ONSR) is of great interest to land managers and conservationists. 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 ONSR. 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 ONSR.

- Between June and August 1994, and in August 1995, we established transects at 35 sites along the Current and Jacks Fork Rivers. Study sites were chosen from among locations accessible by secondary roads or foot trails, or by canoe or small motor craft that were separated by approximately 3 river mi. Transects began at upland points where the forest canopy was dominated by oak (*Quercus* spp.) and hickory (*Carya* spp.) and ran to the river's edge. The vegetation sampling included 28 sites located in secondary forests and 7 located in campground or pastures. Each study plot along the transect was categorized by Ecological Landtype (ELT).

- A total of 12 forest associations were identified using TWINSPAN. Based on the 12 associations, three broader forest groupings were identified: bottomland, transition, and upslope. The three forest groupings represent partially distinct assemblages that fall along a vegetation continuum rather than as discrete assemblages or communities.

- 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 in the ecotonal analyses, and the clustering observed in the TWINSPAN results, suggests very heterogeneous substrate conditions along the ecocline.

- Woody and herbaceous vegetation was correlated with several important environmental gradients, including height above river, soil pH, soil moisture, and soil particle size. Responses differed among the five functional types of vegetation analyzed (dominant trees, overstory trees, understory trees, woody shrubs, herbs). Canonical correspondence analysis (CCA) of overstory trees indicated that vegetation patterns were strongly correlated with slope and sand content. CCA of woody shrubs showed that shrub species distributions were most strongly correlated with organic matter content, soil moisture, and silt.

- Potential management of these forests may have to be approached from a broader landscape perspective rather than the more traditional approach of identifying specific forest communities.

Given the spatial complexity of woody and herbaceous species distributions and composition within the ONSR, 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 or ELT) on a small scale (<5 ha). Managing larger landscape units based on comprehensive vegetation analyses (composite functional type analysis) rather than management zones based on restricted vegetation analyses, may be a more effective management strategy in this spatially complex landscape. Stratifying vegetation by functional types (i.e., trees, herbs, shrubs) in vegetation analyses can alleviate some of these difficulties by providing managers with a broader 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 beta diversity across a changing landscape. 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 individual species.

THE STUDY AREA

The Ozark National Scenic Riverways (ONSR) occupies 26,306 ha along a narrow corridor enclosing a 161 km stretch of the Current River and 55 km of the Jacks Fork River - the latter being a tributary of the former (Fig. 1). The ONSR occupies portions of Dent, Shannon, Carter, and Texas counties in Missouri, USA, and is located on the Salem Plateau of the Ozark Plateaus physiographic province (Fenneman 1938). The Salem Plateau is underlain predominantly by Ordovician age cherty dolomite and cherty limestone, with smaller areas of sandstone and shale (Branson 1944). The upper formations of the Salem Plateau are predominantly Roubidoux sandstone (beds typically 40 - 55m thick) that are underlain first by Gasconade dolomite (beds typically 60 - 80m thick), and then by Eminence dolomite (beds typically 55m thick) (Bridge 1930, Oetking et al. 1966). The entire Salem Plateau is underlain by a Precambrian rhyolite porphyry. The Ozark Plateau has been a continuous land area since the end of the Paleozoic (Branson 1944, 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).

Most of the ONSR area has a karst drainage system that has developed in the carbonate rocks in the region (Vineyard and Feder 1974) and as much as 60% of the two rivers' flow is from karst springs (Jacobson and Primm 1994). The Jacks Fork watershed drains 1046 km^2 in the Salem Plateau. The Current River watershed is substantially larger (9560 km^2) with only a small proportion of that watershed (26,306 ha) protected within the boundaries of the ONSR. The Current and Jacks Fork Rivers experience periodic flooding. Typical yearly floods range from 2-3 m above baseflow, a 25 to 50 year flood reaches 4-6 m above baseflow (Jacobson and Primm 1994). The maximum floodstage recorded in the ONSR occurred along the Jacks Fork in 1904 at 9.4 m. Much of the riparian landscape of the ONSR has been highly disturbed following European settlement around 1820 (Jacobson and Primm 1994). The forests in the ONSR experienced indiscriminate, and widespread clearcutting from 1890 to 1920. These anthropogenic disturbances have altered vegetation cover, forest density, and fire regimes. 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 (Nelson 1987).

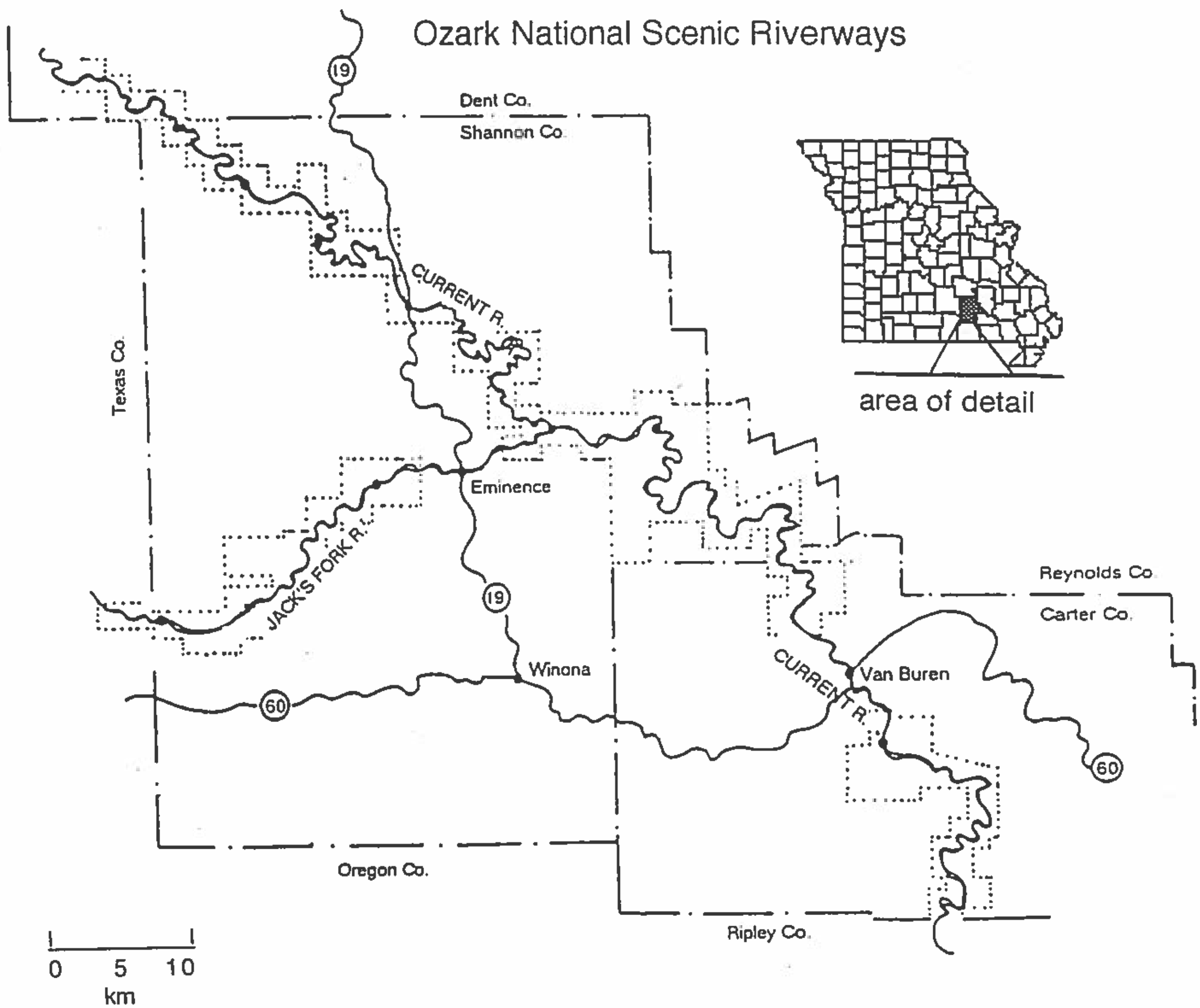

Fig. 1. Map of the Ozark National Scenic Riverways (ONSR) in Missouri. Dotted line represents the ONSR boundaries.

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 1996, 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 five major objectives. 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 primary objectives of this study are presented below:

1) To characterize native species associations on the Current and Jacks Fork Rivers.

Methods used in this study were developed early in the history of quantitative ecology (Gleason 1926, 1927,Curtis and McIntosh 1951, Curtis 1959, Daubenmire 1959, Whittaker 1967) and continue to be be used to assess plant community structure (Dollar et al. 1992, Sagers and Lyon 1997). To be certain that samples were representative of the Park's riparian corridor, sampling sites were chosen haphazardly, biased only by the avoidance of hayfields and campsites (see below). We sampled the trees, shrubs and herbs to be certain that the enitre plant community was included, even though many community analyses are published using only the tree layer (Nigh et al. 1985). In addition to sampling vegetation, shallow soils were characterized, and the slope, aspect and elevation of each plot was measured. Statistical analyses followed the most higly developed and progressive methods available (Palmer 1996).

2) To characterize the systematic changes in plant community structure along physical gradients.

Riparian vegetation is largely influenced by strong physical and hydrologic gradients established by hydroperiod (Sharitz and Mitsch 1993). The effects of this gradients, which vary in time and space across the floodplain, have been described frequently (e.g., Bedinger 1978, Huffman, 1979, Whitlow and Harris 1979, Huffman and Forsythe 1981). Transects are the recommended method for sampling in areas where species assemblages are thought to be strongly influenced by an environmental gradient (Barbour et al. 1987). In this study each transect extended from the river's edge o forested upslope communities of oak and hickory. The gradient was quantified by soil properties, site elevation and slope. Vegetation was sampled in plots along this gradient. Gradients were located haphazardly along the Current and Jacks Fork Rivers, But were typically separated by about 4 km.

We used both traditional and more sophisticated statistical methods to characterize the plant communities along this gradient. Traditional methods include lists by species of basal areas among recognizable communities and DCA ordination which orders study plots according to species composition. More advanced analyses included CCA ordination which analyzes directly environmental gradients and vegetation as well as moving window analysis to detect transitions among species associations.

3) To evaluate demographic parameters of riparian vegetation.

Demographic parameters of the riparian vegetation were evaluated by sorting woody species into groups related to plant age: overstory trees and saplings of overstory species. Each forest type was characterizedby the basal area, stem density and species richness of each age group.

4) To assess the influence of anthropogenic disturbance on species composition.

To assess the influence of anthropogenic change, soil, site and vegetation characters of campsites and old fields were compared with the remaining plots in the sample.

5) To compare vegetation data of the Current and Jacks Fork Rivers riparian zone with established ELT designations.

An ecological landtype (ELT) is defined by the USDA Forest Service as an area of 10 - 100's of acres that is described by the "...potential natural communities, soils, hydrologic function, landform and topography, lithology, climate, air quality and natural processes for cylcing plant biomass and nutrients (e.g., succession, produtivity, fire regimes)" (ECOMAP 1993). Fourteen ELT's within the ONSR have been described based on geomorphology (Castillon et al. 1989), but only four were expected to be commmon in the riparian zone (D. Foster, personal communication).

Multivariate analyses traditionally have been used to characterize the vegetation of desicrete landtypes. Such analyses may produce distinct clusters of sample plots that define the landtype. The accuracy of this approach is test in our data with a discriminant function analysis.

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), maintenance of ecosystem stability (Wiens et al. 1985), provision of important animal and wildlife habitat (Sparks 1995), corridors of movement for animals (Simberloff and Cox 1987), and organic matter to aquatic consumers (Cummins et al. 1989). Many riparian forests also support diverse flora (Gregory et al. 1991; Nilsson et al. 1991; Bratton et al. 1994; Planty-Tabacchi et al. 1996). 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 (Naiman and Décamps 1990, Hansen and di Castri 1992, Hupp 1992, Bendix 1994, Nilsson et al. 1994). These approaches have provided essential information in the formulation of effective protection, management, and restoration efforts in riparian forests (Berger 1990; Naiman and Décamps 1990, Hansen and di Castri 1992, Hupp 1992, Bendix 1994, Nilsson et al. 1994).

Many riparian vegetation studies have employed multivariate statistical techniques to characterize vegetation patterns (Rochow 1972, Robertson et al. 1978, Collins et al. 1981, Hardin et al. 1989, Hupp 1992, Nilsson et al. 1994). Fewer studies have attempted to correlate observed vegetation patterns with underlying environmental gradients (Nilsson et al. 1989, Dollar et al 1992; Ware et al. 1992). Furthermore, most efforts to characterize riparian vegetation (and forest vegetation in general) have centered on the use of dominant and/or commercially important canopy species in forest classification systems (Barnes et al. 1982, McNab and McCorquodale 1994). Yet, for these classifications to be useful in an ecosystem management context, there ecological validity needs to be ascertained (Bailey 1984, Jensen et al. 1991, Sharitz et al. 1992, Slocombe 1993, Bailey et al. 1994, Minshall, 1994). In the United States, the need for proper characterization is also 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).

One approach that addresses the vegetational complexity of forest characterization/classification is functional type analysis. Plant species can be classified into specific guilds or functional types based on a variety of characteristics, including morphology (Raunkiaer 1934), physiology (Mueller-Dumbois and Ellenberg 1974; Smith et al. 1993), reproductive, ruderal or competitive status (Grime 1979) or location in a successional sere (Bazzaz 1979). Each functional type potentially will partition the environmental gradient(s) differently (Austin 1985, 1990, Smith and Huston 1989). Thus, as resource levels change spatially and/or temporally, the growth and distribution of different functional types is predicted to change also. The use of vertically stratified growth forms or vegetation layers (e.g., overstory trees, understory trees, shrubs, herbs) as a means of separating functional types has been demonstrated as an approach that integrates many of the previously described characteristics and has a sound ecological and physiological basis (Noble et al. 1988, Chapin 1993, Grime 1993, Smith et al. 1993, Körner 1994). However, there is limited information on the interactions between different vegetation layers (Lippmaa 1939, McCune and Antos 1981, Hardin and Wistendahl 1983, Dunn and Stearns 1987, Gilliam et al. 1995).

In addition to ascertaining potential differences among functional types, effective characterization and/or management of riparian vegetation also requires assessment of the spatial dimensions of riparian communities, their landscape context, and the transitions between riparian and non-riparian communities (ecotones). The role of ecotones and ecoclines in describing and explaining spatial and temporal vegetation patterns has received renewed attention in recent years (Naiman and Décamps 1990, Holland et al. 1991, Hansen and di Castri 1992, Gosz 1993, Risser

1995), although interest in the structure and ecological impact of ecotones is by no means new (Clements 1905, Leopold 1933, Weaver and Alberton 1956). Given an ecotonal landscape, if specific environmental variables are strongly influencing the distribution and abundance of vegetation, they may also be correlated with the spatial distribution of ecotones and ecoclines (Gosz and Sharpe 1989, Woodward 1993). In addition, different functional types (vegetation layers) may exhibit different ecotonal structures. Thus, before designing and implementing vegetation management strategies, managers need information on the composition, structure, and spatial dimensions of the entire spectrum of vegetation as well as the transitions between vegetation assemblages.

Despite a growing literature of quantitative studies on plant-environment interactions, the spatial context of many of the most detailed riparian studies has been limited to the geolittoral zone (Nilsson 1983; Menges 1986; Nilsson et al. 1989; Roberts & Ludwig 1991; Nilsson et al. 1994) or across small topographic gradients (Titus 1990; Shaffer et al. 1992). However, riparian vegetation is typically linked to vegetation patterns in adjacent communities and the surrounding landscape, especially landscapes with pronounced gradients. Thus, in order to identify these linkages, the composition and distribution of riparian vegetation needs to be assessed in terms of the interactions between plant assemblages and/or communities, environmental gradients, and landscape position.

In this study, we employed both growth form designations (functional types) and ecotonal analysis to characterize vegetation in the riparian landscape. We wanted to determine if the segregation of vegetation data into growth form-based functional types would provide insight into the influence of environmental gradients on existing vegetation patterns in the ONSR. Little specific information is available concerning the riparian forests of the Ozarks (Redfearn et al. 1970, Ware et al. 1992); the vast majority of woody vegetation studies in the Ozarks have focused on dominant canopy species in upland vegetation (Zimmerman and Wagner 1979, Nigh et al. 1985, Pallardy et al. 1988, Cutter and Guyette 1994) or on specific plant assemblages in riparian areas (Witherspoon 1971, Autry 1988, McKenney et al. 1995). Of these studies, most have focused specifically on streamside forests and have not addressed the broader landscape, including the transition of riparian forest vegetation into upland areas.

The specific objectives of this study are listed below. This list relates to the five overall objectives of the study as described by the National Park Service (see Study Objectives section).

- to develop and utilize a standardized sampling strategy to collect descriptive data about the composition and structure of the plant communities on a sample of the Park's riparian corridor
- to use inventory data to validate existing ecological landtype (ELT) maps and descriptions (Miller 1989)
- to assemble and integrate physical and ecological data that contribute to an understanding and characterization of riparian community structure, distribution and dynamics.
- to assess type, location and intensity of disturbances, both natural and man-related, on site.
- to determine the presence of any rare or endangered plant species or communities.
- to determine the presence of any exotic species, the extent of invasion and assess the potential effects on natural communities.
- analyze information collected to develop plans for additional research, monitoring, restoration and management.

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.

OBJECTIVE 1: Standardized sampling

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, we established transects at 35 sites along the Current and Jacks Fork Rivers (see Appendix I for site names and ELT classifications). Study sites were chosen from among locations accessible by secondary roads or foot trails, or by canoe or small motor craft that were separated by approximately 4.8 river km. Transects began at a point where the forest canopy was dominated by oak (*Quercus* spp) and hickory (*Carya* spp) and ran to the river's edge. The vegetation sampling included 28 sites located in secondary forests and the results presented are based on the woody vegetation found on the 130 plots in these forests.

Along each transect, we established 10 X 20m plots spaced at 20m intervals. Plot dimensions were determined from species area curves as the size at which sampling effort was most efficient (see Appendix II). Rectangular plots, rather than square or circular plots, were used because rectangular plots more adequately sample the existing diversity (Bormann 1953). Each plot was categorized by Ecological Landtype (ELT) following Castillon et al. (1989). Shrubs were sampled in subplots within the 10 X 20m plot. A total of 138 - 10 X 20m plots were sampled during the survey, 94 of these plots contained woody vegetation > 1cm dbh.

We categorized plants as either trees or shrubs or herbaceous based on stem diameter, height, and the presence of woody tissue. We segregated the vegetation into four *a priori* defined functional types: major overstory dominant trees, all overstory trees, understory trees, and woody shrubs. All tree species (overstory and understory) >1cm in diameter at 1.3m in height (dbh) and all shrub species were measured. Within a 10 X 20m plot, all trees were sampled, and shrubs were subsampled. Each tree within the plot was identified to species and its diameter was recorded. Shrub species were sampled in four - 3.1 m^2 circular subplots, and their occurrence and cover class within a subplot were recorded. Cover classes followed Daubenmire (1959). Non-tree vegetation was segregated into two height classes: 0.1-1.3m and 0-0.1m in height. This vegetation was analyzed using the cover classes outlined by Daubenmire (1959). In the 0.1-1.3 m layer, the percent cover of each species was estimated from within four - 3.1m^2 circular plots placed regularly within the larger plot. In the 0-0.1m layer, the percent cover of each species was estimated from within 10 - 0.1m^2 rectangular plots placed regularly within the larger plot. The percent cover of each species was calculated for the plot as the mean cover recorded from the subplots. The frequency of each shrub and herbs species was calculated as the percentage occurrence among the total number of subplots. In order to combine data for those herbaceous species found in both height layers into a single matrix, the average of the mean cover of each species from each height class was calculated and used in the combined matrix. Species fidelity was defined as the number of plots of occurrence for each species divided by the total number of plots (94).

Physical Attributes

Each study plot was characterized by three physical factors: slope, aspect, and height above river. The slope and aspect of each plot were measured with a clinometer and compass, respectively. Height above river (c) was calculated from an angle (a) and distance (b) between one observer at the river's edge and another at the edge of the plot as: $c = (\sin a)b$. The study took place during the driest months of the year (June-August), so height above river is measured from at or near baseflow level.

Soils

We collected soils at a depth of 10 cm from three locations chosen haphazardly within each 5 X 10 m plot. Soil was 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 2mm sieve to separate fine and crude soil fractions. The total sample weight and the weight of the smaller size fraction were recorded to calculate the percentage of total sample < 2mm (% 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 Corning pH/ion 350 meter.

Soil Texture: Hydrometer Method

Methods are modified slightly from Bouyoucos (1951). Eighteen g of air-dried, fine soil was dissolved in a 0.1 M sodium hexametaphosphate (HMP) solution by mixing and allowing to soak overnight. Twelve hours later the suspension was transferred to a 500 ml sedimentation cylinder and mixed thoroughly. 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 is a measure of the water retaining capacity of a soil and is measured as the water content after the soil has been thoroughly wetted 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 two h to saturate the soils, then allowed to drain freely for 12 h and 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

Methods follow 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. The furnace temperature was increased gradually to about 900°C and held there for 15 min. The crucible was cooled, and the sample re-weighed. The change in weight after firing is the loss on ignition, which includes water of constitution, organic matter, and some soluble volatile salts.

OBJECTIVE 2: Validation of ELT's

To use inventory data to validate existing Ecological Landtype (ELT) maps and descriptions (Castillon et al. 1989).

ECOMAP, the USDA Forest Service group, defines Ecological Landtype (ELT) as "...subdivisions of Landtype Associations or groupings of Landtype Phases based on similarities in soils, landform, rock types, geomorphic process and plant associations. Land surface form that influences hydrologic function (e.g., drainage density, dissection relief) is often used to delineate different landtypes in mountainous terrain. Valley bottom characteristics (e.g., confinement) are commonly used in establishing riparian Landtype map units." Landtypes are characterized by landform and topography (elevation, aspect, slope gradient and position), phases of soil subgroups, families or series, rock type and geomorphic process and plant associations. In this portion of the study we evaluated the accuracy of assigning ELT designations based on our data and existing ELT descriptions.

METHODS

Existing ecological landtype (ELT) maps were used as a template for overlaying the location of vegetation transects in the current study. The existing ELT maps are based on USGS topographical quad maps for the entire ONSR. The landforms are mapped on 1" = 660' scale enlargements of the topographical quads. These maps are organized into 34 segments that overlap with the standard ONSR tract maps (Figure 2-1). A summary of the ELT's listed for the ONSR and their representative forest cover types (Miller 1981; Castillon et al. 1989) are provided in Table 2-1. The vegetation type descriptions follow after Nelson (1987).

Table 2-1. Descriptions of ecological landtypes (ELT's) found in the ONSR.

ELT	Acres	Hectares	LAND FORM	SLOPE	FOREST TYPE	Nelson (1987)
1	9016	3649	Low Flood	0 to 4	Wet-Mesic Bottomland	4
					Gravel Wash	10
2	26	11	Floodplain - Low Terrace	0 to 4	Calcareous Wet	45
3	5031	2036	High Floodplain - Low Terrace	0 to 4	Mesic Bottomland	1
5	494	200	Upland Waterway	0 to 4	Dry Bottomland	9
6	1065	431	Upland Waterway	0 to 4	Dry-Mesic Bottomland	8
7	2288	926	Toe Slope	0 to 14	Mesic	11
11	8035	3252	Ridge	0 to 8	Dry Chert	19, 20
15	642	260	Flat	0 to 8	Dry Chert	19, 20, 21
17	27170	10996	Side Slope (S&W)	8 to 99	Dry Mesic Chert	19, 20
18	28537	11549	Side Slope (N&E)	8 to 99	Dry Mesic Chert	1
					Dry Mesic Sand	15, 40
22	613	248	Side Slope	5 to 99	Xeric Limestone	32
23	18	7	Side Slope	5 to 99	Dry Limestone	30

SUM	82935	33565

RESULTS

Vegetation sampling plots were assigned an ELT according to the criteria established by Castillon, Miller and Swofford (1989). ELT's most commonly sampled in this survey were wet mesic bottomland, mesic bottomland, upland waterway, and toe slope. Survey data also included plots designated as side slope (ELT 17/18). Study plots included in this survey were generally representative of riparian ELT's in the ONSR with the exceptions of an undersampling of mesic bottomland and an oversampling of toe slopes (Table 2-2). Environmental and soil variables were characterized for each of these ELT's. The composition and relative abundance of tree and shrub species for each ELT were compared to determine if woody species assemblages were associated with each ELT designation (Tables 2-4, 2-5). To further evaluate the links between ELT designation and vegetation, a canonical correspondence analysis (CCA) of study plots was performed (Fig. 2-2).

Table 2-2. Comparison of the relative area of each riparian zone ELT between parkwide total acreage and this survey. (Data for ONSR total acreage from Castillon, Miller and Swofford 1989).

ELT	ELT description	ONSR parkwide total acreage (%)	Survey frequency (%)
1	Wet mesic bottomland	52.0	55.8
3	Mesic bottomland	29.0	11.5
5/6	Upland waterway	7.0	10.6
7	Toe slope	13.0	22.1
17/18	Side slope	-	-

RESULTS

Environmental Characteristics of riparian ELT's

Table 2-3 provides a comparison of the 10 environmental variables measured in this study among six ELT's (gravel wash is listed as distinct from wet mesic bottomland in the following analyses). No significant differences in fines (i.e, coarseness) or container capacity were noted among the six groupings. However, slope, height above river, pH, fines, CC, sand, clay, silt and OM all showed incremental and significant increases moving from the gravel wash to side slope ELT's. Slope and height above river, not unexpectedly, were greater on toe slope and side slope plots than on bottomland plots. A combination of these two variables gives an indication of the frequency and duration of flooding which are important criteria in ELT designation (Castillon et al. 1989). These results indicate a high level of substrate and physical site heterogeneity among the forest groupings in the ONSR landscape.

Table 2-3. Comparison of 10 environmental variables among six Ecological Landtypes (ELT). Values shown are means ± 1SE.

Variable*	Gravel wash	Wet mesic bottomland	Mesic bottomland	Toe slope	Upland waterway	Side slope
Slope	4.8±1.7	4.8±1.0	6.2±2.2	17.6±1.7	15.3±2.5	18.8±2.5
Aspect	234.3±27.3	16.0±17.8	138.1±37.0	227.1±22.9	212.8±31.9	154.5±29.0
HAR	1.2±0.9	1.7±0.3	3.0±0.7	5.6±1.1	11.2±1.9	17.1±1.1
pH	7.1±0.1	6.5±0.1	6.6±0.1	5.5±0.2	6.1±0.3	5.6±0.2
Fines	0.2±0.1	0.7±0.1	0.8±0.1	0.6±0.1	0.6±0.1	0.5±0.0
CC	22.4±1.3	30.4±0.9	33.3±1.6	34.9±1.4	36.7±1.6	38.4±1.4
Sand	72.2±5.9	41.5±5.2	23.8±9.2	18.8±4.8	32.6±7.6	21.9±5.5
Clay	3.7±1.0	5.3±0.6	5.9±1.1	10.3±1.5	10.0±1.7	14.6±3.6
Silt	24.1±5.1	53.2±4.9	69.8±8.4	70.9±4.5	57.4±7.3	63.5±5.0
OM	2.5±0.3	6.5±0.6	7.6±0.9	8.0±0.9	11.0±1.9	12.4±2.1

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

ELT woody species composition

Trees - Table 2-4 provides a summary of the mean basal areas for 14 tree species in six ELT's. Separation of species composition into ELT's is evident, but considerable overlap is also evident, particularly among mesic bottomland and upland groups. Two tree species (14% of the total) occurred in all five forest groups. Sycamore, (*Plantanus occidentalis* L.), American elm (*Ulmus americana* L.), and winged elm (*Ulmus alata* Michx.) were the most common trees on gravel bar plots, although, overall, gravel bars supported little woody vegetation. Species overlap between gravel wash and wet mesic bottomland was 29%, but species overlap among all remaining ELT's was approximately 80%. Sycamore, boxelder (*Acer negundo* L.) and American elm, had the largest basal areas in wet mesic bottomland. The mesic bottomland group had no clear dominant species but boxelder, bur oak (*Quercus macrocarpa* Michx.), white oak (*Q. alba* L.) and sugar maple (*Acer saccharum* Marsh.), had the greatest basal areas. Toe slopes were dominated by oak and hickory species: white oak, black oak (*Q. velutina* Lam.), northern red oak (*Q. rubra* L.), bur oak, and bitternut hickory (*Carya cordiformis* (Wang) K. Koch). Upland waterways had canopy dominants in common with toe slopes: white oak, black oak, and sugar maple. White oak is the single dominant species of side slopes.

The wet mesic bottomland and toe slope groups had the highest tree species richness (13 species). The upslope groups had the highest diversity of oak species. White oaks growing on side slope plots had the largest basal area value in the survey.

The majority of species found in each ELT group had low fidelity values (i.e., occurred on few plots). Even the most dominant tree species in each group (gravel bar - sycamore; wet mesic bottomland- sycamore, box elder, American elm; mesic bottomland - boxelder, bur oak; toe slope - white oak, black oak; side slope -white oak) were not found on all plots. Low fidelity in combination with the large species overlap among ELT's indicates that ELT groupings support no unique species assemblages. Therefore, these species are unlikely candidates as ELT indicators.

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

	Gravel wash	Wet mesic bottomland	Mesic bottomland	Toe slope	Upland waterway	Side slope
number of plots	11	47	12	23	11	19
Platanus occidentalis	679.5±542.1	600.7±190.1	189.5±188.9	20.0±20.0	0	0
Acer negundo	0	303.4±81.7	269.8±127.5	0	4.3±4.3	0
Celtis occidentalis	0	92.8±43.3	3.3±2.3	0.9±0.7	0	0
Ulmus rubra	0	157.2±56.4	64.9±60.5	13.9±7.3	59.3±49.2	3.5±2.1
Ulmus americana	6.0±6.0	183.5±47.5	0	109.2±76.9	111.8±72.0	67.3±49.4
Fraxinus americana	0.6±0.6	3.5±1.5	8.7±8.4	71.5±52.6	17.0±10.4	66.4±36.4
Ulmus alata	4.0±4.0	24.0±15.2	20.2±20.2	8.8±4.5	2.0±2.0	14.3±12.3
Quercus rubra	0	162.4±123.7	0	240.0±106.0	60.0±60.0	135.2±81.8
Quercus macrocarpa	0	152.6±66.8	270.9±270.9	209.0±120.3	3.9±3.9	94.1±67.4
Acer saccharum	0	106.7±53.0	257.6±172.8	204.3±60.42	234.5±74.8	86.6±36.3
Quercus muhlenbergii	0	21.9±16.6	16.1±15.4	16.1±11.0	144.2±60.7	53.1±29.9
Carya cordiformis	0	78.6±36.4	43.9±43.9	300.1±96.0	98.2±56.5	198.2±88.4
Quercus velutina	0	0	20.3±18.6	114.7±63.0	244.8±113.0	215.6±151.6
Quercus alba	0	9.0±9.0	281.5±175.6	645.9±223.9	249.3±113.3	876.7±219.0

Woody shrubs and subcanopy trees - A summary of mean cover classes among the six ELT's is given in Table 2-5. Only 16 of a total of 377 species (4%) appear in Table 2-5 because most species were uncommon in our samples (fidelity 0-8%). Witch hazel (*Hamamelis virginiana* L.) was the most common shrub of gravel bars and was found only on low elevation plots. Pawpaw (*Asimina triloba* (L.) Dunal.), blue beech (*Carpinus caroliniana* Walt.), and spicebush (*Lindera benzoin* (L.) Blume) were the most common shrubs of wet mesic bottomlands, but were found in all forest groups further upland. Ironwood and flowering dogwood (*Cornus florida* L.) were the most abundant shrub on the toe slope ELT, but they were also common in other ELT groups. Species fidelity was very low across all ELT's (1-40%). Of all shrub species in the survey, only flowering dogwood in the upslope ELT's had a fidelity value exceeding 50% (29 of 35 plots or 83%).

