

THE PLANT ECOLOGY OF MAMMOTH CAVE
NATIONAL PARK, KENTUCKY

prepared for the
National Park Service

FINAL REPORT

by

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SUMMARY

Problem: The purpose of this study was to classify analyze and map the principal plant associations which occur in Mammoth Cave National Park.

Method: The forests of Mammoth Cave National Park were analyzed using stand attributes of density, basal area and importance. These data were compared through the use of similarity scalers and ordinated in two dimensional space.

Findings: The dominant forest species of Mammoth Cave National Park associate into seven forest types. The upland and slope oak-hickory stands occupy the largest ordination space with stands grouped as mesophytic occupying the second largest space. The stands dominated by eastern hemlock (Tsuga canadensis) occupy the smallest ordination space. The forests of Mammoth Cave National Park are controlled by physiographic, edaphic and stand age factors which limit the distribution of the characteristic tree species found in each association, a trend reflected in the ordination of stands.

Characteristic tree species in the plant communities of Mammoth Cave include northern red oak (Quercus rubra), tuliptree (Liriodendron tulipifera), white oak (Quercus alba), sugar maple (Acer saccharum) and American beech (Fagus grandifolia). The most mesic communities typically

have American beech and northern red oak as dominant species with sugar maple an important sub-dominant species.

Old growth stands on favorable sites in deep hollows are dominated by a complex of species including several species of oaks, tuliptree, hickory spp., plus red and sugar maple.

On sandstone uplands and along Pennsylvanian aged sandstones a specialized plant community occurs which is dominated by chestnut oak (Quercus prinus). A short distance vertically below these chestnut oak areas eastern hemlock, magnolia and American beech, form another community.

Pignut hickory (Carya glabra), white oak, black oak (Quercus velutina) and several other hickory species reflect the xeric conditions found in the upland communities of the Park.

Only a few floodplain areas were not completely cleared for agriculture prior to the establishment of the Park. In these more mature areas red maple (Acer rubrum), American beech and sugar maple are important woody components of the forest. Along the natural levees of the major rivers through the Park sycamore (Platanus occidentalis) and silver maple (Acer saccharinum) are the major trees. Tall annual herbaceous species form conspicuous bands parallel to the river along narrow topographic boundaries. Verbesina alternifolia covers the lower of these two bands while on

the higher unit Eupatorium rugosum provides the ground cover.

The successional plant communities reflect two major trends. The first involves forest development along a moisture gradient from hydric to mesic conditions. This occurs largely on the larger floodplains of the Green River and up the hollows tributary to the Green River. The second trend is successional recovery on abandoned agricultural land along a time gradient. In the latter pattern black gum (Nyssa sylvatica), dogwood (Cornus florida), winged elm (Ulmus alata) and tuliptree are the important early woody invaders. In later stages blackjack oak (Quercus marilandica) and black locust (an introduced species) (Robinia pseudo-acacia) assume importance.

The 311 plants which were collected during this study were annotated and a summary prepared listing floristic affinities. Forty-four percent of the species range throughout the eastern United States while an additional 23 percent are found in the southeastern United States.

Vegetation maps were prepared from aerial photographs. Seven major mapping units were used on these medium scale maps which emphasize the relationship of land form to the major vegetation types.

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INTRODUCTION

Mammoth Cave in the cave country of the south-central karst region of Kentucky is celebrated in many writings which describe the unusual underground features of the region. However, the National Park has never been the subject of intensive ecological investigation and little has been published on the above-ground ecology of the area. The forest vegetation has been extensively disturbed since settlement, although the valleys in the more rugged topography remain forested. Most of the National Park was made up of farmsteads purchased from the owners during the 1920's and 1930's when the National Park was established. Approximately 51,000 acres are included in Mammoth Cave National Park which is administered by the National Park Service.

Mammoth Cave National Park is roughly triangular with the base extending north-south on the eastern edge for 9 miles while the altitude extends approximately 12 miles on an east-west axis toward Brownsville, Kentucky (Fig. 1). The study area is the National Park with its political boundary also the boundary of this study. Portions of the National Park are located in three physiographic provinces: the Mammoth Cave Plateau, the Pottsville Escarpment and the Western Coalfield (McFarland, 1943). The Mammoth Cave

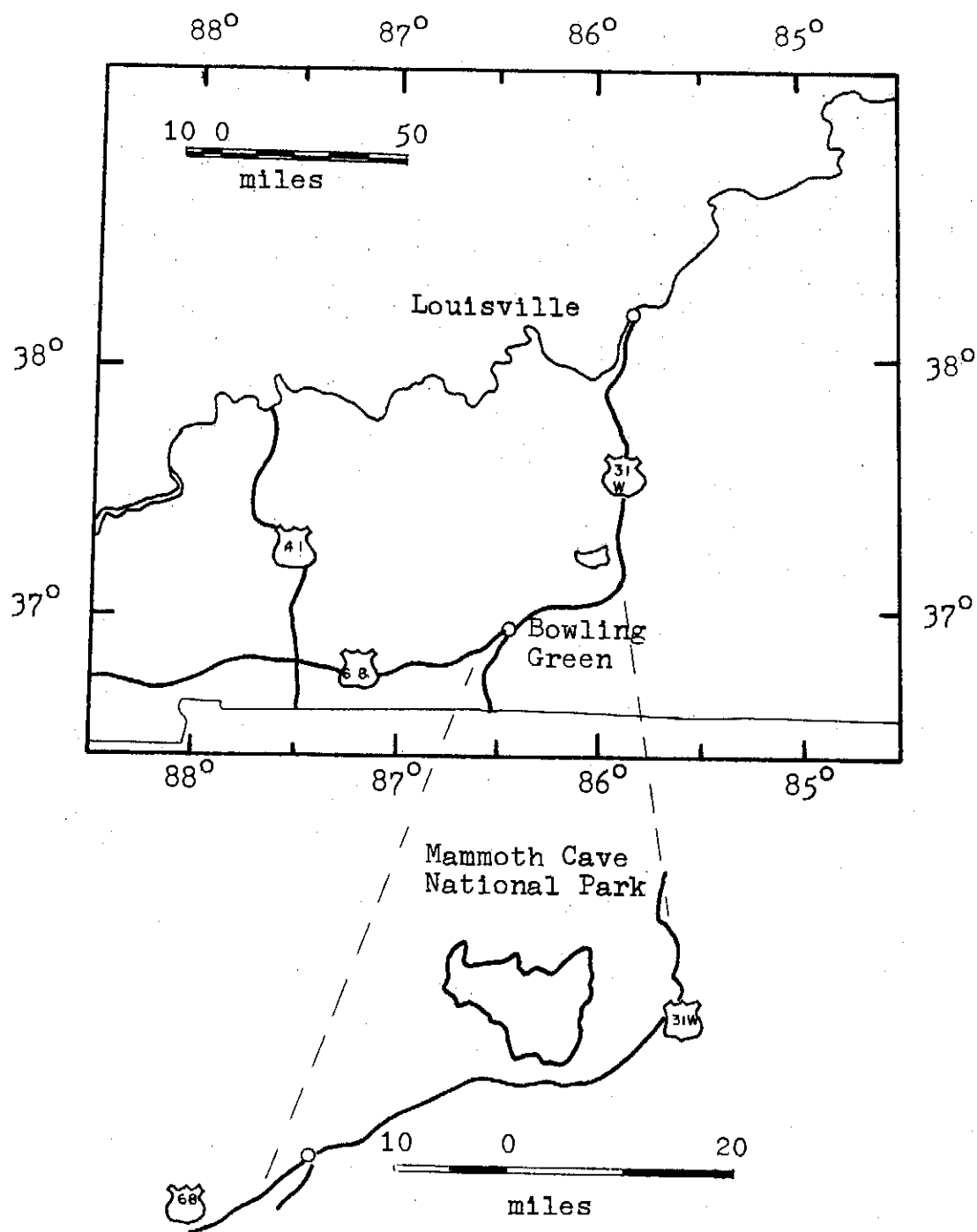


FIGURE 1. Location map of western Kentucky and Mammoth Cave National Park, Kentucky.

Plateau is bounded on the south (within the Park) by the Park boundary and on the north by the Green River. The Pottsville Escarpment is an indistinct east-west trending boundary essentially north of the Green River, except near the western end of the Park, while the Western Coal Field is in the area north of the Green River. The sample areas are located within three Kentucky counties: Barren, Edmonson and Hart.

Mammoth Cave National Park is an important study location by virtue of:

- 1) National Park status (this study was initiated at the request of the National Park Service);
- 2) Location in a region intermediate between southern and northern forest elements;
- 3) Cultural history which is typical of the Central Kentucky region (except that no farming has occurred since the establishment of the National Park Administration); and
- 4) The establishment of the Park has afforded protection to several areas which show very limited disturbance.

Primary objectives of this study include the preparation of a series of contemporary vegetation maps based on quadrangles of the United States Geological Survey prepared at 1:24,000 scale. These vegetation maps were based on air photo interpretation and

ground truth data obtained from quantitative samples. This led to a synthesis of phytosociological data for plant communities. Such data are the basis for understanding the successional patterns within the Park. An interpretation of the potential vegetation of the Park can be developed from these data. A catalog of earlier floristic work in the Park as well as collections made throughout the course of this study is a further primary objective.

Secondary objectives include a summary of the climatic information relative to the vegetation within the Park and a summary of the geology and soils as they relate to the distribution of the plant communities.

The major plant community types within Mammoth Cave National Park (MCNP) are a Mixed Woods Association, a Floodplain Association and an Upland Oak Association. This Upland Oak Association has been largely destroyed since settlement times. Within each of these community associations there are several subtypes.

The Mixed Woods Association is the most widely distributed association. Its best development, in terms of average tree size and species diversity is found in the sinks of the Mammoth Cave Plateau and the valleys formed in the southern margin of the Western Coal Field which drain into the Green River. Within the Floodplain Association

there is a distinct banding of community subtypes along a gradient from the levee to the bottoms, to the first terrace. The larger islands in the Green River show this same banding as well as an additional herbaceous community on the upstream end of the larger islands.

The Upland Oak Association shows segregation based on substrate differentiation. For instance, a chestnut oak forest presently occurs on upland sites which are underlain by Pennsylvanian-aged sandstone.

Old field communities are located on most of the available flat land. The land use prior to Park establishment was intensive agriculture on level sites, including the floodplains, upland plateaus and in the solution valleys. Approximately 60% of the land area of the Park is representative of contemporary forest mosaics which develop 30 to 40 years after agricultural abandonment. The old fields of the upland plateaus support more woody vegetation at this time than the old field communities of the large solution valleys south of the Green River.

Grazing of livestock and selective cutting of the valuable tree species have occurred throughout the slope forests.

Quantitative samples secured from a wide variety of locations were used to clarify the present patterns of forest relationships and succession. These provide a base

for future studies of the plant interactions within the National Park.

This dissertation continued a study initiated by Dr. M.T. Jackson in 1964 on the natural vegetation of Kentucky.

LITERATURE REVIEW

The south-central Kentucky area which includes MCNP was classed as part of the Western Mesophytic Forest Region by Braun (1950). She emphasized that this type contains segregates from both the more mesic Mixed Mesophytic Forest Region and the more xeric Oak-Hickory Forest Region, with local vegetation dependent on site and microclimatic factors. Kuchler (1964) placed this region into an Oak-Hickory forest type when he categorized the potential natural vegetation of the United States.

Only limited work has been done on the plant communities of MCNP. The earliest work, except for some very early unavailable regional studies by the Kentucky Geologic Survey, was a vegetation map done by Ellsworth as a part of the original inventory of land acquired by the Department of the Interior in 1935. This map, (Ellsworth, 1936 and later revisions) in manuscript form, is on file at the National Park accompanied by an unpublished manuscript (Ellsworth, 1934). McInteer (1944) examined the re-vegetation patterns in abandoned fields on Joppa Ridge. Davies (1954) prepared a list of vascular plants which included 635 species, varieties and forms of spermatophytes, and 39 pteridophytes. Henry Lix collected approximately 400 species which are deposited in the

National Herbarium and at Mammoth Cave. Braun (1950) included a section on Mammoth Cave in her description of the vegetation of the Dripping Springs Escarpment and Western Coal Fields. She examined the forest canopy composition in the Big Woods, along the limestone bluffs of the Green River and ravine slopes. Her sample included 836 individual trees distributed among 31 species. A summary of upland old field succession was also included.

Regional (including Kentucky, Tennessee, Ohio and Indiana) vegetation studies that relate to an understanding of MCNP vegetation have been made by numerous workers. Quarterman (1950) documented the successional patterns in the cedar glades of the Nashville Basin of Tennessee, concluding, "That glade communities develop into hardwood stands similar to others in the region not on glade soil." Braun in a large number of papers culminating in her book (1950) discussed the regional vegetation of Kentucky and surrounding states. Of particular interest to this study were her additions to the floral lists of Kentucky appearing in a series of notes on Kentucky plants (1939, 1941). Levering (1968) considered the forest succession of a valley in southern Ohio which apparently has a tree species composition closely approximating that of the valleys of Mammoth Cave.

A study of Fort Hill State Memorial, Highland County,

Ohio, by Braun (1969) emphasized the relationship of topographic variation to the plant communities. She described seven major topographic and soil areas in this study. Although old field areas were considered by Braun, her major emphasis was on the old-growth forest areas that occur within this small (1700-acre) State Memorial.

Indiana forests have been intensively studied for many years. The far-ranging studies of Potzger and Friesner and their students at Butler University from the 1930's to the 1950's (reviewed in Braun 1950) and the more recent studies of Lindsey and his students (Lindsey, Schmelz, and Nichols, 1969; Jackson and Allen, 1969; and others) particularly south of the Quaternary glacial borders of Indiana, have contributed to the understanding of the topographic relationships of old growth forests in this region.

Interest in mapping vegetation has increased with the recent work of Kuchler (1964, 1967), and Kuchler and McCormick (1965). Among the National Parks and Monuments, Death Valley has been recently mapped (Hunt, 1966). Intensive study of other National Park Service administered areas has been done in the Great Smokies (Whittaker, 1956; Crandall, 1958); Yellowstone (Patten, 1968); Lassen Volcanic (Heath, 1967) to name only a few. Vegetation mapping was not a primary goal of these studies, however.

Several forest associations and successional patterns

can be identified within MCNP. Studies of succession on similar substrates from abandoned cropland have been done by McQuilkin (1940), Crafton and Wells (1934), Oosting (1942), Quarterman (1957) and others. Bottomland forests have been studied by Hosner and Minckler (1963), Lindsey et al. (1961) and others. Studies of the oak-hickory associations from the Illinois school of plant ecology include Geis and Boggess (1970), and Dirks-Edmonds (1947). Schmelz and Lindsey (1970) offer an upland oak-hickory species group standard based on the importance values of five species: pignut (Carya glabra (Mill.) Sweet) and shagbark (C. ovata (Mill. K. Koch) hickories, and white (Quercus alba L.), chestnut (Q. prinus L.) and black (Q. velutina Lam.) oaks.

The nomenclature for trees follows Little (1953) throughout this paper, except for Carya ovalis (Wang.) Sarg. which follows Gleason and Cronquist (1963).

Mixed mesophytic forests have been described by Braun (1950). A mixed woods concept emphasizing the transitional nature of the Western Mesophytic Forest Region is also suggested by Braun. A quantitative definition of the mixed woods is also given by Schmelz and Lindsey (1970) which relates the presence of American beech (Fagus grandifolia Ehrh.), sugar maple (Acer saccharum Marsh.), bitternut hickory (C. cordiformis (Wang.) K. Koch), American ash

(Fraxinus americana L.), black walnut (Juglans nigra L.), tuliptree (Liriodendron tulipifera L.) wild black cherry (Prunus serotina Ehrh.), northern red oak (Quercus rubra L.), sassafras (Sassafras albidum (Nutt.) Nees), American basswood (Tilia americana L.), and slippery elm (Ulmus rubra Muhl.).

A concept of Western Mesophytic Forest Region based on the work of these authors was used in this study. Important species components, their probable origin and present segregation into these four major associations, each with more or less distinct sub-types were considered in this study. Some such components grade into one another, as along a major stream valley, while others are remarkably distinct, such as the chestnut oak community on the sandstone outliers south of the Green River.

DESCRIPTION OF STUDY AREA

Location

Mammoth Cave National Park is in the south-central Kentucky karst with the headquarters located at 37° 11' north latitude and 86° 06' west longitude. The Park includes sections of the Interior Lowland Province, the Mammoth Cave Plateau and the Western Coalfield (Lobeck, 1957). The present Park includes 51,354 acres which were acquired over a period beginning in the 1920's by a Commonwealth of Kentucky commission to establish Mammoth Cave National Park (Fig. 1). The National Park Service took over administration of the Park in 1934. Mammoth Cave National Park was formally dedicated in 1946 although management as a National Park has been continuous since 1935. Park lands were acquired largely during the 5 to 10-year period prior to 1935. The last two large in-holdings were acquired in 1960. These are the Great Onyx and Crystal Cave properties on Flint Ridge.

Geology

Stratigraphy

The bedrock of MCNP includes members from the Upper Mississippian and the Lower Pennsylvanian Systems of the Carboniferous Era. The Mississippian rock is limestone alternating with sandstone while the Pennsylvanian rock

in the Park is sandstone (McFarland, 1943).

The Mississippian System which outcrops in the Park region includes members of the Meramecian and Chesterian Series (Upper Mississippian of United States Geologic Survey mapping program). The oldest limestones exposed in the Park belong to an upper member of the St. Louis Formation recently described as the Horse Cave limestone (Pohl, 1970). The Ste. Genevieve Formation is divided into the following members, the Freedonia, the Spar Mt., Karnak, the Joppa and the Aux Vases by Pohl (1970).

Members of the Lower Chester Series lie above the Ste. Genevieve Formation. The United States Geologic Survey (USGS) mapping program has given the name of Girkin Formation without any further subdivision to this limestone member in the region of the Park. Pohl (1970) placed this formation into the Paoli and Ridenhower-Golconda complex. Table 1 illustrates a generalized stratigraphic column for this region. McFarland (1943) divided this part into the Middle Chester and included the Golconda Formation, the Hardinsburg sandstone and the Glen Dean limestone. Pohl and the USGS mapping program introduced the Big Clifty sandstone for a 50 to 60-foot thick member in the Golconda Formation. A thin member, the Haney limestone and shale marks the upper bed of the Golconda Formation. The Hardinsburg sandstone and the Glen Dean limestone are

TABLE 1. Generalized stratigraphic outline of exposed beds in Mammoth Cave National Park. (after Pohl 1970).

System	Series	Formation	Member	Symbol
Quaternary	Wisconsin		Alluvium	Qal
Pennsylvanian	Pottsville	Caseyville	Undifferentiated	Epca
Mississippian	Chesterian	Leitchfield	Waltersburg ss	Ml
			Vienna ls	
			Tar Springs ss	
		Glen Dean ls	Undifferentiated	Mgd
		Hardinsburg ss	Undifferentiated	Mh
		Golconda	Haney ls	Mgh
			Big Clifty ss	Mgb
	Girkin of USGS	Ridenhower	Beech Creek ls	
			Reelsville ls	
			Sample	Mg
			Beaver Bend ls	
		Paoli	Bethel ls	
			Undifferentiated	
	Meramecian	Ste. Genevieve	Aux Vases ls	Msg
			Joppa ls	
			Karnak ls	
			Spar Mt. dolomite	
	Ste. Genevieve of USGS		Fredonia ls	
		St. Louis	Horse Cave ls	

included in the Middle Chester by McFarland (1943). The Upper Chester members included by McFarland are the Tar Springs sandstone, the Vienna limestone and the Waltersburg sandstone. Collectively these members comprise the Leitchfield Formation of the USGS mapping program.

The Pennsylvanian System is represented by the Caseyville Formation which is the lowest member of the Pottsville Series (lower Pennsylvanian Series in the USGS mapping program). The Caseyville is a thick formation which rests unconformably on the Upper Chester Formation. In places post-Mississippian channeling has occurred to the Big Clifty sandstone member in the Golconda Formation. This main channel is noted in the Cub Run, Kentucky, Quadrangle. Within the Park the Caseyville rests unconformably on Upper and Middle Chester members down to the Glen Dean limestone. The Quaternary System is represented by alluvium found along the Green and Nolin Rivers. This alluvium is described by Haynes (1964) as:

Sand, locally crossbedded, silt and clay, poorly sorted: locally contains gravel lenses of rounded to well-rounded quartz and chert pebble and cobbles. Sand, clay and silt are brown, gray and dark gray.

Structure

The geologic structure underlying MCNP is simple with the regional dip of the sedimentary beds toward the

northwest. A post-Pennsylvanian normal fault occurs along Cub Run in the Cub Run, Kentucky, Quadrangle (Sandberg and Bowles, 1965) and extends southward adjacent to the east boundary of MCNP (Haynes, 1964). Because of the extensive solution valley systems south of the Green River, topographic expression of the fault has been obscured. North of the Green River the linearity of Cub Run in relatively horizontal beds reflects structural control of this stream valley.

The dip of the beds varies slightly between the quadrangles which include sections of the Park. In the Mammoth Cave, Kentucky, Quadrangle (Haynes, 1964), the dip is generally northwest with small closed basins occurring in Doyel Valley. In the Rhoda, Kentucky, Quadrangle (Klemic, 1963), the general dip of the beds is almost due west. In the Brownsville, Kentucky, Quadrangle, the dip is generally toward the northwest although the structure is complicated by several normal faults trending southwest-northeast in the southern half of the quadrangle. This series of faults is outside the Park boundaries with only a few small streams (Honey Creek and an unnamed tributary of the Green River trending southwest between Kentucky State Highways 1749 and 1649), reflecting structural control (Gildersleeve, 1965).

Physiographic Divisions and Geomorphology

The Park is located on part of the Mammoth Cave Plateau and the Western Coal Field. The Pottsville escarpment crosses east-west through the northern part of the Park. The Dripping Springs escarpment, which marks the border between the Mississippian Plateau and the Mammoth Cave Plateau is outside the south margin of the Park. All drainage within the Park flows to the Green River. South of the Green River this drainage is largely internal and flows through a series of underground cave passages. There are four levels of dry cave passage, and a fifth level is at the present Green River level. North of the Green River there is a dendritic drainage pattern which has developed on the thick sandstone of the lower Pennsylvanian.

The present topography of MCNP is the result of a tremendous amount of solution by water of the limestone of late Mississippian age, particularly the Girkin and Ste. Genevieve limestones. Water flowing from the sinkhole plain through these limestones to the Green River results in the large solution valleys, sinks in the plateaus and the development of caves under the major ridges of the Mammoth Cave Plateau (White et al. 1970).

The steepest slopes are the ones associated with the Mammoth Cave Plateau and the Green River. Some of these slopes are essentially vertical and are formed in the thick limestones of the upper Mississippian. More gentle slopes

are found associated with the solution valleys. These latter slopes are approximately 20% to 40% with a sharp break occurring at the sandstone outcrops on the upper slope.

Drainage

Drainage within the Park exhibits three forms: the first two are associated with the karst topography south of the Green River, and the third is associated with the Western Coal Field north of the Green River. South of the Green River surface water rarely occurs and soon disappears as sinking springs or dripping springs along the escarpments of solution valleys. A shift to mesic species occurs within close proximity to these springs. The second major flow is through the large spring systems which empty directly into the Green River. There are seven of these major springs known at this time.

North of the Green River the drainage is largely dendritic in pattern and is that associated with a mature landscape developed on the thick sandstone of the lower Pennsylvanian. There are sinking streams in the northeast and northcentral parts of the Park where the Mississippian limestones are exposed. The sinking streams of this region include First Creek, Chicken Hollow and Dry Prong.

Soils

The soils of the Park were derived under forest

vegetation within a moist, humid climate. A soil survey of Barren County was published in 1969 (Latham), but those parts of the Park included in Edmonson and Hart Counties have no soil survey available. Approximately 1,330 acres of the Park lie in Barren County. Latham places this region of the Park into the Weikert-Caneyville-Welston-Zanesville soil association. Residual soils are derived from sandstone and limestone bedrock. In addition there are loess-derived soils, mainly on ridges and alluvial soils along the Green and Nolin Rivers. These latter soils belong to the Newark, Morganfield and Robinsonville soil series. Agricultural limitations of these soil associations are indicated in Table 2.

Agricultural practices caused rapid loss of surface soil layers, often revealing local bedrock. T. L. Poulson and W. White (personal communication) commented that the amount of silt in the lower cave passages probably indicates the increased soil runoff during the time the Park lands were privately owned. Throughout the Park in areas which were cleared for farming the "plow layer" remains evident in the soil profile. Sheet erosion is common on upland sites. On one of the more prosperous farms adjacent to the Park boundary, the surface of the cultivated field is approximately 1 m below the level of the soil within the present Park boundary, which was farmed until 35 years ago. Deep gullies, relatively common along abandoned roadways and upland fields within

TABLE 2. Capability groups, subclasses and units of the major soil associations found in Mammoth Cave National Park.

Soil Association	Capability Classification ¹
Morganfield	I 1
Robinsonville	II - s - 1
Newark	II - w - 4
Zanesville	II - e - 10
Wellston	III - e - 1
Caneyville	VI - s - 1
Weikert	VII - s - 1
Ramsey	VII - s - 1

¹Soil capability classification limitations are as follows: Class I few limitations; Class II some limitations that reduce the choice of plants or require moderate conservation practices; Class III severe limitations; Class VI severe limitations that make these soils unsuited for cultivation and limit their use largely to pasture, woodland, or wildlife food cover; Class VII soils have very severe limitations. The letter e shows that the main limitation is risk of erosion; w shows that water in or on the soil interferes with plant growth; s shows that the soil is limited mainly because it is shallow, droughty, or stony (Latham, 1969).

the present Park, further accentuate the serious problem of sheet and gully erosion of these deeply-weathered residual upland soils.

The upland soils include a loess mantle (Latham, 1969) on a sandstone substrate, while the valley soils of the Caneyville series are characteristically shallow, eroded and have limestone outcrops which "commonly cover about 12% of the surface" (Latham, 1969). Soil series which are found in the Park were rated by Latham as slightly acid to strongly acid as depth increases.

The slope soils are placed into a Weikert-Ramsey stony soil series. The Ramsey soil is a fine sandy loam while the Weikert soil is a silt loam. The Park slope soils are high in sand (Figs. 2 to 6) and frequently stony with small cobbles of friable sandstone common.

During the study, field notes concerning the structure of the surface soil were made. In the case of the stable upland soils, including the study sites shown in Figures 2 to 6, a blocky soil structure is apparent. In a review by Morachan (1966) it was suggested that the "process of soil drying by roots may be enough to bring the clay aggregates together sufficiently close so as to form a domain." Buckman and Brady (1960) discuss the progressive development of soil structure from an aggregate of soil material including clay minerals to a blocklike structure. This blocky structure is characteristic of heavy subsoils, particularly of moist regions (Buckman and Brady, 1960).

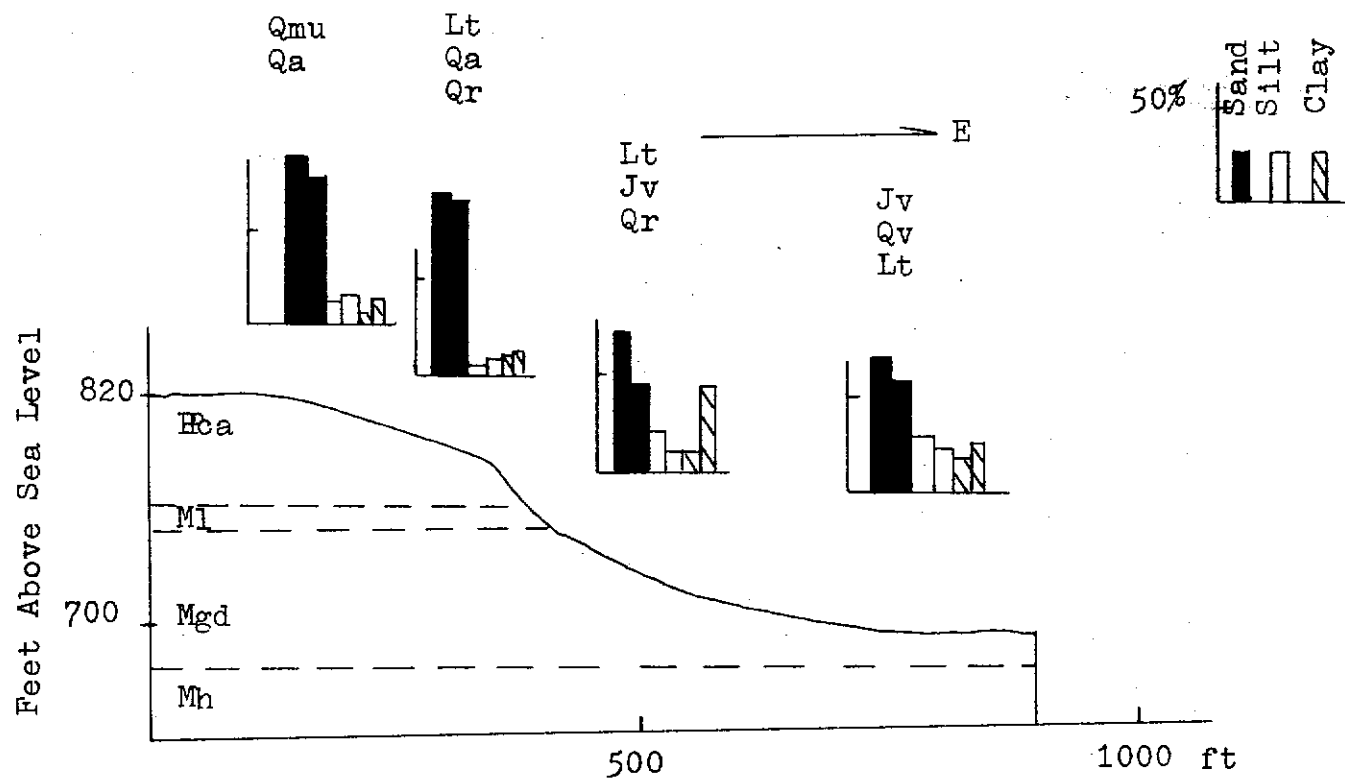


FIGURE 2. Soil texture relationships of soil profiles at Crumps Knob as related to topographic position. The first bar of each pair represents the surface sample, the second bar 30 cm below the surface. The dominant tree species at each sample location are indicated by symbols. Species symbols are listed in Table 1H. Stratigraphy symbols are found in Table 1. Vertical exaggeration is 2X.

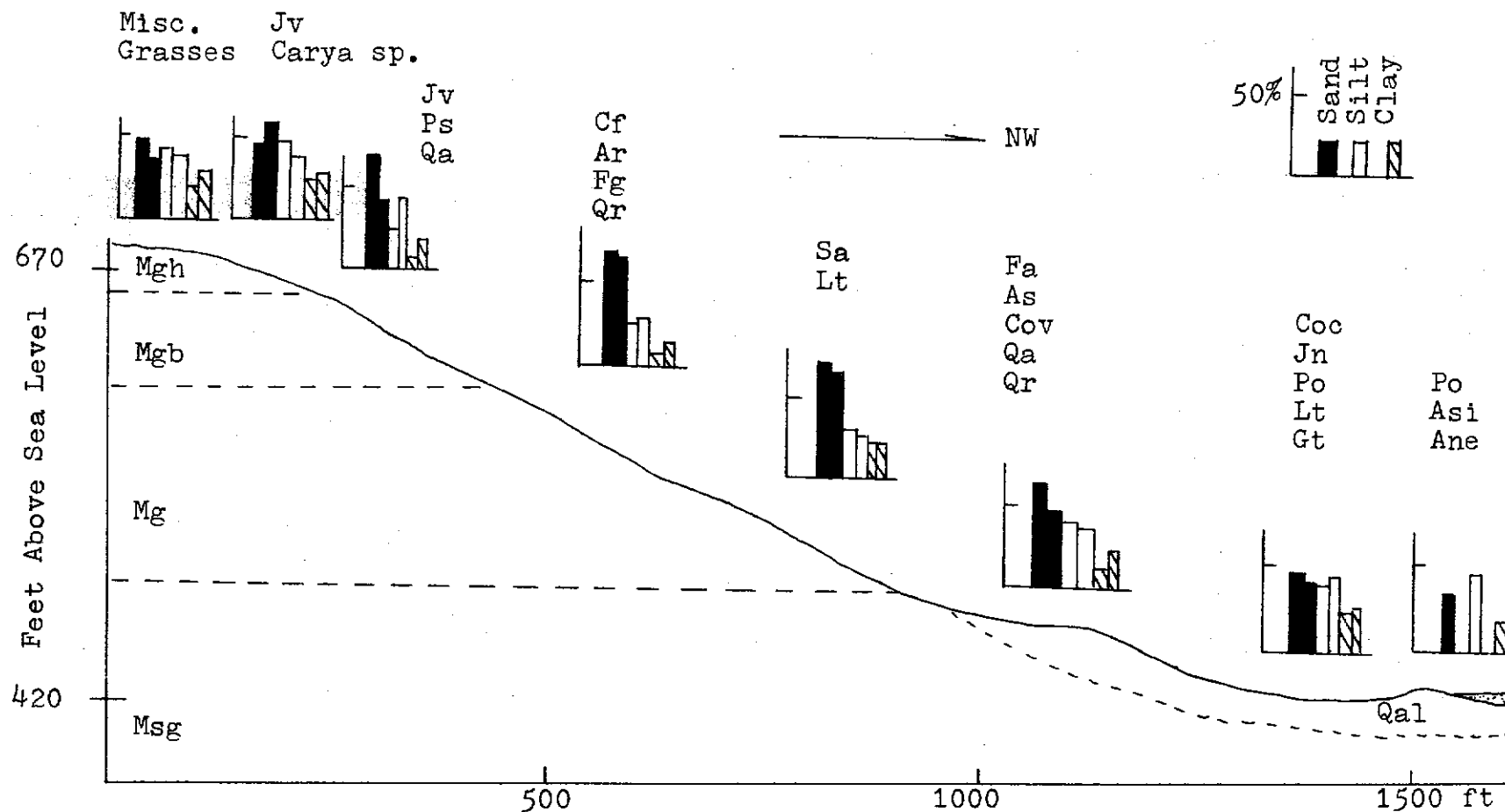


FIGURE 3. Soil texture relationships of soil profiles south of the Green River near the Great Onyx Hotel site as related to topographic position. The first bar of each pair represents the surface sample, the second bar 30 cm below the surface. The dominant tree species at each sample location are indicated by symbols. Species symbols are listed in Table 1H. Stratigraphy symbols are found in Table 1. Vertical exaggeration is 2X.

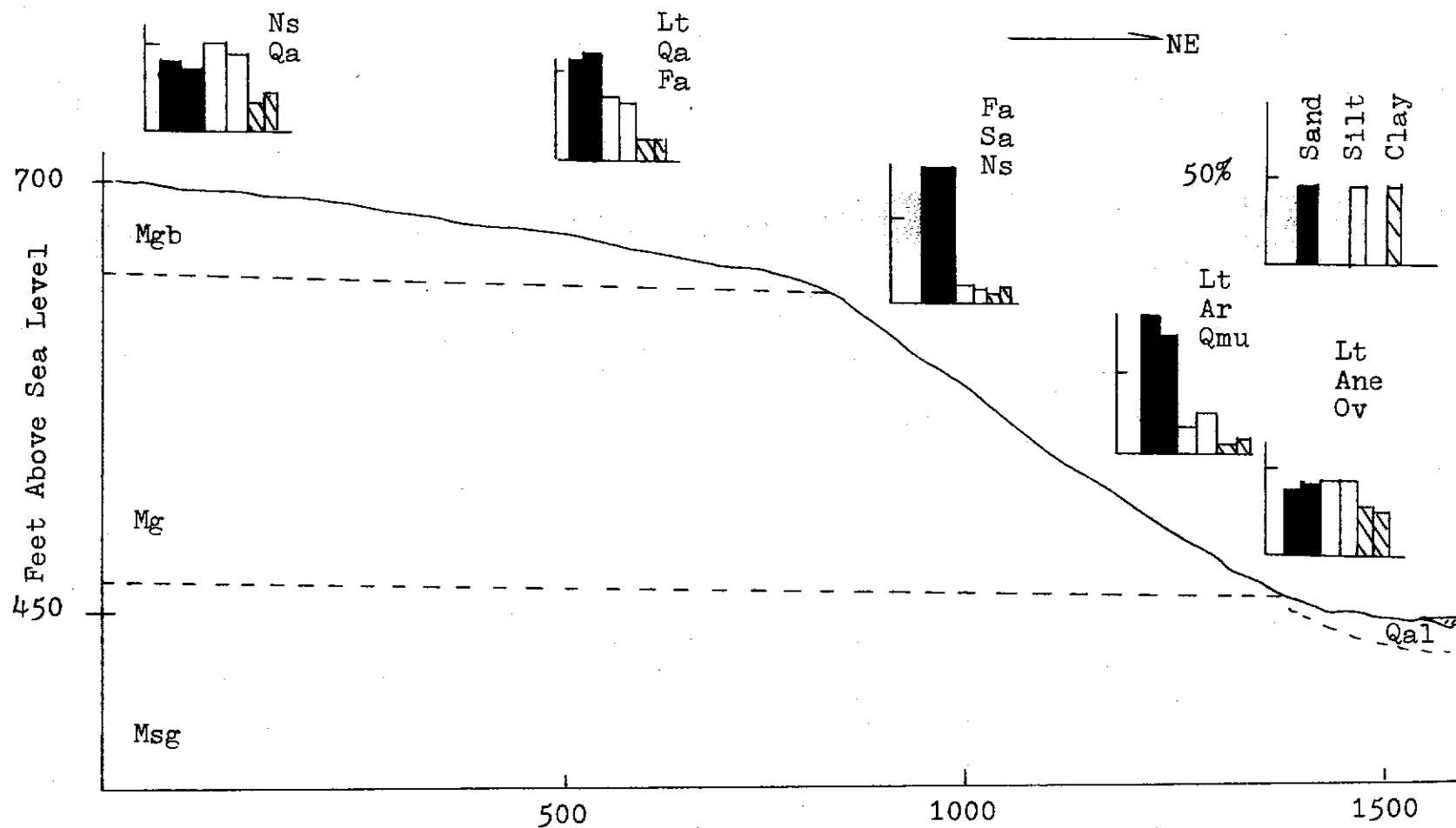


FIGURE 4. Soil texture relationships of soil profiles south of the Green River at Turnhole Bend as related to topographic position. The first bar of each pair represents the surface sample, the second bar 30 cm below the surface. The dominant tree species at each sample location are indicated by symbols. Species symbols are listed in Table 1H. Stratigraphy symbols are found in Table 1. Vertical exaggeration is 2X.

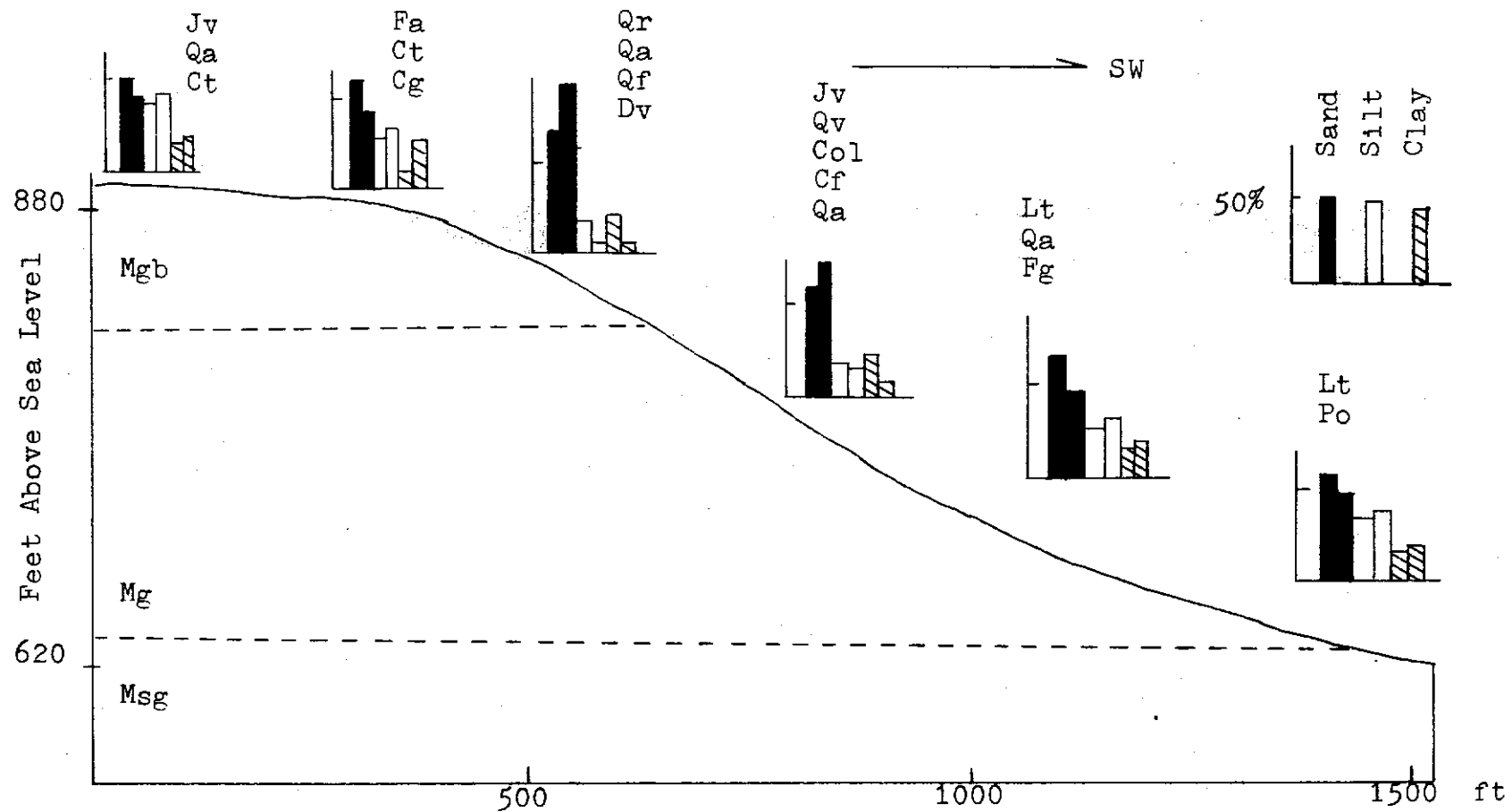


FIGURE 5. Soil texture relationships of soil profiles on slope to Doyel Valley from Mammoth Cave Ridge as related to topographic position. The first bar of each pair represents the surface sample, the second bar is 30 cm below the surface. The dominant tree species at each sample location are indicated by symbols. Species symbols are listed in Table 1H. Stratigraphy symbols are found in Table 1. Vertical exaggeration is 2X.