Table 2-5. A comparison of Importance Values (IVs) of woody shrub species organized by ELT assignment. Values shown are means ± 1SE.

	Gravel wash	Wet mesic bottomland	Mesic bottomland	Toe slope	Upland waterway	Side slope
number of plots	11	47	12	23	11	19
Lindera benzoin	0	8.9±2.6	4.5±2.6	5.3±2.4	4.5±3.5	2.8±1.5
Hamamelis virginiana	7.3±7.3	0.2±0.2	3.1±3.1	0	0	0
Cercis canadensis	0.6±0.6	1.3±0.5	1.1±0.8	3.0±1.6	4.5±2.2	3.9±1.8
Asimina triloba	0	23.9±6.0	7.0±3.7	4.3±2.2	5.0±3.4	4.2±2.0
Carpinus caroliniana	0	9.8±3.7	3.1±2.2	20.4±9.6	8.5±3.7	10.2±7.8
Cornus amomum	0	0.4±0.3	0	0	0	0
Sambucus canadensis	0	0.3±0.3	0±	0	0	0
Sassafras albidum	0	0.1±0.1	0	1.8±1.1	4.2±4.0	2.6±2.4
Staphylea trifoliata	0	1.5±1.0	0	1.1±1.1	2.6±2.6	1.4±1.4
Vitis cinera	0	1.5±0.8	0	1.0±0.5	0.1±0.1	0.3±0.2
Cornus florida	0	1.0±0.6	1.7±1.7	20.3±4.6	24.2±7.3	35.3±5.9
Crataegus spp.	0	1.2±1.1	3.0±3.0	0.1±0.1	0	1.2±1.1
Ostrya virginiana	0	2.1±1.2	1.3±1.0	1.6±0.9	4.1±2.3	2.6±1.0
Bumelia lanuginosa	0	0	1.5±1.0	0.1±0.1	0	0.1±0.1
Rhus spp.	0	0	0.5±0.5	0	0.1±.01	0
Ilex decidua	0	0	0	1.2±1.1	0	0

Historical Database

We relocated the plots used by Redfearn et al. (1970) in their investigation of the vegetation in the ONSR. Figure 2-2 provides an overlay of ELT types on a DCA ordination of 66 forest plots. As can be seen, the ELT designations are not well matched with the ordination of plots.

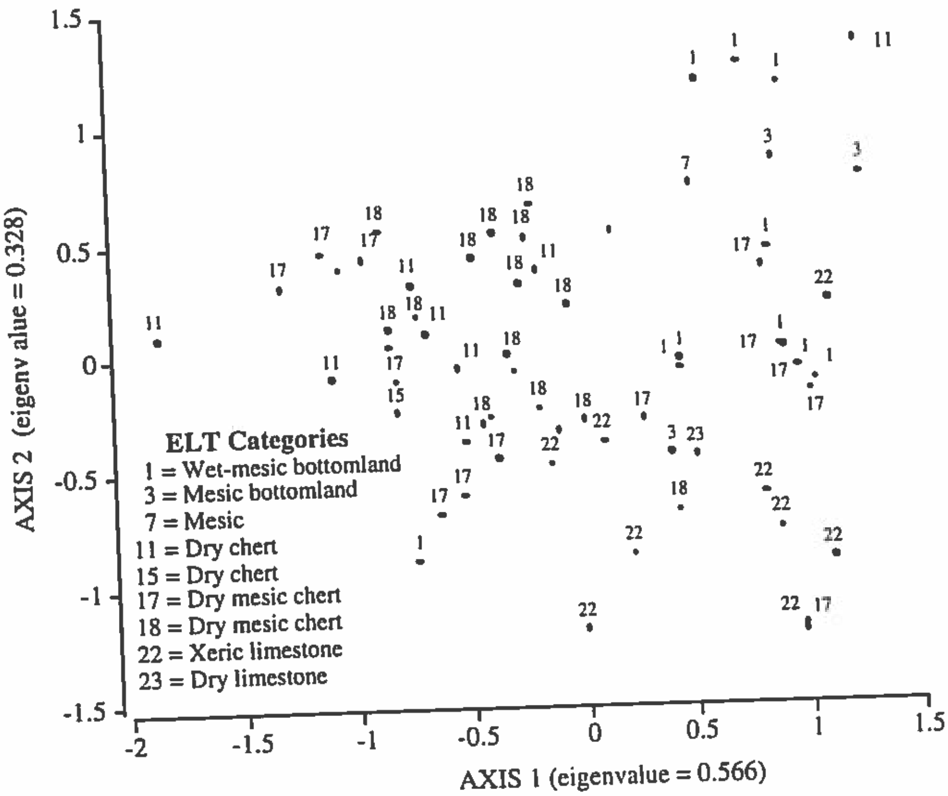

Figure 2-2. Canonical correspondence analysis (CCA) biplot for all trees >10 cm dbh sampled in 1969 with overlay of ecological landtypes (ELT's) found in the ONSR. See Table 2-1 for ELT descriptions.

Accuracy of ELT Designations

Multivariate analyses traditionally have been used to characterize the vegetation of discrete landtypes. Analyses such as canonical analysis, principle components analysis, and canonical correspondence analysis may produce distinct clusters of plots that define the landtype. For instance, Pregitzer and Barnes (1984) present an ordination based on the basal areas of seven overstory species. Their data from upland sites fell into distinct clusters of points that corresponded to unique landtypes. Similarly, trends are apparent in the ordinations of our data when the number of tree species is reduced from 54 to 14 (Fig. 2-3). Lowland sites tend to be grouped and are somewhat distinct from more upland sites in the canonical correspondence analysis (CCA). However, our data do not show a distinctive clustering of points. Instead, the distribution of study plots in our data is continuous, which suggests that ELTs grade one into the other in these lowland sites.

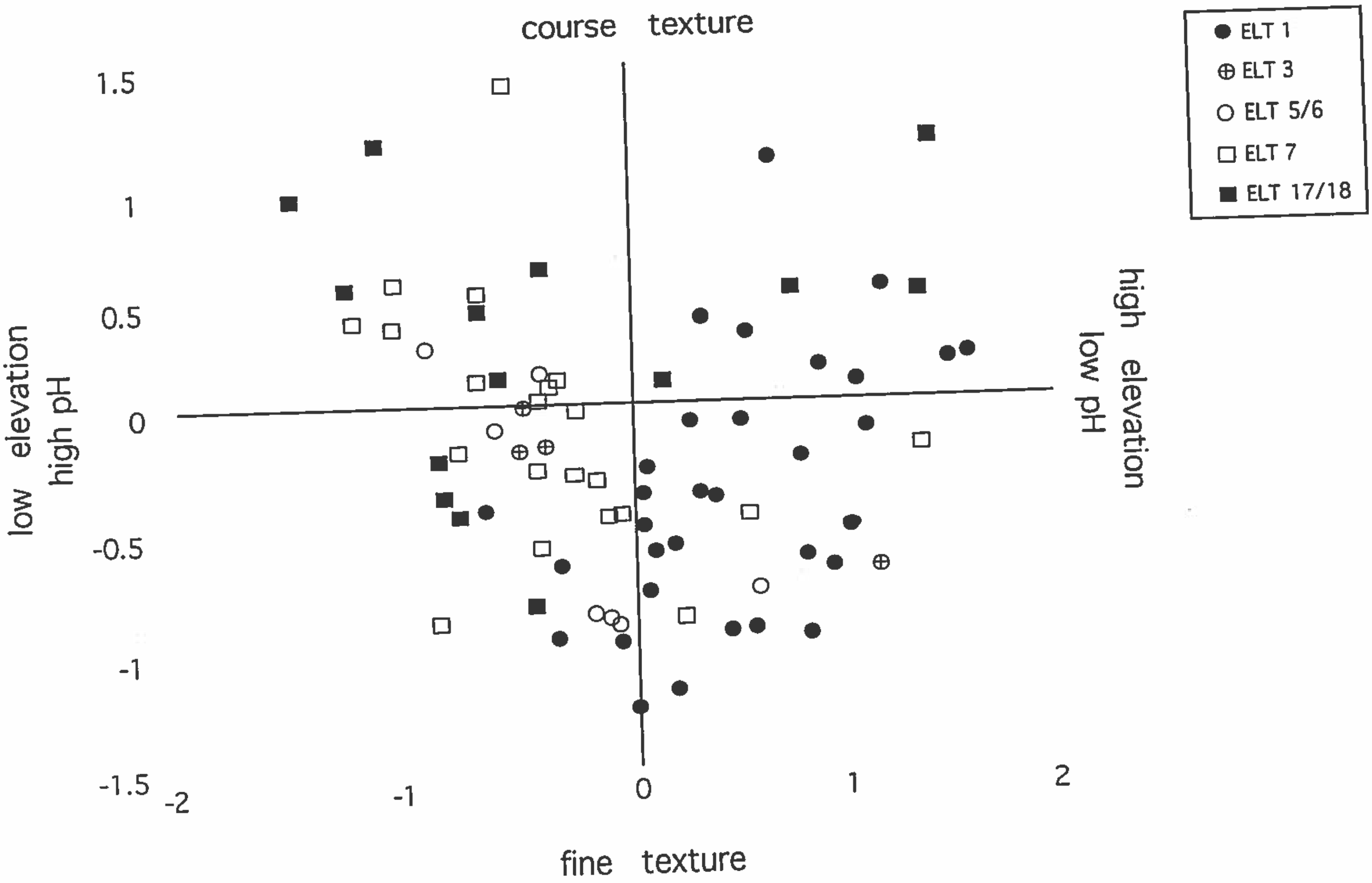

Fig. 2-3. CCA ordination of 14 common tree species of the ONSR with ELT overlay. Elevation and soil pH were important environmental determinants of Axis 1. Soil texture was an important determinant of Axis 2.

The question that remains is whether the data would more resemble Pregitzer and Barnes (1984) if the number of study plots were increased. I tested this hypothesis with a discriminant analysis using the reduced data set of 14 common tree species. Beginning with an ordination of 80 plots, I randomly eliminated 10, 20, 40 and 50 plots. Each random elimination step was replicated five times. Following each round, I tallied the number of plots classified in each ELT. Accuracy is defined here as the proportion of the plots that were categorized in only one ELT.

Unlike Pregitzer and Barnes, most of the study plots fell in to more than one ELT designation. The accuracy of the classification was a function of the number of plots included in the analysis. Accuracy decreased as the number of plots in the sample increased (Fig. 2-4). That is, as the number of plots increased, it became more difficult to accurately classify any single plot. Accuracy continues to decline with increasing sample size when assignment to 2, 3, 4 or 5 ELTs is considered (Fig. 2-5). These results are the outcome of the distribution of sampling plots. Because the distribution of sampling plots is continuous, increasing the sample size increases the amount of overlap among ELT units. This outcome would be nearly impossible if the data were truly clustered.

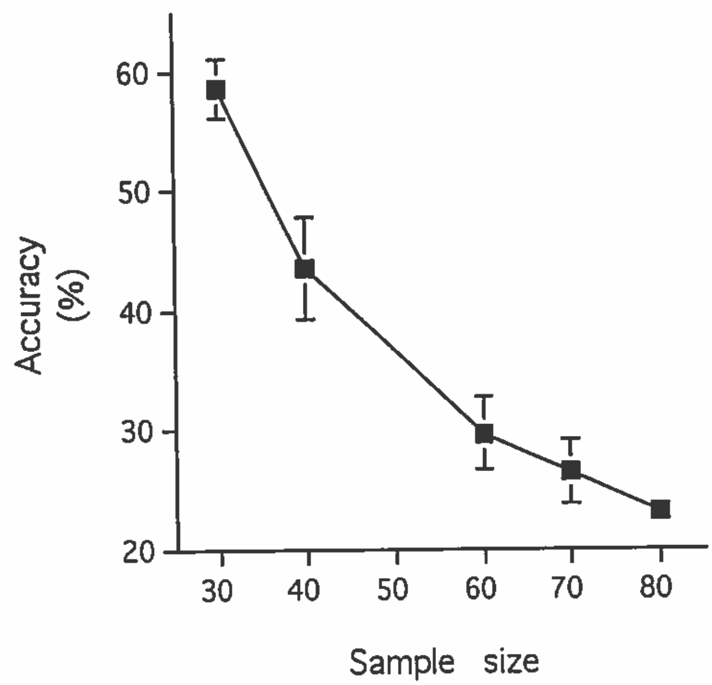

Fig. 2-4. Accuracy of ELT assignment as a function of sample size. Accuracy is defined as the proportion of study plots assigned to a single ELT designation. Symbols represetn the mean (±1 SE) of five replicates when the sample size is 30, 40, 60, 70, or 80 study plots.

We conclude from this analysis that increasing the number of sample plots will fill in the existing gaps in the graded distribution of data points. Increasing the number of plots would very likely increase the precision of the estimate of the mean values for each ELT but would not reduce the variance about the mean. Therefore, increasing the number of sampling plots will not decrease the probability of erroneously assigning an ELT.

Vegetation requires 100's-1000's of years of succession to become stable (Olson 1958, Chadwick and Dalke 1965, Fonda 1974) and using vegetation to characterize land types has proven especially useful in stable, relatively undisturbed upland forests (Pregitzer and Barnes 1984, Hix 1988). The cycle of disturbance in the riparian zone, however, is on the order of 1 - 5 years. It is unlikely, then, that riparian vegetation will ever reach a stable, climax state. Plant associations in chronically disturbed areas are the products of chaotic combinations of dispersal ability, ecological tolerances of colonizing species, and previous land use history (Barbour et al. 1986), and are expected to be less regular than in stable, late successional seres. Although random species mixes may eventually mature into regular and predictable species associations, the earliest stages of succession are characterized by erratic mixtures produced by chance events (Loucks 1970). Our results are entirely consistent with this view. It is likely that the use of landform (e.g., geomorphology) may be appropriate to describe ELTs in the riparian zone, whereas the use of vegetation may prove more productive in less dynamic systems, such as upland forests. Physical characters (slope, aspect, soil characteristics) accounted for over 81% of the variance in our data set. In surveys of the riparian zone, therefore, an ELT may be more adequately described by landform, soil properties, and other physical characteristics than by plant species assemblages.

Management implications

Neither plant species associations nor the CCA indicate that vegetation segretates according to ecological landtypes. Clearly, more research is needed in this area. Extensive sampling of soils and landforms is needed both in the riparian areas and the upland forests. Identification of understory tree, shrub, and herbaceous units may also be helpful in categorizing vegetation and assessing the value of existing ELT maps. ELT designations may be more useful for canopy trees than for categorizing the overall vegetation types.

OBJECTIVE 3: Plant Species Assemblages

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 detrended correspondence analysis (DCA) and canonical correspondence analysis (CCA) ordinations were conducted on plant species-environmental variable matrices using the programs PC-ORD (McCune and Mefford 1995) and CANOCO 3.10 (ter Braak 1990). Importance values (IV's) were calculated for all tree species for each sampling plot as the sum of relative density (100% max) + relative dominance (max 100%). The maximum IV possible for a monotypic plot was thus 200%. Tree species IV's or total basal areas were used in all the ordination and classification methods described. Mean cover values were used for herbaceous species. The DCA procedure used segment detrending, nonlinear rescaling of axes, and no downweighting of rare species (Hill and Gauch 1980). The CCA procedure involved linear combination of variables for site scores, no transformation of species abundance matrices, and the use of a Monte Carlo permutation test to test the significance of the first axis eigenvalue (ter Braak 1990). To determine if different functional types exhibited differential responses to the same suite of environmental variables, separate CCA ordinations were performed on four a priori defined functional types: major overstory dominants, all overstory trees, understory trees, and woody shrubs. Appendix III contains a list of all species encountered and their classification into functional types.

Classification

Classification of woody plant assemblages was also conducted with aid from the program TWINSPAN (Hill 1979). TWINSPAN classifications were partially modified to help clarify the validity of the indicator species detected (Dale 1995). The soil and environmental variables measures described in the Methods section were transformed, when necessary, to meet the assumptions of normality. Correlations between environmental variables and ordination axes scores were run using Minitab 8.2 (Minitab 1991). Significance is reported at the alpha = 0.05 level, unless noted otherwise in the text.

Classification of herbaceous species assemblages was also conducted using cluster analysis (McCune & Mefford 1995). Relative Euclidean distance was used as a distance measure and Ward's method was used for group linkage. To evaluate the variation in herbaceous vegetation and environmental variables among clusters, analysis of variance tests were performed using the general linear model (GLM) procedure in Minitab 8.2 (Minitab 1991). Total species richness was defined at the sum of species across sub-sample plots within each larger sample plot. Species fidelity was defined as the number of plots where a species was found out of the total plot number. Significance is reported at the alpha = 0.05 level, unless otherwise noted.

To test if there was any relationship between the herb and tree layer, cluster analysis groupings were compared using a KAPPA chi-square statistic. An 8x8 contingency table was created based on the eight clusters found via cluster analysis for both the herb and tree layer. Cells contained the number of common plots found between each pairing of herb and tree layer clusters. The null hypothesis was that there was overlap in clusters between layers (i.e., a coupling of vegetation clusters between the herb and tree layers). Any significant result would result in a rejection of the null hypothesis (i.e., layer clusters were not coupled). The presence of ecotonal features in the vegetation data were determined by the use of differential DCA profiles using DCA scores (Hill 1979, Hobbs 1986). DCA graphical profiles were created by plotting sample plot scores from the first axis of DCA ordinations versus plot position on transects. We used transect position as a surrogate for elevation of the plot above the river. In a DCA graphical profile, the steeper the profile slope, the more abrupt the change in the composition of vegetation, and the more abrupt the ecotone.

Detection of Ecotones

The presence of ecotones in the vegetation data were determined using both a combined dataset of all woody vegetation and by segregating the data into vegetation layers (i.e., dominant trees, overstory trees, understory trees, shrubs, herbs). Data were compiled from all appropriate transects into a single elevation transect. A 'moving window' algorithm (8 frames) was used to calculate a squared Euclidean distance (SED) between the two windows as they 'moved' along the elevation transect for the combined dataset (Brunt and Conley 1990). SED is an effective edge/ecotone detection technique for multivariate (i.e. multi-species) data sets (Ludwig and Cornelius 1987, Brunt and Conley 1990). Using this technique, a SED graphical profile is produced whereby ecotones appear as peaks (maximum values of the difference metric). These peaks indicate that the rate of species attribute change is at a maximum (Johnston et al. 1992). A second ecotone detection method was also employed. Differential DCA profiles were derived from each vegetation layer using DCA scores (Hill 1979, Hobbs 1986). DCA graphical profiles were created by plotting sample plot scores from the first axis of the respective DCA ordinations versus transect position. In this study, transect position was used as a surrogate for elevation of the plot above the river. In a DCA graphical profile, the steeper the profile slope, the more abrupt the change in the composition of vegetation, and the more abrupt the ecotone.

RESULTS

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 ONSR (Jacobson and Primm 1994). Thus, the sampling regime was effective in surveying across several environmental gradients and vegetation assemblages in the riparian landscape. The corresponding range in plot locations relative to river elevation (0.1 - 40.0 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 multicollinearity 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).

CCA and DCA Ordinations

In all CCA ordinations performed, the Monte Carlo permutation test indicated that the eigenvalues for the first axes were all significant ($P < 0.05$). Comparison of eigenvalues and environmental variable correlations with the first three axes of both the DCA and CCA ordinations were very similar. 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).

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. Significant correlations between variables are noted by a * (= P < 0.05).

Variable †	Slope	Aspect	HAR	pH	Fines	Cont cap	Sand	Silt	Clay	OM
Slope										
Aspect	-0.079									
HAR	0.386*	-0.060								
pH	-0.217	-0.088	-0.473*							
Fines	-0.071	0.176	-0.012	-0.215						
Cont cap	0.382*	-0.111	0.436*	-0.150	-0.150					
Sand	-0.165	0.018	-0.123	0.456*	-0.247	-0.126				
Silt	0.118	-0.031	0.142	-0.380*	0.219	0.268	-0.877*			
Clay	0.383*	0.066	0.129	-0.257	-0.093	0.134	-0.553*	0.362*		
OM	0.385*	-0.094	0.363*	-0.006	-0.003	0.880*	-0.260	0.414*	0.233	
units	deg	deg	m	pH	%	%	%	%	%	% LOI
Mean	20.7	-	8.75	6.07	60.2	33.9	33.8	8.1	58.1	8.3
Median	16.0	-	4.35	6.19	57.0	33.6	27.8	5.6	66.7	6.8
Range										
low	0.0	-	0.1	3.54	1.2	20.2	0.0	0.0	0.0	0.6
high	65.0	-	40.0	7.40	99.9	52.5	97.2	36.1	99.4	43.1

† Variables are defined as follows: slope = slope (^{o}) through the vegetation plot; aspect = aspect of plot (^{o}); HAR = height above river of vegetation plot (m); pH = soil pH of top 10 cm of soil; Fines = % of total sample < 2 mm dia; Cont cap = container capacity of soil samples (%); Sand = % sand in soil; Silt = % silt in soil; Clay = % clay in soil; OM = organic matter content (%) in top 10 cm of soil determined by LOI (loss on ignition).

Functional Type Analysis

A comparison of 'intraset correlations' (ter Braak 1986) with the first three CCA ordination axes of the four functional types for woody species is given in Table 3-2. A listing of all woody species encountered in the sampling, tree species basal area, and functional type are presented in Table 3-3. Comparisons of environmental variable correlations across all three CCA axes (Table 3-2) reveal overlap in the variables with the strongest correlations (HAR, pH, cont cap, OM, slope, silt, sand, fines, aspect). The main differences appear to be in terms of which axes exhibit the correlations.

Table 3-2. A comparison of CCA ordination results between dominant trees and three functional type groupings: overstory trees, understory trees, and shrubs (see Table 3-3) for categorization of dominants, overstory, understory, and shrub species). Eigenvalues, and both environmental variable and species-environment correlations with CCA ordination axes, are shown for comparison.

	DOMINANT TREES			OVERSTORY			UNDERSTORY			SHRUBS		
	AXIS			AXIS			AXIS			AXIS		
	1	2	3	1	2	3	1	2	3	1	2	3
Eigen-values	0.511	0.243	0.170	0.569	0.313	0.200	0.510	0.256	0.175	0.907	0.863	0.631
Variables *												
Slope	-0.553	0.031	-0.295	0.474	0.209	-0.087	0.393	-0.540	-0.130	0.500	0.012	0.276
Aspect	0.331	0.046	0.423	-0.063	-0.215	-0.409	-0.079	0.155	0.088	0.129	0.020	-0.007
HAR	-0.701	0.250	0.078	0.770	0.310	0.135	0.888	-0.026	0.329	0.555	-0.038	0.236
pH	0.631	-0.545	-0.147	-0.754	-0.237	-0.366	-0.677	-0.148	0.224	-0.170	0.595	-0.409
Fines	-0.001	-0.251	0.414	0.458	-0.740	0.081	0.194	0.027	0.011	0.518	-0.077	-0.054
Cont cap	-0.699	-0.265	-0.061	0.500	0.049	-0.571	0.123	-0.101	0.334	0.759	-0.159	0.160
Sand	0.474	0.211	-0.498	-0.479	0.118	-0.066	-0.224	-0.565	0.593	-0.098	0.641	-0.484
Silt	-0.487	-0.249	0.614	0.471	-0.235	0.036	0.024	0.415	0.056	0.236	-0.749	0.166
Clay	-0.347	-0.213	0.098	0.261	0.166	-0.087	0.324	-0.157	-0.224	-0.056	-0.283	0.379
OM	-0.641	-0.362	0.073	0.481	-0.202	-0.573	0.208	-0.001	0.031	0.881	0.011	0.045
Spp-Envt†	0.814	0.699	0.542	0.870	0.738	0.720	0.832	0.711	0.583	0.956	0.950	0.819

* Descriptions of environmental variables and how they were determined can be found in the Methods section and at the bottom of Table 3-1.

† Spp-Envt correlations refer to Pearson correlations between sample scores that are linear combinations of environmental variables and sample scores that are based on species data.

Table 3-3. Latin binomials, functional type (Func Type) designation, and basal areas for all woody species encountered in this study. Nomenclature follows Steyermark (1968). The 14 most dominant tree species are indicated by boldface in the BA column.

Latin binomial	Func Type*	BA †	Latin binomial	Func Type	BA
Acer negundo	O	**100.5**	*Nyssa sylvatica*	O	1.0
Acer rubrum	O	2.3	*Ostrya virginiana*	U	17.8
Acer saccharinum	O	10.1	*Parthenocissus quinquefolia*	S	
Acer saccharum	O	**163.0**	*Philadelphus hirsutus*	S	
Aesculus glabra	O	11.8	*Philadelphus pubescens*	S	
Agrimonia pubescens	S		*Physocarpus opulifolius*	S	
Agrimonia rostellata	S		*Pinus echinata*	O	15.8
Amelanchier arborea	S		*Platanus occidentalis*	O	354.5
Ampelopsis arborea	S		*Populus deltoides*	O	38.6
Asimina triloba	U	29.1	*Prunus serotina*	O	2.9
Betula nigra	O	4.4	*Quercus alba*	O	**314.7**
Bumelia lanuginosa	U	0.3	*Quercus bicolor*	O	3.3
Campsis radicans	S		*Quercus falcata*	O	14.0
Carpinus caroliniana	U	33.3	*Quercus imbricaria*	O	0.3
Carya cordiformis	O	**157.1**	*Quercus lyrata*	O	24.4
Carya glabra	O	15.7	*Quercus macrocarpa*	O	**113.8**
Carya illinoensis	O	8.0	*Quercus marilandica*	O	3.7
Carya lacinosa	O	0.1	*Quercus muhlenbergii*	O	**48.5**
Carya ovata	O	2.6	*Quercus rubra*	O	**157.3**
Carya texana	O	6.1	*Quercus shumardii*	O	6.2
Carya tomentosa	O	**29.9**	*Quercus stellata*	O	5.0
Catalpa speciosa	O	1.4	*Quercus velutina*	O	**88.2**
Celtis laevigata	O	10.9	*Rhamnus caroliniana*	U	2.5
Celtis occidentalis	O	**40.0**	*Rhus aromatica*	S	
Celtis tenuifolia	S		*Rhus glabra*	U	9.8
Cercis canadensis	U	17.6	*Rosa sp.*	S	
Cornus drummondii	U	0.7	*Salix nigra*	O	6.9
Cornus florida	U	50.4	*Sambucus canadensis*	S	
Corylus americana	S		*Sassafras albidum*	U	2.0
Cotinus obovatus	S		*Staphylea trifolia*	U	0.1
Crataegus viridis	O	1.8	*Tilia americana*	O	0.9
Diospyros virginiana	O	14.2	*Toxicodendron radicans*	S	
Fagus grandiflora	O	0.2	*Ulmus alata*	O	19.1
Fraxinus americana	O	**34.3**	*Ulmus americana*	O	**132.4**
Fraxinus pennsylvanica	O	24.0	*Ulmus pumila*	O	2.2
Fraxinus quadrangulata	O	0.3	*Ulmus rubra*	O	**91.3**
Gleditsia triacanthos	O	2.0	*Viburnum prunifolium*	U	1.0
Hamamelis virginiana	U	1.2	*Viburnum rufidulum*	S	
Ilex decidua	U	0.3	*Vitis aestivalis*	S	
Juglans cinerea	O	3.1	*Vitis cinerea*	S	
Juglans nigra	O	19.3	*Vitis riparia*	S	
Juniperus virginiana	O	**44.0**	*Vitis rupestris*	S	
Lindera benzoin	U	6.5	*Vitis vulpina*	S	
Morus rubra	O	21.1	*Zanthoxylum americanum*	S	

* Func Type refers to plant functional type: O = overstory tree (50 species); U = understory tree (15 species); S = woody shrub (23 species)

† BA = basal area (m^2/ha) summed across all 94 plots; boldfaced values note the 14 most dominant species

All Tree Species Combined

Fig. 3-1 is a biplot of the CCA ordination for all tree species (n=65). The eigenvalues for the first two axes (λ_1= 0.624 and λ_2= 0.334, respectively) indicate separation along the measured gradients. Six 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 = 0.789) and pH (r = -0.757). Fines (particle size < 2mm dia) showed the highest correlation with the second axis (r= -0.801). Separation of vegetation plots located on gravel bar and directly adjacent to the river channel is represented by points in the upper left quadrant of the ordination (low elevation, high pH). CCA ordination of species (results not presented) indicated that bottomland tree species such as *Platanus occidentalis*, *Salix nigra*, and *Ulmus pumila* were dominant in the upper left quadrant. Some separation of plots supporting upland oak assemblages were also noted in the upper right quadrant of the ordination (high elevation, low pH). Upland species such as *Quercus alba*, *Q. velutina*, *Q. marilandica*, and *Carya texana* were noted in CCA species ordinations in this quadrant. 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 proportion of fines or stoniness on the second axis.

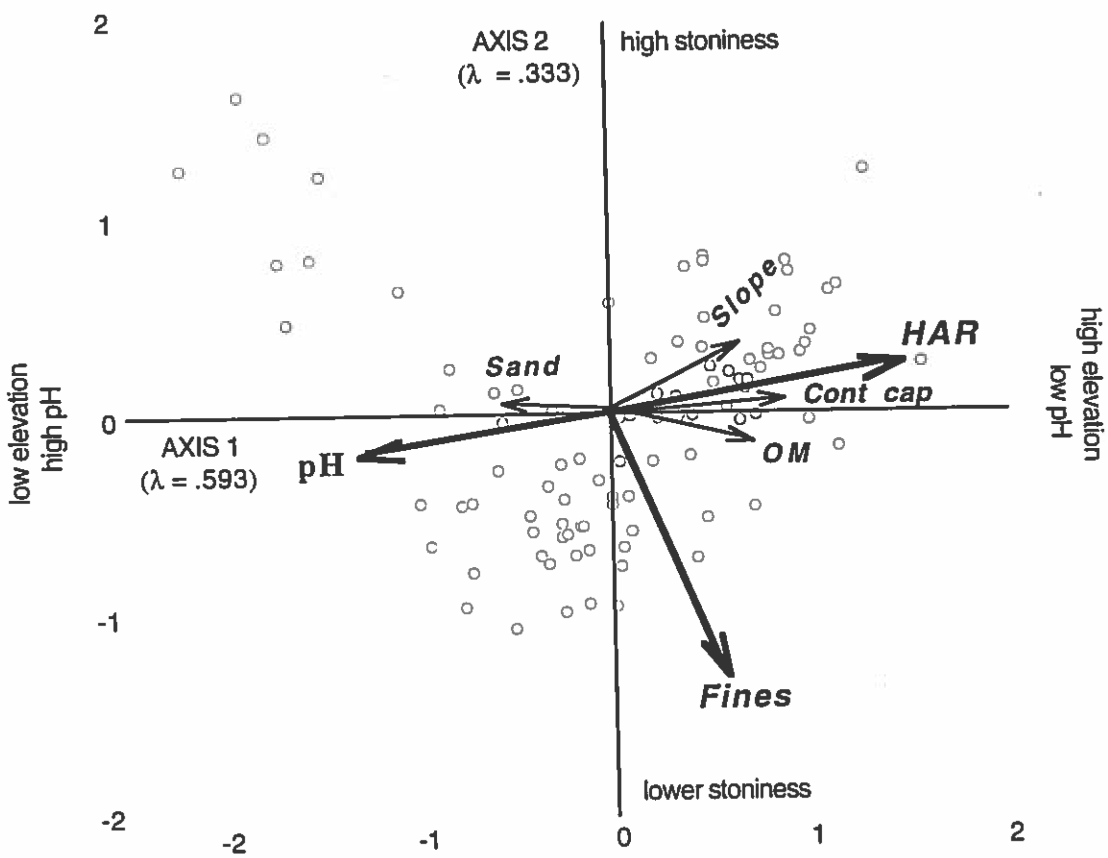

Fig. 3-1. CCA ordination of 94 plots and 65 woody species (>1cm dbh) with 10 environmental variables. Biplot vectors shown represent the major explanatory environmental variables (see Table 3-1 for codes). Thicker vector lines represent stronger 'intraset correlations' (after ter Braak 1986).