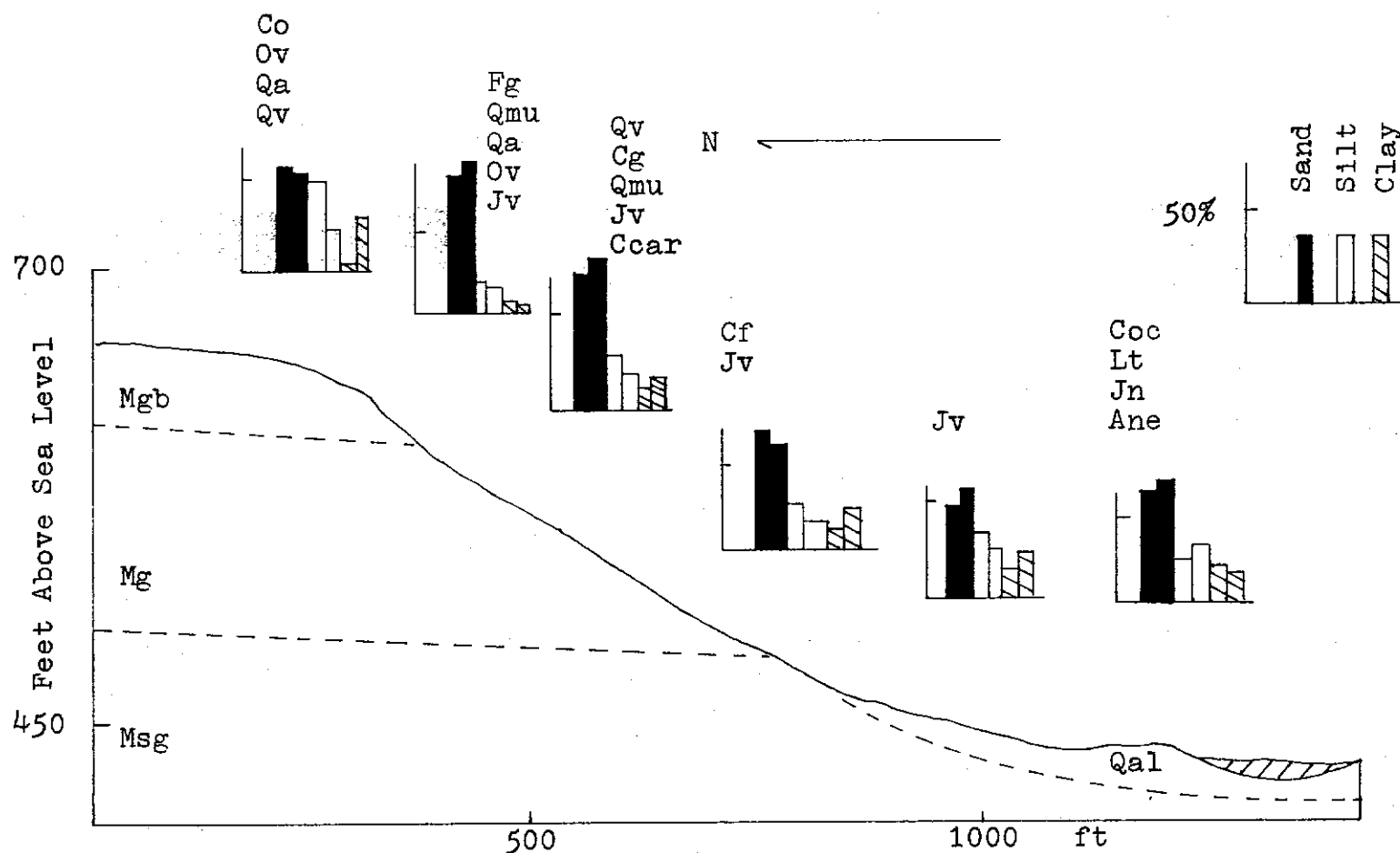


FIGURE 6. Soil texture relationships of soil profiles north of the Green River at Turnhole Bend as related to topographic position. The first bar of each pair represents the surface sample, the second bar 30 cm below the surface. The dominant tree species at each sample location are indicated by symbols. Species symbols are listed in Table 1H. Stratigraphy symbols are found in Table 1. Vertical exaggeration is 2X.

No time scale is offered for this effect to be evident in field soil analysis, but it is of interest to recognize in the Park the appearance of blocky soil structure in the plow layer of the more stable soils which have had a vegetation cover since abandonment 30 to 35 years ago. On the less stable soils, (slopes and floodplains) structure is not evident and would not be expected, because of the deteriorative effects due to gravity, or deposition from flooding.

Little organic matter is incorporated within the upper layers of the soil profiles due to rapid oxidation in the moist, humid climate. In the forest soils, the A₀ horizons are characteristically less than 5 cm deep.

Litter depth, following winter compaction, is generally 1 to 3 cm with a gradual decrease during the summer. At the peak of leaf fall during late September and October litter depth on forested uplands approaches 10 cm. Floodplain litter is nearly absent since large volumes of leaves are blown into the Green River and overflow removes the remainder.

Soil colors range from red-yellow podzolic soils on well-drained level sites underlain with limestone bedrock to black-brown alluvial soils on the floodplain. These soils are included in the following orders of the new classification: alfisols (red-yellow podzolic soils), ultisols (red-yellow podzolic soils), entisols (alluvial soils), and inceptisols (lithosols) (Latham, 1969).

Climate

Climatic records have been maintained at the Park since 1935. The Köppen classification is Cfa indicating mild winters, hot summers and evenly distributed rainfall. Storms generally move along a southwest-northeast frontal path and contain moisture from the west Gulf coast. Some rain, particularly during the May to September period, is due to local thundershowers.

Average monthly temperatures range from a low of 34.7°F in January to 75.5°F in July. The average annual precipitation is 51.3 inches (see Tables 3 and 4 for additional climatic data).

Precipitation is evenly distributed throughout the year. September and October are the driest months while June is the wettest of the summer visitor season. January is the wettest month of the year (Fig. 7).

The average annual snowfall is about 10 inches, with the highest monthly average occurring during March. Persistence of snow cover is limited, with most snows melting within 2 weeks following a storm.

The maximum flood height recorded in the Park occurred in 1962 and exceeded 50 feet. With the recent construction of dams on the Green and Nolin Rivers, such flood levels should not occur again. A crest of 28 feet was recorded during the spring of 1970. Figures 8 and 9 illustrate the effect of precipitation on the level of the Green River during January and June, respectively. The

TABLE 3. Monthly precipitation, range and probability of occurrence.
(inches)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10% ¹	1.7	1.7	2.0	2.3	1.6	2.2	2.1	1.3	0.7	0.6	1.9	1.5
20%	1.9	2.2	3.5	3.0	2.1	2.6	2.7	1.1	1.3	1.4	2.5	1.9
30%	3.4	2.4	5.0	3.6	2.9	3.1	3.2	2.9	2.3	1.6	2.9	2.8
40%	4.0	3.2	5.8	4.0	3.3	3.7	3.7	3.6	2.9	2.1	3.4	3.4
50%	4.4	4.1	5.9	4.3	3.6	4.5	3.7	4.0	3.1	2.5	3.7	3.8
60%	5.9	4.6	6.4	4.6	3.8	4.8	4.8	4.3	3.5	2.8	3.9	4.4
70%	6.9	6.2	7.2	5.2	5.3	6.0	5.7	4.8	4.9	3.5	4.5	5.1
80%	7.8	7.0	7.7	6.2	6.2	7.4	6.7	5.6	5.3	4.0	5.7	6.1
90%	10.7	9.5	8.6	6.6	7.3	8.5	7.9	7.7	6.1	4.4	8.8	7.3
Max ²	20.0	10.3	11.4	6.9	10.5	9.1	10.2	9.3	7.1	6.1	13.1	10.7
Min	0.9	0.1	1.4	1.1	1.3	0.6	0.8	0.8	0.1	T	1.1	0.7
Maximum observed 71.3 inches (1950) ³												
Minimum observed 31.8 inches (1963) ³												
Average 51.3 inches ³												

¹Probability of this amount of precipitation or less each month.

²Range for each month.

³Based on 34-year record, 1935-1968.

TABLE 4. Monthly average temperature, range and probability of occurrence.
(degrees Fahrenheit)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10% ¹	28.3	30.4	39.0	53.1	60.5	68.6	71.1	70.0	65.1	53.1	40.3	30.4
20%	29.8	31.8	41.7	53.8	61.6	70.1	71.4	72.5	66.0	54.3	42.2	32.0
30%	32.9	34.3	43.7	54.5	62.9	71.4	74.4	73.9	67.1	56.0	43.9	34.5
40%	34.6	37.4	45.2	55.9	64.2	71.9	75.3	74.6	67.8	57.7	44.7	36.7
50%	35.0	38.1	46.2	57.3	64.9	72.0	75.8	75.0	68.0	58.3	45.9	37.3
60%	35.9	38.7	47.5	57.9	66.1	72.5	76.0	75.7	68.6	58.6	47.0	38.9
70%	37.4	40.6	48.6	59.0	67.2	73.6	77.0	75.9	70.0	59.2	47.7	40.7
80%	38.0	43.1	51.8	60.3	68.4	74.3	78.3	77.4	72.4	61.2	48.3	41.5
90%	42.0	44.0	53.9	62.0	68.9	76.7	79.1	77.9	73.3	62.3	49.3	42.8
Average ²	34.7	37.8	46.7	57.2	65.2	72.4	75.5	74.9	68.8	58.1	45.7	37.5
Max ³	46.4	46.9	56.2	62.8	72.2	80.3	80.4	80.3	75.3	64.6	50.3	47.9
Min ³	18.0	26.7	32.9	51.3	59.5	66.9	70.1	68.6	64.0	51.3	40.1	26.3

¹Probability of this average temperature or lower each month.

²Based on a 34-year record, 1935-1968.

³Range of each month.

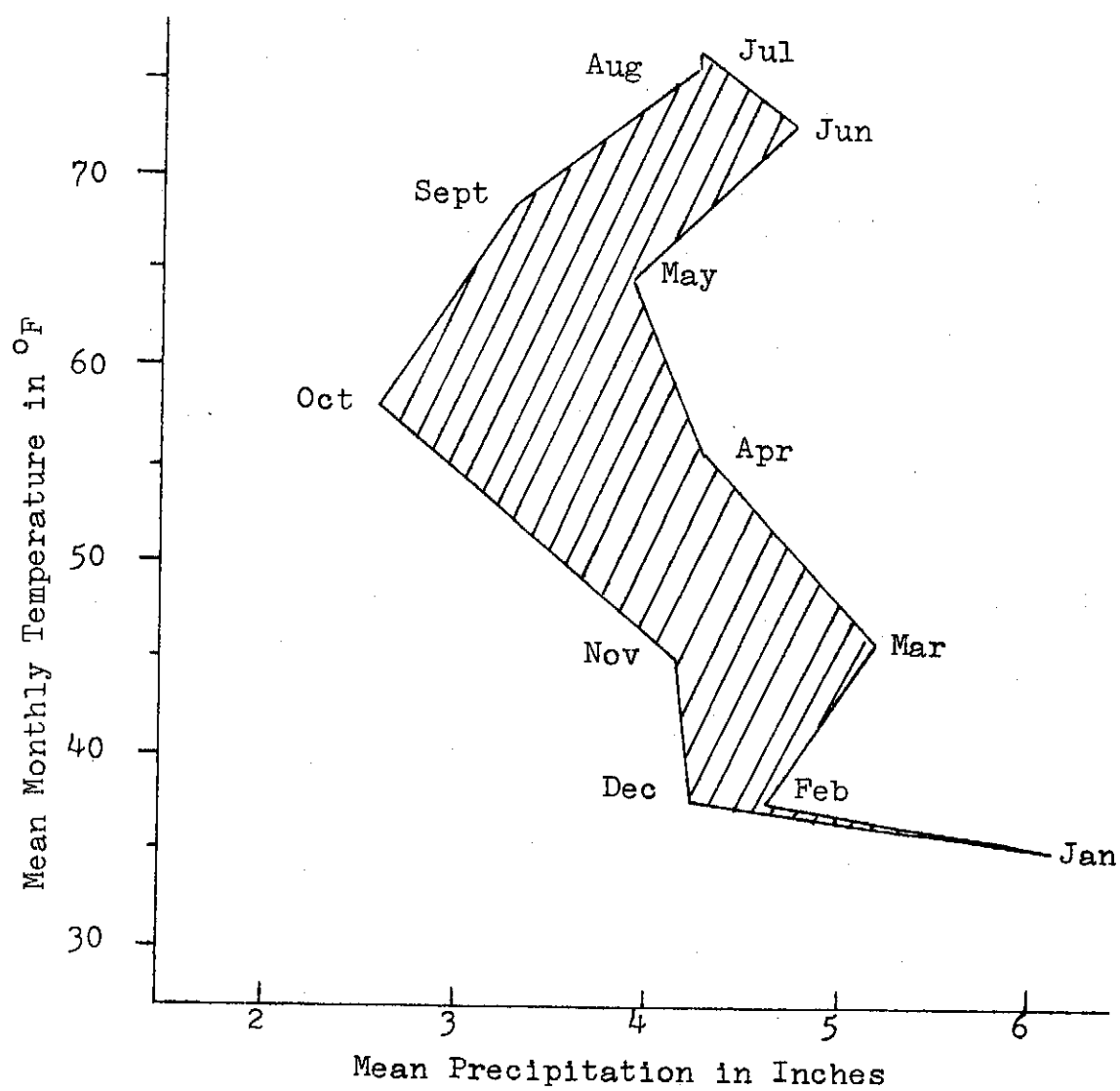


FIGURE 7. Climatograph for Mammoth Cave National Park.

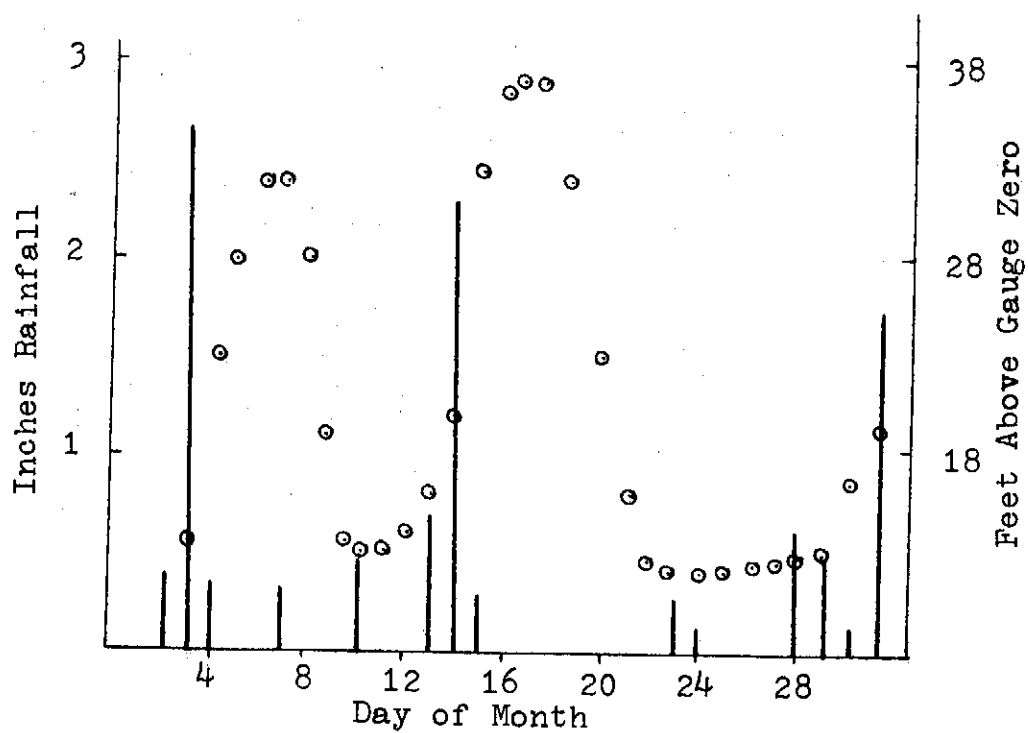


FIGURE 8. Precipitation record for January 1951 and its effect on the level of Green River at Brownsville, Kentucky.

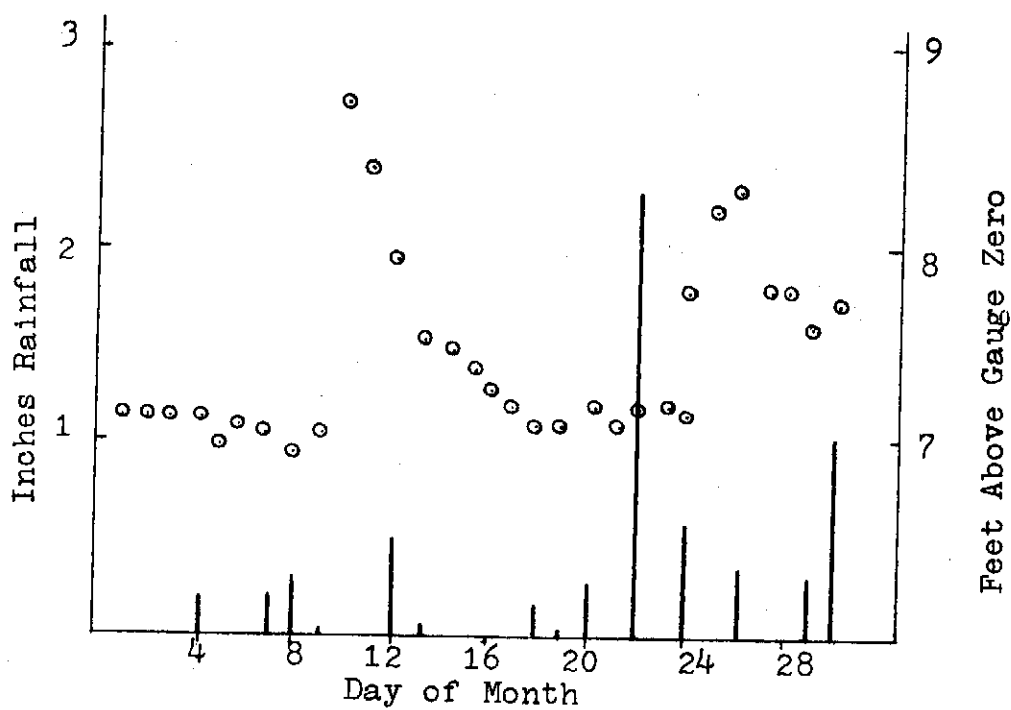


FIGURE 9. Precipitation record for June 1951 and its effect on the level of Green River at Brownsville, Kentucky.

river level axis is increased ten-fold in the two figures. The retarding effect of vegetation on water runoff is illustrated by this comparison.

River levels in the Park region (Mumfordsville and Brownsville gauge data) rise and fall quickly when compared with the downstream stations which are located in the Western Coal Field. The peaks in the Park region are directly influenced by surface runoff and when this runoff ceases after a storm the river falls quickly and again is fed by the subsurface drainage characteristic of karst regions. The lag period from rainfall to maximum stream response is about 2 days.