Dominant Trees

Fig. 3-2 indicates that in the ordination of dominant trees, fines were not as strongly correlated with axis 2 ($r = -0.251$) or axis 3 ($r = 0.414$) compared to axis 2 ($r = -0.801$) of the overall CCA depicted in Fig. 3-2. Furthermore, container capacity and OM increase in importance relative to the results shown in Fig. 3-2. Overall, the dominant trees appear to be more influenced by OM and container capacity (a correlate of soil moisture potential), and less by fines, compared to the overall CCA results (Table 3-2). Plots containing upland oak and hickory species were found exclusively in the upper right quadrant. Bottomland species were noted in the upper left quadrant, and a varied assortment of wet-mesic to mesic species were noted in the lower quadrants, including *Acer saccharum*, *Acer negundo*, *Ulmus rubra*, *Juglans cinerea*, and *Quercus rubra*

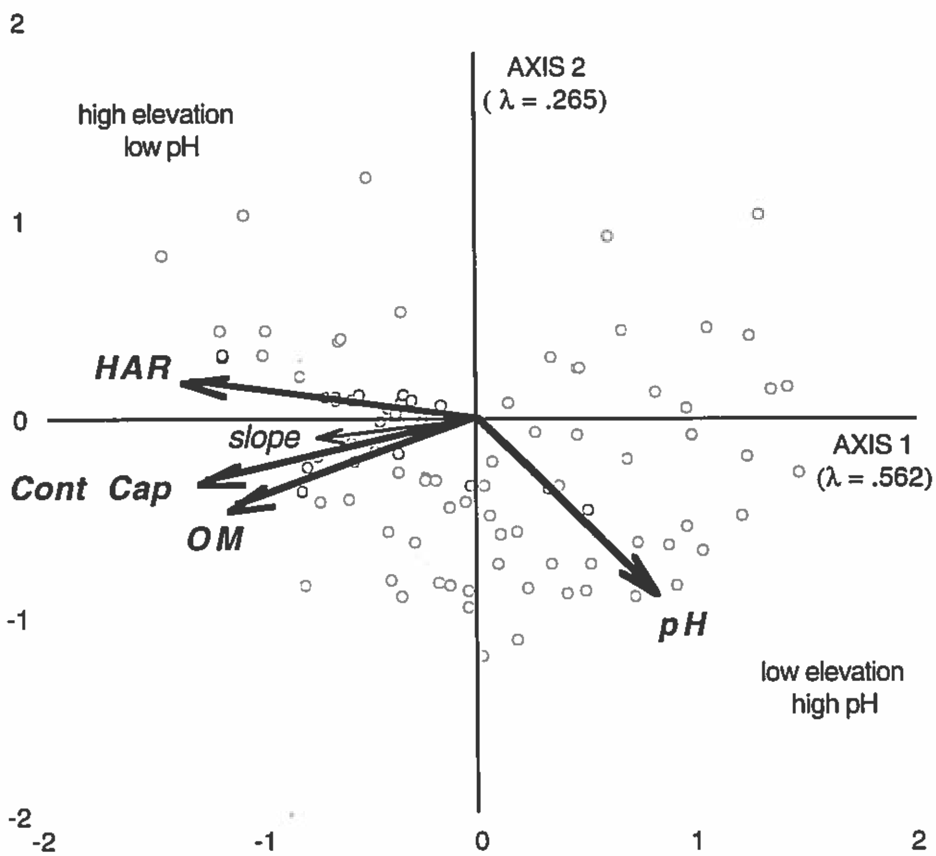

Fig. 3-2. CCA ordination of 93 plots and the 14 most dominant tree species found throughout the ONSR with 10 environmental variables. Biplot vectors shown represent the major explanatory environmental variables (see Table 3-1 for codes).

Overstory Trees

A CCA ordination of plots based solely on overstory trees (n = 50 species) was also performed (Fig 3-3). The environmental variable correlations across all three CCA axes were very similar to the results observed for the overall CCA ordination (Table 3-2). This is not surprising owing to the large influence of overstory trees (high IV's) on the results of the overall CCA ordination. Thus, the segregation of all overstory trees from the overall woody species matrix did not indicate any substantial variation in species responses to environmental gradients.

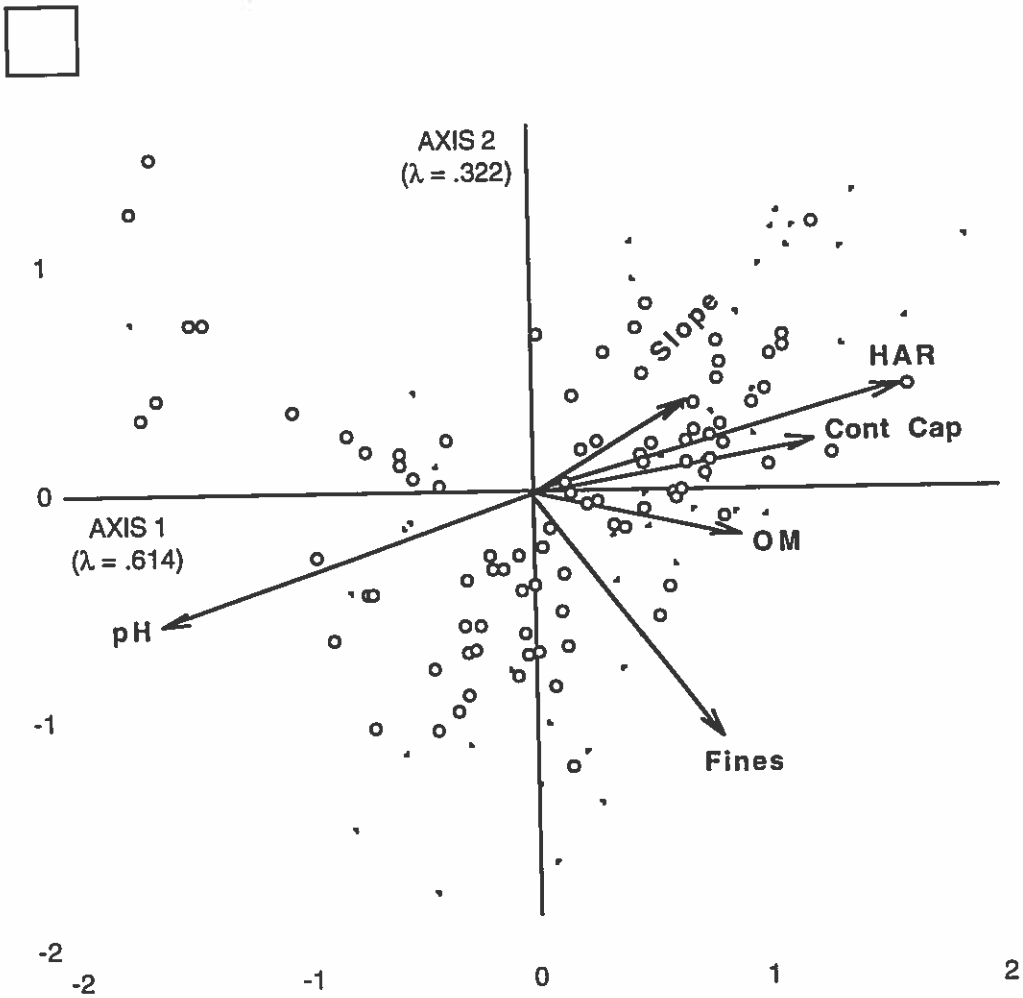

Fig. 3-3. CCA ordination of 94 plots and 50 overstory tree species (> 1 cm dbh) with 10 environmental variables. Biplot vectors shown represent the major explanatory variables (see Table 3-1 for codes).

Understory Trees

The CCA biplot for understory tree species (15 total species) is illustrated in Fig. 3-4. Similar to the overall, dominant overstory, and overstory functional type ordinations, strong correlations were observed between the first CCA axis and HAR (r = 0.888) and pH (r = -0.677). However, distinct differences from the other functional type ordinations were evident. Strong correlations between sand and CCA axes 2 and 3 (r = -0.565 and r = 0.593, respectively) and between CCA axis 2 and slope (r = -0.540) were noted. The correlation of axis 2 with fines (r = 0.027) also was much weaker compared to the overstory and overall CCA ordinations. CCA ordination of understory species (results not presented) indicated that *Cornus florida* was the only species in the upper right quadrant. Bottomland species such as *Sambucus canadensis* and *Asimina triloba* were centered in the upper left quadrant. The species positively correlated with percent sand included *Rhus aromatica*, *R. glabra* and *Staphylea trifolia*; species positively correlated with increased slope included *Sassafras albidum*. These results indicate that understory trees exhibited a differential response to the same underlying environmental gradients compared to the other functional types, thus reflecting a differential environmental responses between overstory and understory tree species.

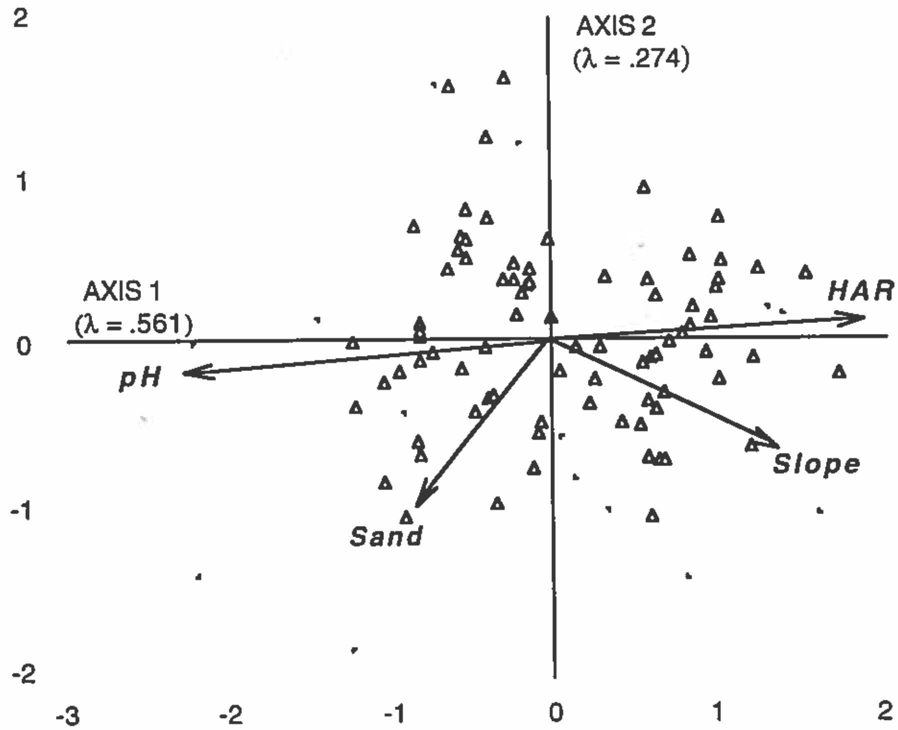

Fig. 3-4. CCA ordination of 81 plots and 15 understory trees (>1cm dbh) with 10 environmental variables. Biplot vectors shown represent the major explanatory variables (see Table 3-1 for codes).

Woody Shrubs

A woody shrub functional type was also analyzed (n = 23 species). The CCA biplot for woody shrubs is shown in Fig. 3-5. The relationships between woody shrubs and the measured environmental variables strongly differed from the other functional types. CCA axis 1 was strongly correlated with OM (r = 0.881) and cont cap (r = 0.759). Axis 2 showed the strongest correlations with silt (r = -0.749) and sand (r = 0.641). Correlations with pH (r = 0.595, axis 2) and HAR (r = 0.555, axis 1) were still evident, but not as pronounced. Overall, woody shrub responses to environmental gradients differed substantially from the other functional types analyzed with species on shrub plots more strongly correlated with container capacity, OM, and silt than the other ordinations.

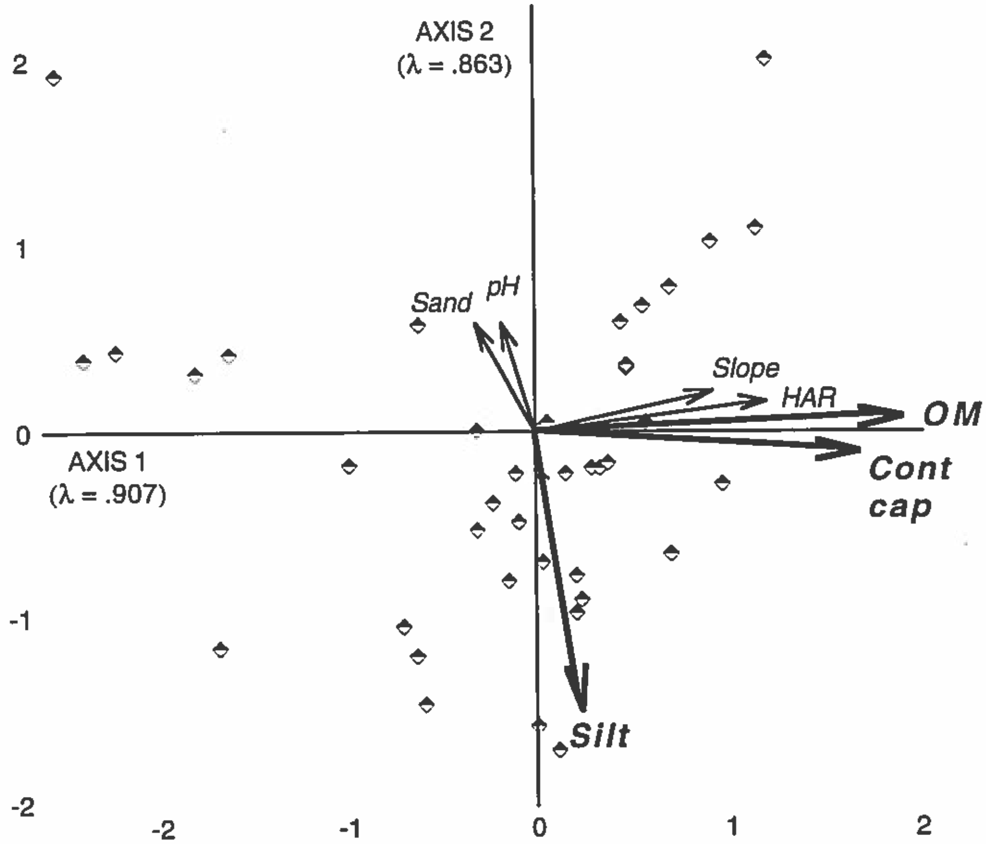

Fig. 3-5. CCA ordination of 41 plots and 23 woody shrub species (cover estimates) with 10 environmental variables. Biplot vectors shown represent the major explanatory environmental variables (see Table 3-1 for codes). Thicker vector lines represent stronger 'intraset correlations' (after ter Braak 1986).

Herbaceous Species

Fig. 3-6 is a biplot of the canonical correspondence analysis (CCA) for all herbaceous species (n = 264) on 94 plots with 10 environmental variables. Although many of the environmental variables were correlated with one another, CCA is not prone to multicollinearity effects (ter Braak 1990; Palmer 1993). The eigenvalues for the first two axes (0.553 and 0.517, respectively) indicate acceptable levels of separation of plot scores along the measured environmental gradients. The five variables most strongly correlated with the first two CCA axes are represented by vectors on the biplot in Fig. 3-6. The biplot shows that pH (r = -0.708) and HAR (r = 0.791) were the dominant environmental gradients influencing vegetation patterns on the first CCA axis and fines exhibited the strongest correlation (r = -0.905) with the second CCA axis. Secondary gradients of importance included slope, cont cap, and OM. 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 *Melothria pendula* L., *Acalypha rhomboidea* Raf. var. *rhomboidea*, *Amorpha fruticosa* L., and *Cuscuta compacta* Juss. Species adapted to drier and more acidic conditions were found on the far right of the first CCA axis, including *Aster anomolus* Engelm. and *Cunila origanoides* (L.) Britt.

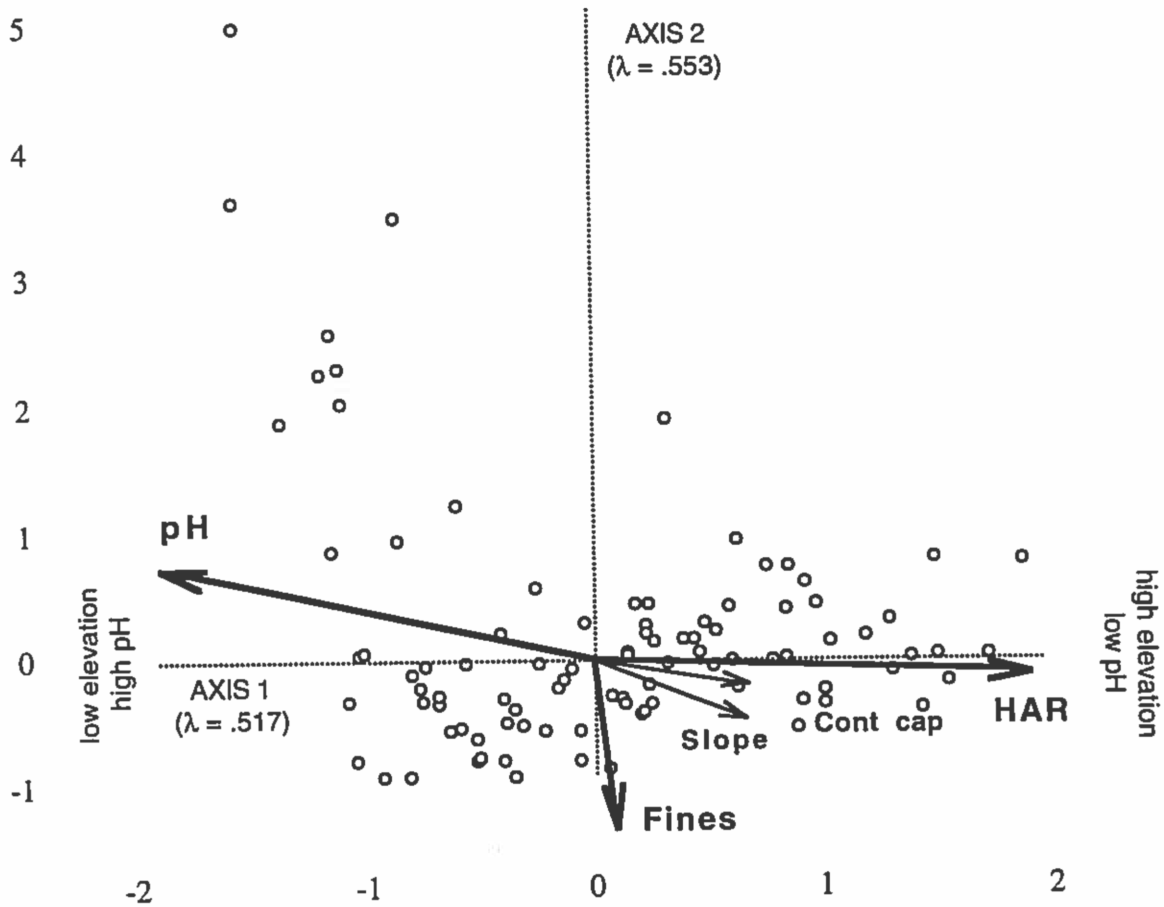

Fig. 3-6. CCA biplot for all herb species on 94 plots with 10 environmental variables. Biplot vectors shown represent the major explanatory variables (see Table 3-1 for codes). Thicker lines represent stronger 'intraset correlations' (after ter Braak 1986).

These results provide strong evidence that different functional types of woody and herbaceous vegetation in the ONSR riparian landscape 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 five functional types are not completely 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 woody shrubs and herbaceous species.

Classification of Woody Vegetation

To determine if discrete assemblages of all trees and shrubs were evident in the ONSR, TWINSPAN was used to classify the overall woody vegetation data (Hill 1979). The analysis was stopped at level 5 and the subsequent TWINSPAN results were used to aid in the classification of the woody vegetation. While the TWINSPAN results indicated 20 associations, we collapsed these groups to form a total of 12 associations based on the high degree of species similarity in some of the groups. To graphically depict these associations on the CCA ordinations, the centroids of each association (and their standard deviations) were calculated from CCA scores on the first two axes, and then were plotted (Fig. 3-7). Three distinct groupings of the 12 associations can be ascertained from Fig. 3-7. The bottomland association (group 12) has a mean height above river of 3.5m (thus clearly prone to flooding) and is the only group that clearly separated out on the CCA plot. A cluster of upland groups dominated by upland oak (*Quercus*) and hickory (*Carya*) species is indicated by the cluster of groups 1, 2, 3 and 4 on the high elevation, low pH side of CCA axis 1. The third cluster (groups 5 - 11) are relatively close in ordination space and many associations exhibit a high degree of overlap. The clustering and species overlap of these latter groups is not unexpected based on the differential responses of functional types observed and depicted in Fig.'s 3-1, 3-2, 3-3, 3-4, 3-5 and 3-6 and in Table 3-2.

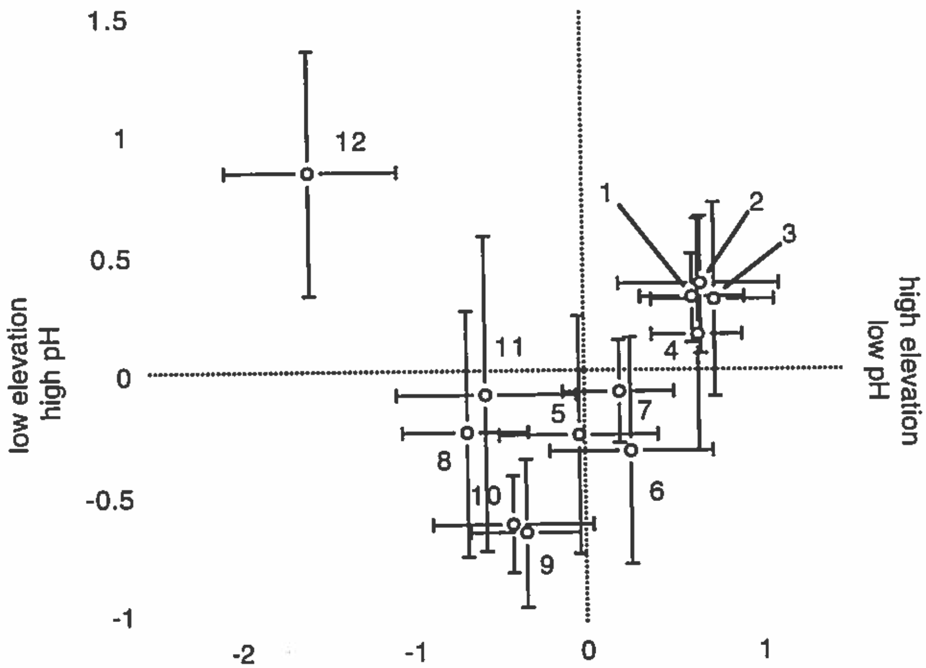

Fig. 3-7. CCA ordination of 94 plots and 70 tree species (>1cm dbh) with 10 environmental variables. Centroids of the 12 vegetation associations determined with the aid of TWINSPAN are shown, as are the standard errors on the two ordination axes.

The three forest groupings represent partially distinct assemblages that fall along a vegetation continuum rather than as discrete assemblages or communities. The characteristics of each group and the rationale for their segregation are presented below.

Environmental characteristics of forest groups

Table 3-5 provides a comparison of the 10 environmental variables measured in this study among the 3 forest groups. No significant differences in aspect, sand, silt, clay or fines were noted among the three groups. However, HAR, pH, OM, and cont cap all showed incremental and significant increases moving from the bottomland to transition to the upslope forests. It is not surprising that these same variables exhibited the strongest correlations with the CCA ordination axes. Slope, not unexpectedly, was higher on the transition and upslope plots than the bottomland plots. The coefficients of variation (CV's) in Table 3-5 are generally quite high for most variables (range 38-105%), except pH (range 6-16%) and container capacity (19%). These results indicate a high level of substrate and physical site heterogeneity within the forest groupings in the ONSR landscape.

Species composition of disturbed sites

Trees - Comparisons of the overall basal area and species richness of disturbed sites differs from other forest groups. Total basal area was reduced 89% in disturbed sites relative to mesic bottomland sites. Species richness in campsites an hayfields was 54% lower than in mesic bottomlands. Of the five most important tree species of the mesic bottomland forest group, white oak, bur oak, sugar maple, boxelder, and sycamore, only sycamore was common in disturbed sites. White oak, bur oak, and sugar maple were missing from disturbed sites.

Table 4-2. A comparison of basal areas ($m^2\ ha^{-1}$) of tree species organized by ELT designation. Values shown are means ± 1SE.

	Disturbed	Gravel wash	Wet mesic bottomland	Mesic bottomland	Toe slope	Upland waterway
number of plots	7	11	47	12	23	11
Quercus velutina	**0**	0	0	20.3±18.6	114.7±63.0	244.8±113.0
Quercus alba	**0**	0	9.0±9.0	281.5±175.6	645.9±223.9	249.3±113.3
Fraxinus americana	**0**	0.6±0.6	3.5±1.5	8.7±8.4	71.5±52.6	17.0±10.4
Ulmus alata	**0**	4.0±4.0	24.0±15.2	20.2±20.2	8.8±4.5	2.0±2.0
Quercus muhlenbergii	**0**	0	21.9±16.6	16.1±15.4	16.1±11.0	144.2±60.7
Carya cordiformis	**0**	0	78.6±36.4	43.9±43.9	300.1±96.0	98.2±56.5
Quercus macrocarpa	**0**	0	152.6±66.8	270.9±270.9	209.0±120.3	3.9±3.9
Acer saccharum	**0**	0	106.7±53.0	257.6±172.8	204.3±60.42	234.5±74.8
Quercus rubra	**0**	0	162.4±123.7	0	240.0±106.0	60.0±60.0
Ulmus rubra	**9.5±9.5**	0	157.2±56.4	64.9±60.5	13.9±7.3	59.3±49.2
Acer negundo	**10.2±8.7**	0	303.4±81.7	269.8±127.5	0	4.3±4.3
Celtis occidentalis	**2.5±2.5**	0	92.8±43.3	3.3±2.3	0.9±0.7	0
Platanus occidentalis	**72.7±72.6**	679.5±542.1	600.7±190.1	189.5±188.9	20.0±20.0	0
Ulmus americana	**57.3±57.3**	6.0±6.0	183.5±47.5	0	109.2±76.9	111.8±72.0

Shrubs and subcanopy trees - Table 4-3 provides a comparison of understory species among ELT groups. The composition and relative abundance of shrub species is completely altered in the disturbed sites relative to the mesic bottomland forest ELT's. Of the 10 most abundant species in the mesic bottomland forest, nine were absent in campsites and hayfields. Overall, species richness of shrubs is reduced in disturbed sites (90% decrease). 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.

Table 4-3. A comparison of Importance Values (IVs) of woody shrub species organized by ELT designation. Values shown are means ± 1SE.

	Disturbed	Gravel wash	Wet mesic bottomland	Mesic bottomland	Toe slope	Upland waterway
number of plots	7	11	47	12	23	11
Lindera benzoin	**1.8±1.8**	0	8.9±2.6	4.5±2.6	5.3±2.4	4.5±3.5
Hamamelis virginiana	0	7.3±7.3	0.2±0.2	3.1±3.1	0	0
Cercis canadensis	0	0.6±0.6	1.3±0.5	1.1±0.8	3.0±1.6	4.5±2.2
Asimina triloba	0	0	23.9±6.0	7.0±3.7	4.3±2.2	5.0±3.4
Carpinus caroliniana	0	0	9.8±3.7	3.1±2.2	20.4±9.6	8.5±3.7
Cornus amomum	0	0	0.4±0.3	0	0	0
Sambucus canadensis	0	0	0.3±0.3	0	0	0
Sassafras albidum	0	0	0.1±0.1	0	1.8±1.1	4.2±4.0
Staphylea trifoliata	0	0	1.5±1.0	0	1.1±1.1	2.6±2.6
Vitis cinera	0	0	1.5±0.8	0	1.0±0.5	0.1±0.1
Cornus florida	0	0	1.0±0.6	1.7±1.7	20.3±4.6	24.2±7.3
Crataegus spp.	0	0	1.2±1.1	3.0±3.0	0.1±0.1	0
Ostrya virginiana	0	0	2.1±1.2	1.3±1.0	1.6±0.9	4.1±2.3
Bumelia lanuginosa	0	0	0	1.5±1.0	0.1±0.1	0
Rhus spp.	0	0	0	0.5±0.5	0	0.1±.01
Ilex decidua	0	0	0	0	1.2±1.1	0

Management implications

Shifts in species composition from mesic bottomlands to campsite and hayfield are predominantly from trees, shrubs and forbs to grasses which represent transition from shade-tolerant, native species to sun tolerant, exotic herbs that tolerate mowing and 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).

Assuming that campsites and hayfields are situated on former mesic bottomland sites, our study demonstrates reductions in soil organic matter content. 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 form 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: Rare Species

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 ONSR were compared with existing lists of rare and endangered species that were (1) known to exist in the ONSR (Hensold et al. 1986; ONSR 1993), and (2) that were listed as rare on endangered on state of Missouri (MDP 1992) and/or federal listings (Cook et al. 1987; Federal Register 11/6/91 and 11/21/91). The plant species known to occur in and around the ONSR that are federally significant or Missouri state listed are given in Table 5-1 (based on Henshold et al. 1986; ONSR 1993).

RESULTS

No species found in Table 5-1 were encountered in our vegetation sampling. Thus, no new information on the location or size of any threatened, federally significant or State listed plants was garnered. However, some interesting patterns nonetheless emerged based on the plant species that were sampled. A total of 88 woody species (overstory and understory trees, woody shrubs and vines) representing 31 plant families were identified in this study (Appendix III). A total of 264 herbaceous species representing 48 families were also identified in the vegetation sampling (Appendices III and IV). Because the sampling was conducted in late summer, the herbaceous totals do not include many spring ephemeral species.

Species Richness and Fidelity

A summary of the overall fidelity of the herbaceous and woody species encountered in the study is presented in Fig. 5-1. The herbaceous species plot in Fig. 5-1 shows that the majority of the species sampled were uncommon; cumulative totals of species fidelity show that 39.4% of the species were found on a single sample site, 56.9% on 2 sample sites, 68.1% on 3 sample sites, and 73.3% on 4 sample sites. The 42 plant species that had fidelity values > 10% accounted for only 15.6% of the total number of species encountered. The influence of rarer species on the overall level of herbaceous species richness in the ONSR cannot be overstated. The plot of woody species richness in Fig. 2-2 shows a more equitable distribution of species across plots with 41.5% of the species found on 4 plots or less. The 25 woody species that had fidelity values > 10% accounted for 35.7% of the total number of species.

Table 5-1. Flowering plant species known to occur in or near the ONSR that are either federally significant or Missouri State listed.

Species	Common Name	Federal Status*	State Status*
	federally significant		
Arabis missouriensis	deam's rock cress	C2	SU
Aster furcatus	forked aster	C2	WL
Calamagrostis insperata	reed bent grass	C2	R
Carex decomposita	epiphytic sedge	3C	WL
Cypriedium candidum	small white lady-slipper	3C	E
Cypripedium reginae	showy lady slipper	C2	WL
Draba aprica	whitlow grass	3C	WL
Plantago cordata	heart-leaf plantain	3C	SU
Plantethera leucophaea	eastern fringed prairie orchid	T	EXT
Platanthera flava	rein orchid	3C	SU
Silene regia	royal catchfly	C2	WL
Sporobulus ozarkanus	blad grass	C2	SU
Sullivantia renifolia	kidney-leaved sullivantis	C2	WL
Tomanthera auriculata	auriculate false foxglove	C2	WL
Trillium pusillum	ozark wake robin	C2	R
	state listed		
Alopecurus aequalis	floating foxtail grass	R	C,D
Anemone quinquefolia	wood anemone	E	S
Aster dumosus	tradescant aster	R	D
Berberis canadensis	american barberry	R	S,T
Campanula aparinoides	marsh bellflower	E	S
Campanula rotundifolia	harebell	E	S
Carex albicans	bellows-beaked sedge	E	S
Carex aquatilis	water sedge	E	C
Carex buxbaumii	brown bog sedge	R	D
Carex cherokeensis	cherokee sedge	R	D
Carex comosa	bristly sedge	R	C
Carex sterilis	sedge	U	S
Carex straminea	straw sedge	U	S
Carex stricta	tussock sedge	R	D,S
Delphinium exaltatum	tall larkspur	WL	S
Eleocharis lanceolata	lance-like spike rush	SU	D
Galium boreale	northern bedstraw	R	S,T
Glyceria acutiflora	sharp-scaled manna grass	R	S
Gratiola viscidula	hedge hyssop	E	S
Hedyotis boscii	bluet	E	C
Juncus debilis	weak rush	E	S
Lemna triscula	star duckweed	R	C,S
Liparis loeselii	loesel's twayblade	E	C,S
Ludwigia microcarpa	a false loosestrife	E	S
Lyonia mariana	stagger bush	E	D
Najas gracillma	thread-like naiad	E	T
Oenothera perennis	small sundrops	E	D
Oryzopsis racemosa	mountain rice	E	S
Phlox carolina	carolina phlox	E	C
Phlox maculata	wild sweet william	R	C
Plantago cordata	heart-leaved plantain	WL	C,S
Populus tremuloides	quaking aspen	R	D
Scirpus polyphyllus	leafy bulrush	R	C
Toxicodendron toxicarium	poison oak	WL	S
Trautvetteria caroliniensis	false bugbane	R	S
Tridens flavus	grass	EXT	S
Viola cucullata	marsh blue violet	R	S
Waldsteinia fgragarioides	barren strawberry	R	S,T
Zigadenus elegans	white camas	R	S

Codes: Federal Status - E = endangered; T = threatened; C = candidate for federal listing (C2-taxa that are candidates, 3A-taxa thought to be extinct). Missouri status - E = endangered; R = rare; SU = status undetermined; WL = watch list; EXT = extirpated.

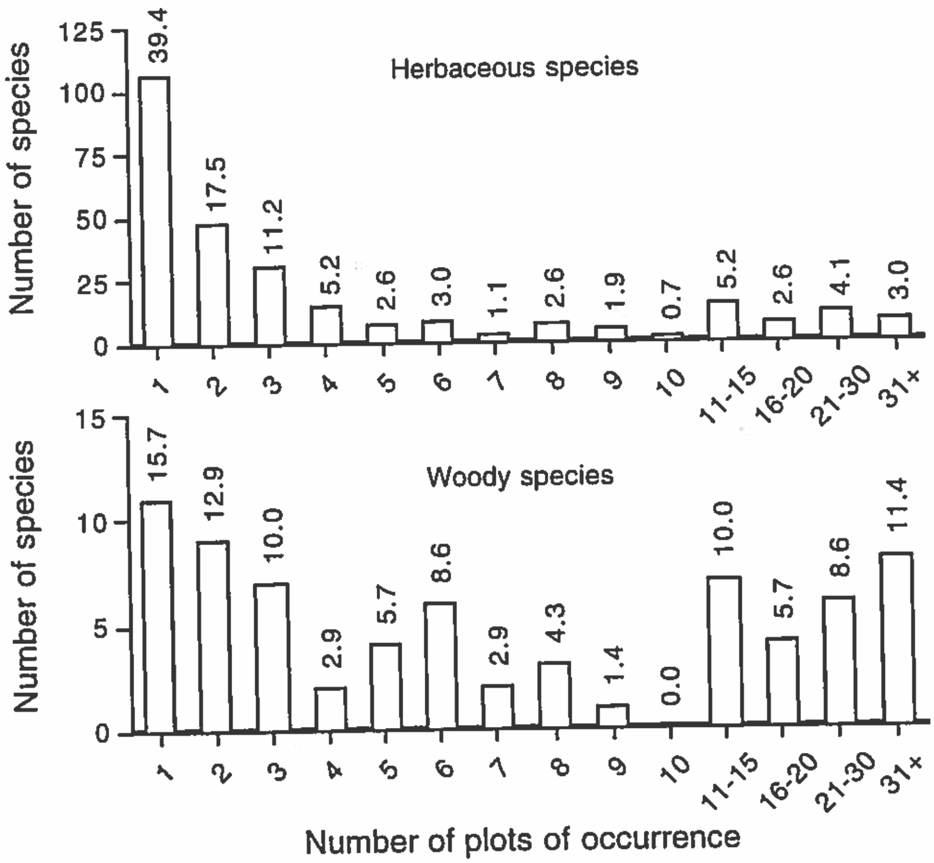

Fig 5-1. Comparison of herbaceous species (above) and woody species (below) fidelity on 94 sample plots in the ONSR. Numbers above the bars represent the percentage of the total number of species found in each plot occurrence category.

OBJECTIVE 6: Exotic Species

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

METHODS

Species lists compiled from all the herbaceous and woody species encountered in our vegetation sampling efforts were cross-checked with those species defined as exotic by Steyermark (1968) and Yatskievych and Turner (1990). Table 6-1 provides a listing of all exotic species encountered in the sampling and their overall occurrence across all study plots.

RESULTS AND 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 groups but were found more frequently in disturbed areas such as gravel washes and bottomland forest groups (Table 6-1). The distributions of pest 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 wet mesic bottomlands and toe slopes. The absence of a closed canopy is likely to promote invasions into disturbed sites such as gravel bars (Cavers and Harper 1967, Rejmanek 1989). Further, a number of sites 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.

The bottomland forests of the ONSR appear to be susceptible to invasion by pest species. Upland waterways and side slopes accounted for less that 20% of the pest infested sites, while gravel wash and wet mesic bottomland accounted for nearly 60%. Fescue appears to be the largest pest species in the ONSR, and is most successful in wet mesic bottomland forest.

Restoration of secondary forest in old fields will facilitate the elimination of exotics from the ONSR, but there is little that can be done to slow the colonization of gravel washes and wet mesic bottomland by pests. We suggest that restoration efforts in old fields be doubled, and that that large gravel bars and wet mesic bottomland forest be monitored for the growth of pest species populations.

Table 6-1. List of all exotic species encountered in the ONSR vegetation sampling.

Species	Common Name	Gravel wash	Wet mesic bottomland	Mesic bottomland	Toe slope	Upland waterway	Side slope
Albizia julibrissin	Mimosa tree	0	0	0	0	0	0
Cnidoscolus texanus	Bull Nettle	0	0	0	0	0	0
Cynodon dactylon	Bermuda grass	0	0	0	0	0	0
Dactylus glomerata	Orchard grass	0	0	0	0	0	0
Digitaria spp.	Crabgrass	3.3	0	0	0	0	0
Diospyros virginiana	Persimmon	0	0	0	3.3	0	0
Festuca spp.	Fescue	6.7	30.0	0	6.7	3.3	0
Gleditsia triacanthos	Honey Locust	0	10.0	0	0	0	0
Hordeum vulgare	Barley	0	0	0	0	0	0
Lespedeza spp.	Bush clover	0	3.3	0	0	0	3.3
Leonurus cardiaca	Motherwort	0	0	0	0	0	0
Lonicera japonica	Honeysuckle	0	0	0	3.3	0	6.7
Lythrum salicaria	Purple loosestrife	0	0	0	0	0	0
Medicago sativa	Alfalfa	0	0	0	0	0	0
Pueraria lobata	Kudzu	0	0	0	0	0	0
Rosa multiflora	Multiflora rose	0	0	3.3	0	0	3.3
Rubus spp.	Blackberry	0	3.3	3.3	3.3	0	3.3
Tamarix ramosissima	Tamarisk	0	0	0	0	0	0
Proportion of plots with pest species		10.0%	46.7%	6.7%	16.7%	3.3%	16.7%

OBJECTIVE 7: Synopsis

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

DISCUSSION

Classification

Woody vegetation in the ONSR (defined as all woody species > 1cm dbh) is responding directly or indirectly to several important environmental variables/gradients, including elevation (height above river), soil pH, soil moisture (container capacity, sand content), and soil particle size (fines). Woody vegetation responses to these gradients have been observed in other studies in the Ozarks. Topographic and soil pH gradients have been shown to be highly correlated with vegetation type in a study of larger trees (> 10.16 cm dbh) in the ONSR (Ware et al. 1992), in upland sugar maple stands (Nigh et al. 1985), and in similar riparian-upland landscapes in central (Pallardy et al. 1988) and northern (Dollar et al. 1992) Missouri. Strong correlations between vegetation assemblages and soil water holding capacity have also been noted in Missouri forests (Zimmerman and Wagner 1979, Robertson et al. 1984, Nigh et al. 1985, Ware et al. 1992). However, all of the regional studies mentioned above analyzed only a fraction of the woody vegetation (i.e., either large trees or specific suites of tree species) and did not segregate vegetation into functional groups. A more detailed and finer-grained analysis provided by our analysis reveals some of the specific interactions between the observed environmental gradients and woody vegetation.

Value of Stratifying Vegetation by Functional Type

That vegetation patterns are often correlated with patterns of resource variation and resource gradients has been well established in vegetation science (Gleason 1926, Whittaker 1956, 1967, 1978, Austin 1980, Smith and Huston 1989). Different plant species and/or groups of species may have different resource-use strategies, physiologies, and competitive abilities, and thus may be segregated into different functional types or groups. Much attention has been focused on the use of functional type designations in ecosystem and landscape studies (Solomon and Shugart 1993, Schulze and Mooney 1994); functional types are important in characterizing vegetation in landscapes with complex vegetation patterns and/or environmental gradients. O'Neill et al. (1986) noted that many vegetation studies avoid complexity (deliberately or inadvertently) by overemphasizing a single type of observation set. In the case of most forest studies in the Ozarks, and many efforts to characterize riparian vegetation, the observational set of choice has been canopy tree species (Barnes et al. 1982). The differing responses of the four defined functional types (vegetation layers) in the present study point to the importance of analyzing woody vegetation data as heterogeneous groupings of functional types rather than as a homogeneous grouping of similar responding species (Lippmaa 1939; McCune and Antos 1981; Dunns and Stearn 1987). The results of the CCA (e.g., biplots in Fig.'s 4 and 5) provide specific, quantifiable, variables that can help explain differential responses of functional types experiencing similar suites of environmental conditions.

Woody vegetation analysis that is constrained by focusing solely on canopy dominants, specific size classes or makes no distinction between functional groups and/or vegetation layers, may overlook key ecological relationships and important response variables. For example, distinct vegetation patterns observed in forest landscapes at coarse resolution levels may be strongly influenced by canopy dominants and thereby mask potential plant-environment relationships that can only be observed at a finer resolution level (e.g., functional types). Thus, the results of this study are important in that they demonstrate that functional type analysis can provide an additional level of resolution in characterizing vegetation responses along complex environmental gradients and that ecological concepts can be applied to forest characterization and management (Sharitz et al. 1992). Identifying and segregating different functional types in vegetation datasets prior to multivariate assessments, classification, and ordinations can provide detailed and more comprehensive information on the response of woody plant species to underlying gradients. Furthermore, vegetation layer/functional type analyses can be used in a management context to identify important landscape characteristics, including zones of richness, key habitats, and vegetation layer interactions. Vegetation layer analyses also present an opportunity to move away from riparian classifications based primarily on commercial species and/or canopy dominants and towards a more comprehensive, landscape-based classification scheme.

Vegetation-Environment Interactions and Substrate Heterogeneity

Integrating vegetation analyses with environmental and physiographic variables can provide a more robust basis for classification and characterization than vegetation analyses alone (Rowe 1984; Hix 1988; Palmer 1993). The CCA results in this study indicate that both trees and herb species are influenced by, and sorting out along, pronounced landscape scale gradients, namely elevation, pH, and soil particle size. Herb communities secondarily are responding to slope and soil container capacity. However, the high variability among environmental variables, indicates that substrate heterogeneity may be an important micro-scale influence on vegetation in the ONSR. Spatial heterogeneity in substrate conditions can have important consequences on population dynamics and biodiversity (Pulliam 1988). Riparian floodplain soils are often highly variable in nutrient content and texture (Peterson & Rolfe 1982) and soils and soil parent materials have been shown to have a strong influence on vegetation type and species distributions in the Ozarks (Read 1952; Autry 1988; Dollar, Pallardy & Garrett 1992 ; Ware et al. 1992) and in other riparian systems (Ward & Stanford 1983; Nilsson et al. 1989).

The riparian landscape in the ONSR contains a diverse and patchy mosaic of soil conditions and plant substrates; micro-environmental variability and substrate heterogeneity are likely quite high. The soils in the Ozarks are some of the oldest on the planet (Fenneman 1938, Oetking et al. 1966). The existing strata of dolomite, chert, and sandstone have provided a diverse array of parent materials and exhibit a complex geomorphology in the ONSR (Jacobson and Primm 1994). In addition, the steep topography in the ONSR means that talus slopes, colluvium, and alluvial influences are all present within a relatively small-scale landscape. Furthermore, the lack of glaciation in the Ozarks means that *in situ* soil development and pedogenesis have had ample time to evolve (Krusekopf 1963). Other factors contributing to substrate heterogeneity and discontinuous gradients include periodic flooding, complex micro-topography, an underlying karst topography, complex soil water table dynamics, and fire (Steyermark 1959, Read 1952, Gates 1983, Cutter and Guyette 1994). The pronounced dry periods occurring in summer and winter may add an additional layer of variability via moisture stress.

While specific detailed studies would help verify the extent of the variability of many of these factors at the landscape scale, the environmental and physical variability within the ONSR makes classification of vegetation a complicated endeavor. The difficulty in delimiting vegetation boundaries in the ONSR, despite the presence of an obvious elevation gradient, is similar to problems reported in altitudinal vegetation studies (Druitt et al. 1990, Auerbach and Shmida 1993). The proposed influence of substrate heterogeneity is consistent with the lack of crisp and spatially distinct ecotonal boundaries observed in our results. It also is consistent with the TWINSPAN results and the differential responses of growth form-based functional groups to various underlying environmental gradients.

The existence of high levels of substrate heterogeneity in the ONSR potentially complicate management regimes based on discrete soil or landscape units. The substrate complexity in the landscape and the associated complexity in vegetation tracking this heterogeneity means that specific landscape position (e.g., elevation, aspect) is not necessarily correlated with specific environmental gradients and/or vegetation at the microscale. Thus, managers may have to consider the development of broader and more macroscale substrate classifications that incorporate microscale heterogeneity.

Species Richness, Fidelity, and Landscape Position

The tree (n = 70) and herb species (n = 265) richness observed in this study is substantially higher than results from other investigations of temperate vegetation based on similar scale studies (Bell 1974b; Brewer 1980; Rogers 1980, 1981; Parker & Leopold 1983; Robertson, MacKenzie & Elliot 1984; Dunn & Stearns 1987; Parker 1989; Dollar, Pallardy & Garrett 1992) but on par with some other studies in the floodplain forests of the southern USA (Gemborys & Hodgkins 1971; Robertson, Weaver & Cavanaugh 1978) and in Sweden (Nilsson 1983; Nilsson et al. 1989; Nilsson et al. 1994). The observed low fidelity of the majority of herb species in the present study, however, does coincide with the results of other herb studies (Rogers 1980; Nilsson et al 1994; Bratton, Hapeman & Mast 1994).

The lack of any strong relationship between landscape position, namely elevation (height above river), and herb species richness in the ONSR is in stark contrast to the results of other riparian studies that have indicated an increase in species richness with elevation (Bell 1974b; Bell & del Moral 1977; Robertson, Weaver & Cavanaugh 1978 ; Frye & Quinn 1979; Menges 1986). While there was high variability in species richness at low elevations and in the flood prone plots in the current study, no pronounced patterns of increasing richness with elevation were observed. Furthermore, no strong correlations between herb or woody species richness and any of the environmental variables measured were observed. The observed equability of species richness with elevation is likely the result of numerous interacting factors, including substrate heterogeneity in space (Ward & Stanford 1983) and time (Fowler 1988), complex fertility gradients (Day et al. 1988), limited impact of flooding at low elevations, asexual reproduction as a hedge against many of the flooding episodes/ disturbances, and spatial mass effect maintaining sink populations of species on non-optimal microsites (Shmida & Wilson 1985).

Vegetation Layers and Ecotones

Different vegetation layers have been shown to respond differently to a variety of gradients (Bell 1974; Rogers 1980, 1981; Ehrenfeld & Gulik 1981; McCune & Antos 1981; Dunn & Stearns 1987). The lack of any significant coupling of the tree and herb layer assemblages in this study (based on cluster analysis), indicates that the different vegetation layers are responding differently to the underlying influence of strong elevation and pH gradients in the ONSR. While these gradients have been shown to be important in other riparian forest studies in and around the Ozark region (Nigh, Pallardy & Garrett 1985; Pallardy, Nigh & Garrett 1988; Dollar, Pallardy & Garrett 1992 ; Ware et al. 1992), all the studies cited excluded analysis of the herb layer and thus did not evaluate the entire complexity of the riparian landscape (O'Neill et al. 1986). Thus, inference of tree layer results to the entire plant biota is not appropriate and should be avoided.

The presence of ecotones and their manifestation is influenced by a host of factors, including edaphic conditions, geomorphology, disturbance, and climate (Risser 1990; van der Maarel 1990). The results of our ecotonal analysis (DCA profiles) indicate distinct differences in ecotonal distribution and structure between the tree and herb layer in the ONSR. There are high rates of species turnover in the tree layer with numerous discontinuities observed, especially at the lower elevations. The herb layer, on the other hand, exhibited high species turnover rates and sharp ecotonal boundaries only at the lowest elevations. Thus, although the CCA revealed the two vegetation layers were responding to the same overall gradients, the two vegetation layers were still responding at different positions in the landscape and at different scales.

Successional Influences on Vegetation

Succession is also influencing the composition and structure of vegetation in the ONSR and our results should be interpreted within a successional context. The forests of the ONSR are essentially all secondary forests that are products of large-scale, indiscriminate clearcutting that occurred at the turn of the century (Jacobson & Primm 1994). Secondary succession is often driven by interspecific differences in resource uptake and tolerance (Connell & Slayter 1977; Canham et al. 1994). Thus, the existence of strong pH, HAR, and soil particle size gradients in the ONSR is providing the edaphic backdrop for successional change. Successional influences are affecting both vegetation layers. While it is possible to identify successional influences in the tree layer, such as recruitment of late-successional species in established stands, identifying and predicting successional influences is more problematic for the herb layer. Several studies have indicated that the recovery of late successional herbs often lags behind tree species after major anthropogenic disturbances such as clearcutting (Flaccus 1959; MacLean & Wien 1977; Brewer 1980; Duffy & Meier 1992; Duffy 1993), although the length of the lag period has been debated (Johnson, Ford & Hale 1993). Ascertaining successional influences on herb layer vegetation is complicated by several factors, including limited information on life history and demography of many herb species (Thompson 1980; Bierzychudek 1982), the capacity for asexual reproduction among many herb species means that the presence of a given species may be more an artifact of micro-scale disturbance history than a general indicator of a successional sere, and spring and summer herbs can exhibit differential responses to disturbance (Moore & Vankat 1986).

MANAGEMENT

Given the observed separation of species composition and structure among the tree and herb layers, the consequences of these results for biodiversity management (i.e., plant diversity) become non-trivial issues. The inability to predict the composition of the herb understorey from the canopy trees with any detailed accuracy, renders much of traditional community classification limited, at best, in terms of characterizing herb species assemblages. Recognizing the limitations of traditional community classification is especially important in light of mandates to preserve, protect, and manage for plant diversity. In the ONSR, herb species outnumber tree species nearly 4 to 1. Hence, effective management strategies need to encompass the herb layer and identify the biotic and abiotic conditions that maintain the high level of species richness. Monitoring vegetation changes will require comprehensive sampling on a landscape scale, rather than focusing on traditional classification of canopy dominants. The ability to elucidate key environmental gradients influencing vegetation patterns is a necessary component in predicting vegetation change and in the preservation of the rich plant diversity in these landscapes.

Management Suggestions

1. Expand the vegetation survey in time and space to get a more extensive representation of the plant biodiversity in the ONSR

2. If possible, resurvey the exact plots used by Redfearn et al. (1970) and/or Witherspoon (1971) to verify potential changes in herbaceous vegetation

3. A soil survey should be conducted within the riparian corridor to get a handle on complex soil substrate heterogeneity and a quantitative assessment of potential soil variability

4. Periodic measures of restoration efforts (e.g., riparian plantings) should be conducted to compare restoration efforts with existing vegetation patterns and dynamics; such an approach would enable assessment of the long term success or failure of these efforts in terms of species recruitment, biodiversity, and invasion of exotic species

5. Manage entire landscape rather than specific units; because rare species and plant diversity are essentially scattered across landscape, it may be more prudent to preserve the entire mosaic and avoid designations that do not account for all patterns of plant diversity/classification.

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Appendix I.

ONSR vegetation sampling sites, ELT descriptions and designation, and USGS Quad location.

Site name	Plot #	Description	ELT designation	USGS Quad
Andy U.C.R.	1	side slope		Lewis Hollow
Andy U.C.R.	2	upland waterway		
Andy U.C.R.	3	upland waterway		
Andy U.C.R.	4	mesic bottomland		
Andy U.C.R.	5	wet mesic		
Andy U.C.R.	6	wet mesic		
Baptist U.C.R.	1	upland waterway		Montauk
Baptist U.C.R.	2	wet mesic		
Baptist U.C.R.	3	wet mesic		
Baycreek J.F.	1	side slope		Bartlett
Baycreek J.F.	2	wet mesic		
Baycreek J.F.	3	wet mesic		
Baycreek J.F.	4	wet mesic		
Baycreek J.F.	5	gravel wash		
Blue Spring Primitive Area	1	wet mesic		Pine Crest
Blue Spring Primitive Area	2	campsite		
Blue Spring Primitive Area	3	campsite		
Blue Spring Primitive Area	4	mesic bottomland		
Bluff View J.F.	1	upland waterway		Pine Crest
Bluff View J.F.	2	mesic bottomland		
Bluff V iew J.F.	3	gravel wash		
Buck Hollow J.F.	1	toe slope		Pine Crest
Buck Hollow J.F.	2	gravel wash		
Burnt Cabin J.F.	1	toe slope		Alley Spring
Burnt Cabin J.F.	2	toe slope		
Burnt Cabin J.F.	3	toe slope		
Cedar Creek L.C.R.	1	toe slope		Grandin
Cedar Creek L.C.R.	2	toe slope		
Coldwater Ranch C.R.	1	side slope		Eminence
Coldwater Ranch C.R.	2	wet mesic		
Coleman's Failure L.C.R.	1	side slope		Big Spring
Coleman's Failure L.C.R.	2	toe slope		
Coleman's Failure L.C.R.	3	toe slope		
Copperhead J.F.	1	side slope		Jam Up Cave
Copperhead J.F.	2	upland waterway		
Copperhead J.F.	3	upland waterway		
Copperhead J.F.	4	upland waterway		
Copperhead J.F.	5	wet mesic		
Copperhead J.F.	6	gravel wash		
Fat Bottom L.C.R.	1	wet mesic		Big Spring
Fat Bottom L.C.R.	2	wet mesic		
Fat Bottom L.C.R.	3	wet mesic		
Fat Bottom L.C.R.	4	wet mesic		
Fat Bottom L.C.R.	5	wet mesic		
Fat Bottom L.C.R.	6	wet mesic		
Gooseneck L.C.R.	1	toe slope		Grandin
Gooseneck L.C.R.	2	toe slope		
Horse Camp J.F.	1	side slope		Alley Spring
Horse Camp J.F.	2	toe slope		

Appendix I. cont.

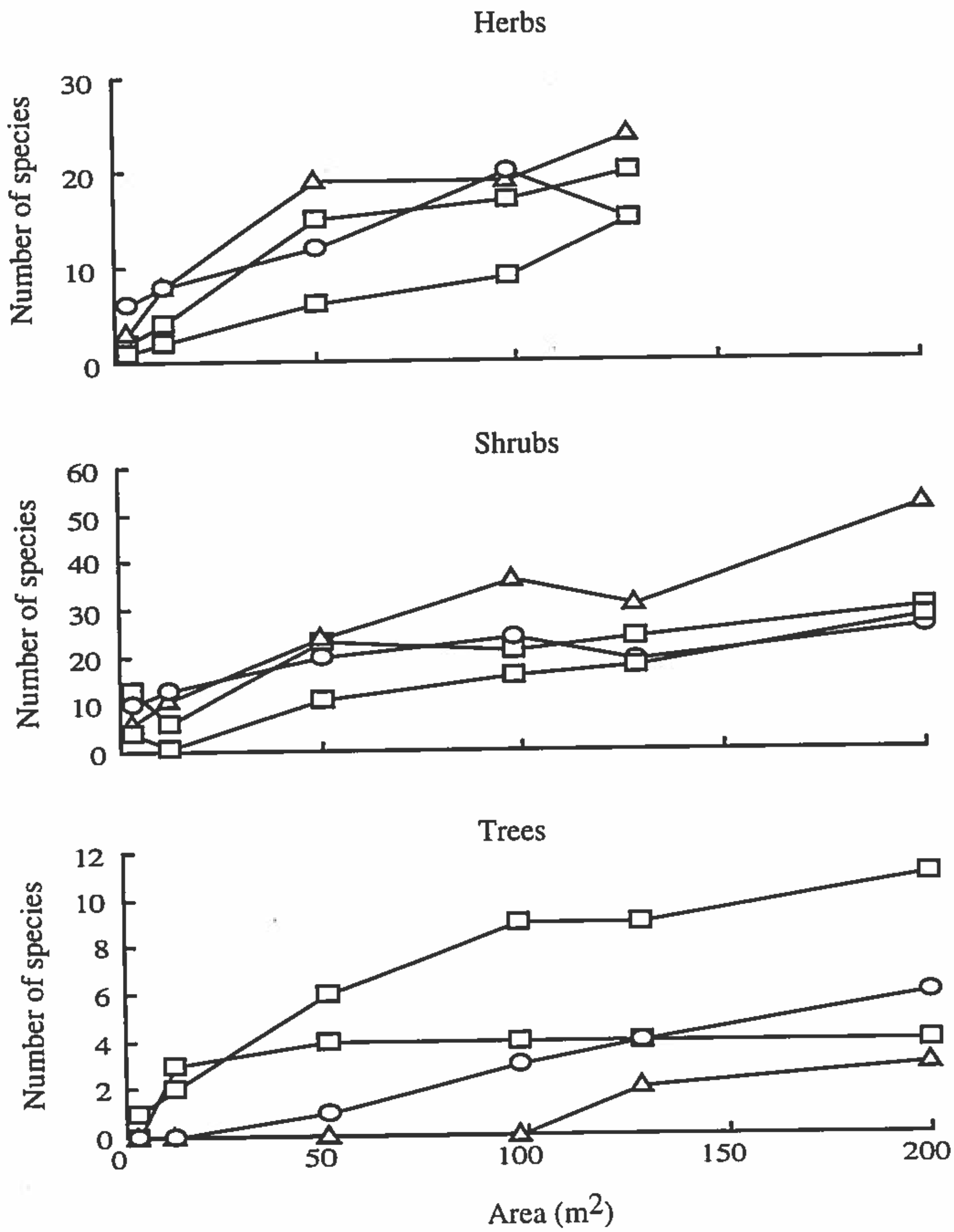
Site name	Plot #	Description	ELT designation	USGS Quad
Horse Camp J.F.	3	wet mesic		Alley Spring
Horse Camp J.F.	4	wet mesic		
Horse Camp J.F.	5	wet mesic		
Hwy 106 Bridge	1	gravel wash		Powder Mill
Hwy 106 Bridge	2	wet mesic		
Jerktail U.C.R.	1	side slope		Eminence
Jerktail U.C.R.	2	toe slope		
Keaton Primitive Area	1	campsite		Alley Spring
Keaton Primitive Area	2	campsite		
Keaton Primitive Area	3	hayfield		
Log Yard L.C.R.	1	wet mesic		Van Buren
Log Yard L.C.R.	2	wet mesic		
Log Yard L.C.R.	3	wet mesic		
Old Ferry	1	toe slope		Powder Mill
Old Ferry	2	side slope		
Old Ferry	3	side slope		
Owl Bend	1	gravel wash		Powder Mill
Owl Bend	2	gravel wash		
Owl Bend	3	campsite		
Owl Bend	4	campsite		
Paint Rock (Lambert Chute) L.C.R.	1	wet mesic		Exchange
Paint Rock (Lambert Chute) L.C.R.	2	wet mesic		
Paint Rock (Lambert Chute) L.C.R.	3	wet mesic		
Paint Rock (Lambert Chute) L.C.R.	4	wet mesic		
Paint Rock (Lambert Chute) L.C.R.	5	wet mesic		
Paint Rock (Lambert Chute) L.C.R.	6	wet mesic		
Panther L.C.R.	1	wet mesic		Big Spring
Panther L.C.R.	2	wet mesic		
Pin Oak L.C.R.	1	side slope		Van Buren North
Pin Oak L.C.R.	2	toe slope		
Pin Oak L.C.R.	3	toe slope		
Pin Oak L.C.R.	4	gravel wash		
Pulltite U.C.R.	1	upland waterway		Round Spring
Pulltite U.C.R.	2	upland waterway		
Pulltite U.C.R.	3	mesic bottomland		
Pulltite U.C.R.	4	mesic bottomland		
Round Spring	1	wet mesic		
Round Spring	2	mesic bottomland		
Rymers J.F.	1	side slope		Jam Up Cave
Rymers J.F.	2	toe slope		
Rymers J.F.	3	gravel wash		
Rymers J.F.	4	gravel wash		
Senator's House C.R.	1	side slope		Big Spring
Senator's House C.R.	2	wet mesic		
Senator's House C.R.	3	wet mesic		

Appendix I. cont.