During the regular spring floods fresh alluvium is deposited annually to the 25 to 30-foot contour above gauge zero. Deposits to the 50-foot contour have occurred twice since the Park was established (in 1937 and 1962). Flood duration depends on several factors including: the length, areal extent and total rainfall of the storm; the degree of soil saturation; the amount of land which is under cultivation, in forests (degree of canopy closure) or remaining fallow. Thus any specific times for flood duration are of limited value, although in a general way it can be stated that flooding effects during the winter and early spring on the floodplain physiographic unit are longer (up to 2 weeks) and more severe than during the summer. These annual winter and early spring floods limit invasion by perennial forbs into the floodplain community,

which instead is made up of annuals that reach maturity in mid to late summer (July-August).

Land Use

Land use within the Park boundaries before administration by the National Park Service was in the form of small subsistence farms with all the level land on the floodplain, in the solution valleys and on the upland farmed in corn, hay and tobacco, while most forested slopes were pastured by cattle and hogs. In addition, these forests were, for the most part, selectively cut. Row crops were important in the alluvial soils of the Morganfield, Newark and Dickson Associations, while the upland soils in the Zanesville series were frequently in hay, pasture or small grains. In the solution valleys, row crops were planted, but to a larger extent cover crops such as hay and pasture were more common. The important crops of the region today (Table 5) are corn, sorghum (grain and silage), wheat, hay, tobacco and pasture. The slope soils in the Weikert and Ramsey Associations remained forested in pre-Park days although they were pastured by cattle and hogs. Tobacco was an important cash crop with the location of the tobacco patch shifted every 2 to 3 years as the soil "gave out" from intensive cultivation. Today tobacco is the third most important cultivated crop by total acres tilled of those listed in the current Census of Agriculture (Bureau of Census 1972) in the three counties comprising

TABLE 5. Current land use on farms in Barren, Edmonson and Hart Counties, Kentucky.¹

Crop	County		
	Barren	Edmonson	Hart
Corn			
Grain	16,498	3,574	8,533
Silage	3,649	298	1,912
Sorghums			
Grain	21	20	16
Silage	343	25	78
Wheat	1,066	78	217
Other small grains	1,426	--	241
Hay	30,912	8,326	19,530
Tobacco	4,033	666	2,844
Woodland			
Pastured	16,343	7,028	15,167
Not pastured	14,386	11,372	22,950
Total	30,729	18,400	38,117
Acres farmed in county	277,524	104,269	218,649
Average farm size (acres)	89.7	109.6	108.1
Percentage of county in farms	92.7	54.7	81.3

¹Data are from the Bureau of Census, 1972.

the MCNP region.

Fire was used by the early farmers to control weeds and reduce stubble from the land. Today, soil scientists recommend low tillage and incorporation of organic matter into the soil. However, the farming practices of 35 or more years ago did not recognize the importance of returning plant residues to the soil after the crop was harvested.

Farms which were purchased for inclusion within the National Park ranged from 150 acres to less than 10 acres. Today farms north of the Park boundary in the Western Coal Field, in Edmonson and Hart Counties, average approximately 109 acres. South of the Park in Barren County the average farm size is 87.1 acres. More than 75% of the farms are less than 150 acres in size in these 3 counties. Many local farm owners presently work in the Park or the surrounding communities and operate their small farms during their free time in the evening and on days off. Small herds of cattle and tobacco represent the major cash crops of the region.

Vegetation

The forest of MCNP is part of the Western Mesophytic Forest Region of Braun (1950) which is a transition region made up of many mosaics representing elements from the Mixed Mesophytic Forest Region and the Oak-Hickory Forest Region. Braun described the vegetation of Mammoth Cave (p. 147-150) as Mixed Mesophytic Forest on the mesic

slopes, and a prevailing upland community of oak-tuliptree and beech forest on the ravine flats.

According to Braun (1950), the mixed mesophytic forests of MCNP occur on:

. . . ravine slopes where beech forms 44%, tuliptree and sugar maple 26% of a forest with fifteen canopy species; . . . on the upland a white oak-black oak-tuliptree type in which the three dominants comprise 72% of the canopy. In this last area, three species of hickory taken together are only about half as abundant as was chestnut [Castanea dentata (Marsh.) Borkh.] .

Braun also pointed out that a more luxuriant aspect of the mixed forest occurs on the limestone soils of slopes of the Green River where a damp mull humus favors a herbaceous layer. On some of these slopes beech and maple are dominant, collectively comprising over 50% of the canopy. She further commented that there is an increase in the oaks and hickories on the higher slopes and a decrease in the continuity of the herbaceous layer.

Braun (1950) commented that:

Not all upland communities of the Mammoth Cave region belong to the oak-tuliptree type, although this seems to have been the prevailing type on the better soil areas. Some communities are more xeric. On flatter uplands with poor soil, post oak (Quercus stellata), together with southern red oak (Q. falcata), black oak (Q. velutina), and blackjack oak (Q. marilandica), characterize a forest community whose relationships are with the Ozark upland.

Except for Braun's discussion of the ravine forests she did

not mention the floodplain as a forest association in MCNP.

Ellsworth (1934) placed the floodplain community into a river birch-sycamore type of the American Forestry Association. Ellsworth's description of the type included the following information:

. . . sycamore [Platanus occidentalis L.] frequently reaches a height of 100 feet and a diameter of 6 feet. Common associates are slippery elm, blue beech [Carpinus caroliniana] Walt. , black willow Salix nigra Marsh. , hackberry Celtis occidentalis L. , box-elder Acer negundo L. , and cottonwood. In addition to the presence of this type in the deep alluvial soil of the Green River bottomlands, it is also common in very limited stands in the bottoms of valley sinks where the drainage is poor. In some instances sycamore and black willow growing in sinks, have been covered to a depth of 3 or 4 feet by soil washing in from adjacent hillsides.

He stated that the total area of this type is approximately 500 acres in MCNP.

The hemlock-tuliptree-beech segregate of the Mixed Mesophytic Forest Region was not studied by Braun (1950) in MCNP. Ellsworth (1934) notes the occurrence of hemlock (Tsuga canadensis (L.) Carr.) as Type 11 of the American Society of Forester's Forest Types. He states that this type occurs in several very small areas, the largest being about 4 acres.

It grows in moist cool glades in an almost pure state with occasional yellow poplar [tuliptree], holly, and umbrella magnolia. It prefers north slopes; on such situations it reaches its best development. Some of the trees found were about 12 inches in diameter. Mountain laurel Kalmia latifolia L. and

burning bush Euonymus atropurpureus Jacq. are plentiful in this type. Total area 10 acres.

Braun (1950) described climatic conditions at the close of the Tertiary as generally dryer over the "whole interior of the continent" She then suggested

A physiographic pattern, and a pattern of forest distribution similar to that of the present had been attained by the close of the Tertiary in the area which is now unglaciated eastern America.

The dominant types in the oak-hickory forest region were, therefore, the oak associations according to her analysis.

The degree of periglacial climatic effects has been debated for several years (Flint, 1971), but the current literature indicates that the influence of the ice sheet on vegetation communities extended only a relatively short distance from the ice margin. Since MCNP is located approximately 175 air miles south of the Wisconsin ice margin the periglacial climatic effects of that advance were minimal. Braun (1950) cited as indirect evidence of this that all indications of Pleistocene infiltration of northern species are gone so that the climatic effects could not have been very pronounced.

Within the Park, the forest stands reflect the diversified mosaic that is expected in the Western Mesophytic Forest Region. The existence of stands dominated by species characteristic of other forest regions, e.g. Beech-Maple, Oak-Chestnut along sandstone

outcrops on the upper slopes, or an attenuated Mixed Mesophytic Forest (white basswood (Tilia heterophylla Vent.) absent and buckeye (Aesculus octandra Marsh.) uncommon) reveal the effect of physiographic limits on the distribution of the characteristic dominants of this forest region.

METHODS

Forest Community Analysis

Aerial Photograph Mapping

The forest communities were delineated initially on 1:20,000 panchromatic aerial photographs which were flown in October 1966. These were used to prepare generalized vegetation maps of MCNP. The scale selected for the present series of maps is 1:24,000 using standard topographic maps as the base. Individual mapping units were then established on 1:20,000 Agriculture Stabilization and Conservation Service (ASCS) photographs, and transferred to a photographically-reduced, uncontrolled mosaic. Acetate overlays were prepared on standard topographic quadrangles by tracing selected cultural and topographic data for positional control. Such overlays were then placed on the photographs of the Park and the vegetation mapping units traced from the photographs to the overlays.

Limited information on cultural history can be identified from the photographs. Fencelines, eroded upland pastures, and some abandoned roads are obvious. Soft-textured depressional areas in the solution valleys were found to be the remains of farm ponds, frequently with building foundations nearby. Larger scale photographs are

necessary for reliable data on the size, crown diameter relationships of the eastern red cedar invasion into old fields.

An attempt was made to use floating dot and parallel wedge data from the air photos to determine canopy heights. However, the photos available for the Park were unsuitable for reliable measurements between stereo pairs, so these data were taken by direct measurement in the field.

A key to forest associations and their subtypes was prepared. The importance of physiography in determining limits of mapping units on air photos is emphasized in this table. The vegetation of this region is associated with landforms characteristic of Mammoth Cave Plateau, Western Coalfield interface so that it can be routinely identified on the airphotos. Training photos for this key include: 1) upland plateaus versus valleys and bottoms ALG-4GG-110,111; 2) for forest association separation in valleys and bottoms photos 4GG-112,113; 3) for sinks and solution valleys south of the Green River ALM-5GG-109,110 (this stereo pair includes Hunts Sink as well as slopes into Doyel Valley and the permanent plot sites on Mammoth Cave Ridge); 4) for areas north of the Green River ALM-5GG-55,56.

Forest Analysis

Forest composition data were taken by two standard methods. The primary method which was used was the

variable-radius plotless method described by Shanks (1954). The principles for using this method were established by Bitterlich in 1948 and introduced by Grosenbaugh to this country in 1952 according to Shanks (1954). (This method is referred to as the Bitterlich method of forest sampling.) The original purpose of the Bitterlich method was to rapidly determine basal area of a forest stand. Lindsey, Barton, and Miles (1958) concluded that this plotless method is preferred for basal area.

In practice this method is simple to apply. A sighting device, which subtends a fixed angle of $104.18'$ (for the 10 square feet per acre factor), is used. (The derivation of the visual angle is discussed in Appendix A.) This device determines if the tree being tallied is proportional to its diameter as related to the distance from the sighting point. The viewing angle determines the basal area multiplier factor. The multiplier factor is used to determine the basal area per unit area at each sample point. A tree is acceptable if it is within a distance which is equal to or less than 33 times its diameter for the 10-factor. Thus each tree accepted equals 10 ft^2 of basal area per acre when the 10-factor is used. If a factor of 5 is used, 20 trees must be tallied to yield a basal area of 100 ft^2 per acre, since trees are accepted only if they occur within a distance equal or less than 66 times their diameter. For example 5 white oaks tallied would yield 25 ft^2 per acre for this species.

A Relaskop was used for the sighting device. This instrument automatically corrects for slope angle, an important consideration at Mammoth Cave since the majority of the forest samples were taken on slopes of valleys where the forest was not completely cleared prior to Park establishment. A total of 6,413 trees was sampled at 332 Bitterlich points within the 4 major associations and the hemlock-tuliptree segregate (Table 6).

The 5-factor multiplier was used in this study because of its greater sensitivity to smaller individual trees. The multipliers of larger value, e.g. 10, 20, 40 yield similar information for the basal area of the stand, but do this by sampling fewer large trees.

Density per acre and basal area per acre of the individual tree species can be obtained using the Bitterlich method (Appendix A). Relative density and relative basal area (per cent values) were calculated and then averaged to obtain an integrated percentage importance value, which indicates the relative contribution of each species to the stand.

Frequency in plot sampling is a measure of distribution of the component species within the community. The variable-radius Bitterlich sampling method does not measure the same distribution factor since the occurrence of a species at a point is partly dependent on the size of the tree (Shanks, 1954, Rice and Penfound, 1955). In addition, the size of the area sampled at each

TABLE 6. Classification of stands, by association, with number of species, trees, and sampling points. P indicates plot sampling, F indicates full tally. First number = number of species, second number = number of sample points, third number = number of trees.

Stand Name	Association				
	Mixed Woods	Floodplain	Upland	Old Field	Hemlock Segregate
Big Hollow	27-20-392				
Big Woods, Ravine	17-P				
Big Woods, Slope	23-P				
Big Woods, Upland			17-P		
Boardcut Island		9-10-196			
Cedar Sink, Slopes	26-21-430				
Cedar Sink, Valley				12-P	
Chicken Prong Hollow	21-19-348				
Crumps Knob	20-15-355				
Deer Park Hollow	19-P				
Doyel Valley Slopes	21-20-373				
First Creek Drainages					26-16-290
Good Spring Church			19-9-212		
Houchin Ferry		12-10-224			
Great Onyx			17-5-108		
Hickory Cabin and Brooks Knob				13-15-219	
Hunts Sink S.	26-F				
Hunts Sink N. (upper)	13-P				
Hunts Sink N. (lower)	15-P				
Hunts Sink N. (S. slope)	11-P				
Indian Hill Chestnut	17-9-209				
Indian Hill	17-8-140				
Joppa Ridge				11-15-123	

TABLE 6. (continued).

Stand Name	Association				
	Mixed Woods	Floodplain	Upland	Old Field	Hemlock Segregate
Joppa Ridge and Mammoth Ridge			17-15-265		
Lee Ridge			18-15-247		
Mammoth Cave Ridge				10-20-147	
Mammoth Ferry		16-P-188			
New Ferry		5-P-130			
New Ferry Side Valley	17-5-124				
Permanent Plots 1-7				7-P	
Sand Cave Island		5-5-98			
Salts Sink	11-F				
Salts Sink W.	11-P				
Sloans Crossing N.	23-20-452				
Sloans Crossing S.			17-12-212		
Smith Valley			25-20-358		
Turnhole Bend	17-5-77				
Wet Prong	14-8-156				
Wilson Cave Hollow	21-15-340				
Totals					
Stands Sampled	20	4	6	12	1
Trees Sampled	3396	836	1402	489	290
Bitterlich points	165	25	76	50	16
Plots or Full Tallies	9	2	1	8	

point varies when the Bitterlich method is used, so that a frequency determination would depend upon differences in the area sampled at each point. The frequency values obtained from Bitterlich sampling data represent vegetational contribution of a species rather than its dispersion in an area. Since density and basal area are combined to give the importance value, Bitterlich frequency values were not included in the reported data (see Jackson and Petty, 1971 for a discussion of various phytosociological measures).

Density per acre is calculated from Bitterlich data by summing the products of a constant (Table 1A) times the number of trees tallied in each size class as estimated to within a 4-inch size class increment.

Vegetation other than trees was sampled qualitatively by using the Stratum Rank method developed by Lindsey et al. (1961) for rapid evaluation, in the field, of the contribution of each species to the total plant community. Species within each synusium or stratum are assigned a numerical value within the range of 1 thru 9 as based on the density-cover relationships of the species in question. Table 7 gives the criterion for each rank of this method. An advantage of this method is that a worker can quickly collect data for many species within several strata at each sampling location.

The value of Stratum Rank 1 was used according to the criteria advanced by Lindsey et al. (1961), but since my

TABLE 7. Stratum rank method of vegetation analysis based on a species relative contribution to density and cover within a given stratum within the community (from Lindsey et al. 1961).

Stratum Rank Number	Descriptive Criteria
1	A species of which a single individual was observed in the stand.
2	Two to several individuals, but both very infrequent numerically and having quite inconsequential cover.
3	Three to several individuals furnishing substantial cover.
4	Subordinate species, not dominant or subdominant by contributing significance to both numbers and cover.
5	Third or fourth subdominant species in a stand of two clear dominants, and only if species subordinate to them all have rather low stratum rank.
6	In a stand having only two dominants, but the one having a marked lesser number and importance is classed as Stratum Rank 6.
7	A stand having only two species sharing clear dominance (e.g., beech and maple).
8	A species so outstanding as to be called the sole dominant of its stand (never given to more than one species in a stand).
9	A sole dominant species in which no other single species exceeds Stratum Rank 2.

sample points for a given stand frequently covered a large area (often extending over 2 miles of linear distance) a rare species might be encountered a second time. Thus a rare species was often seen more than once in a stand, but Stratum Rank 1 remains the most appropriate to assign to it.

Cover classes were divided into seven classifications: 1) one specimen; 2) sparse; 3) less than 10%; 4) 10-25%; 5) 25-50%; 6) 50-75%; 7) more than 75%. These cover classes were used to characterize the canopy, sapling, shrub and seedling strata. Ground cover estimates may exceed 100% in forest stands because of the layering characteristic of the deciduous forest. Separation between the tall shrub and low tree transgressives was made on the basis of species and the height (ca. 15 feet) of the individual.

Rectangular plot sampling (Bormann, 1953) was used in a few cases where special interest in a particular stand justified more intensive analysis. Criteria for such decisions included: 1) very limited disturbance as indicated from Park records; 2) on-site observation of high diversity; 3) unusually large diameter trees; or 4) as a comparison for Bitterlich data. Plot sampling was done in Big Woods, along the floodplain of the Green River, a side valley of Doyel Valley, and old fields in Cedar Sink Valley using 0.2 acre plots 200 feet by 43.6 feet (Lindsey, 1955). Hunts Sink and Salts Sink were full tallied (Lindsey, Barton, and Miles, 1958).

Old Field Communities

In addition to general surveys of old field communities using the Bitterlich method, nine 0.1-acre permanent rectangular plots (100 x 43.6 ft) were tallied, and the position of each tree was mapped. The dbh or height above the ground is indicated on Plates 1-9. These locations were marked by 6-foot metal fence posts which serve as reference points for the centerline of each 100-foot plot. Each post was labeled with a metal tag giving the date of placement, number of the plot and my name. Further details of location are given in Appendix B.

The line intercept method was used for sampling herbaceous plants in the permanent plots. In this method, a steel tape was dropped along a line within the 0.1-acre plot and the species present were tallied if they touched the tape. The length of the species intercept was also recorded. The distance of crown intercept of woody species above the tape was also tallied. The 100-foot distance between the posts and 4 randomly selected 25-foot distances were sampled, within each plot.

Additional observations taken were topographic position, surface soil texture, and probable past land use history. Topographic position was classified according to the following: alluvial terrace (high, low, near creek), ravine, draw, lower slope, mid-slope, upper slope, ridge, summit, seep, sink, or perched water table. The elevation of the sample points was taken from the appropriate

topographic quadrangle. The slope percentages were measured with the Relaskop. Parent material was determined by comparison with the USGS quadrangles. Probable land use history was classified as fire, agriculture, or logged (selective or clear cut).

Synthetic Analysis

Three diversity indices were calculated for each stand. The Shannon-Weiner index, derived from information theory, (Pielou, 1969) is a measure of the information contained per unit whose occurrence has a probability of $P_1, P_2, \dots, P_S$. Pielou comments that this index measures the degree of uncertainty of a particular individual belonging to a specific species in a many-species population. Simpson (1949) proposed an index which measures the degree of diversity when sampling is done from an infinite population of individuals classified into a finite number of groups. This index (1) has been termed Simpson's Diversity Index.

$$\frac{\sum n_i (n_i - 1)}{N (N - 1)} \quad (1)$$

Where:

n_i = individual value for each species

N = total value for all species

$\sum n = N$.

Values range from 0 to 1 with populations showing high diversity approaching zero.

The McIntosh diversity index (2) has elements of both

the information theory and the Simpson Index.

$$\frac{N - \sqrt{n_1^2}}{N - \sqrt{N}} \quad (2)$$

Where:

n_1 = individual value for each species

N = total value for all species

This index expresses observed diversity as a proportion of the maximum possible diversity (McIntosh, 1972).

A comparison of species in common between stands was made using the following index (Curtis, 1959).

$$\text{Coefficient of Similarity} = \frac{2w}{a + b} \quad (3)$$

Where:

a = sum for all values in one stand

b = sum for all values in another stand

w = sum for the lower value for each measure.

Values can range from zero for two stands that have no species in common to 1.00 for two identical stands. There were 45 tree species and 39 stands compared in these calculations.

Climate

Limited climatic data were taken, using three maximum-minimum thermometer stations at each of two locations. Valley station data were taken in a tributary valley of Doyel Valley while sink data were taken in Hunts Sink. At each station 6 Taylor maximum-minimum thermometers were placed in shelter boxes 12 inches and 60 inches above

ground level. Two stations were established on opposite facing slopes at the lowest point in each location.

TABLE 8. Location and site description of the maximum-minimum thermometer stations. Symbols follow Table 1H.

Location	Symbol	Geology	Slope Facing	Dominant Cover
Sink - 1	S - 1	Big Clifty Girkin contact	SE	Qa, Qr
Sink - 2	S - 2	Alluvium		Lb
Sink - 3	S - 3	Big Clifty	NW	Ar, Cg, Lt
Valley - 1	V - 1	Big Clifty Girkin contact	NW	Qa, Lt
Valley - 2	V - 2	Alluvium		none
Valley - 3	V - 3	Girkin	SW	Jv

Readings were taken throughout the spring and summer of 1968, 1969, and 1970.