Site name	Plot #	Description	ELT designation	USGS Quad
Senator's House C.R.	4	wet mesic		Big Spring
Senator's House C.R.	5	wet mesic		
Senator's House C.R.	6	gravel wash		
Shawnee Creek	1	wet mesic		Eminence
Terry Chute L.C.R.	1	side slope		Big Spring
Terry Chute L.C.R.	2	toe slope		
Terry Chute L.C.R.	3	wet mesic		
Terry Chute L.C.R.	4	wet mesic		
Tripper J.F.	1	wet mesic		Alley Spring
Tripper J.F.	2	wet mesic		
Troublesome U.C.R.	1	side slope		Round Spring
Troublesome U.C.R.	2	wet mesic		
Troublesome U.C.R.	3	wet mesic		
Two Rivers	1	wet mesic		Eminence
Two Rivers	2	wet mesic		
Two Rivers	3	wet mesic		
Two Rivers	4	wet mesic		
Two Rivers	5	mesic bottomland		
Two Rivers	6	mesic bottomland		
Two Rivers	7	mesic bottomland		
Two Rivers	8	mesic bottomland		
Two Rivers	9	mesic bottomland		
Two Rivers	10	mesic bottomland		
Welch U.C.R.	1	side slope		Cedar Grove
Welch U.C.R.	2	toe slope		
Welch U.C.R.	3	toe slope		
Welch U.C.R.	4	toe slope		
Welch U.C.R.	5	toe slope		
Wide Ford	1	side slope		Lewis Hollow
Wide Ford	2	side slope		
Wide Ford	3	upland waterway		
Wide Ford	4	upland waterway		
Widowmaker L.C.R.	1	side slope		Big Spring
Widowmaker L.C.R.	2	toe slope		

Appendix II.

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 ONSR 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 greater than the average asymptote for each vegetation layer at each site (i.e., $100m^2$).



Appendix III.

Ozark National Scenic Riverway Herbaceous Plant Species List.
Total number of herbaceous species: 264
Total number of herb families: 48

FAMILY	SPECIES	CODE	SUM OF MEAN COVER
Acanthaceae	*Dicliptera bracheata* (Pursh) Spreng.	Dicbra	5.65
	Justicia americana (L.) Vahl.	Jusame	0.85
	Ruellia pedunculata Torr.	Rueped	1.25
	Ruellia strepens L.	Ruestr	2.00
Aizoaceae	*Mollugo verticillata* L.	Molver	0.10
Araceae	*Arisaema dracontium* (L.) Schott	Aridra	1.05
Aristolochiaceae	*Aristolochia serpentaria* L.	Ariser	1.60
	Aristolochia tomentosa Sims	Aristo	1.30
	Asarum canadense L.	Asacan	14.75
Asclepiadaceae	*Matelea gonocarpa* L.	Matgon	0.35
Balsaminaceae	*Impatiens pallida* Nutt.	Imppal	13.60
Berberidaceae	*Podophyllum peltatum* L.	Podpel	5.30
Boraginaceae	*Cynoglossum officinale* L.	Cyaoff	0.25
	Cynoglossum virginianum L.	Cynvir	0.20
Campanulaceae	*Campanula americana* L.	Camame	0.25
	Lobelia appendiculata A. DC.	Lobapp	0.10
	Lobelia sp.	Lobspp	0.25
Caprifoliaceae	*Lonicera* sp.	Lonspp	0.10
	Sambucus canadensis L.	Samcan	0.60
Caryophyllaceae	*Saponaria officinalis* L.	Sapoff	3.60
	Silene stellata (L.) Ait.	Silste	1.25
Commelinaceae	*Tradescantia longipes* Anders. & Woodson	Tralon	1.20
	Tradescantia ohiensis Raf.	Traohi	0.25
Compositae	*Ambrosia artemisiifolia* L.	Ambart	2.15
	Ambrosia trifida L.	Ambtri	1.00
	Antennaria plantaginifolia (L.) Hook.	Antpla	0.60
	Aster anomalus Engelm.	Astano	0.10
	Aster cordifolius L.	Astcor	2.30
	Aster drummondii (Lindl.) Shinners	Astdru	4.80
	Aster oolentonginensis Riddell	Astool	0.20
	Aster patens Ait.	Astpat	0.60
	Aster sp.	Astspp	0.30
	Bidens frondosa L.	Bidfro	1.45
	Cacalia plantaginea Nutt.	Cocpla	0.85
	Conyza canadensis L.	Concan	1.25
	Elephantopus carolinianus Willd.	Elecar	0.60

FAMILY	SPECIES	CODE	SUM OF MEAN COVER
Compositae cont.	*Erechtites hieraciifolia* (L.) Raf.	Erehie	0.30
	Eupatorium coelestinum L.	Eupcoe	0.25
	Eupatorium fistulosum Barratt	Eupfis	1.00
	Eupatorium purpureum L.	Euppur	0.35
	Eupatorium rugosum Houtt.	Euprug	1.00
	Helianthus divaricatus L.	Heldiv	0.35
	Heliopsis helianthoides (L.) Sweet	Helhel	0.50
	Heterotheca subaxillaris (Lam.) Britt. & Rusby	Hetsub	0.30
	Krigia biflora (Walt.) Blake	Kribif	0.65
	Lactuca canadensis L.	Laccan	2.25
	Lactuca sp.	Lacspp	2.25
	Parthenium integrifolium L.	Parint	1.15
	Polymnia uvedalia L.	Poluve	8.75
	Prenanthes altissima L.	Prealt	1.80
	Rudbeckia fulgida Ait.	Rudful	0.50
	Rudbeckia hirta L.	Rudhir	0.25
	Rudbeckia laciniata L.	Rudlac	10.35
	Rudbeckia subtomentosa Pursh	Rudsub	0.25
	Rudbeckia triloba L.	Rudtri	1.55
	Senecio aureus L.	Senaur	1.00
	Senecio obovatus Muhl.	Senobo	3.40
	Solidago arguta Ait.	Solarg	6.05
	Solidago caesia L.	Solcae	8.60
	Solidago canadensis L.	Solcan	0.25
	Solidago sp.	Solspp	0.10
	Solidago ulmifolia Muhl.	Solulm	1.25
	Verbesina alternifolia L.	Veralt	6.85
	Verbesina helianthoides Michx.	Verhel	6.10
	Verbesina sp.	Verspp	5.75
	Verbesina virginica L.	Vervir	20.80
	Vernonia baldwinii Torr.	Verbal	2.00
	Vernonia gigantea Torr.	Vergig	1.35
	Xanthium strumarium L.	Xanstr	0.75
Convolvulaceae	*Convolvulus arvensis* L.	Conarv	1.25
	Convolvulus sepium L.	Consep	1.00
	Cuscuta compacta Juss.	Cuscom	0.10
	Ipomea coccinea L.	Ipococ	0.80
	Ipomea sp.	Ipospp	0.10
Cucurbitaceae	*Melothria pendula* L.	Melpen	0.30
	Sicyos angulatus L.	Sicang	0.10
Cyperaceae	*Carex grayi* Carey	Cargra	0.25
	Carex laxiflora Lam.	Carlax	0.70
	Carex physorhynchia Liebm.	Carphy	0.35
	Carex rosea Schkuhr	Carros	2.25
	Carex sp.	Carspp	16.75
Dioscoreaceae	*Dioscorea oppositifolia* Walt.	Dioopp	3.45
	Dioscorea quaternata (Walt.) J.F. Gmel.	Dioqua	13.15
Equisetaceae	*Equisetum laevigatum* Eat.	Equlae	1.90
Euphorbiaceae	*Acalphya rhomboidea* Raf.	Acarho	0.50
	Acalypha virginica L.	Acavir	0.20

FAMILY	SPECIES	CODE	SUM OF MEAN COVER
Euphorbiaceae cont.	*Croton monanthogynus* Michx.	Cromon	0.20
	Euphorbia corollata L.	Eupcor	0.35
	Euphorbia cyathophora Raf.	Eupcya	0.20
	Euphorbia dentata Michx.	Eupden	2.15
	Euphorbia nutans L.	Eupnut	0.30
	Euphorbia sp.	Eupspp	0.10
Geraniaceae	*Geranium maculatum* L.	Germac	11.70
Gramineae	*Arundinaria gigantea* Michx.	Arugig	4.95
	Brachyelytrum erectum (Schreb.) Beauv.	Braere	7.45
	Bromus japonicus Thunb.	Brojap	0.25
	Bromus pubescens L.	Bropub	0.35
	Bromus secalinus L.	Brosec	1.00
	Chasmanthium latifolium L.	Chalat	32.75
	Danthonia spicata (L.) Beauv.	Danspi	0.95
	Diarrhena americana Beauv.	Diaame	1.10
	Digitaria ischaemum (Schreb.) Muhl.	Digisc	0.40
	Digitaria sanguinalis (L.) Scop.	Digsan	0.75
	Digitaria violascens Muhl.	Digvio	0.20
	Eleusine indica (L.) Gaertn.	Eleind	7.10
	Elymus canadensis L.	Elycan	19.00
	Elymus riparius Wieg.	Elyrip	5.90
	Elymus virginica L.	Elyvir	13.20
	Festuca arundinacea Walt.	Fesaru	9.45
	Festuca elatior L.	Fesela	1.55
	Festuca octoflora Walt.	Fesoct	0.60
	Leersia virginica Willd.	Leevir	16.35
	Muhlenbergia sobolifera (Muhl.) Trin.	Muhsob	1.25
	Muhlenbergia sylvatica Torr.	Muhsyl	1.75
	Muhlenbergia tenuifolia (Willd.) BSP.	Muhten	1.20
	Muhlengergia schreberi J.F. Gmel.	Muhsch	12.50
	Panicum boscii Poir.	Panbos	17.20
	Panicum clandestinum L.	Pancla	2.25
	Panicum microcarpon Muhl.	Panmic	0.25
	Poa annua L.	Poaann	0.35
	Poa sylvestris Gray	Poasyl	0.25
	Tridens flava (L.) Hitchc.	Trifla	0.20
Hydrophyllaceae	*Hydrophyllum brownei* Nutt.	Hydbro	0.50
	Hydrophyllum virginianum L.	Hydvir	1.10
Iridaceae	*Iris cristata* Ait.	Iricri	3.10
	Sisynrichium campestre Bickn.	Siscam	0.35
Labiatae	*Blephilia ciliata* (L.) Benth.	Blecil	2.00
	Blephilia hirsuta (Pursh) Benth.	Blehir	0.50
	Cunila origanoides (L.) Britt.	Cunori	1.00
	Mentha sp.	Menspp	0.25
	Monarda bradburiana Beck	Monbra	0.75
	Monarda russeliana Nutt.	Monrus	0.65
	Perilla frutescens (L.) Britt.	Perfru	2.80
	Prunella vulgaris L.	Pruvul	0.35
	Salvia lyrata L.	Sallyr	3.45
	Scutellaria cardrophylla L.	Scucar	0.35
	Scutellaria elliptica Muhl.	Scuell	1.70

FAMILY	SPECIES	CODE	SUM OF MEAN COVER
Labiatae cont.	*Scutellaria incana* Biehler	Scuinc	0.30
	Scutellaria ovata Hill	Scuova	0.55
	Scutellaria sp.	Scuspp	0.20
	Stachys tenuifolia Willd.	Staten	0.20
	Teucrium canadense L.	Teucan	0.25
	Trichostema brachiatium L.	Tribra	0.20
Leguminosae	*Amphicarpa bracteata* (L.) Fern.	Ampbrac	68.45
	Desmodium cuspidatum (Muhl.) Loud.	Descus	0.50
	Desmodium glutinosum (Muhl.) Wood	Desglu	9.80
	Desmodium marilandicum (L.) DC.	Desmar	0.50
	Desmodium nudiflorum (L.) DC.	Desnud	76.70
	Desmodium paniculatum (L.) DC.	Despan	10.15
	Desmodium pauciflorum (Nutt.) DC.	Despau	0.50
	Desmodium sp.	Desspp	0.25
	Lespedeza hirta (L.) Hornem.	Leshir	0.50
	Lespedeza procumbens Michx.	Lespro	0.95
	Lespedeza violaceae (L.) Pers.	Lesvio	0.25
	Stylosanthes biflora (L.) BSP.	Stybif	0.10
	Vicia caroliniana Walt.	Viccar	0.10
Liliaceae	*Smilacina racemosa* (L.) Desf.	Smirac	7.35
	Smilax tamnoides L.	Smitam	27.6
	Trillium sessile L.	Trises	1.75
	Uvularia grandiflora Sm.	Uvugra	1.70
Menispermaceae	*Calycocarpum lyonii* (Pursh) Gray	Callyo	0.60
	Cocculus carolinus (L.) DC.	Cocpla	0.85
	Menispermum canadense L.	Mencan	6.35
Nyctaginaceae	*Mirabilis nyctaginea* (Michx.) MacM.	Mirnyc	0.25
Onagraceae	*Circaea lutetiana* L.	Cirlut	0.50
	Oenothera laciniata Hill	Oenlac	0.20
Ophioglossaceae	*Botrychium virginianum* (L.) Sw.	Botvir	5.55
Oxalidaceae	*Oxalis dillenii* Ait.	Oxadil	0.30
	Oxalis stricta L.	Oxastr	3.05
Papaveraceae	*Sanguinara canadensis* L.	Sancan	7.10
Passifloraceae	*Passiflora lutea* L.	Paslut	0.60
Phrymaceae	*Phryma leptostachya* L.	Phrlep	4.50
Phytolaccaceae	*Phytolacca americana* L.	Phyame	0.25
Plantaginaceae	*Plantago lanceolata* L.	Plalan	1.55
	Plantago rugellii Dcne.	Plarug	0.85
Polemoniaceae	*Phlox paniculata* L.	Phlpan	3.75
	Polemonium reptans L.	Polrep	8.10
Polygonaceae	*Polygonum persicaria* L.	Polper	1.85
	Polygonum punctatum Ell.	Polpun	0.95
	Polygonum scandens L.	Polsca	0.25

Appendix III. cont.

FAMILY	SPECIES	CODE	SUM OF MEAN COVER
Polygonaceae cont.	*Polygonum* sp.	Polspp	0.35
	Polygonum virginianum L.	Polvir	14.05
Ranunculaceae	*Anemone virginiana* L.	Anevir	1.15
	Anemonella thalictroides (L.) Spach	Anetha	1.20
	Cimicifuga racemosa (L.) Nutt.	Cimrac	12.35
	Clematis catesbyana Pursh	Clecat	0.10
	Clematis versicolor Small	Clever	0.30
	Clematis virginianum L.	Clevir	0.40
	Hepatica nobilis var. *obtusa* DC.	Hepnob	8.35
Ranunculaceae	*Ranunculus hispidus* Michx.	Ranhis	0.85
	Ranunculus sp.	Ranspp	0.25
	Thalictrum diocium L.	Thadio	0.40
	Thalictrum revolutum DC.	Tharev	0.25
	Thalictrum thalictroidea Muhl.	Thatha	3.15
Rosaceae	*Geum canadense* Jasq.	Geucan	7.80
	Porteranthus stipuletus Jacq.	Porsti	1.10
	Potentilla canadensis L.	Potcan	0.35
	Potentilla simplex Michx.	Potsim	1.85
	Rubus sp.	Rubspp	2.75
Rubiaceae	*Cephalanthus occidentalis* L.	Cepocc	0.30
	Diodia teres Walt.	Dioter	0.50
	Galium arkansanum Gray	Galark	1.90
	Galium circaezans Michx.	Galcir	3.10
	Galium concinnum T. & G.	Galcon	14.15
	Galium pilosum Ait.	Galpil	9.55
	Galium sp.	Galspp	0.25
	Galium tinctorium L.	Galtin	9.20
	Galium triflorum Michx.	Galtri	3.10
	Galium virgatum Nutt.	Galvir	0.75
	Hedyotis purpurea (L.) Lam.	Hedpur	9.70
Saxifragaceae	*Hydrangea arborescens* L.	Hydarb	5.80
Scrophulariaceae	*Gerardia* sp.	Gerspp	0.50
	Gratiola neglecta Torr.	Graneg	0.10
	Kickxia elantine (L.) Dumort.	Kicela	3.10
	Pedicularis canadensis L.	Pedcan	1.70
Solanaceae	*Solanum ptycanthum* Michx.	Solpty	0.50
Umbelliferae	*Angelica venenosa* (Greenway) Fern.	Angven	0.30
	Cicuta maculata L.	Cicmac	0.30
	Cryptotaenia canadensis (L.) DC.	Crycan	66.30
	Osmorhiza longistylis (Torr.) DC.	Osmlon	9.05
	Thaspium trifoliatum (L.) Gray	Thatri	1.00
	Zizia aurea (L.) W.D.J. Koch.	Zizaur	0.60
			919.50
Uritcaceae	*Boehmeria cylindrica* (L.) Sw.	Boecyl	0.50
	Parietaria pensylvanica Muhl.	Parpen	0.60
	Pilea pumila (L.) Gray	Pilpum	33.60
	Urtica diocia L.	Urtdio	79.55

Appendix III. cont.

FAMILY	SPECIES	CODE	SUM OF MEAN COVER
Verbenaceae	*Phyla lanceolata* L.	Phylan	1.40
	Verbena urticifolia L.	Verurt	0.60
Violaceae	*Hybanthus concolor* (T.F. Forst.) Spreng.	Hybcon	2.30
	Viola palmata L.	Viopal	3.15
	Viola pubsecens Ait.	Viopub	11.30
	Viola sagittata Ait.	Viosag	2.15
	Viola sororia Willd.	Viosor	24.10
	Viola sp.	Viospp	5.75
	Viola striata Ait.	Viostr	19.40

Appendix IV.

Ozark National Scenic Riverway Woody Plant Species List.
Total number of Species: 88
Total number of Families: 31

Family	Species	Common Name	Code
Aceraceae	*Acer negundo* L.	boxelder	ACNE
	Acer rubrum L.	red maple	ACRU
	Acer saccharinum L.	silver maple	ACES
	Acer saccharum Marsh.	sugar maple	ACSA
Anacardiaceae	*Cotinus obovatus* Raf.		COOB
	Rhus aromatica L.	sumac	RHAR
	Rhus glabra L. var. *glabra*	sumac	RHGL
	Toxicodendron radicans (L.) Kuntze	poison ivy	TORA
Annonaceae	*Asimina triloba* (L.) Dunal	pawpaw	ASTR
Aquifoliaceae	*Ilex decidua* Walt.	possum haw	ILDE
Betulaceae	*Betula nigra* L.	river birch	BENI
	Carpinus caroliniana Walt.	ironwood/musclewood	CACA
	Ostyra virginiana (Mill.) K. Koch	hophornbeam	OSVI
Bignoniaceae	*Campsis radicans* L.	trumpet vine	CARA
	Catalpa speciosa Warder ex. Engelm.	catalpa	CASP
Caprifoliaceae	*Sambucus canadensis* L.	elderberry	SAMC
	Viburnum prunifolium L.	viburnum	VIPR
	Viburnum rufidulum Raf.	viburnum	VIRU
Cornaceae	*Cornus drummondii* C.A. Meyer	roughleaf dogwood	CODR
	Cornus florida L.	dogwood	COFL
	Nyssa sylvatica Marsh.	blackgum	NYSL
Corylaceae	*Corylus americana* Walt.	hazelnut	COAM
Cupressaceae	*Juniperus virginiana* L.	red cedar	JUVI
Ebenaceae	*Diospyros virginiana* L.	persimmon	DIVI
Fagaceae	*Fagus grandifolia* Ehrh.	beech	FAGR
	Quercus alba L.	white oak	QUAL
	Quercus bicolor Willd.	swamp white oak	QUBI
	Quercus falcata Michx.	southern red oak	QUFA

Appendix IV. cont.

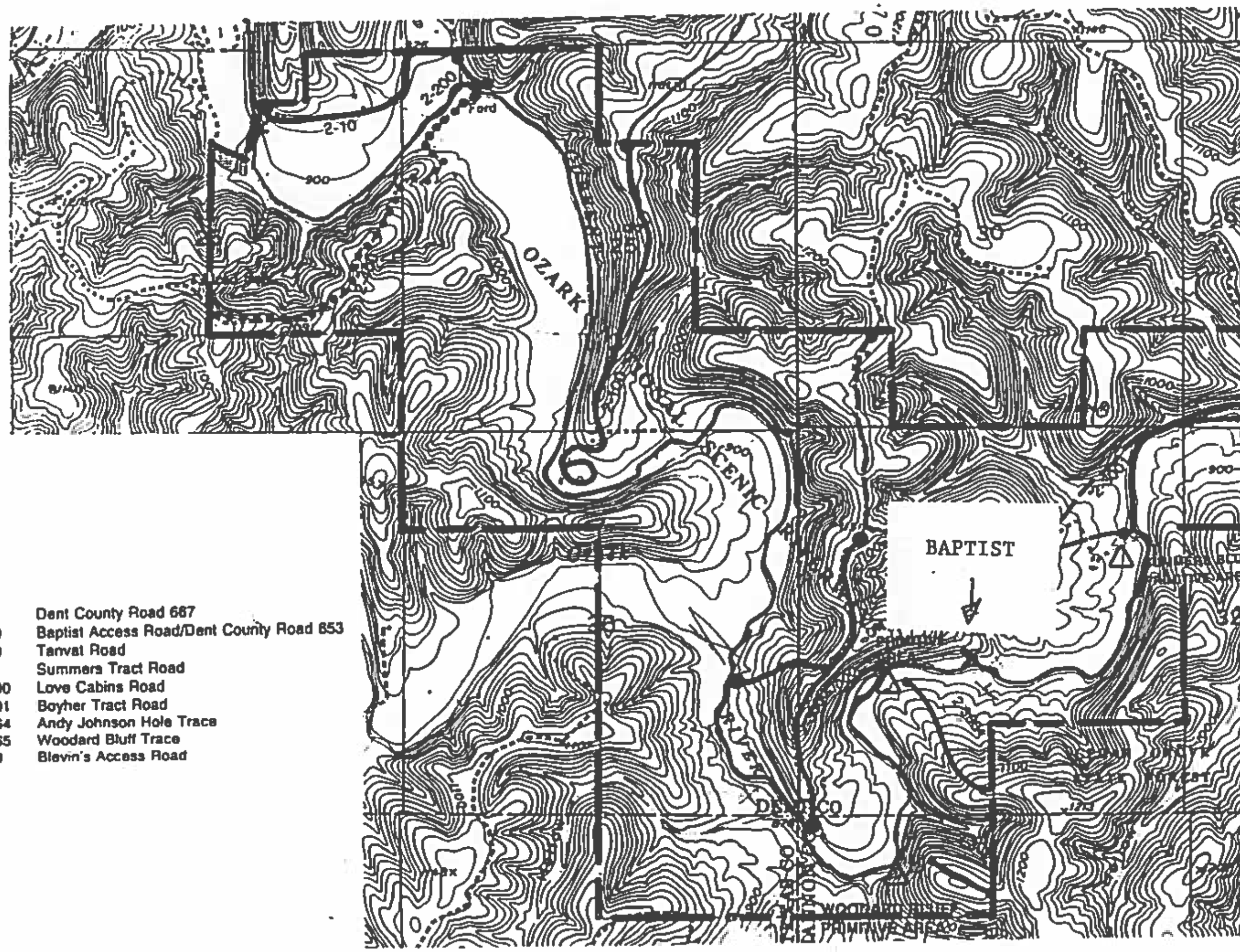
Family	Species	Common Name	Code
Fagaceae cont.	*Quercus imbricaria* Michx.	shingle oak	QUIM
	Quercus lyrata Walt.	overcup oak	QULY
	Quercus macrocarpa Michx.	bur oak	QUMC
	Quercus marilandica Muenchh.	blackjack oak	QUMA
	Quercus muhlenbergii Engelm.	chinkapin oak	QUMU
	Quercus rubra L.	northern red oak	QURU
	Quercus shumardii Buckl.	shumard oak	QUSH
	Quercus stellata Wangenh.	post oak	QUST
	Quercus velutina Lam.	black oak	QUVE
Hamamelidaceae	*Hamamelis virginiana* L.	witch hazel	HAVI
	Liquidambar styraciflua L.	sweetgum	LIST
Hippocastanaceae	*Aesculus glabra* Willd.	buckeye	AEGL
Juglandaceae	*Carya cordiformis* (Wangenh.) K. Koch	bitternut hickory	CACO
	Carya glabra (Mill.) Sweet	pignut hickory	CAGL
	Carya illinoensis (Wangenh.) K. Koch	pecan	CAIL
	Carya lacinosa (Michx. f.) Loud.	shellbark hickory	CALA
	Carya ovata (Mill.) K. Koch	shagbark hickory	CAOV
	Carya texana Buckl.	black hickory	CATE
	Carya tomentosa (Poir.) Nutt.	mockernut hickory	CATO
Juglandaceae cont.	*Juglans cinerea* L.	butternut	JUCI
	Juglans nigra L.	black walnut	JUNI
Lauraceae	*Lindera benzoin* (L.) Blume	spice bush	LIBE
	Sassafras albidum (Nutt.) Nees	sasafras	SASA
Leguminosae	*Cercis canadensis* L.	redbud	CECA
	Gleditsia triacanthos L.	honeylocust	GLTR
Moraceae	*Morus rubra* L.	red mullberry	MORU
Oleaceae	*Fraxinus americana* L.	white ash	FRAM
	Fraxinus pennsylvanica Marsh.	green ash	FRPE

Appendix IV. cont.

Family	Species	Common Name	Code
Oleaceae	*Fraxinus quadrangulata* Michx.	blue ash	FRQU
Pinaceae	*Pinus echinata* Mill.	shortleaf pine	PIEC
Plantanaceae	*Platanus occidentalis* L.	sycamore	PLOC
Rhamnaceae	*Rhamnus caroliniana* Walt.	carolina buckthorn	RHCA
Rosaceae	*Agrimonia pubescens* Wallr.	cocklebur	AGPU
	Agrimonia rostellata Wallr.	cocklebur	AGRO
	Crataegus viridis L.	hawthorn	CRVI
	Physocarpus opulifolius (L.) Maxim.	ninebot	PHOP
	Prunus serotina Ehrh.	black cherry	PRSE
	Rosa sp.	wild rose	ROSP
Rutaceae	*Zanthoxylum americanum* L.	prickly ash	ZAAM
Salicaeae	*Populus deltoides* Bartr. ex Marsh.	poplar	PODE
	Salix nigra Marsh.	black willow	SANI
Sapotaceae	*Bumelia lanuginosa* (Michx.) Pers.	bumelia	BULA
Saxifragaceae	*Philadelphus hirsutis* Nutt.		PHHI
	Philadelphus pubescens L. var. *verrucosus* (Schrad.) Hu	mock orange	PHPU
Staphyleaceae	*Staphlyea trifolia* L.	bladdernut	STTR
Tiliaceae	*Tilia americana* L.	basswood	TIAM
Ulmaceae	*Celtis laevigata* Willd.	sugarberry	CELA
	Celtis occidentalis L.	hackberry	CEOC
	Celtis tenuifolia Nutt.	hackberry	CETE
	Ulmus alata Michx.	winged elm	ULAL
	Ulmus americana L.	american elm	ULAM
	Ulmus pumila L.	siberian elm	ULPU
	Ulmus rubra Muhl.	slippery elm	ULRU
Vitaceae	*Ampelopsis arborea* (L.) Koehne	grape	AMAR
	Parthenocissus quinquefolia (L.) Planch.	virginia creeper	PAQU
	Vitis aestavalis Michx.	grape	VIAE
	Vitis cinerea Engelm.	grape	VICI
	Vitis riparia Michx.	grape	VIRI
	Vitis vulpina L.	grape	VIVU

Appendix V.

Maps of transect sites along the Current and Jacks Fork Rivers. End of the transect is marked at the river's edge with an "X". Maps are portions of 7.5" USGS topo maps reproduced from Roads and Trails Study and Environmental Assessment, Ozark National Scenic Riverways-Missouri, United States Department of the Interior, Midwest Region.



2-10 Dent County Road 687
2-100 Baptist Access Road/Dent County Road 653
2-200 Tanvat Road
2-201 Summers Tract Road
2-3000 Love Cabins Road
2-3001 Boyher Tract Road
2-3064 Andy Johnson Hole Trace
2-3065 Woodard Bluff Trace
2-400 Blevin's Access Road

North

0 1/2 MI.

CLOSED TRACES

ACCESS TO EASEMENT, PRIVATE OR STATE LAND ONLY

ROAD OWNED BY COUNTY OR STATE

NPS OWNED / MAINTAINED

NPS OWNED / UNMAINTAINED

△ CAMPGROUND OR PRIMITIVE C... AREA

Trail IO-XX FOOT TRAIL

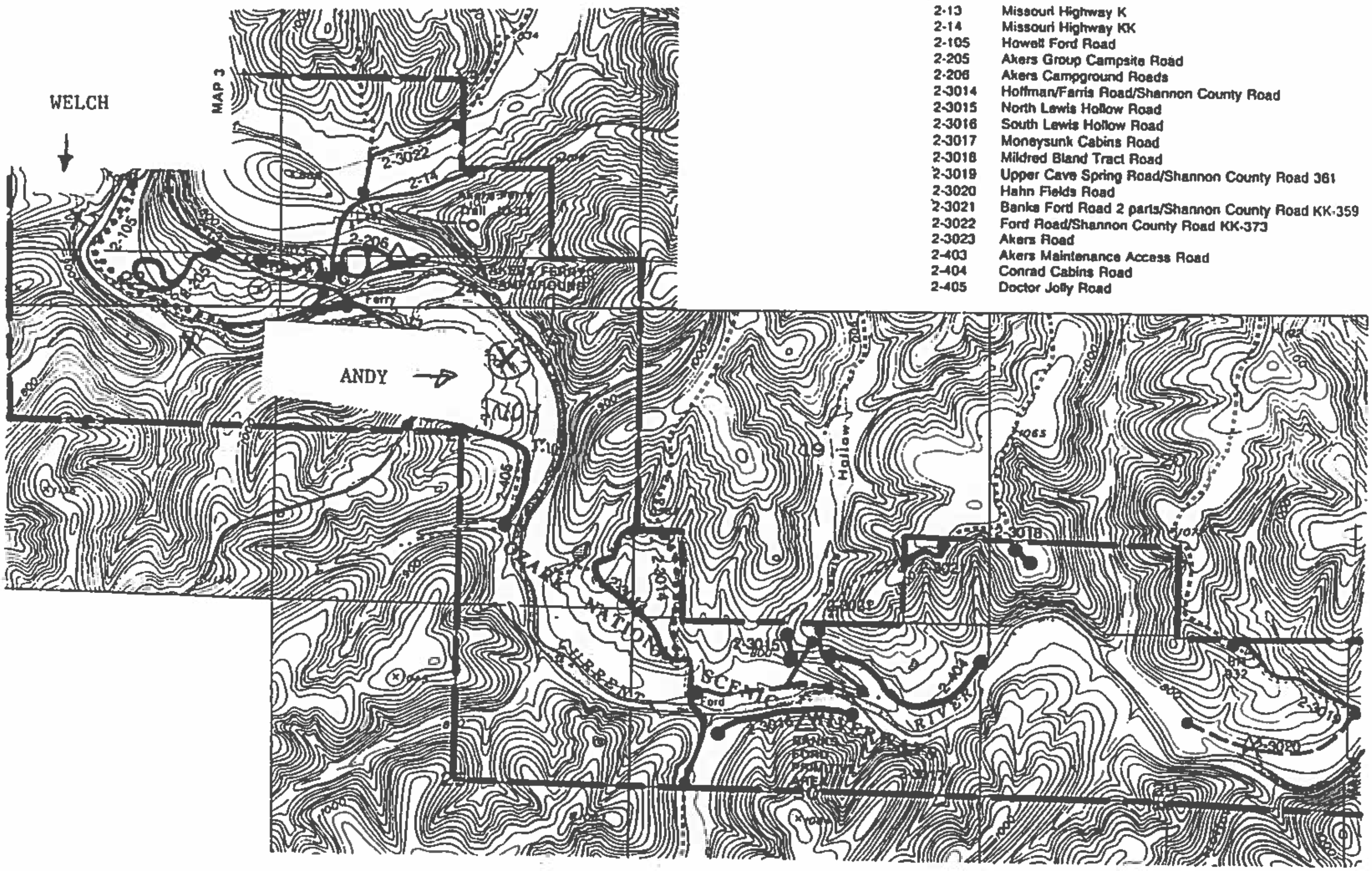
Horse Trail IO-XX HORSE TRAIL

NPS BOUNDARY

TRAILS AND ROADS INVENTORY
OZARK NATIONAL SCENIC RIVERWAYS

MAP 1

DSC / AUG 91-614 / 40037A



2-13 Missouri Highway K
2-14 Missouri Highway KK
2-105 Howell Ford Road
2-205 Akers Group Campsite Road
2-206 Akers Campground Roads
2-3014 Hoffman/Farris Road/Shannon County Road
2-3015 North Lewis Hollow Road
2-3016 South Lewis Hollow Road
2-3017 Moneysunk Cabins Road
2-3018 Mildred Bland Tract Road
2-3019 Upper Cave Spring Road/Shannon County Road 361
2-3020 Hahn Fields Road
2-3021 Banks Ford Road 2 parts/Shannon County Road KK-359
2-3022 Ford Road/Shannon County Road KK-373
2-3023 Akers Road
2-403 Akers Maintenance Access Road
2-404 Conrad Cabins Road
2-405 Doctor Jolly Road

CLOSED TRACES
ACCESS TO EASEMENT, PRIVATE OR STATE LAND ONLY
ROAD OWNED BY COUNTY OR STATE
NPS OWNED / MAINTAINED
NPS OWNED / UNMAINTAINED
CAMPGROUND OR PRIMITIVE CAMPING AREA
Trail ID-XX FOOT TRAIL
Horse Trail ID-XX HORSE TRAIL
NPS BOUNDARY

North

0 1/2 MI.