Soil temperatures were taken during the spring of 1969 in the employee residence area.

Soils

A series of soils was sampled from the upland to the floodplain at the Great Onyx Environmental Science Study Area (ESSA) site, and north and south of Turnhole Bend. At Crumps Knob and the slopes from Mammoth Cave Ridge to Doyel Valley, soils were sampled along transects from one erosional surface to another. Samples of 100 g each were taken of surface and subsurface soils (35 cm). Soil texture was determined by the Bouyoucos method (Pramer and Schmidt, 1967). One hundred twenty soil samples were collected for

pH measurements. An electric pH meter was used for these measurements. Surface soil examinations were made in the field for texture, character, and the humus layer depth at each of the forest sampling points.

RESULTS

Forty-five tree species (> 4 inches dbh) were encountered in the 44 sampling areas indicated in Table 6. These stands were dominated by 13 different species.

The arrangement of tree species according to communities along moisture and topographic setting is illustrated in Figure 10. Mixed stands occurred throughout the Park on the slopes of the solution valleys and streams associated with the Green River. Most commonly these stands were dominated by northern red oak with additional stands dominated by white oak or American beech. These mixed stands were impressive with frequent large stems reaching heights approaching 100 feet. In Hunts Sink one 48-inch dbh tuliptree measured an incredible 180 feet tall. The canopy closure was generally above 50%. The herbaceous flora was most diverse in these stands with an almost continual floral display from early spring (April) through fall (September).

Associated with the uplands were stands of less diversity than the mixed woods of the slopes. The most important species in the least disturbed stands were again white and red oak although there is less diversity (Table 9). The less important species showed a shift to more xeric species and an increased importance of the genus Carya (hickories). These stands were more open than the mixed

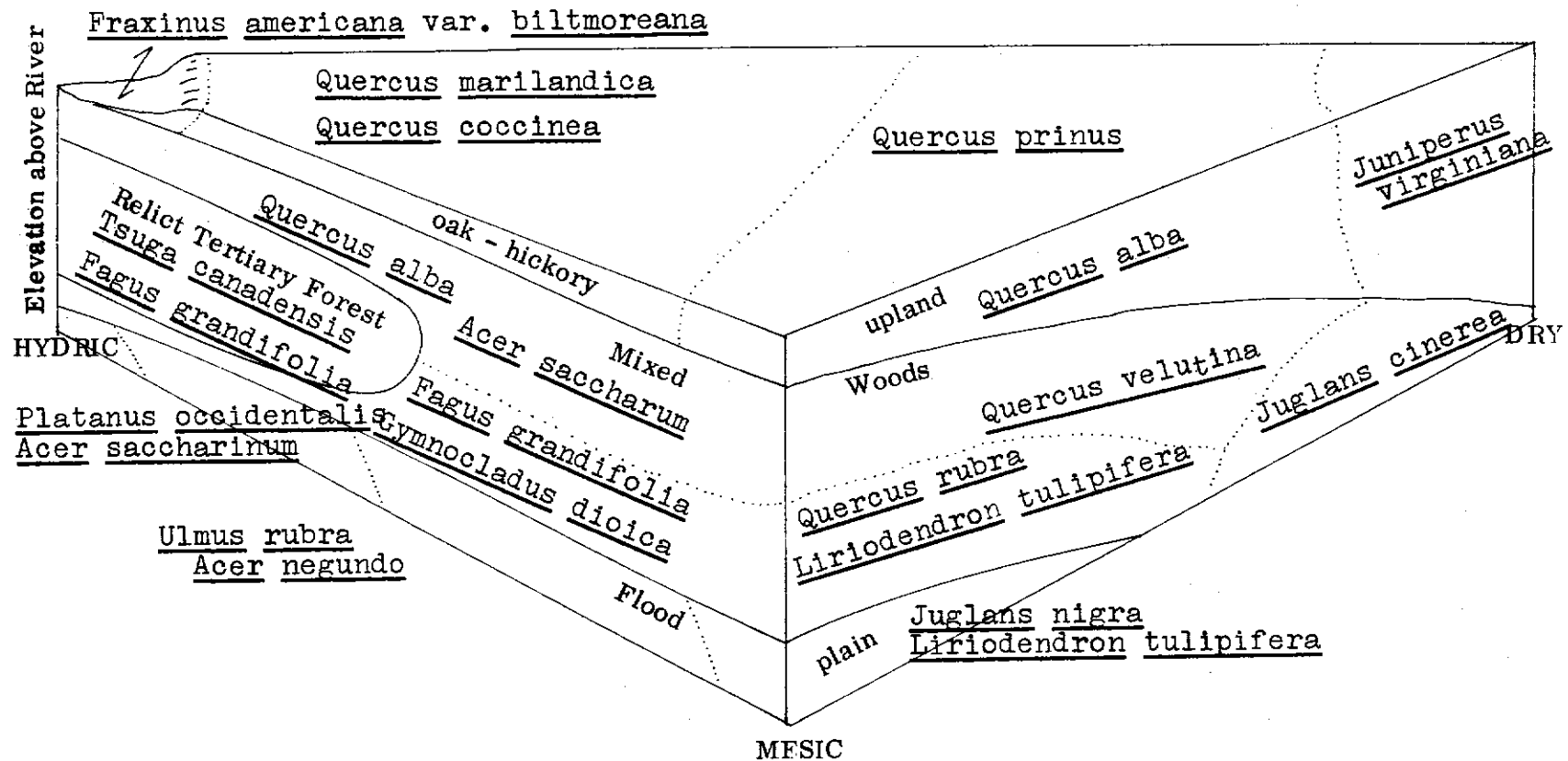


FIGURE 10. The dominant forest trees of Mammoth Cave National Park, Kentucky, arranged according to moisture and elevation gradients.

TABLE 9. Percentage presence in 39 stands, number of stands as leading dominant, mean importance value in stands of occurrence, and maximum importance value of trees over 4 inches dbh in a single stand. The tree species are arranged in order of percent presence.

Species	% Presence	No. Stands		Mean Importance Value		Maximum Importance Value
		As Leading Dominant		All Stands	Where Present	
<i>Liriodendron tulipifera</i>	94.7	3	0.62	8.08	36	
<i>Nyssa sylvatica</i>	78.9	1	0.16	6.14	15	
<i>Cornus florida</i>	78.9	0	0.16	6.33	14	
<i>Carya glabra</i>	78.9	0	0.14	5.35	11	
<i>Quercus alba</i>	76.3	12	5.43	17.66	34	
<i>Quercus rubra</i>	71	3	0.69	9.00	25	
<i>Quercus velutina</i>	71	4	0.87	8.45	25	
<i>Acer rubrum</i>	65.8	0	0.26	10.32	18	
<i>Fraxinus americana</i>	65.8	0	0.07	2.71	8	
<i>Carya tomentosa</i>	63.1	0	0.09	3.56	13	
<i>Carya cordiformis</i>	60.5	0	0.05	1.76	4.4	
<i>Carya ovata</i>	55.3	0	0.05	2.14	4.5	
<i>Sassafras albidum</i>	55.3	0	0.05	1.96	6.7	
<i>Acer saccharum</i>	52.6	0	0.18	6.98	26	
<i>Oxydendrum arboreum</i>	52.6	0	0.12	4.74	19	
<i>Fagus grandifolia</i>	50.0	2	0.37	7.17	28	
<i>Juglans nigra</i>	47.4	0	0.04	1.70	2.5	
<i>Quercus stellata</i>	36.8	0	0.09	3.41	11	
<i>Quercus falcata</i>	34.2	0	0.10	3.83	15	
<i>Quercus muehlenbergii</i>	34.2	0	0.04	1.61	6.5	
<i>Carya ovalis</i>	31.6	0	0.07	2.59	8.3	
<i>Platanus occidentalis</i>	26.3	1	0.31	12.06	40	
<i>Juniperus virginiana</i>	23.7	3	2.21	28.77	78	
<i>Quercus prinus</i>	18.4	2	0.80	15.53	42	
<i>Fraxinus pennsylvanica</i>	18.4	1	0.18	7.18	34	
<i>Ostrya virginiana</i>	18.4	0	0.04	1.39	4	
<i>Diospyros virginiana</i>	15.8	0	0.05	1.87	4.0	
<i>Juglans cinerea</i>	15.8	0	0.02	0.83	1.7	
<i>Quercus marilandica</i>	15.7	0	0.04	1.70	4.3	
<i>Acer negundo</i>	14.2	1	0.32	12.56	54	
<i>Acer saccharinum</i>	13.1	1	0.51	19.72	50	
<i>Pinus virginiana</i>	10.5	3	2.43	31.60	62	
<i>Quercus coccinea</i>	10.5	0	0.05	1.97	4.3	
<i>Celtis occidentalis</i>	10.5	0	0.05	1.93	2.5	
<i>Liquidambar styraciflua</i>	7.9	0	0.02	0.94	1.9	
<i>Prunus serotina</i>	5.3	0	0.05	1.90	3.3	
<i>Illex opaca</i>	5.3	0	0.07	2.75	3.6	
<i>Salix nigra</i>	2.6	0	0.16	6.10	6.1	
<i>Gleditsia triacanthos</i>	2.6	0	0.06	2.30	2.3	
<i>Gymnocladus dioica</i>	2.6	0	0.02	0.85	0.85	

TABLE 9. Continued

Species	%	No. Stands		Mean Importance Value		Maximum Importance Value
		Presence	As Leading Dominant	All Stands	Where Present	
<i>Betula lutea</i>	2.6		0	0.02	0.85	0.85
<i>Carpinus caroliniana</i>	2.6		0	0.01	0.22	0.22
<i>Robinia pseudoacacia</i>	2.6		0	0.01	0.38	0.38
<i>Magnolia tripetala</i>	2.6		0	0.02	0.85	0.85
<i>Quercus macrocarpa</i>	2.6		0	0.01	0.38	0.38

woods of the slopes and have a reduced herbaceous flora.

Only two species dominated the old field sere, eastern red cedar (Juniperus virginiana L.) and Virginia pine (Pinus virginiana Mill.). Fifteen tree and shrub species were identified in these old fields but the dominant species of the less disturbed upland stands were either not present or of minor importance at this time.

Leading Dominants

The leading woody dominants are compared according to importance value in Table 9 (Curtis and McIntosh, 1951). Thirteen species of the 45 tree species encountered during the forest sampling were leading dominants, according to this method. One-quarter of the stands were dominated by white oak although three species, tuliptree, pignut hickory and dogwood (Cornus florida L.), had a higher presence value. Three other species had a higher mean importance value in the stands in which they occur. These were sugar maple, eastern red cedar and Virginia pine. Each of these species was particularly important in young stands. This was also observed by McIntosh (1972).

Other species dominating in more than one stand were American beech, eastern red cedar, tuliptree, Virginia pine, chestnut oak, northern red oak, and black oak. The stands dominated by eastern red cedar and Virginia pine were seral stands occurring in abandoned fields. The hemlock stand was a composite of several locations. The areal extent of the

individual hemlock locations was too small to permit adequate Bitterlich sampling so these data are combined into Table 22D. The stands dominated by sycamore, box-elder, green ash (Fraxinus pennsylvanica Marsh), and silver maple (Acer saccharinum L.) were associated with the floodplains of the major streams. The mean importance value for these four species were very similar (Table 9) indicating that few species are involved in this association. The diameter of the old growth sycamores, particularly at abandoned ferry crossings where they were left standing as anchors for the cables, is a convincing argument for their old age. At least 6 trees were measured in excess of 70 inches dbh.

In the two stands dominated by American beech, the average size of the trees in these stands was 10.6 inches dbh, somewhat larger than the average size for all trees measured (10.2 inches dbh). This suggests that these stands occurred on better sites or were less disturbed prior to the establishment of the Park.

A single stand, dominated by eastern red cedar, was grouped with the mixed woods stands because of its relatively high diversity when compared with the seral stands where eastern red cedar was the leading dominant (Table 10). In this instance eastern red cedar occurred on limestone outcrops which had a south-facing aspect above the Green River. The second leading dominant in this stand was white oak, a dramatic contrast to the seral stands where the second leading dominant was either American ash or

TABLE 10. Mean indices of diversity of trees, mean importance (%) of the leading dominant, the second dominant as a percentage of the first and mean number of species in each group of stands. Diversity index follows McIntosh (1972).

Most important species	Mean index of diversity (Importance Value)	Mean Importance Value (%) of leading dominant	Second dominant as percentage of first	Mean number of species
Old Fields				
Juniperus virginiana	0.31	71	7.7	10.7
Pinus virginiana	0.49	52	20	14
Upland Stands				
Quercus alba	0.70	25	76	18
Quercus velutina	0.75	19	92	17
Pinus virginiana	0.73	24	50	17
Nyssa sylvatica	0.73	21	90	19
Quercus rubra	0.72	22	77	18
Floodplain Stands				
Platanus occidentalis	0.59	33	58	16
Fraxinus pennsylvanica	0.53	34	94	5
Acer negundo	0.47	54	31	9
Acer saccharinum	0.39	50	80	5
Hemlock Stands				
Tsuga canadensis	0.73	21	86	26

TABLE 10. (continued).

Most important species	Mean index of diversity (Importance Value)	Mean Importance Value (%) of leading dominant	Second dominant as percentage of first	Mean number of species
Mixed Woods				
Quercus velutina	0.76	18	58	22
Quercus alba	0.73	22	67	18.5
Quercus rubra	0.72	24	75	20
Fagus grandifolia	0.67	28	75	20
Quercus prinus	0.64	37	58	19
Juniperus virginiana	0.63	35	40	13
Liriodendron tulipifera	0.57	35	88	9

black gum (Nyssa sylvatica Marsh).

The floodplain stands had intermediate average diversity (Table 10). With the exception of one stand (Mammoth Ferry full census) these stands had the fewest species present of any mature stand studied.

The relationships of the dominant species to each other are shown in Tables 11-12. White oak was the second average leading dominant in stands dominated by American beech, tuliptree, chestnut oak, northern red oak and eastern red cedar (tie with black oak), indicating its wide distribution throughout the forests of MCNP (Table 11). There were four leading dominants of the floodplain (Table 12). Sycamore and silver maple were the important secondary species in these stands.

Herb and Shrub Stratum

Herbs

An annotated species list of plants collected during this study is contained in Appendix G. During an earlier, more complete study, Davies (1954) reported 630 species of flowering plants. Table 1G summarizes the vascular plant collections of Faller and of Davies, including new additions.

The majority of the species collected during this study have ranges in the eastern or southeastern United

TABLE 11. Mean importance value (%) of major tree species in stands in which a species is the leading dominant (Mixed woods, Upland woods, and Successional woods). Symbols are found in Table 1H.

Leading Dominant									
	Lt	Ns	Qa	Qv	Qr	Fg	Qpr	Jv	Pv
Lt	35	0.4	8.4	3.4	1.2	6.8	1.5	2.1	9.8
Ns	4.5	21	6.0	8.4	5.1	1.0	1.6	2.8	3.1
Qa	31	7.8	21.4	9.1	15.1	16	14.3	4.7	4.0
Qv	9.6	10	6.4	18.8	7.6	0.5	6.5	4.7	4.2
Qr	8.5	6.3	6.8	9.3	23.3	3.9			
Fg			2.1	0.9	0.8	28	6.4	0.1	
Qpr			1.3		0.1		37	2	
Jv								62	13.5
Pv									30.7

TABLE 12. Mean importance value (%) of major tree species in stands in which a species is the leading dominant (Floodplain stands). Symbols are found in Table 1H.

		Leading Dominant			
		Ane	Asi	Po	Fp
Ane		54	5.9	1	2.2
Asi		17	50	13	13
Po		6.9	40	33	34
Fp					32

States (Table 13). Introduced weedy species make up the majority of those plants whose ranges are Europe, Eurasia, eastern Asia or China. Several exotic species persist at old farmsteads throughout the Park.

TABLE 13. Summary of species collected according to range as given by Gleason and Cronquist (1963).

Locality	Percent of Species
Eastern U.S.	44
Southeastern U.S.	23
Europe, Eurasia	7
Eastern N.A.	6
Central U.S.	5
Remainder ¹	10

¹The remaining 10% include the following ranges: Northern U.S., Circumboreal, Local Tenn. and Ky., Southern U.S., Ozark region, Western U.S., Eastern Asia and China.

The distribution of selected herbs in the major plant communities is indicated in Table 14. The density of the herbaceous cover was lowest in the upland woods and greatest in the floodplain forests. The herb community of the mixed woods included species whose cover and distribution values were rarely above Stratum Rank 3. Few conspicuous herbaceous species were common to the three physiographic units. Herbaceous species which are essentially restricted to the upland woods include Houstonia caerulea, Chimaphila maculata and Coreopsis major.

TABLE 14. Stratum Rank values of selected herbs in major plant communities.

Species	Upland Woods	Mixed Forests	Floodplain
<i>Houstonia caerulea</i>	3		
<i>Galium circaezans</i>	3		
<i>Chimaphila maculata</i>	2		
<i>Dentaria heterophylla</i>	2		
<i>Mertensia virginica</i>	2		
<i>Coreopsis major</i>	2		
<i>Panax quinquefolium</i>	1		
<i>Houstonia purpurea</i>	1		
<i>Viola sagittata</i>	1		
<i>Hypericum</i> sp.	1		
<i>Smilacina racemosa</i>	1	3	
<i>Potentilla simplex</i>	2	2	
<i>Galium triflorum</i>	2	2	2
<i>Podophyllum peltatum</i>		4	
<i>Mentha piperita</i> (cultivar)		3	
<i>Anemonella thalictroides</i>		3	
<i>Polygonatum biflorum</i>		2	
<i>Oxalis grandis</i>		2	
<i>Arisaema triphyllum</i>		2	
<i>Erythronium americanum</i>		2	
<i>Desmodium rotundifolium</i>		2	
<i>Geranium maculatum</i>		1	
<i>Polemonium reptans</i>		1	
<i>Hydrastis canadensis</i>		1	
<i>Tiarella cordifolia</i>		1	
<i>Saururus cernuus</i>		1	
<i>Viola pennsylvanica</i>			6
<i>Veroesina virginica</i>			4
<i>Heracleum lanatum</i>			3
<i>Urtica dioica</i>			3
<i>Arundinaria gigantea</i>			3
<i>Uniola latifolia</i>			3

Species commonly associated with rich mixed woods and slope communities included Arisaema triphyllum, Erythronium americanum, Hydrastis canadensis, and Tirella cordifolia. These species were most often seen in the least disturbed areas north of the Green River. Several plants were restricted to the bottom lands of the floodplains, or to areas of seeps and high water tables. Included in this group were the grasses Arundinaria gigantea, and Uniola latifolia.

Species found in abundance on the larger floodplains included Verbesina virginica, Heracleum lanatum and Urtica dioica. The herb stratum of the floodplain flowers conspicuously from July through early September. Verbesina alternifolia (SR 8) and Eupatorium coelestinum (SR 8) are separated from each other along the physiographic boundary between the low bottom and first terrace. Grasses which have high stratum ranks are Uniola latifolia (SR5) and Sorghum halepense (SR 6). On the youngest parts of the Green River islands Impatiens biflora is assigned Stratum Rank 6 or 7. The spring and early summer flora is limited to a few herbaceous perennials which flower on the floodplain because of the annual deposition of silts during winter floods.

Woody Species

Tables 15 and 16 show the contribution of woody species to the herb, shrub and sapling strata of upland and mixed woods. In the herb layer, woody species which had

TABLE 15. Stratum Rank values of tree reproduction in
Wilson Cave Hollow communities.

Species	Herb Layer	Shrub Layer	2-4" Diameter
<i>Cornus florida</i>	3	3	5
<i>Acer saccharum</i>	4		3
<i>Acer rubrum</i>	3		2
<i>Cercis canadensis</i>	3	2	
<i>Sassafras albidum</i>	2		
<i>Carya</i> sp.	2		
<i>Asimina triloba</i>	2		
<i>Juniperus virginiana</i>	1 ¹		
<i>Fagus grandifolia</i>		3	2
<i>Quercus alba</i>			3
<i>Nyssa sylvatica</i>			2
<i>Carya ovata</i>			2
<i>Liriodendron tulipifera</i>			2
<i>Fraxinus americana</i>			1 ¹
<i>Oxydendrum arboreum</i>			2

¹Stratum Rank 1 indicates only one individual observed
at no more than two observation points in the stand.

TABLE 16. Stratum Rank values of woody species in herb, shrub and sapling strata in late secondary seral stages of the Upland Forest Association. (Based on 25 sampling points.)