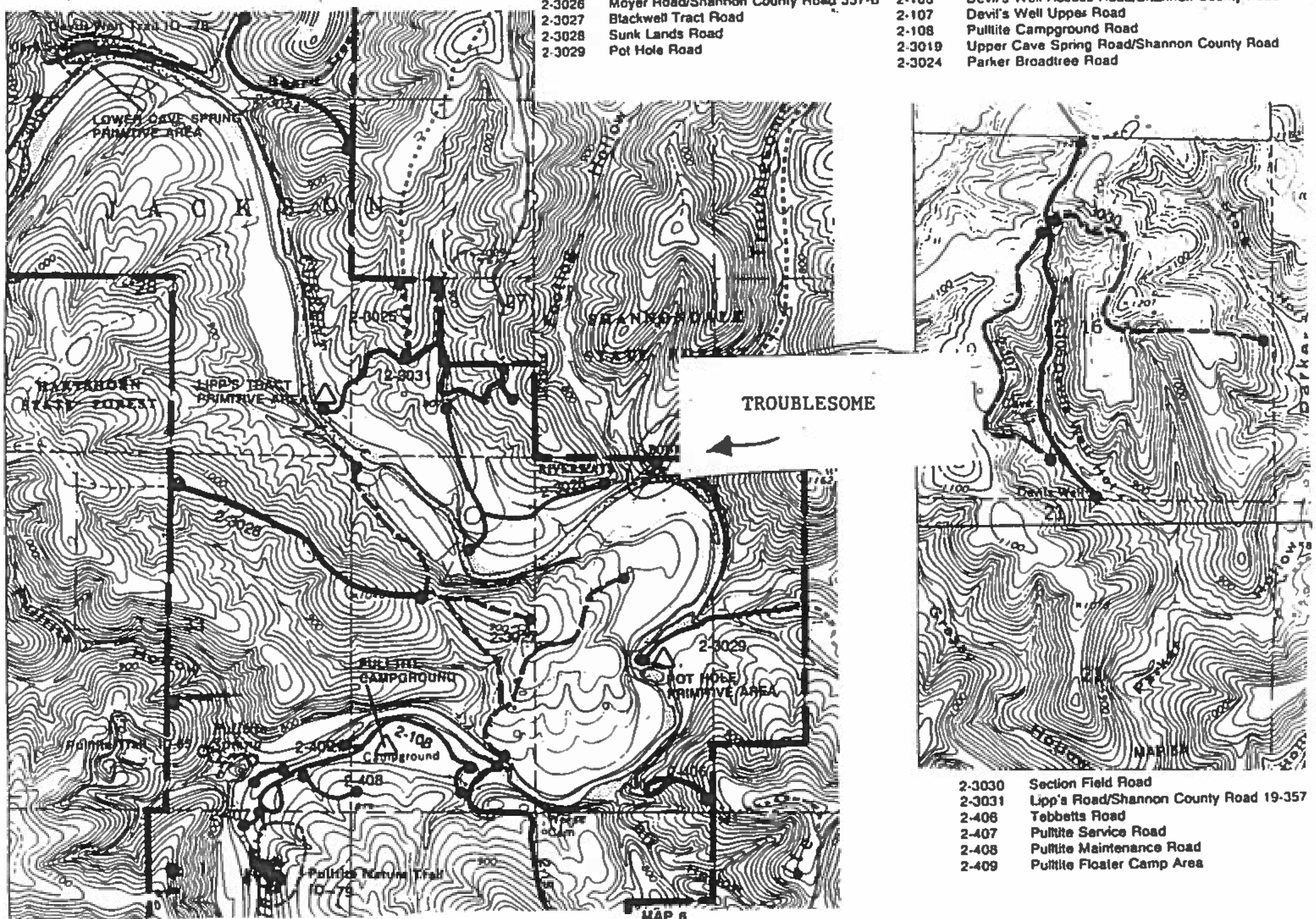
TRAILS AND ROADS INVENTORY
OZARK NATIONAL SCENIC RIVERWAYS

MAP 4

DSC / AUG 91-614 / 40037A

MATCH TO MAP 5A

2-3025	Lipp's Spur Road	2-15	Pulltite Road/Shannon County Road EE-356
2-3026	Moyer Road/Shannon County Road 357-B	2-106	Devil's Well Access Road/Shannon County Road
2-3027	Blackwell Tract Road	2-107	Devil's Well Upper Road
2-3028	Sunk Lands Road	2-108	Pulltite Campground Road
2-3029	Pot Hole Road	2-3019	Upper Cave Spring Road/Shannon County Road
		2-3024	Parker Broadtree Road



2-3030	Section Field Road
2-3031	Lipp's Road/Shannon County Road 19-357
2-406	Tebbetts Road
2-407	Pulltite Service Road
2-408	Pulltite Maintenance Road
2-409	Pulltite Floater Camp Area

North

0 1/2 MI.

CLOSED TRACES

ACCESS TO EASEMENT, PRIVATE OR STATE LAND ONLY

ROAD OWNED BY COUNTY OR STATE

NPS OWNED / MAINTAINED

NPS OWNED / UNMAINTAINED

CAMPGROUND OR PRIMITIVE CAMPING AREA

Trail ID-XX FOOT TRAIL

Horse Trail ID-XX HORSE TRAIL

NPS BOUNDARY

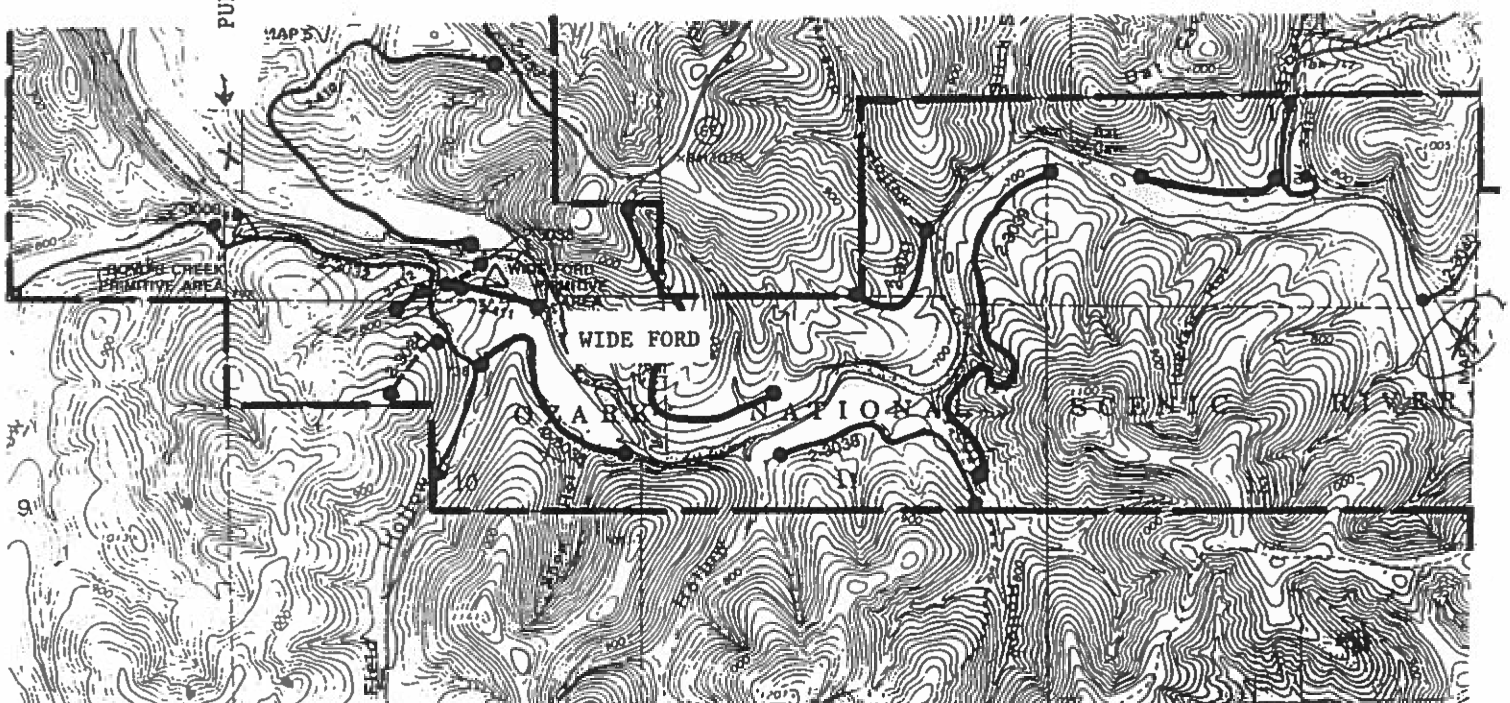
TRAILS AND ROADS INVENTORY
OZARK NATIONAL SCENIC RIVERWAYS

MAP 5

DSC / AUG 91-614 / 40037A

2-15 Pulltite Road
2-3032 Boyd's Creek Road/Shannon County Road
2-3033 Wide Ford Road
2-3034 Boyd's Creek School House Road
2-3008 Boyd's Creek Spur Road
ler Tract Road
ed O'Gwynn Road

2-3038 Mill Hollow Road/Shannon County Road 327
2-3039 Goehler/Stringer Road
2-3040 Jones Hollow Road/Shannon County Road
2-3041 Upper Sugarcamp Hollow Road
2-410 Pulltite Water Tower Road/Shannon County Road
2-411 Lewis Cabin Road
2-412 Spurgeon Road
2-413 Alton Club Road/Shannon County Road 19-D

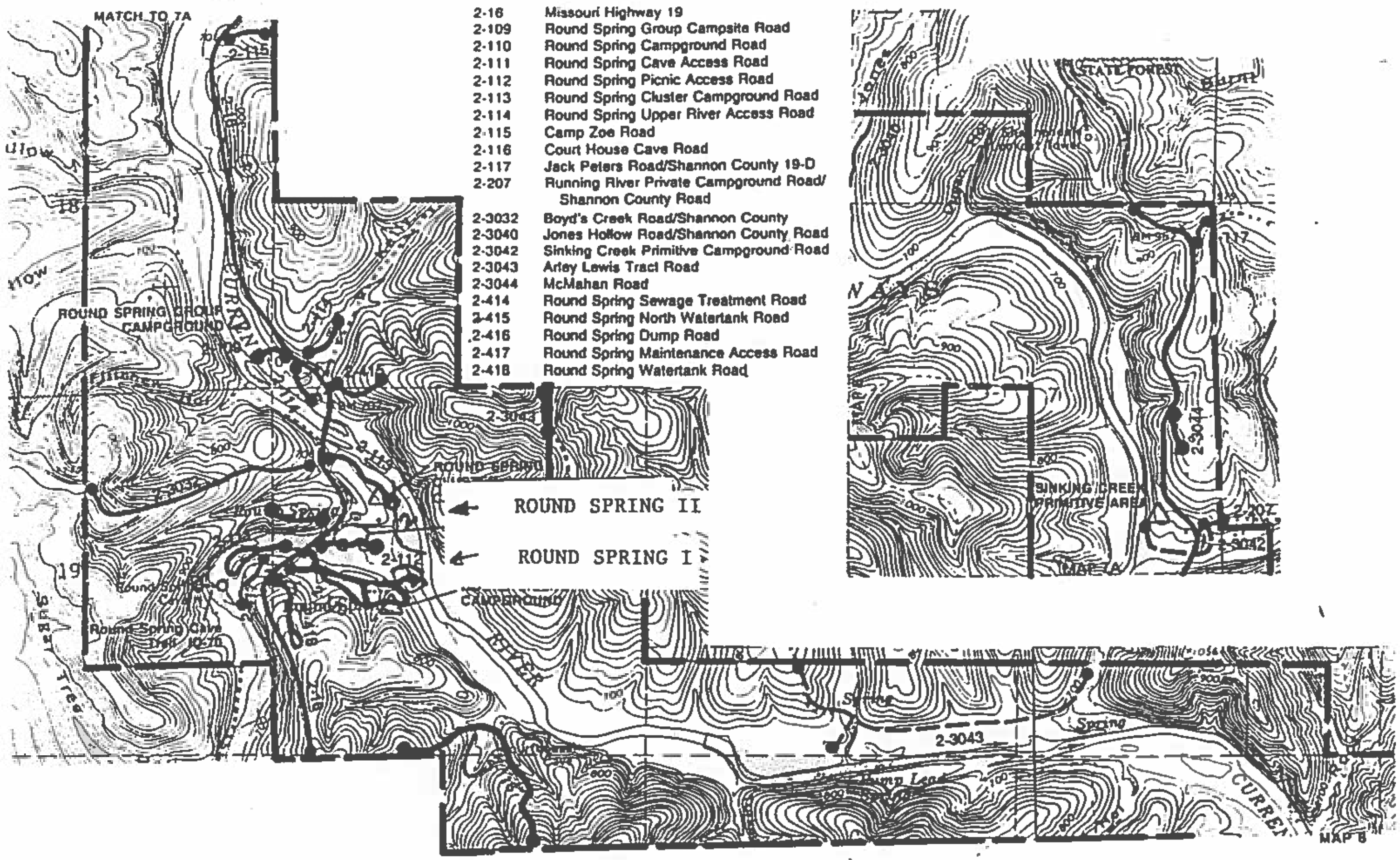


CLOSED TRACES
ACCESS TO EASEMENT, PRIVATE OR STATE LAND ONLY
ROAD OWNED BY COUNTY OR STATE
NPS OWNED / MAINTAINED
NPS OWNED / UNMAINTAINED
CAMPGROUND OR PRIMITIVE CAMPING AREA
Trail ID-XX FOOT TRAIL
Horse Trail ID-XX HORSE TRAIL
NPS BOUNDARY

North
0 1/2 MI.

TRAILS AND ROADS INVENTORY
OZARK NATIONAL SCENIC RIVERWAYS

MAP 6 DSC / AUG 91 / 414 / 40037A



CLOSED TRACES

ACCESS TO EASEMENT, PRIVATE OR STATE LAND ONLY

ROAD OWNED BY COUNTY OR STATE

NPS OWNED / MAINTAINED

NPS OWNED / UNMAINTAINED

△ CAMPGROUND OR PRIMITIVE CAMPING AREA

Trail IO-XX FOOT TRAIL

Horse Trail IO-XX HORSE TRAIL

NPS BOUNDARY

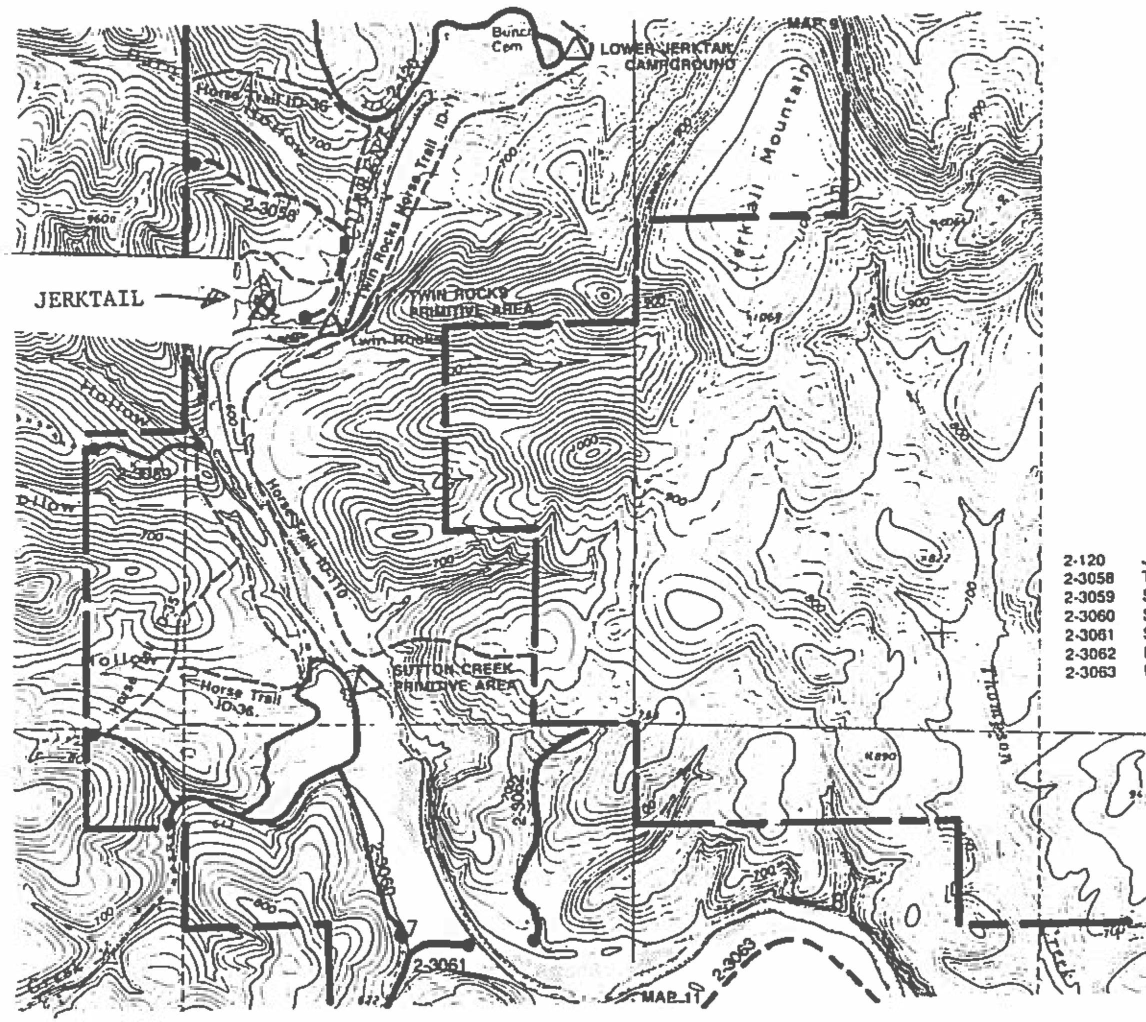
North

0 1/2 MI.

TRAILS AND ROADS INVENTORY
OZARK NATIONAL SCENIC RIVERWAYS

MAP 7

DSC / AUG 91-614 / 40037A



2-120 Jerktail Road/Shannon County Road 224
2-3058 Twin Rocks Road
2-3059 Seldom Seen Road/Shannon County Road
2-3060 Sutton Creek Road/Shannon County 19-208
2-3061 South Powell Road
2-3062 Powell Tract Road
2-3063 Broadfoot Tract Road

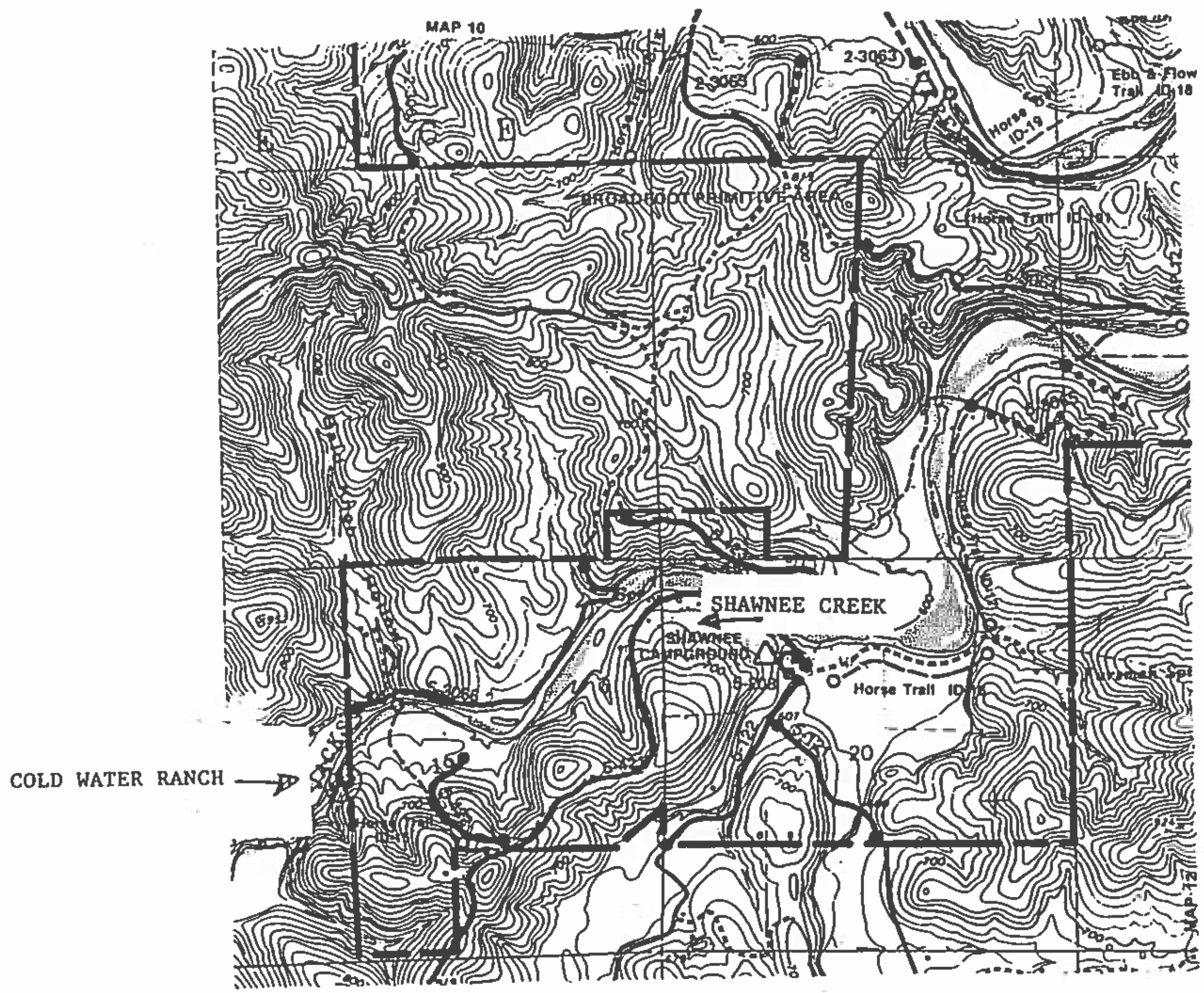
North

0 — 1/2 MI.

- ••••••••••• CLOSED TRACES
- ACCESS TO EASEMENT, PRIVATE OR STATE LAND ONLY
- ROAD OWNED BY COUNTY OR STATE
- NPS OWNED / MAINTAINED
- NPS OWNED / UNMAINTAINED
- △ CAMPGROUND OR PRIMITIVE CAMPING AREA
- Trail IO-XX — FOOT TRAIL
- Horse Trail IO-XX — HORSE TRAIL
- NPS BOUNDARY

TRAILS AND ROADS INVENTORY
OZARK NATIONAL SCENIC RIVERWAYS

MAP 10 DSC / AUG 91-614 / 40037A



2-3061	South Powell Road
2-3063	Broadfoot Tract Road/Shannon County Road
5-121	Shawnee Shop Road/Shannon County 106-211
5-122	Shawnee Creek Road/Shannon County 106-211
5-208	Shawnee Campground Road
5-3064	Nelson Tract Road/Shannon County 206
5-3065	Shed Tract Trace
5-3066	Powell Springs Road
5-421	Blue Bird Ranch Road/Shannon County Road
5-422	Crancer Tract Road
5-423	Smith Road

CLOSED TRACES

ACCESS TO EASEMENT, PRIVATE OR STATE LAND ONLY

ROAD OWNED BY COUNTY OR STATE

NPS OWNED / MAINTAINED

NPS OWNED / UNMAINTAINED

CAMPGROUND OR PRIMITIVE CAMPING AREA

Trail ID-XX — FOOT TRAIL

Horse Trail ID-XX — HORSE TRAIL

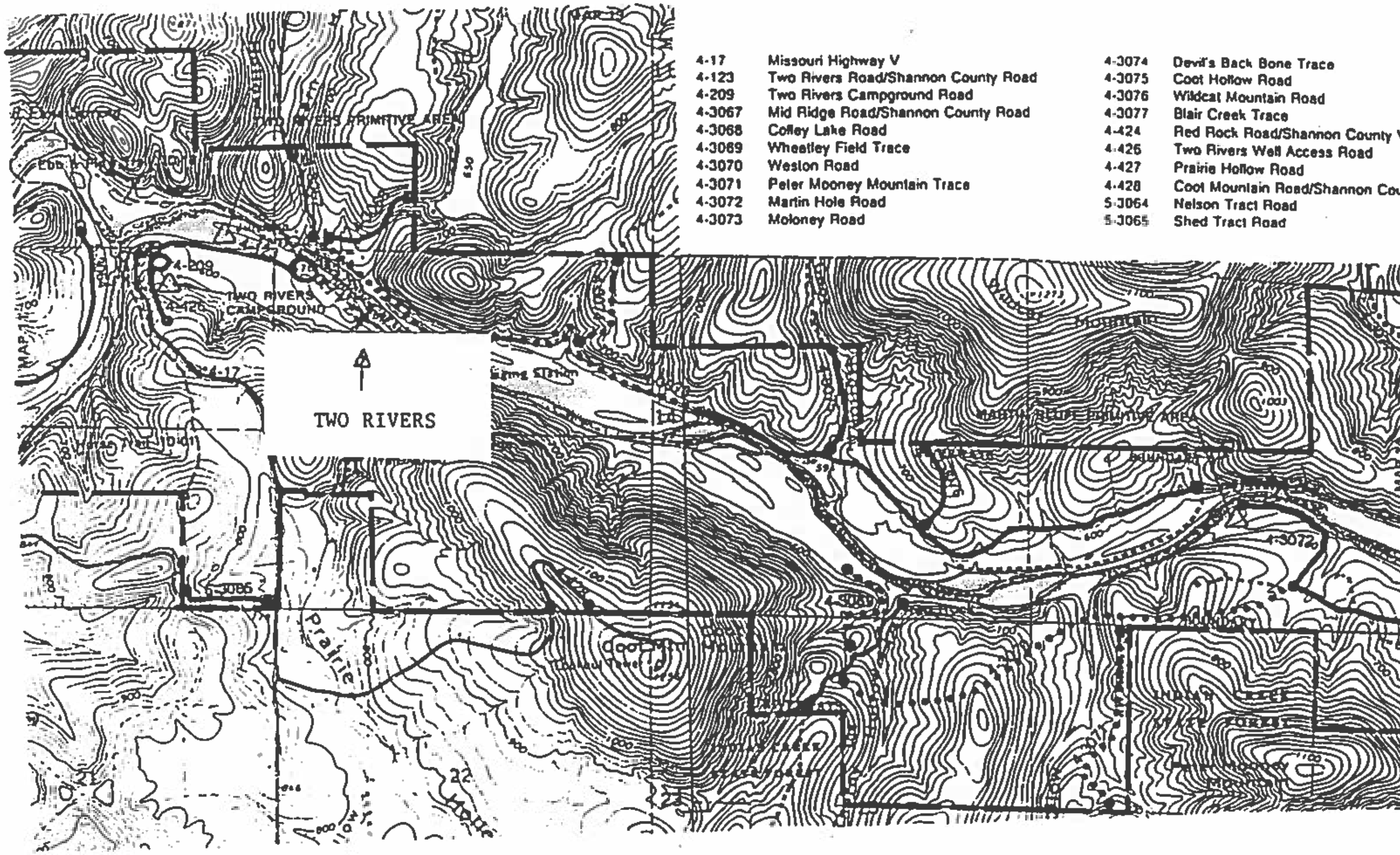
NPS BOUNDARY

North

0 1/2 MI.

TRAILS AND ROADS INVENTORY
OZARK NATIONAL SCENIC RIVERWAYS

MAP 11 DSC / AUG 91-614 / 40037A



North

0 1/2 MI.