Species	Stratum		
	Herbs	Shrubs	Saplings
<i>Juniperus virginiana</i>	1 ¹		
<i>Asimina triloba</i>	1		
<i>Liriodendron tulipifera</i>	2		
<i>Sassafras albidum</i>	3		
<i>Cornus florida</i>	2	4	5-6 ²
<i>Nyssa sylvatica</i>	2	2	3
<i>Quercus velutina</i>	1-2	1	
<i>Quercus marilandica</i>		2	
<i>Quercus prinus</i>		2	
<i>Oxydendrum arboreum</i>		2	2
<i>Carya glabra</i>			2
<i>Acer saccharum</i>			2
<i>Cercus canadensis</i>			1
<i>Carya ovata</i>			1
<i>Quercus stellata</i>			1
<i>Acer rubrum</i>	2		2
<i>Quercus alba</i>	2		2

¹SR 1 indicates a very rare species occurring at less than five stations.

²When a range is used it indicates variation in the SR for this species at several stations.

higher stratum ranks include flowering dogwood, sugar maple, red maple, redbud, and sassafras. In the shrub layer (1.5 to 2 meters tall) dogwood, redbud, spicebush and American beech were found. In the sapling size classes tree species in Wilson Cave Hollow included dogwood, sugar maple, red maple, beech and white oak.

During the early flowering of spring ephemerals in the mixed woods, Dentaria laciniata occurred in each of 25 square meter plots sampled with densities as high as 42 plants per m². Erigenia bulbosa and Claytonia virginica were next most common with up to 22 plants per m². Ground cover was estimated to be 50% in these plots. Other common plants of the mixed woods association included Erythronium americanum, Viola sp., Dentaria heterophylla, Arisaema triphyllum, Asclepias variegata, Stellaria pubera, Dioscorea quaternata, Desmodium rotundifolium, Phacelia bipinnatifida, Iris sp., Monarda clinopodia, Uvularia perfoliata, Epifagus virginiana, Sanguinaria canadensis, Phlox sp., Anemone quinquefolia, Saxifraga virginensis, Mitella diphylla, Sanicula canadensis, Zizia aptera, Boehmeria cylindrica, and Campanula americana.

The floodplain association does not have a well developed sapling stratum and young woody plants were rarely observed in the dense herbaceous cover which is present from early summer through the fall. Woody shrubs are essentially absent. Lianas are common, however, with Aristolochia durior (SR 6) most important of this

group. Arundinaria gigantea forms, in well-drained areas of the floodplain and higher parts of the islands, canebrakes (SR 9) of limited extent. Individuals of this species 5 m tall were measured on Boardcut Island. Distribution of Arundinaria gigantea within the Park is not confined to the floodplain of the Green River. Clumps of A. gigantea are found associated with seeps at geologic contacts between sandstone and limestone, but most of these clumps are short (1-1.5 m tall). Watson (1969) points out, in her study of Salts Cave prehistory, the importance of A. gigantea to the aboriginal cavers of the region who used cane bundles for torch lights. She further suggests that this species was more widely distributed within the Park before European man entered the region. Present recovery patterns and the wide distribution of small clumps would further support this observation.

Successional Importance of Tree Species

An examination of stand table data suggested that an inverse relationship between species presence and average importance value exists with regard to the successional trends of MCNP forests. A successional importance index (4) which weights the occasional or rare member of the present day stand was devised to examine

this concept:

$$\frac{1}{\frac{\sum_1^n v_3}{\sum_1^j \text{Stands}}}, \quad (4)$$

where j equals the total number of stands under consideration in an association and n equals the total number of Importance Value values available for a species. The successional index differs from a fidelity index (Greig-Smith, 1964, page 204) by weighting the minor species of the present-day stands in an effort to predict their future influence. Table 17 indicates that as the floodplain area becomes drier (through reduced flooding and/or increased distance and height from the present river level) tuliptree, sugar maple, red maple, and American beech will become more important.

Successional species are normally less common in stable communities while they are more common in disturbed or unstable communities. Sampling in a series of specific habitats (floodplain, uplands, or mixed woods) would, by chance, reflect rare to common species in each of the sampled stands. Combining these observations (a successional index) with indices of diversity, which measure stand complexity, an analysis of the role a particular species plays in the development of a community can be made.

Values ranged from a minimum (3.5%) for sycamore to a maximum (125%) for red maple in the floodplain association

(Table 17). In the other associations, which have more species, the extreme values were closer together indicating a wider distribution of tree species throughout the stands. The values in the mixed woods range from 5 to 27 and in the upland woods the values range from 5.6 to 77 (Tables 18 and 19).

White oak has the lowest successional potential in the mixed woods and upland forests while sycamore has the lowest potential on the floodplain. Trees with the highest values, in their respective groupings of stands are red maple (floodplain) tuliptree (upland forests) and American beech (mixed woods). The forest species of the mixed woods show the least variation while the floodplain species show the greatest variation.

Diversity of Forest Sampling Units

Figures 11 and 12 show the relationships between the major types of forest units in MCNP based on two types of diversity indices. A comparison between the methods of Simpson and McIntosh shows no change in order of the major groups. When the Simpson Index is examined, the mixed woods are closer to the median value than the other stand groupings with high diversity. This suggests that individual trees encountered in this community will less frequently belong to a different species than in the hemlock or upland stands.

In contrast, the McIntosh Index combines elements of

TABLE 17. Successional importance of selected tree species in four floodplain stands.

Species	Presence (%)	Average Importance Value	Successional Importance
<i>Platanus occidentalis</i>	100	28	3.5
<i>Acer saccharinum</i>	100	23	4.3
<i>Acer negundo</i>	100	16	6.3
<i>Fraxinus pennsylvanica</i>	75	12	10.8
<i>Ulmus rubra</i>	50	10	20.0
<i>Liriodendron tulipifera</i>	50	7	30.0
<i>Acer saccharum</i>	50	3	67.0
<i>Acer rubrum</i>	50	2	125.0
<i>Fagus grandifolia</i>	25	11	37.0

TABLE 18. Successional importance of selected tree species in 22 Mixed Woods stands.

Species	Presence (%)	Average Importance Value	Successional Importance
<i>Quercus alba</i>	100	19.3	5
<i>Liriodendron tulipifera</i>	91	11.3	10
<i>Quercus rubra</i>	91	8.1	14
<i>Carya glabra</i>	91	4.9	23
<i>Quercus velutina</i>	82	8.1	15
<i>Nyssa sylvatica</i>	82	6.3	19
<i>Acer saccharum</i>	68	8.1	18
<i>Acer rubrum</i>	64	6.1	26
<i>Fagus grandifolia</i>	54	6.9	27

TABLE 19. Successional importance of selected tree species
in five upland forest stands.

Species	Presence (%)	Average Importance Value	Successional Importance
Quercus alba	100	16.9	5.9
Quercus rubra	100	10.8	9.2
Nyssa sylvatica	100	10.6	9.4
Carya glabra	100	8.4	12.0
Quercus stellata	80	6.2	9.9
Quercus velutina	60	16.9	9.9
Carya tomentosa	60	4.6	36
Liriodendron tulipifera	60	2.2	77
Acer rubrum	40	10.0	25

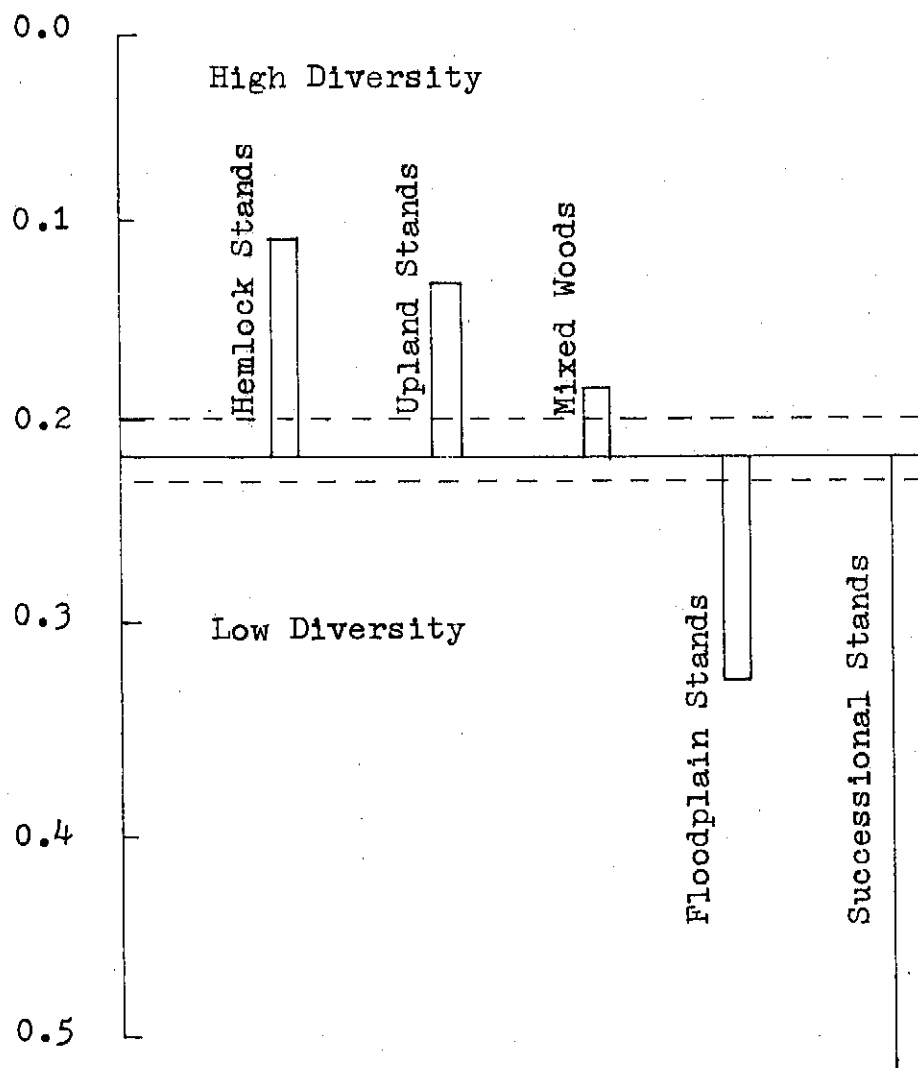


FIGURE 11. The four forest associations ordered according to Simpson's Index of Diversity. The dividing line represents the average diversity value of all 39 stands. The broken line is one standard deviation from the mean diversity value of all stands.

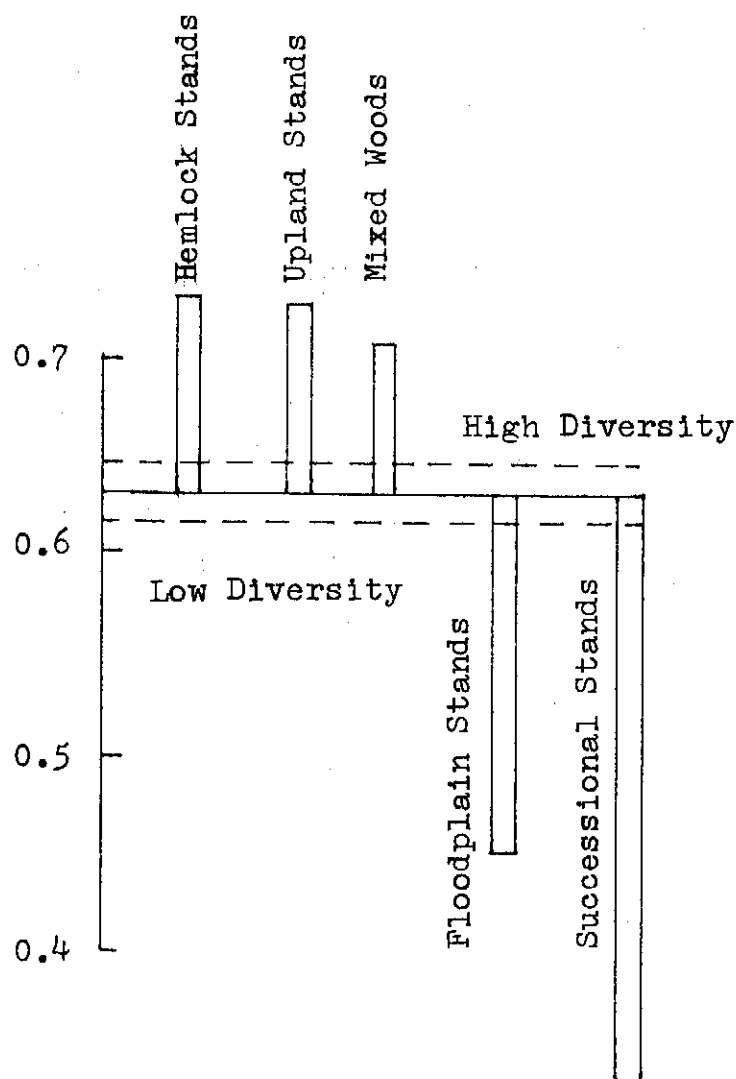


FIGURE 12. The four forest associations ordered according to the McIntosh Index of Diversity. The dividing line represents the average diversity value of all 39 stands. The broken line is one standard deviation from the mean diversity value of all stands.

information theory (McIntosh, 1972) with the probability of encountering an individual of a given species. These results (Fig. 12) suggest that the mixed woods stands, upland and hemlock stands each contain very similar amounts of information.

The floodplain and successional stands have a lower than average diversity as based on either index.

A similar analysis was made using the Shannon-Weaver Index which is entirely based on information theory. Using this method, the upland stands contained slightly more information (diversity) than the combined hemlock stands. The remaining groups were in the same order.

Twenty stands were placed in the mixed woods group for diversity analysis while four were considered floodplain stands, seven were considered upland stands and five were grouped as successional stands. The First Creek hemlock stand is a composite of several sampling units because of the limited areal extent of this vegetation type.

The richness of species in each stand is shown in Table 20. Stands where several microhabitats were encountered along a linear sampling unit (slopes to solution valleys, hollows and ravines) had the highest numbers of tree species. Stands located on uplands and plateaus were intermediate in species richness. Block diagrams of these topographic relationships (Figs. 21, 22, 23, 24) show the principal species and their relationships to land form. Successional stands have between 10-14

TABLE 20. Forest stands arranged according to number of species present. Refer to Table 21 for stand symbols.

Number of Species	Stands
20	HSF, BWS, SCN, CSVS, CK, CHP, WCH, FCH, SVW, DVS
15-19	MFF, BWR, IHC, DPH, BWV, TBN, MCNF, GSC, JRMR, LR, GOS, SSC, US
10-14	HSS, HSL, WP, HSU, HCBK GVSL, CSVO, JROF, MCOF
10	SSF, NFF, SCI, BI

species, except for a combined stand table based on 0.1-acre plots (Upland Successional Stand). The floodplains have the fewest species present.

Stand Table Summary

Tables 21, 22, and 23 summarize stand table data from Appendix D. Table 21 separates successional (9.9 inches dbh or less) from maturing stands (greater than 9.9 inches dbh) on the basis of average tree diameter (dbh). These two groups of stands are arranged along an arbitrary moisture gradient which illustrates the distribution of the dominant tree species. The most mesic stands, Wet Prong and Big Hollow, do not have successional equivalents although each of the other moisture categories have at least one successional stand equivalent. Sixty-one percent of the successional stands sampled are of the xeric type. This reflects the past land use where the flat land in the Park supported agriculture. The rapid growth of trees on the floodplain since abandonment of agriculture is emphasized by the large average dbh at Sand Cave Island and New Ferry Floodplain.

The density per acre of tree species ranged from 318 to 90 while total basal area per acre ranged from 134 ft² to 22 ft² (in one of the successional stands). Although two methods of forest sampling were used the results, considering variation in habitat and forest type, are consistent.

Table 21. The relationships of tree size, as an indicator of stand maturity, to site moisture condition and dominant tree species. Stand symbols are used in Figures 13 and 14. Tree symbols follow Table 1 H.

Stand Name	Stand Symbol	DBH $\bar{X}$	Dominant Species	Moisture Condition
<u>Maturing Stands</u>				
Wet Prong	WP	10.3	Fg, As, Qa	M
Big Hollow	BH	10.1	Fg, Qa, Lt, As	M
Salts Sink Full	SSF	14.9	Lt, Qa	DM
Hunts Sink Full	HSF	14.1	Qv, Qa, Lt	DM
Big Woods Ravine	BWR	12.0	Qa, Lt, Fg	DM
Deer Park Hollow	DPH	10.7	Qa, Lt, Qr	DM
Sloan Crossing North	SCN	10.0	Qa, Lt, Qr, Cf	DM
Turnhole Bend North	TBN	10.0	Qa, As	DM
Hunts Sink Full	HSF	12.5	Qv, Qa, Lt	X
Hunts Sink Lower	HSL	12.1	Qr, Qa, Ct	X
Indian Hill Chestnut	IHC	12.0	Qpr, Cov	X
Big Woods Slope	BWS	11.8	Qa, Qv, Lt, Ct	X
Big Woods Upland	BWU	10.6	Qa, Qv, Cg	X
Cedar Sink Valley Slopes	CSVs	9.9	Qr, Qv, Cf	X
Crumps Knob	CK	9.9	Qa, Cg, Qpr, Ar, Ns	X
Hunts Sink Upper	HSU	9.9	Qa, Ar, Oxa, Qf	X
Mammoth Ferry Floodplain	MFF	13.5	Po, Ur, Asi, Fg	H
New Ferry Floodplain	NFF	12.0	Fp, Po, Ur	H
Sand Cave Island	SCI	10.5	Asi, Po	H
<u>Successional Stands</u>				
Mammoth Cave New Ferry	MCNF	9.6	Qa, As, Fa, Cf, Cg	DM
Wilson Cave Hollow	WCH	9.2	Qa, Qr, As	DM
First Creek Hemlock	FCH	8.9	Ts, Qpr, Fg	DM
Cedar Sink Valley Old Field	CSVO	6.9	Jv, Jn	DM
Joppa Ridge Old Field	JROF	5.6	Jv, Ns	DM
Mammoth Cave Old Field	MCOF	5.6	Jv, Fa	DM
Chicken Prong Hollow	CPH	9.6	Qpr, Qa, As, Fg	X
Good Spring Church	GSC	9.5	Qa, Ar, Cg, Qr	X
Smith Valley West	SVW	8.8	Qv, Cf, Qa, Ns	X
Doyel Valley Slopes	DVS	8.5	Qv, Ns, Qst, Cf	X
Hickory Cabin, Brooks Knob	HCBK	8.2	Pv, Cf	X
Joppa Ridge, Mammoth Ridge	JRMR	8.1	Qv, Qr, Cg, Cf	X
Lee Ridge	LR	8.0	Qr, Qa, Cg, Cf	X
Great Onyx Succession	GOS	7.9	Pv, Lt, Cf	X
South Sloan Crossing	SSC	7.9	Ns, Oxa, Qst, Qv	X
Green River Valley	GVSL	7.3	Jv, Qa, Qv, Ar	X
Upland Successional	US	4.8	Pv, Jv, Cf	X
Boardcut Island	BI	9.0	Ane, Asi, Lt	H

M = Mesic, DM = Dry Mesic, X = Xeric, H = Hydric

TABLE 22. Summary of stands sampled at Mammoth Cave National Park arranged according to average basal area per tree.

Stand	Total Density (N/acre)	Total Basal area (ft ² /acre)	Average BA tree (ft ² /tree)
Salts Sink Full Census	110	134	1.21
Hunts Sink north, south facing	130	140	1.08
Mammoth Ferry Floodplain	132	131	0.99
Hunts Sink south Full Census	90	77	0.85
Hunts Sink north lower slopes	133	107	0.80
Indian Hill	164	130	0.79
Big Woods (ravine)	139	109	0.78
New Ferry Floodplain	190	149	0.78
Big Woods (slope)	118	89	0.76
Deer Park Hollow	145	91	0.63
Big Woods Upland	131	80	0.61
Sand Cave Island	162	98	0.60
Wet Prong	166	97	0.58
Big Hollow	173	97	0.56
Sloans Crossing north	208	114	0.55
Turnhole Bend North	143	77	0.54
Cedar Sink Valley Slopes	195	103	0.53
Crumps Knob	210	111	0.53
Hunts Sink north upper slopes	213	113	0.53
Chicken Prong Hollow	186	94	0.50
Mammoth Cave New Ferry	235	117	0.50
Good Spring Church	243	94	0.49
Wilson Cave Hollow	248	114	0.46
Boardcut Island	229	99	0.44
First Creek Hemlock	228	97	0.43
Smith Valley	212	89	0.42
Doyel Valley Slopes	243	93	0.39
Hickory Cabin, Brooks Knob	198	73	0.37
Joppa and Mammoth Ridge	240	86	0.36
Lee Ridge	236	83	0.35
Sloans Crossing South	266	90	0.34
Great Onyx Succession	318	108	0.34
Green Valley South Facing	381	111	0.29
Cedar Sink Valley Succession	188	48	0.26
Joppa Ridge Old Field	186	31	0.17
Mammoth Cave Ridge Old Field	216	36	0.17
Upland Successional Stands	175	22	0.13

TABLE 23. Classification of stands according to sums of importance values grouped according to genera: xeric (Quercus-Carya), mesic (Fagus-Acer saccharum), and hydric (Platanus-Juglans-Acer saccharinum, A. negundo). Data from Appendix D.

Stand	Species Group			Stand	Species Group		
	Xeric	Mesic	Hydric		Xeric	Mesic	Hydric
Oak Hickory				Mixed Woods			
JRMR	80	-	-	BH	31	38	-
BWU	73	-	-	Hemlock Stands			
HSL	73	9	-	FCH	35	22	-
LR	72	1	-	Beech Maple			
IHC	69	7	-	WP	24	56	-
CPH	68	19	-	Floodplains			
TBN	66	11	-	SCI	-	-	90
GSC	62	1	-	BI	-	-	78
CSVs	61	3	-	NFF	-	-	52
BWS	60	1	-	MFF	-	22	46
CK	60	4	-	Successional Stands			
WCH	57	13	-	GVSL	39	-	-
DVS	56	1	-	GOS	31	3	-
SCN	52	5	-	CSVO	3	-	11
SVW	51	7	-				
HSU	49	-	-				
HSS	47	8	-				
SSC	47	-	-				
SSF	46	-	-				
BWR	45	17	-				
DPH	43	9	-				
HSF	42	6	-				
MCNF	39	16	-				

The stands with the largest trees were located in large tracts held in single ownerships over a long period of time (Salts Sink, Hunts Sink, Mammoth Ferry Floodplain and Big Woods) (Table 22). The average basal area per tree in these areas was above $0.76 \text{ ft}^2/\text{tree}$. Stands in other areas received more intensive logging before the establishment of the Park and reflect this with lower average basal area per tree.

When the stands are re-arranged according to decreasing importance values by generic groups (Table 23) 23 stands clearly show the dominance of oak and hickory species. The majority of the oak-hickory group (83%) is located south of the Green River and is associated with the Mammoth Cave Plateau. The mixed woods (Big Hollow) and the beech-maple (Wet Prong) sampling areas are located north of the Green River in the Western Coalfield physiographic province. The hemlock combined stands are also found along outcrops of the Lower Pennsylvanian sandstone which marks the escarpment of the Western Coalfield. This escarpment is north of the Green River in the eastern section of the Park. It crosses the Green River at approximately Turnhole Bend, with hemlock occurring on Indian Hill, Crumps Knob and Brooks Knob.

Ordination Analysis

A two dimensional ordination analysis was prepared. This ordination was based on the similarity between the 38

stands sampled during this study (Figs. 13 and 14). These basic figures were used to establish clusters of related stands in an effort to identify seral trends and the most probable potential natural vegetation for MCNP. Figure 15 reflects a convergence of stands with larger average diameters into the central core space of the ordination. Figure 16 demonstrates possible moisture and time-successional gradients in ordination space. Combining the assumptions of Figures 15 and 16 at least two alternative seral axes can be illustrated (Fig. 17). Figure 18 clusters stands according to seven dominant species or dominant species group (in the case of the floodplain stands).

The solid lines of Figure 17 converge on a beech-maple dominated forest represented by Wet Prong stand. An alternative view is suggested by the interrupted lines which converge on the old growth stands in the central clusters identified as Western Mesophytic and chestnut oak knobs. The dotted line from the central cluster to the beech-maple dominated forest indicates limited "flow" along this seral axis due to the limited physiography available for this forest type in MCNP. Figure 18 demonstrates the isolation in ordination space of the successional stands (dominated by eastern red cedar,) and the floodplain stands (dominated by sycamore, silver maple and green ash) when compared to the more mature stands.

The stands dominated by white oak form the central

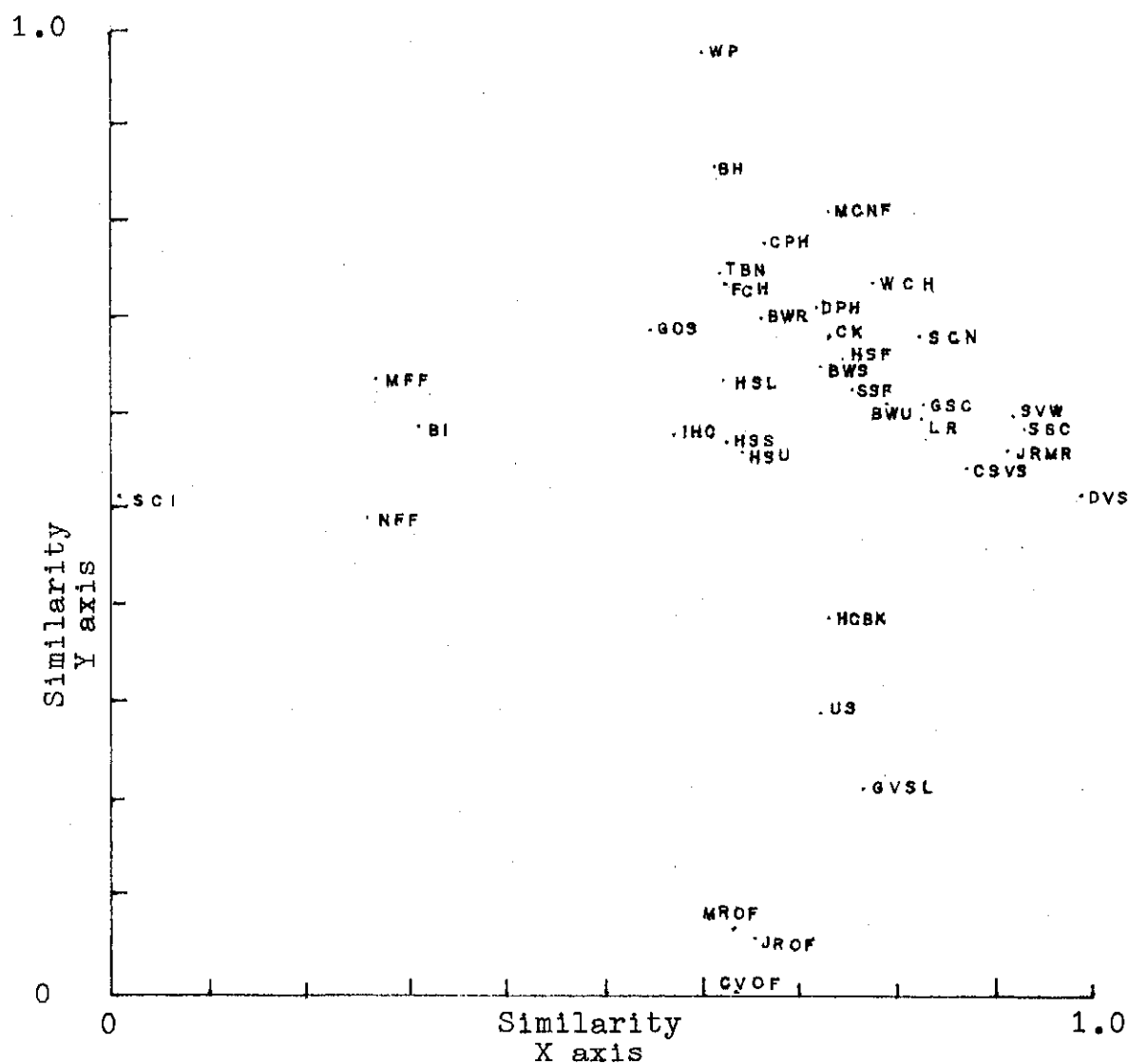


FIGURE 13. A two dimensional ordination based on similarity index comparisons of 38 forest stands at Mammoth Cave National Park, Kentucky. This figure includes data from all physiographic units and successional stages sampled in this study. Refer to Table 21 for the key to stand symbols used in this figure.

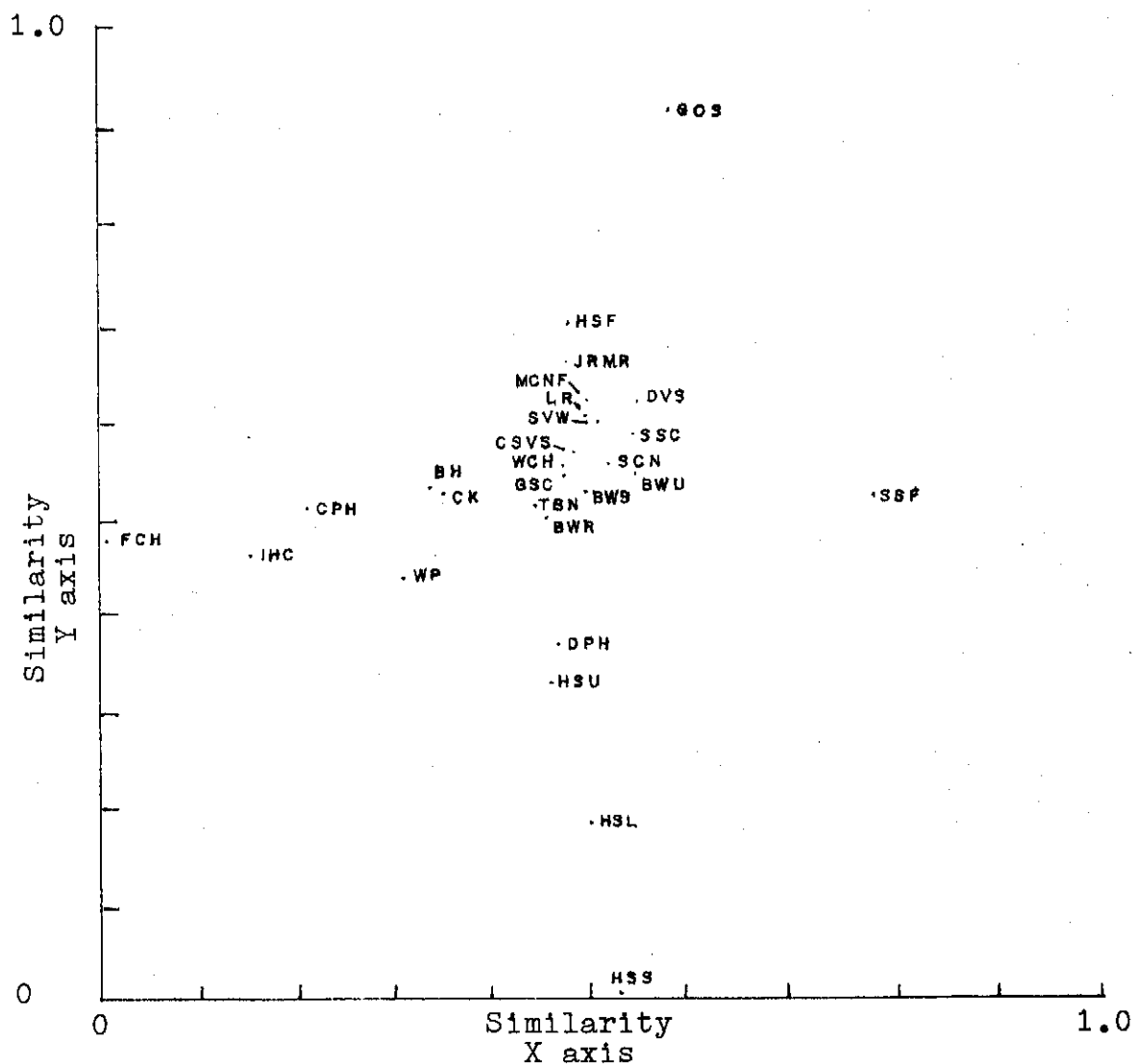


FIGURE 14. A two dimensional ordination based on similarity index comparisons of 28 forest stands at Mammoth Cave National Park, Kentucky. This figure excludes data from stands sampled on floodplains or in old field successional stages. Refer to Table 21 for the key to stand symbols used in this figure.

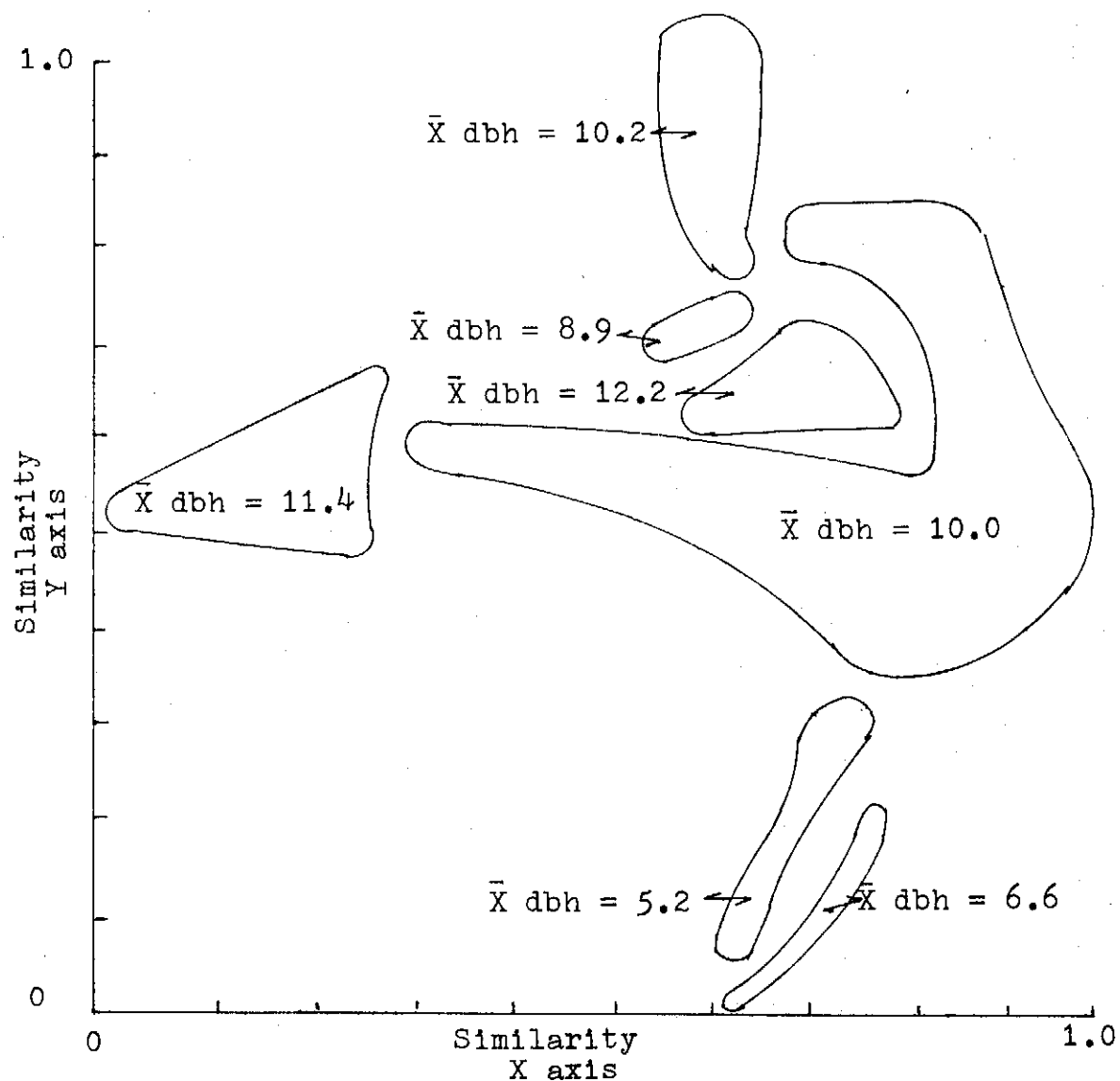


FIGURE 15. Clusters of similar forest stands based on a two dimensional ordination and arranged by average diameter of trees in the stand.

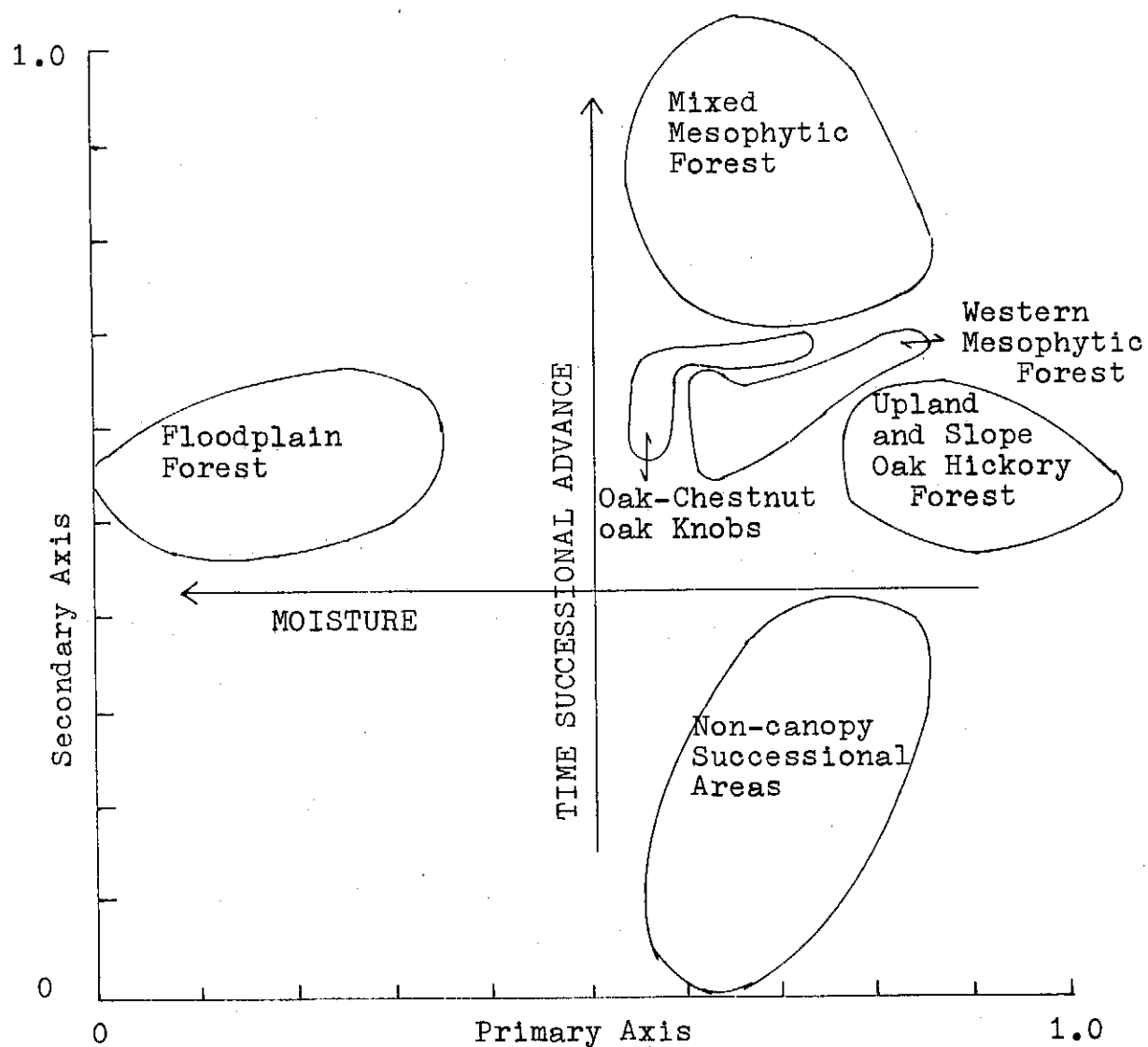


FIGURE 16. Clusters of similar stands based on a two dimensional ordination along moisture and successional gradients at Mammoth Cave National Park, Kentucky.