CLOSED TRACES

ACCESS TO EASEMENT, PRIVATE OR STATE LAND ONLY

ROAD OWNED BY COUNTY OR STATE

NPS OWNED / MAINTAINED

NPS OWNED / UNMAINTAINED

△ CAMPGROUND OR PRIMITIVE CAMPING AREA

Trail ID-XX FOOT TRAIL

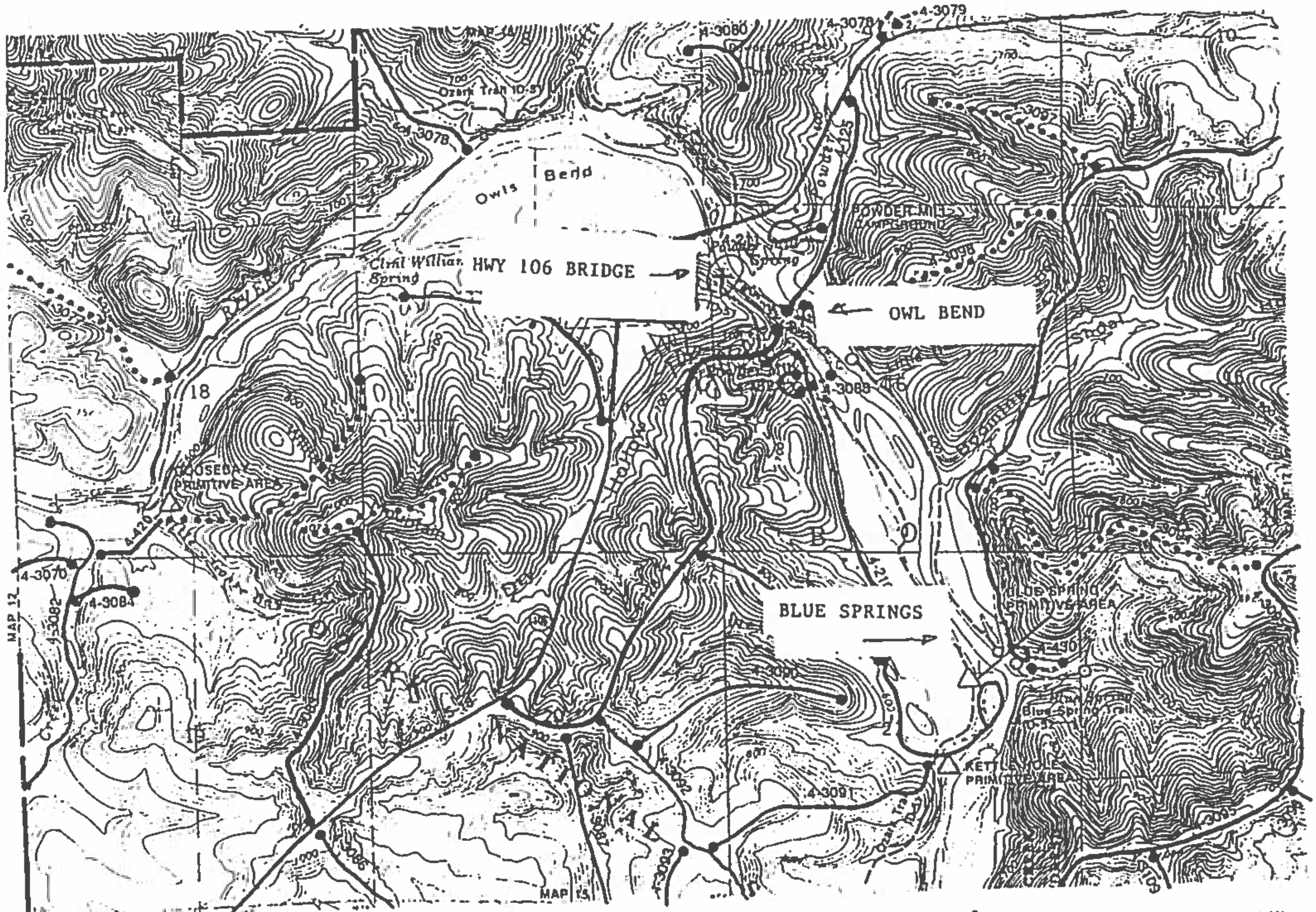
Horse Trail ID-XX HORSE TRAIL

NPS BOUNDARY

TRAILS AND ROADS INVENTORY
OZARK NATIONAL SCENIC RIVERWAYS

MAP 12

DSC / AUG 91-614 / 40037A



North

0 1/2 MI.

- CLOSED TRACES
- ACCESS TO EASEMENT, PRIVATE OR STATE LAND ONLY
- ROAD OWNED BY COUNTY OR STATE
- NPS OWNED / MAINTAINED
- NPS OWNED / UNMAINTAINED

△ CAMPGROUND OR PRIMITIVE CAMPING AREA

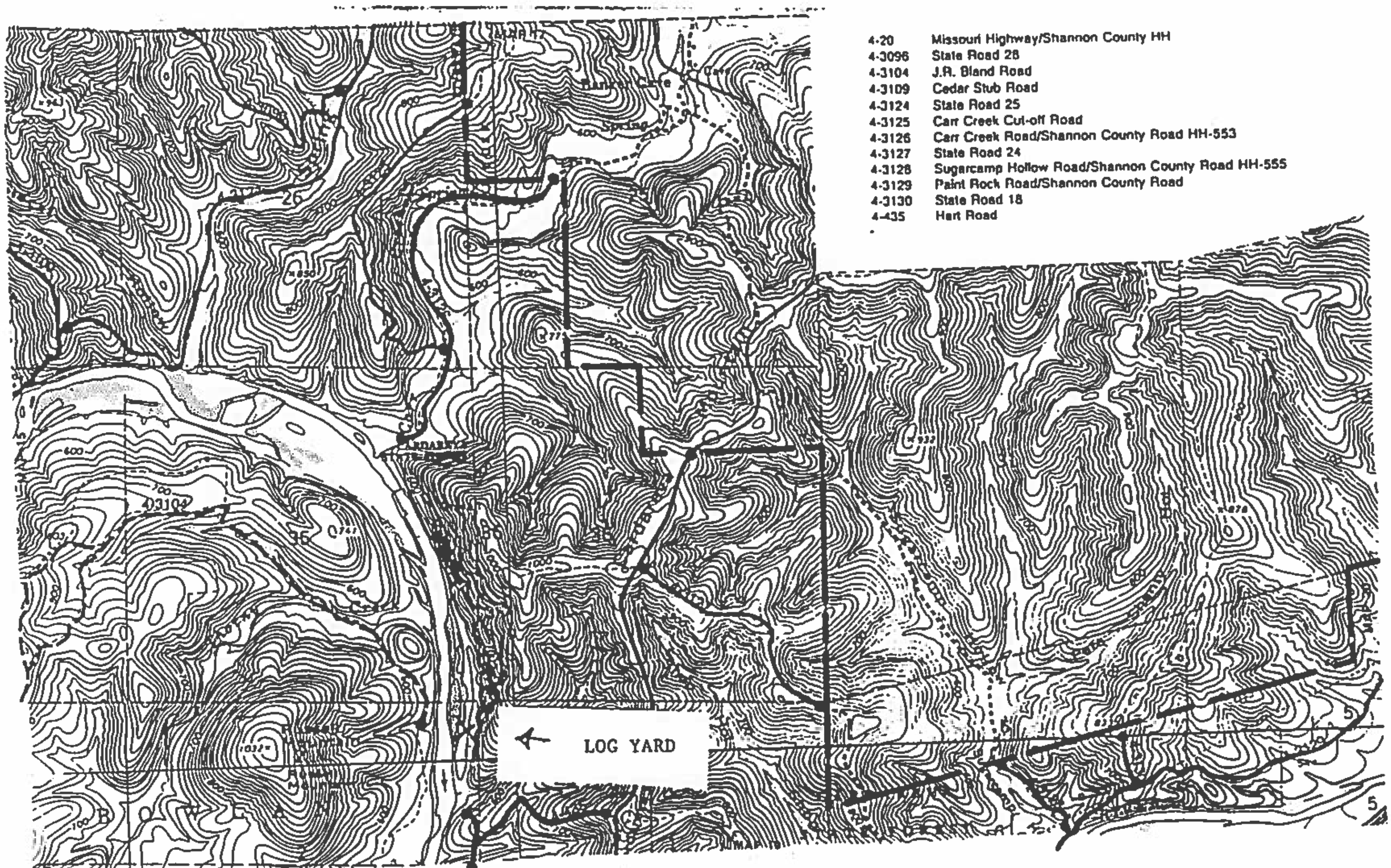
Trail 10-XX FOOT TRAIL

Horse Trail 10-XX HORSE TRAIL

TRAILS AND ROADS INVENTORY
OZARK NATIONAL SCENIC RIVERWAYS

MAP 14

DSC / AUG 91-614 / 40037A



CLOSED TRACES

ACCESS TO EASEMENT, PRIVATE OR STATE LAND ONLY

ROAD OWNED BY COUNTY OR STATE

NPS OWNED / MAINTAINED

NPS OWNED / UNMAINTAINED

△ CAMPGROUND OR PRIMITIVE CAMPING AREA

Trail ID-XX FOOT TRAIL

Horse Trail ID-XX HORSE TRAIL

NPS BOUNDARY

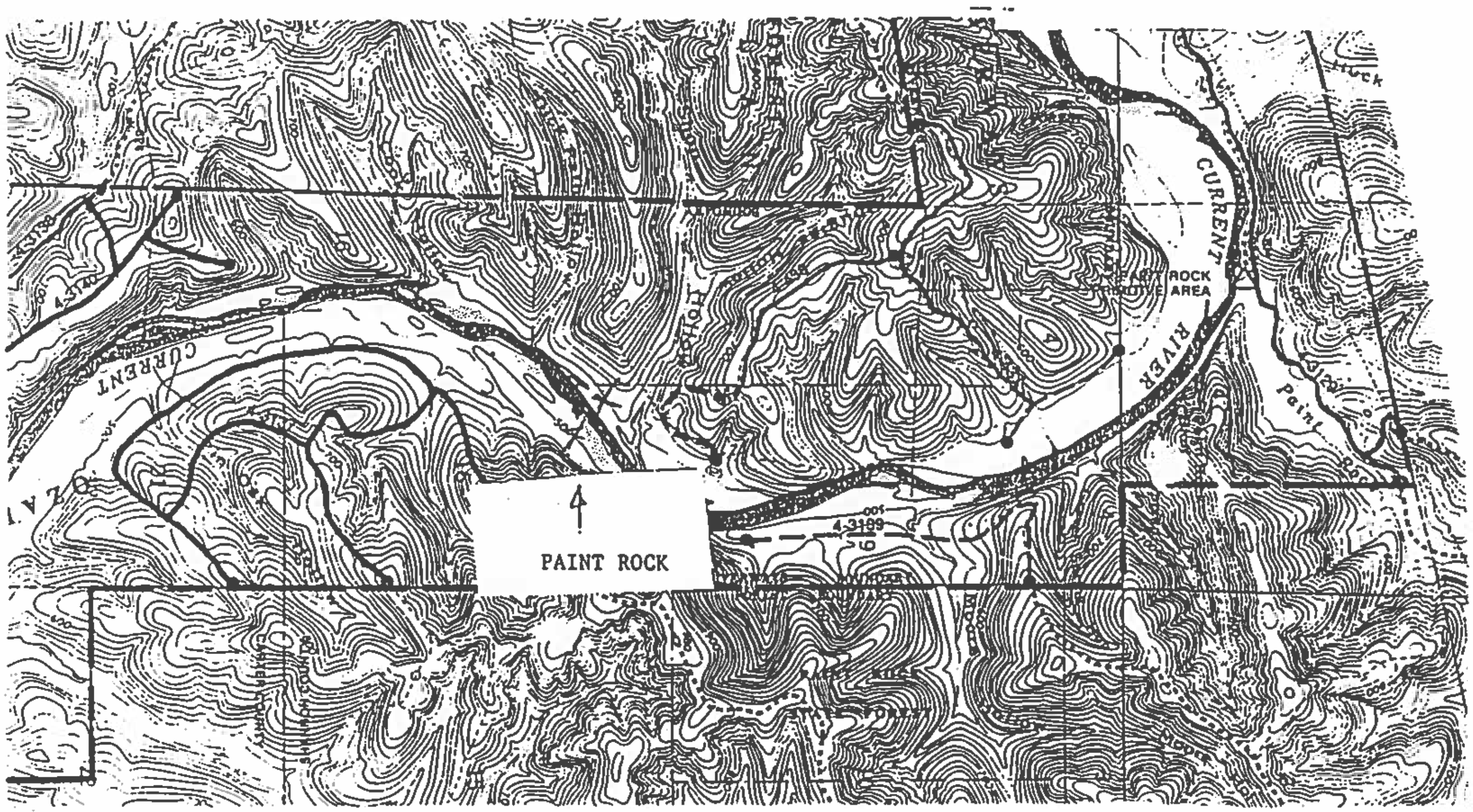
North

0 1/2 MI.

TRAILS AND ROADS INVENTORY
OZARK NATIONAL SCENIC RIVERWAYS

MAP 18

DSC / AUG 91-614 / 40037A



4-3129	Paint Rock Road/Shannon County Road
4-3137	Pin Oak Hollow Area Road
4-3138	East Chilton Creek Road
4-3139	Gravel Spring Road
4-3140	Piles Tract Road
4-437	Weaver Tract Road
4-438	Schwartz Tract Road

CLOSED TRACES

ACCESS TO EASEMENT, PRIVATE OR STATE LAND ONLY

ROAD OWNED BY COUNTY OR STATE

NPS OWNED / MAINTAINED

NPS OWNED / UNMAINTAINED

CAMPGROUND OR PRIMITIVE CAMPING AREA

Trail ID-XX FOOT TRAIL

Horse Trail ID-XX HORSE TRAIL

NPS BOUNDARY

North

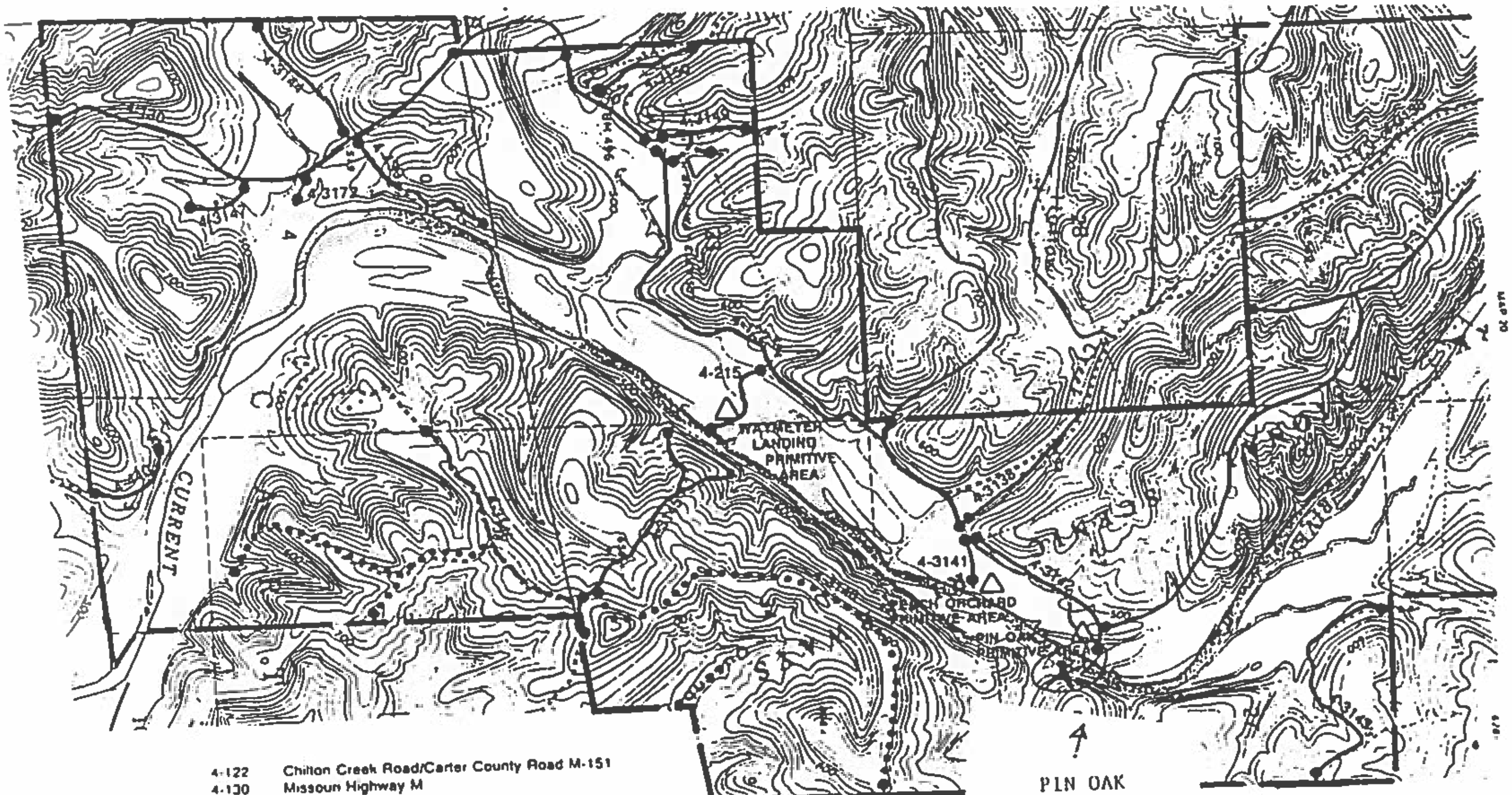
0 1/2 MI.

TRAILS AND ROADS INVENTORY

OZARK NATIONAL SCENIC RIVERWAYS

MAP 20

DSC / AUG 91-614 / 40037A



4-122 Chilton Creek Road/Carter County Road M-151
4-130 Missouri Highway M
4-3172 Crafton Easement Road
4-215 Waymeyer River Access Road
4-3138 East Chilton Creek Road
4-3140 Pile's Tract Road
4-3141 Peach Orchard Primitive Campground Road
4-3142 Pin Oak Primitive Campground Road
4-3143 Dazey Farm Road/Carter County Road D-123
4-3144 Mill Creek Road/Carter County Road M-146

4-3145 Waymeyer Easement Road
4-3146 Keathley Tract Road
4-3147 Tuttle Easement Road
4-3148 Dusenberry Ridge Trace
4-3149 Lofton Lake Road
4-3150 Rogers Creek Road
4-439 Rogers Creek Road
4-440 Raft Yard Road

North

0 1/2 MI.

CLOSED TRACES

ACCESS TO EASEMENT, PRIVATE OR STATE LAND ONLY

ROAD OWNED BY COUNTY OR STATE

NPS OWNED / MAINTAINED

NPS OWNED / UNMAINTAINED

CAMPGROUND OR PRIMITIVE CAMPING AREA

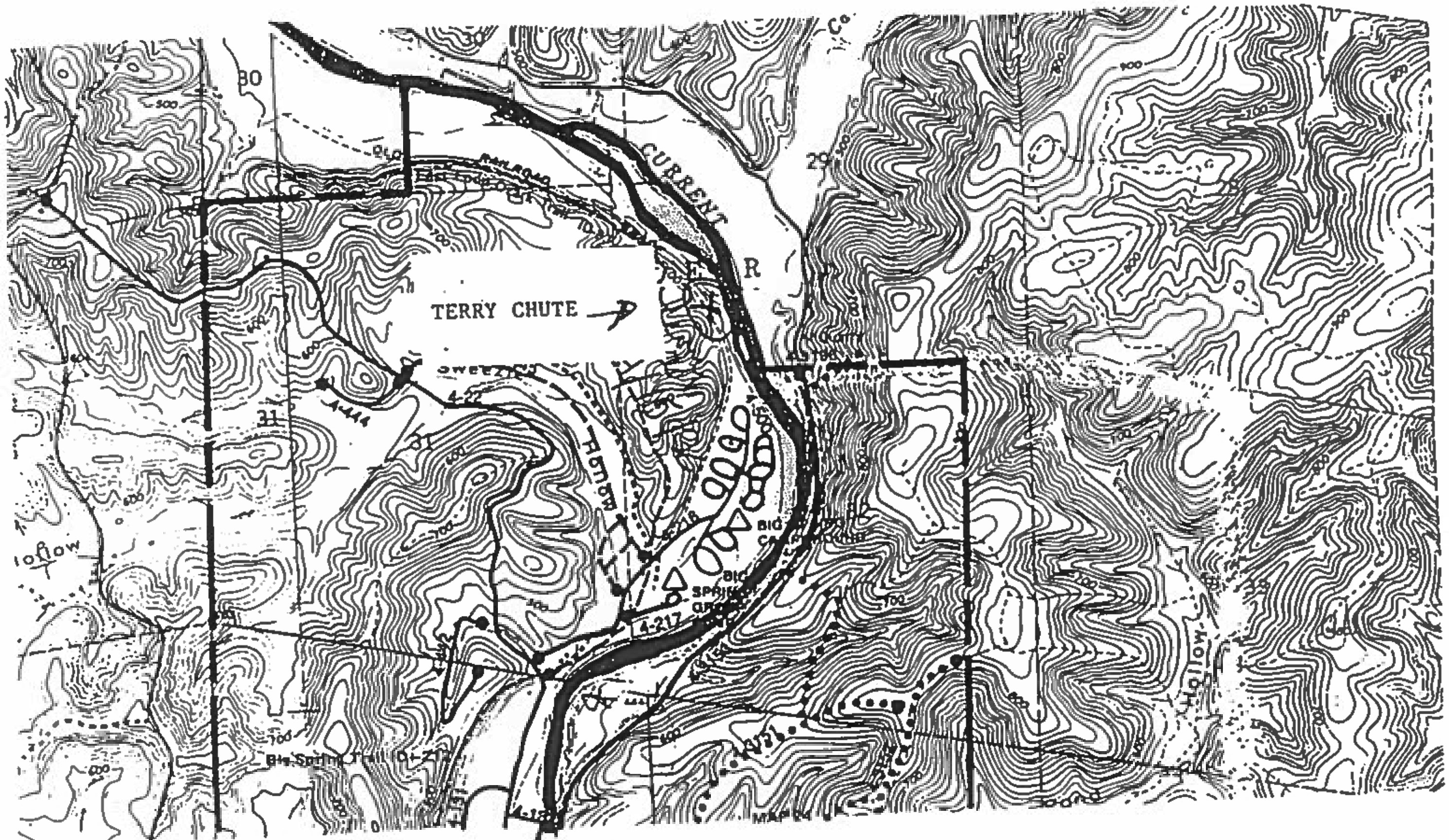
Trail ID-XX FOOT TRAIL

Horse Trail ID-XX HORSE TRAIL

NPS BOUNDARY

TRAILS AND ROADS INVENTORY
OZARK NATIONAL SCENIC RIVERWAYS

MAP 21



4-22	Pea Vine Road
4-131	Big Spring Picnic Area Loop
4-132	Big Spring Boat Launch Road
4-216	Big Spring Campground Road
4-217	Big Spring Group Camp Road
4-3151	Campbell Tract Trace
4-3152	Beaver Pond Area Trace
4-3153	Old Tram Road
4-3196	Granite Quarry Trace
4-442	Watertank Road
4-444	Big Spring Fire Cache Road
4-445	Sweezie Hollow Road
4-500	Big Spring Camp Loops

North

0 — 1/2 MI.

CLOSED TRACES

ACCESS TO EASEMENT, PRIVATE OR STATE LAND ONLY

ROAD OWNED BY COUNTY OR STATE

NPS OWNED / MAINTAINED

NPS OWNED / UNMAINTAINED

CAMPGROUND OR PRIMITIVE CAMPING AREA

Trail IO-XX FOOT TRAIL

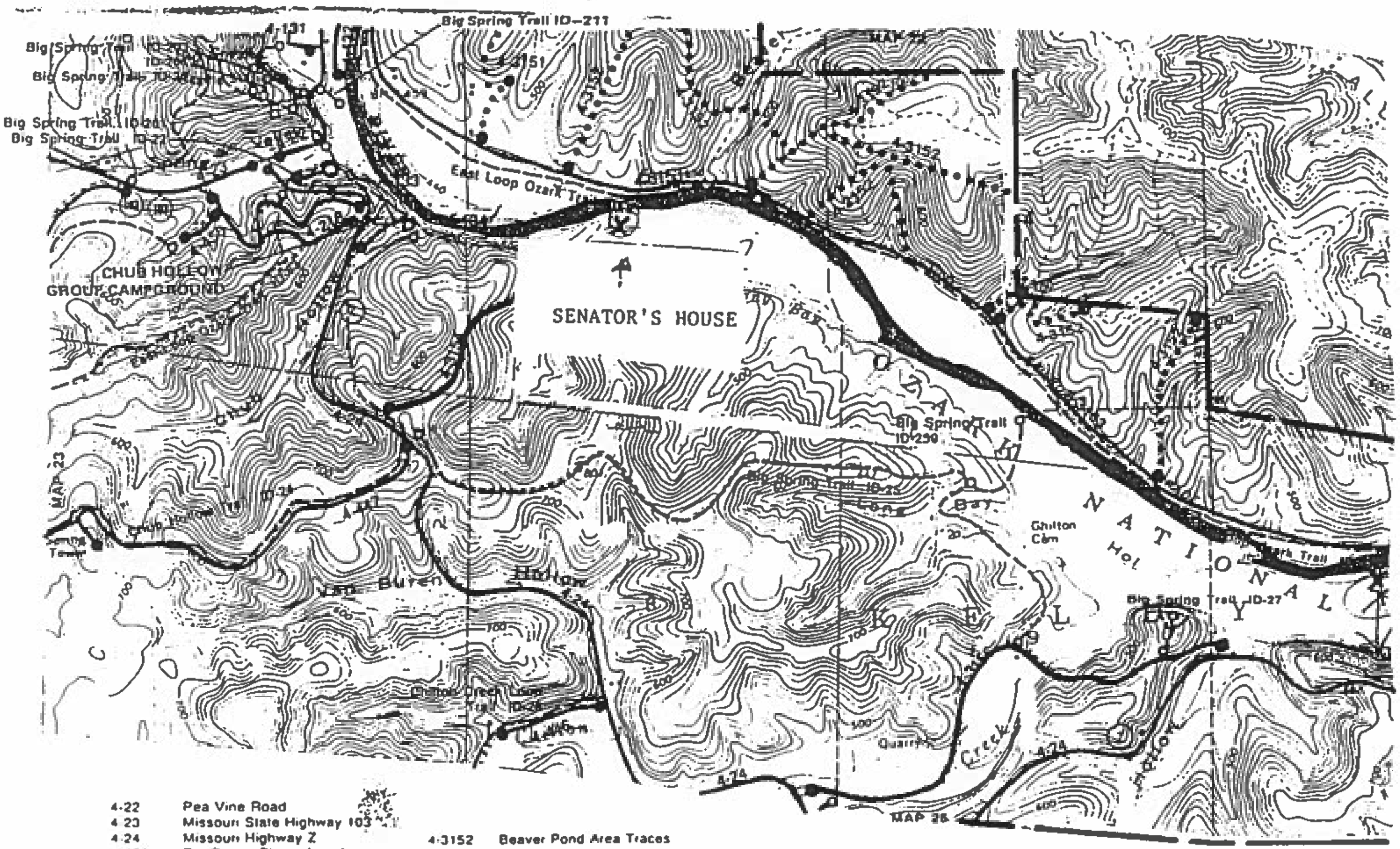
Horse Trail IO-XX HORSE TRAIL

NPS BOUNDARY

TRAILS AND ROADS INVENTORY
OZARK NATIONAL SCENIC RIVERWAYS

MAP 22

DSC / AUG 91-614 / 40037A



FAT BOTTOM

4-22	Pea Vine Road	4-3152	Beaver Pond Area Traces
4-23	Missouri State Highway 103	4-3153	Old Tram Road
4-24	Missouri Highway Z	4-3154	Montgomery Easement Road
4-131	Big Spring Picnic Area Loop	4-3155	Partney House Road/Carter County Road Z-206
4-132	Big Spring Boat Launch Road	4-446	Iron Mine Road
4-133	Big Spring Lodge Road	4-447	Big Spring Lookout Tower Road
4-134	Chub Hollow Road	4-450	Big Spring Maintenance Access Road
4-218	Big Spring Cabin Road		
4-3151	Campbell Tract Trace		

CLOSED TRACES

ACCESS TO EASEMENT, PRIVATE OR STATE LAND ONLY

ROAD OWNED BY COUNTY OR STATE

NPS OWNED / MAINTAINED

NPS OWNED / UNMAINTAINED

CAMPGROUND OR PRIMITIVE CAMPING AREA

Trail ID-XX FOOT TRAIL

Horse Trail ID-XX HORSE TRAIL

NPS BOUNDARY

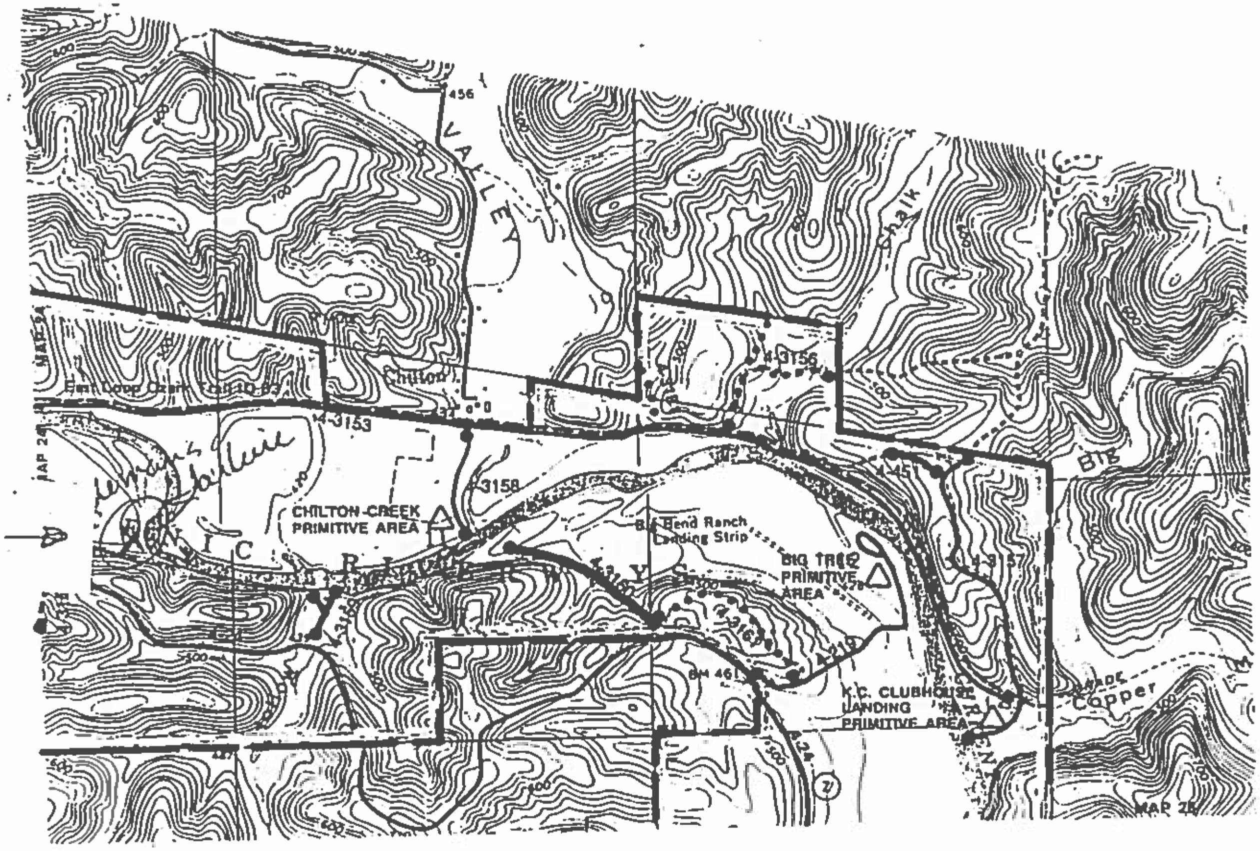
North

0 1/2 MI.

TRAILS AND ROADS INVENTORY
OZARK NATIONAL SCENIC RIVERWAYS

MAP 24 DSC / AUG

COLEMAN'S FAILURE



4-24	Missouri Highway Z	4-3159	Smith Cabin Road
4-219	Big Tree Primitive Campground Road	4-3160	Hafferty Tract Road
4-3153	Old Tram Road	4-3161	Radford Tract Trace
4-3156	Chalk Bank Trace	4-3162	Pistol Range Road
4-3157	K.C. Clubhouse Road	4-3181	Aldridge Valley Trace
4-3158	Chilton Landing Road/Carter County Road T-209	4-451	Kelley Cabin Road

CLOSED TRACES

ACCESS TO EASEMENT, PRIVATE OR STATE LAND ONLY

ROAD OWNED BY COUNTY OR STATE

NPS OWNED / MAINTAINED

NPS OWNED / UNMAINTAINED

CAMPGROUND OR PRIMITIVE CAMPING AREA

Trail ID-XX FOOT TRAIL

Horse Trail ID-XX HORSE TRAIL

NPS BOUNDARY

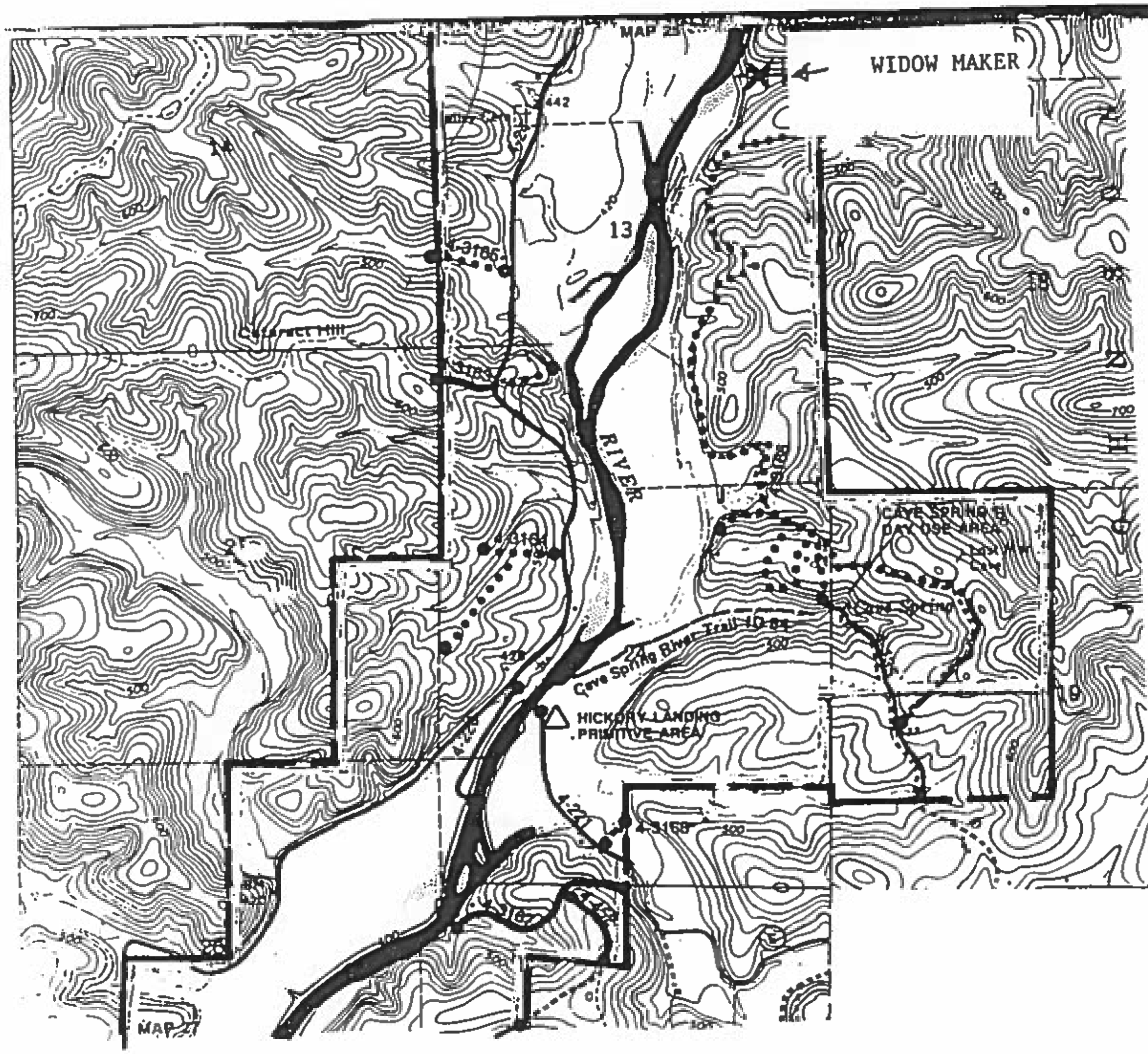
North

0 1/2 MI.

TRAILS AND ROADS INVENTORY
OZARK NATIONAL SCENIC RIVERWAYS

MAP 25

DSC / AUG 91



4-24	Missouri Highway Z/Carter County Road Z-21
4-135	Cave Spring Access Road/Carter County E-2
4-220	Cataract Landing Road
4-221	Hickory Landing Access Road
4-3163	Cataract Hill Trace
4-3164	Coal Bank Cave Road
4-3165	Wilson Tract Trace
4-3166	Lost Man Cave Road
4-3167	Porter Tract Road
4-3168	Conner Lake Trace
4-452	Yantis Tract Road

North

0 1/2 MI.

CLOSED TRACES

ACCESS TO EASEMENT, PRIVATE OR STATE LAND ONLY

ROAD OWNED BY COUNTY OR STATE

NPS OWNED / MAINTAINED

NPS OWNED / UNMAINTAINED

CAMPGROUND OR PRIMITIVE CAMPING AREA

Trail ID-XX
FOOT TRAIL

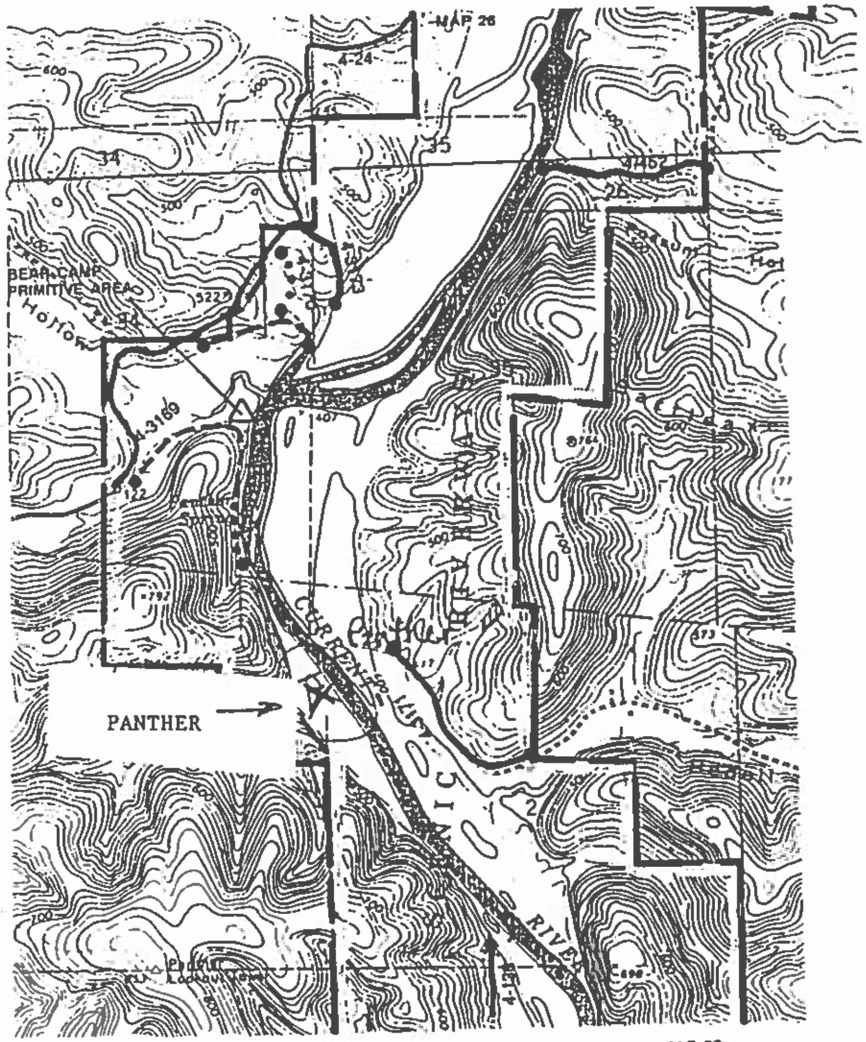
Horse Trail ID-XX
HORSE TRAIL

NPS BOUNDARY

TRAILS AND ROADS INVENTORY
OZARK NATIONAL SCENIC RIVERWAYS

MAP 26

DSC / AUG 91-614 / 40037A



MAP 28

4-24	Missouri Highway Z/Carter County Z-217
4-136	Grubb Hollow Access Road
4-3169	Panther Spring Road
4-3170	Hooper Hollow Road
4-3171	Bedell Hollow Road
4-3173	Hooper Field Road
4-452	Yantis Tract Road

CLOSED TRACES

ACCESS TO EASEMENT, PRIVATE OR STATE LAND ONLY

ROAD OWNED BY COUNTY OR STATE

NPS OWNED / MAINTAINED

NPS OWNED / UNMAINTAINED

△ CAMPGROUND OR PRIMITIVE CAMPING AREA

Trail ID-XX FOOT TRAIL

Horse Trail ID-XX HORSE TRAIL

NPS BOUNDARY

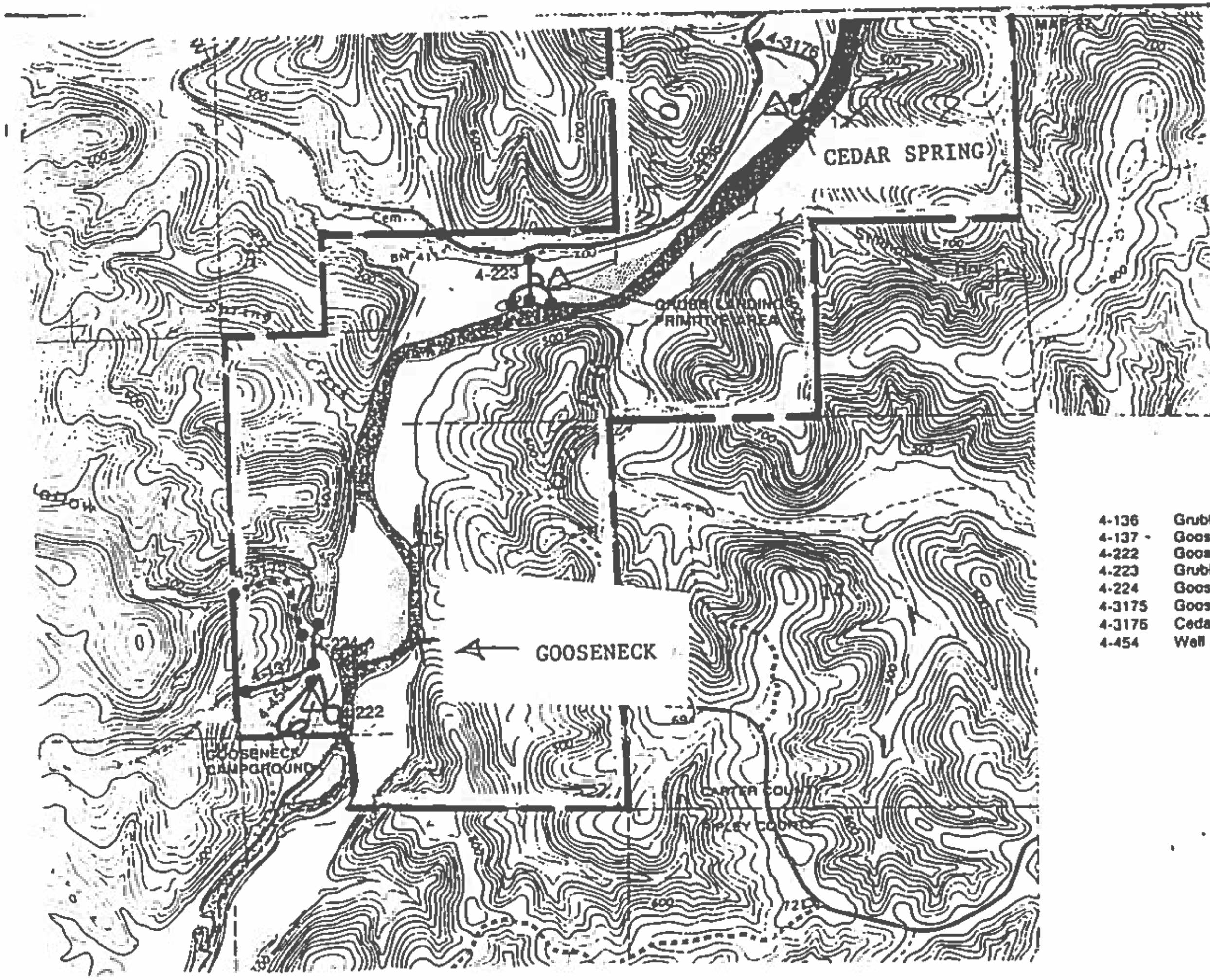
North

0 1/2 MI.

TRAILS AND ROADS INVENTORY
OZARK NATIONAL SCENIC RIVERWAYS

MAP 27

DSC / AUG 91-614 / 40037



4-136 Grubb Hollow Access Road/Carter County Road F-227
4-137 Gooseneck/Hawes Campground Access Road
4-222 Gooseneck/Hawes Campground Loop
4-223 Grubb Hollow Primitive Campground Road
4-224 Gooseneck/Hawes Primitive Campground Loop
4-3175 Gooseneck Hollow Trace
4-3176 Cedar Spring Primitive Campground Road
4-454 Well Access Road

CLOSED TRACES
ACCESS TO EASEMENT, PRIVATE OR STATE LAND ONLY
ROAD OWNED BY COUNTY OR STATE
NPS OWNED / MAINTAINED
NPS OWNED / UNMAINTAINED

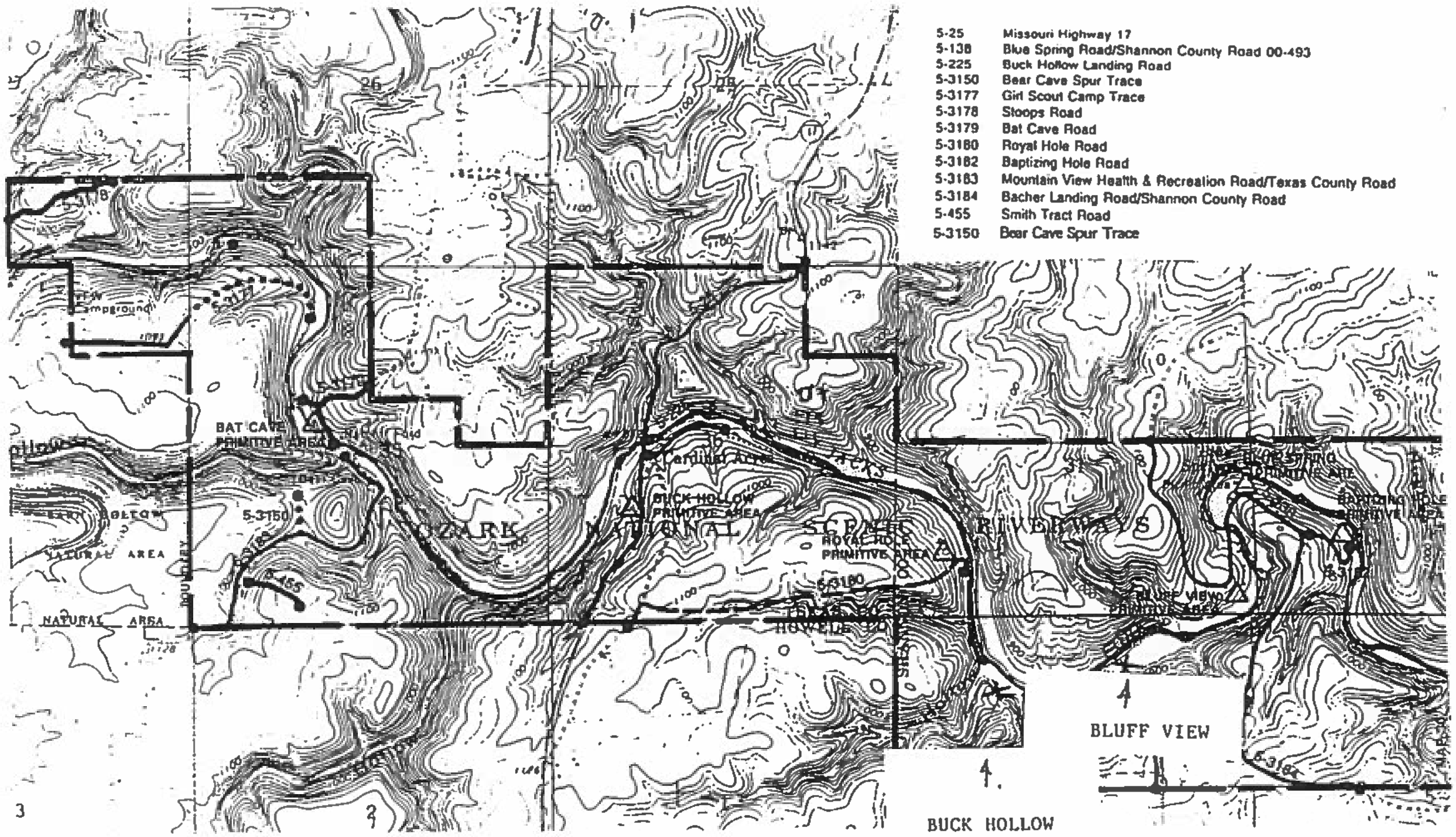
△ CAMPGROUND OR PRIMITIVE CAMPING AREA
Trail ID-XX FOOT TRAIL
Horse Trail ID-XX HORSE TRAIL
NPS BOUNDARY

North

0 1/2 MI.

TRAILS AND ROADS INVENTORY
OZARK NATIONAL SCENIC RIVERWAYS

MAP 28 DSC / AUG 91-614 / 40037



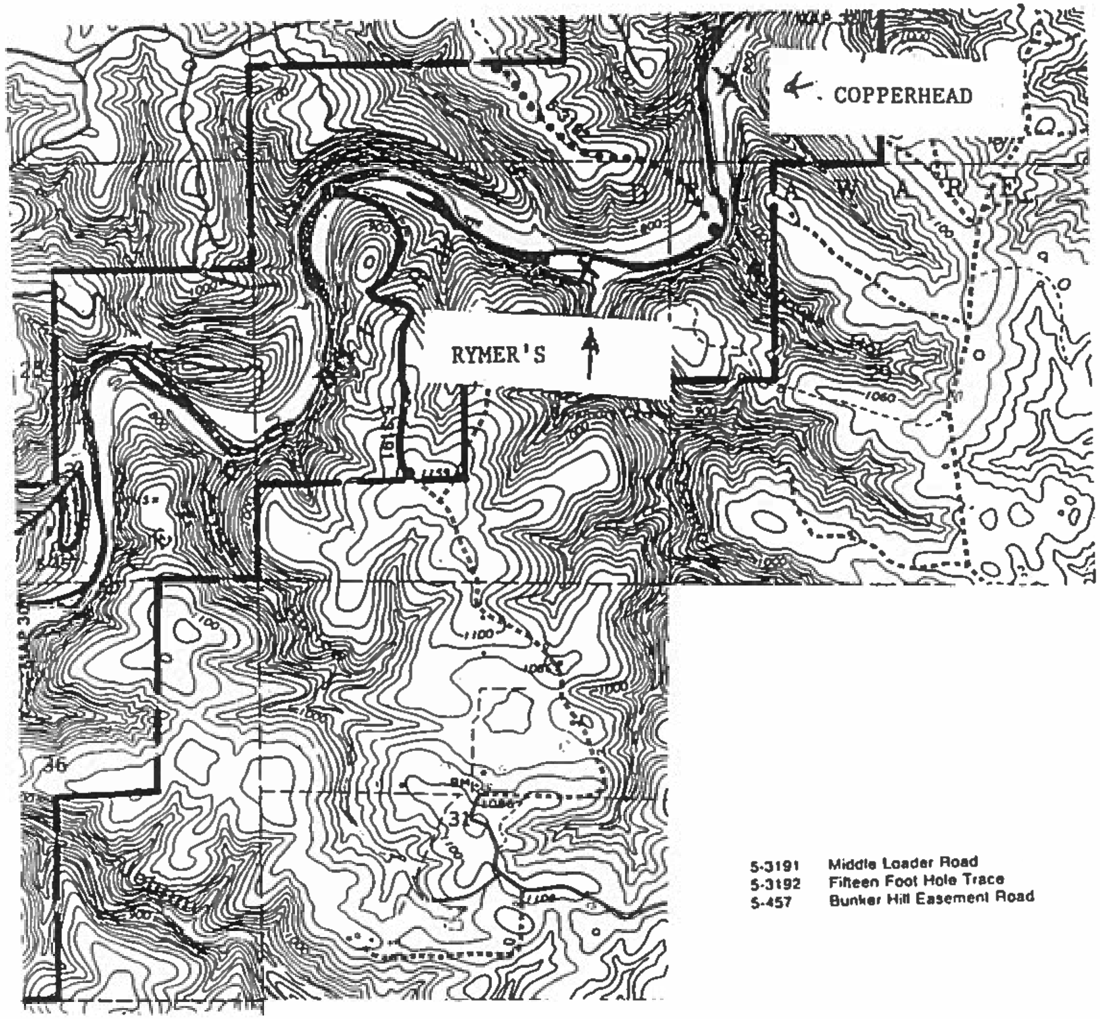
- CLOSED TRACES
- ACCESS TO EASEMENT, PRIVATE OR STATE LAND ONLY
- ROAD OWNED BY COUNTY OR STATE
- NPS OWNED / MAINTAINED
- NPS OWNED / UNMAINTAINED
- △ CAMPGROUND OR PRIMITIVE CAMPING AREA
- Trail ID-XX FOOT TRAIL
- Horse Trail ID-XX HORSE TRAIL
- NPS BOUNDARY

North

0 1/2 MI.

TRAILS AND ROADS INVENTORY
OZARK NATIONAL SCENIC RIVERWAYS

MAP 29 DSC / AUG 91-614 / 40037A



5-3191 Middle Loader Road
5-3192 Fifteen Foot Hole Trace
5-457 Bunker Hill Easement Road

CLOSED TRACES
ACCESS TO EASEMENT, PRIVATE OR STATE LAND ONLY
ROAD OWNED BY COUNTY OR STATE
NPS OWNED / MAINTAINED
NPS OWNED / UNMAINTAINED

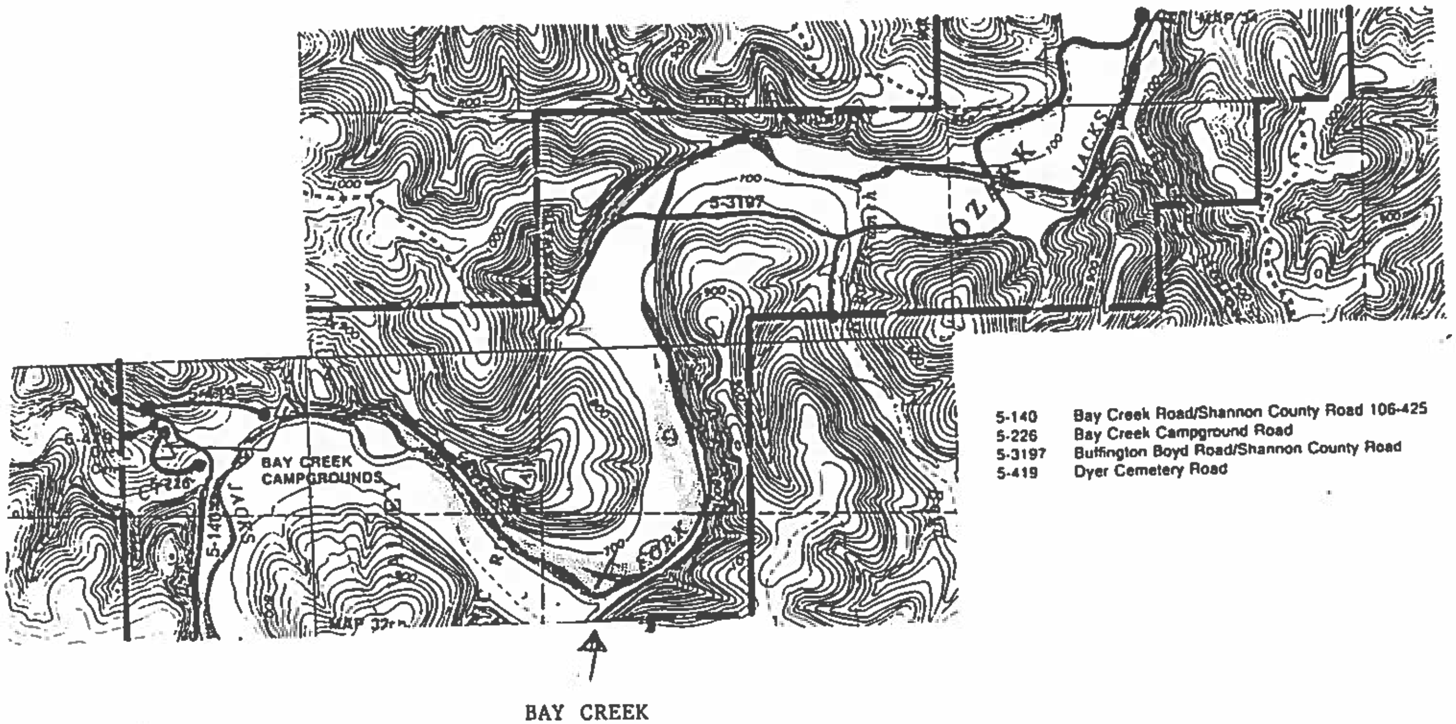
△ CAMPGROUND OR PRIMITIVE CAMPING AREA
Trail IO-XX FOOT TRAIL
Horse Trail IO-XX HORSE TRAIL
NPS BOUNDARY

North

0 1/2 MI.

TRAILS AND ROADS INVENTORY
OZARK NATIONAL SCENIC RIVERWAYS

MAP 31 DSC / AUG 91-614 / 40037A



5-140	Bay Creek Road/Shannon County Road 106-425
5-226	Bay Creek Campground Road
5-3197	Buffington Boyd Road/Shannon County Road
5-419	Dyer Cemetery Road

CLOSED TRACES

ACCESS TO EASEMENT, PRIVATE OR STATE LAND ONLY

ROAD OWNED BY COUNTY OR STATE

NPS OWNED / MAINTAINED

NPS OWNED / UNMAINTAINED

△ CAMPGROUND OR PRIMITIVE CAMPING AREA

Trail ID-XX FOOT TRAIL

Horse Trail ID-XX HORSE TRAIL

NPS BOUNDARY

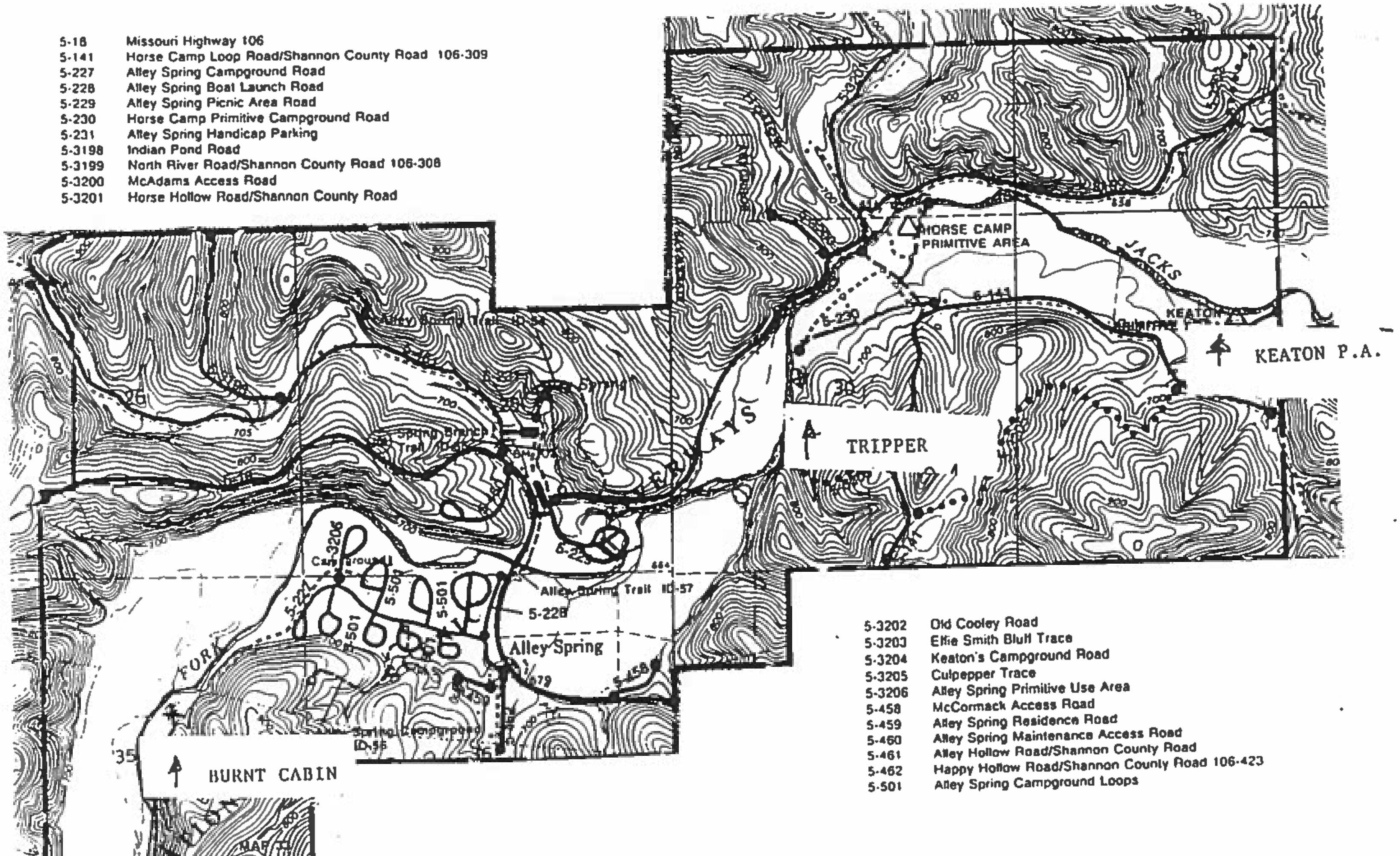
North

0 1/2 MI.

TRAILS AND ROADS INVENTORY
OZARK NATIONAL SCENIC RIVERWAYS

MAP 33 DSC / AUG 91-614 / 40037A

5-18 Missouri Highway 106
5-141 Horse Camp Loop Road/Shannon County Road 106-309
5-227 Alley Spring Campground Road
5-228 Alley Spring Boat Launch Road
5-229 Alley Spring Picnic Area Road
5-230 Horse Camp Primitive Campground Road
5-231 Alley Spring Handicap Parking
5-3198 Indian Pond Road
5-3199 North River Road/Shannon County Road 106-308
5-3200 McAdams Access Road
5-3201 Horse Hollow Road/Shannon County Road



5-3202 Old Cooley Road
5-3203 Effie Smith Bluff Trace
5-3204 Keaton's Campground Road
5-3205 Culpepper Trace
5-3206 Alley Spring Primitive Use Area
5-458 McCormack Access Road
5-459 Alley Spring Residence Road
5-460 Alley Spring Maintenance Access Road
5-461 Alley Hollow Road/Shannon County Road
5-462 Happy Hollow Road/Shannon County Road 106-423
5-501 Alley Spring Campground Loops

CLOSED TRACES
ACCESS TO EASEMENT, PRIVATE OR STATE LAND ONLY
ROAD OWNED BY COUNTY OR STATE
NPS OWNED / MAINTAINED
NPS OWNED / UNMAINTAINED

CAMPGROUND OR PRIMITIVE CAMPING AREA
Trail ID-XX FOOT TRAIL
Horse Trail ID-XX HORSE TRAIL
NPS BOUNDARY

North
0 1/2 MI.

TRAILS AND ROADS INVENTORY
OZARK NATIONAL SCENIC RIVERWAYS

MAP 34 DSC / AUG 91-614 / 40037A