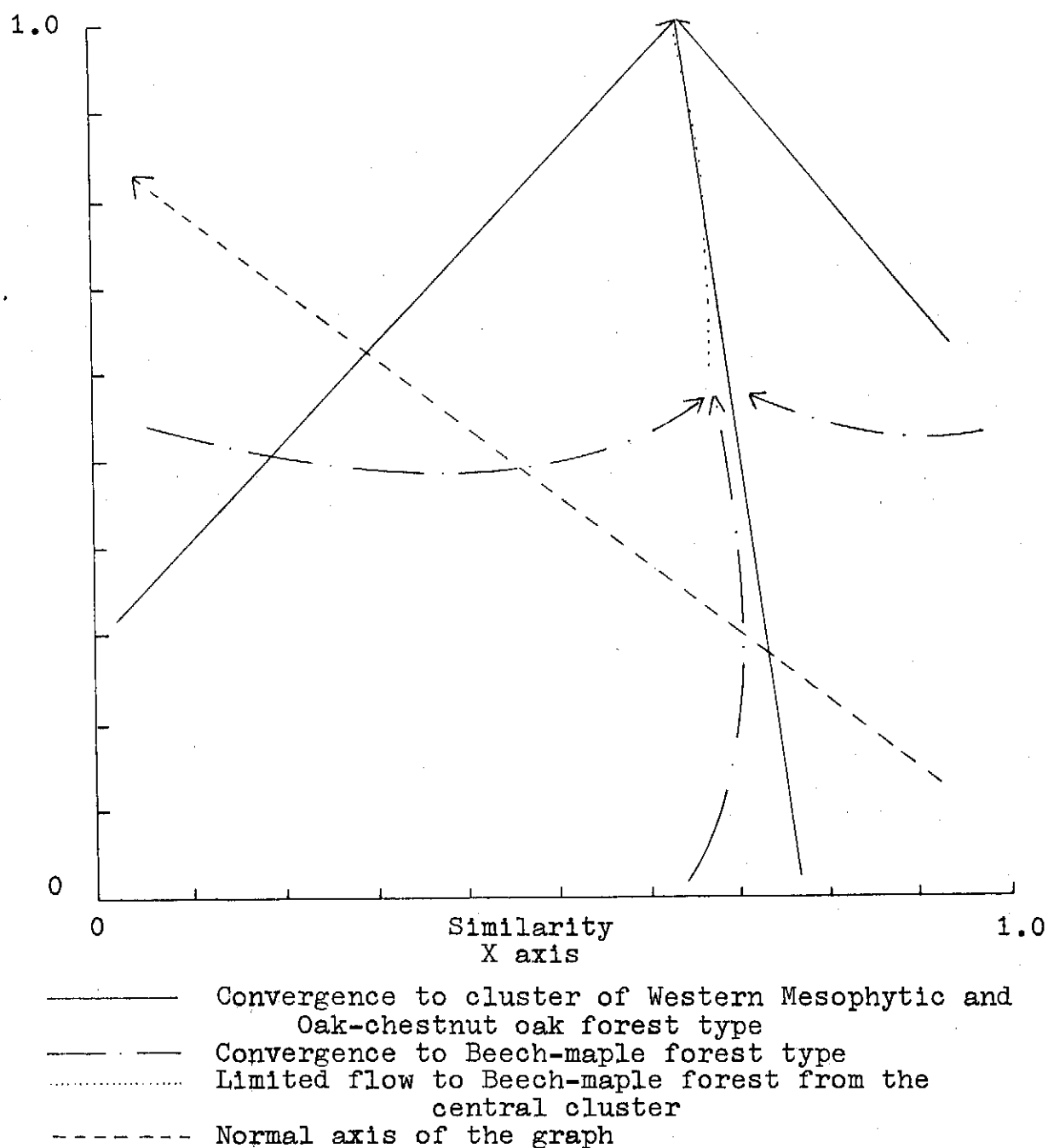


FIGURE 17. Alternative seral axes based on a two dimensional ordination of 38 forest stands at Mammoth Cave National Park, Kentucky.

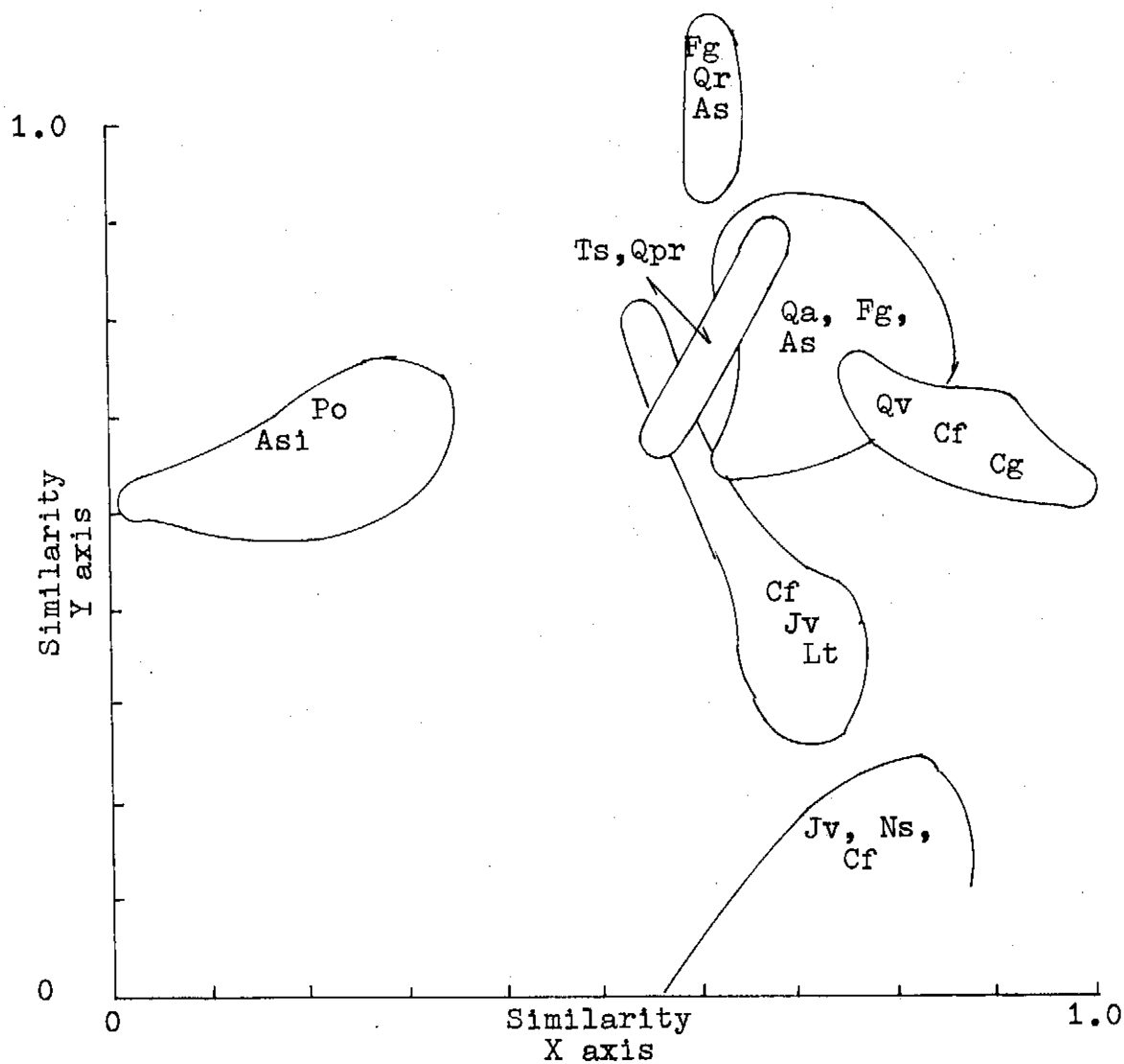


FIGURE 18. Dominant species clusters based on a two dimensional ordination of 38 forest stands at Mammoth Cave National Park, Kentucky. Symbols follow Table 1H.

core of this ordination. These stands include Turnhole Bend North, Big Woods Ravine, Deer Park Hollow, Crumps Knob, Big Woods Slope, Hunts Sink, Wilson Cave Hollow, Mammoth Cave New Ferry at a side valley and a stand near Good Spring Church. On an axis trending toward the dry upland sites, black oak dominated in four stands. These include Joppa Ridge, Mammoth Ridge Upland Stands, Sloans Valley in a west trending drainage and the Doyel Valley Slope Stand. These last two stands occupy very similar locations with respect to aspect and bedrock geology.

Stands characterized by northern red oak include Wet Prong Hollow and Big Hollow. Both of these stands are located north of the Green River where streams originate on Lower Pottsville rocks of Pennsylvanian Age. These northern red oak stands are most distantly spaced from the old field stands dominated by eastern red cedar.

The stands located on the floodplain occupy similar ordination space although each stand is dominated by a different species.

Thus the stands in the central ordination space are stands dominated by white oak, chestnut oak and northern red oak. In the peripheral ordination space, stands are dominated by eastern red cedar, black oak, American beech and several floodplain species (e.g., sycamore, green ash and silver maple).

When the successional stands and floodplain stands

are removed from the ordination (Fig. 14) stands dominated by white oak still occupy central ordination space. The peripheral stands of this second ordination are the First Creek Hemlock Stand, Great Onyx Succession and the stands of Salts and Hunts Sinks. This ordination demonstrates the close relationship of the Indian Hill Chestnut Oak forest and the Chicken Prong Hollow Stand to the First Creek Stands. Each of these three stands are located on substrate of Lower Pennsylvanian Age. The Indian Hill Chestnut Oak forest is located on an outlier of the Caseyville Formation south of the Green River while the First Creek Hemlock Stands and the Chicken Prong Hollow Stand are located north of the Green River.

Successional Change and Sub-type Stability

Forests of MCNP have sustained selective cutting or clearing with the possible exceptions being the Big Woods area, a few sinks on the Mammoth Cave Plateau and the very steep slopes in the hollows and ravines where eastern hemlock is found. An examination of size class-density tables (Appendix F) (following the method of Schmelz and Lindsey, 1965) indicates one or two species were selectively removed while the land was in private ownership. Normally a population in which the individuals have an indeterminate life span, will show a log-normal regression slope with respect to age. There is a direct relationship between tree age and dbh so these figures are based on an estimate of tree age using the diameter of the tree.

These data suggest that white oak has been the tree species selectively removed for timber (Fig. 19). Data for Chicken Prong Hollow and other stands indicate that selective cutting occurred earlier north of the Green River than for stands south of the Green River such as Cedar Sink Valley slopes.

During the early 1900's cutting of timber for railroad ties was an important local industry. The log-density plots reflect this selective use of white oak. Although there seems to have been extensive cutting of white oak in MCNP, the present stands reflect the vigor with which this species has re-established itself (Table 9).

Replacement of American chestnut is also of interest in MCNP. The vegetation map by Ellsworth (1936) indicated several slope stands where this species was an important member of the canopy during 1934 and 1935 when his field data were collected.

Today isolated individual stump sprouts are found on several landforms throughout MCNP. The majority of these, however, were observed along Upper Mississippian sandstone outcrops on the slopes of the major solution valleys south of the Green River. The most of these specimens become no larger than 1 inch diameter at the ground and between 3 and 4 m tall. At this stage, before any fruiting material is produced, cankers are present on the main stem and the young trees die.

Crumps Knob has a concentration of chestnut logs,

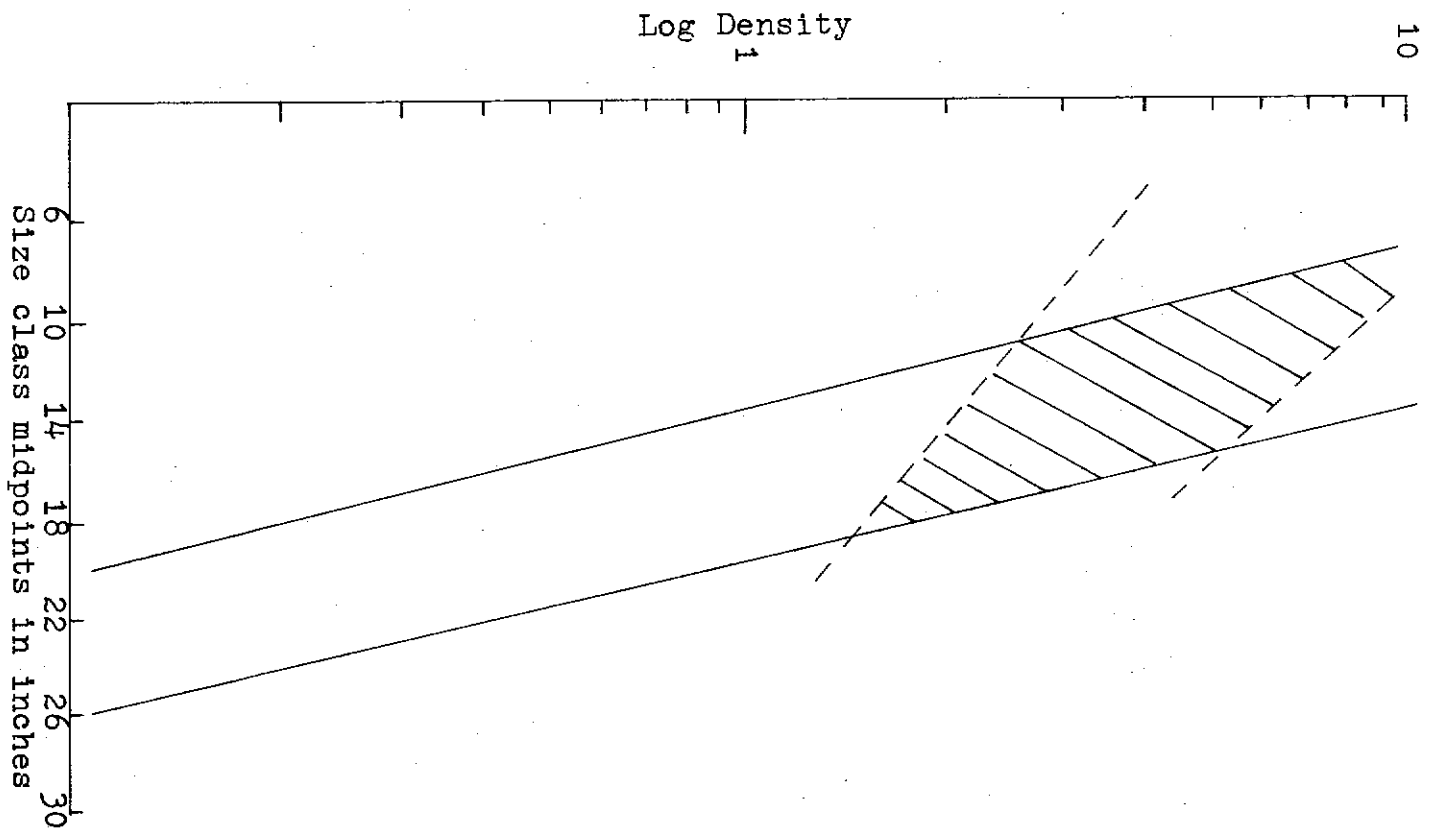


FIGURE 19. A composite log density plot of white oak in all oak-hickory stands indicated in Table 21. The cross hatched area indicates a size class range where there are fewer than expected individuals of this species.

which if included in the stand attributes table, would make this species one of the co-dominants in this stand. The log density data (Table 4E) for this stand does not suggest a replacement species for American chestnut. If chestnut oak is the replacement species, more individuals would be expected in the smaller size classes than are evident in Table 4E.

The age of these upland trees was determined by counting tree rings which were obtained from increment coring. Figure 20 shows growth rates from selected trees growing on sandstone. These indicate that the 6 to 10 inch size classes of white oak are at least 65 years old. Thus, the smaller white oaks were established soon after the selected cutting during the last half of the 19th century. Park records and old American chestnut stumps reflect extensive salvage operations which took place during the chestnut blight (1930's) throughout the Park. However, there was no evidence of a tree ring width increase or "release" following these operations in the trees sampled. Thus, the growth rates and the replacement rates of existing canopy trees indicate that this sub-type has not fully adjusted to the loss of American chestnut.

Succession in other, older stands of MCNP is difficult to evaluate for two reasons: 1) the many individual tracts of land each had different woods management; 2) very few slope forests were clear cut so a continuum of successional stages are not represented.

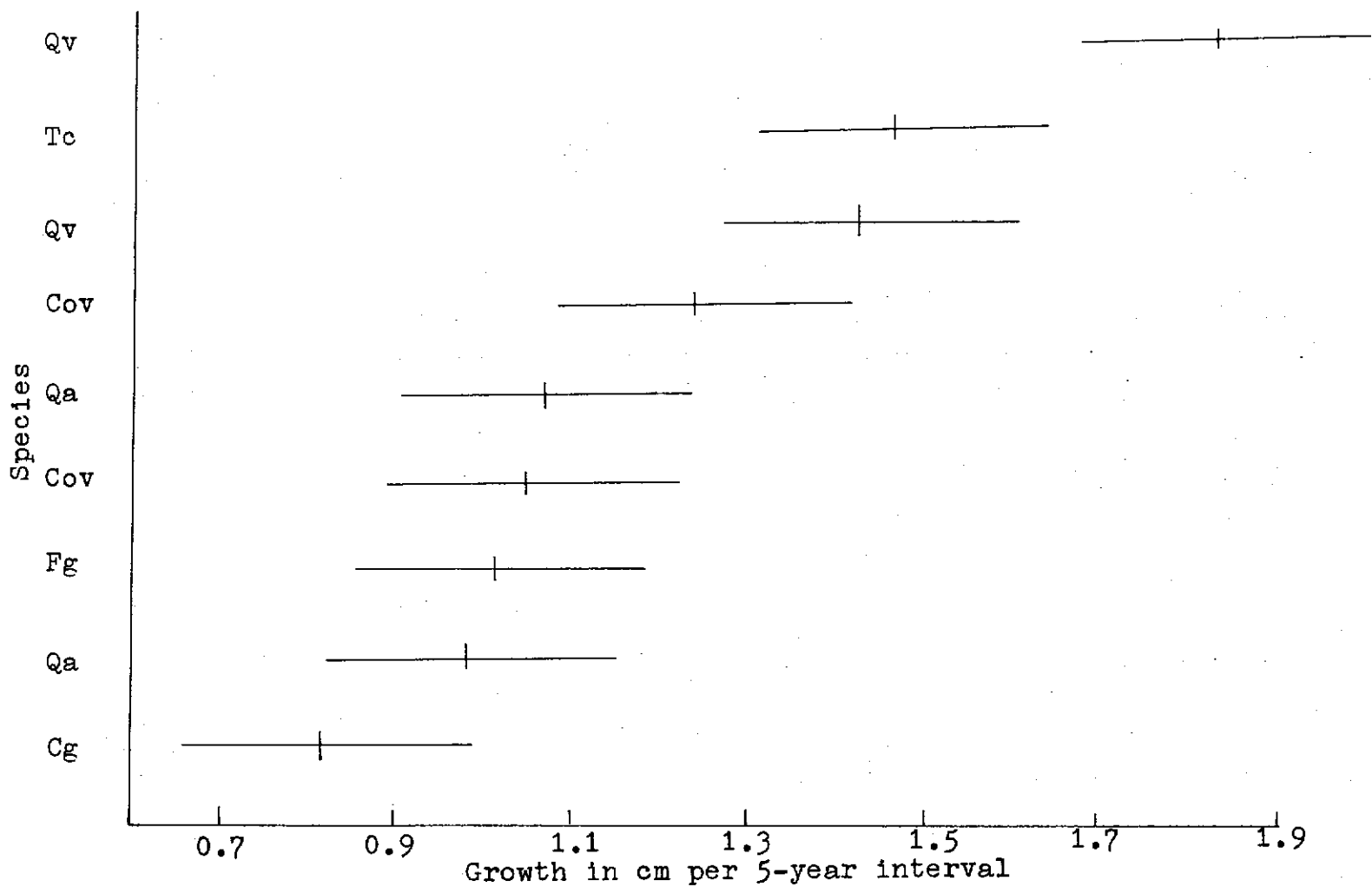


FIGURE 20. Diameter growth rates for selected trees growing on sandstone uplands. The length of the line indicates the 95% confidence interval of the 5 year cumulative growth period.

Similarity Indexes

Four tables of similarity indexes used to calculate the positions of the 38 forest stands in ordination space were prepared (Tables 24, 25, 26, and 27). These four tables have the stands grouped by the generalized classification of mixed woods, floodplains, upland woods and successional stands. This grouping of the stands illustrates best the stands which are most similar or dissimilar within these general groups. Several stands had no species in common with some of the remaining stands (e.g., the floodplain stands with the successional stands).

Similarity ranged from a high of 0.79 to a low of 0.11 among the mixed woods. Indian Hill and Green River Limestone Slopes stands were the least similar to the rest of the stands in the mixed woods group. These stands occur on different substrates, although both are located on south-facing slopes. The Indian Hill stand is located on an outlier of Pennsylvanian sandstone at the western extreme of the Park while the Green River Limestone Slopes stand is located on Mississippian limestone between Bruce Hollow (the New Ferry Road) and the Historic Entrance Hollow. Wilson Cave Hollow, Mammoth Cave New Ferry and Hunts Sink have similarities above 0.55 indicating similar species structure in these separated stands. Wilson Cave Hollow has high

TABLE 24. A matrix table of mixed woods similarity co-efficients used to compile the ordinations in Figures 13 and 14.

Stand	BH	BWS	BWR	CSV	CPH	CK	DPH	DVS	HSF	HSS	IH	MCNF	SSF	SCN	TB	WP	WCH	GRV
BH	1	0.42	0.46	0.26	0.45	0.48	0.48	0.17	0.49	0.33	0.23	0.40	0.32	0.44	0.50	0.61	0.51	0.27
BWS		1	0.67	0.55	0.37	0.52	0.64	0.36	0.48	0.43	0.32	0.35	0.49	0.59	0.52	0.22	0.63	0.37
BWR			1	0.46	0.38	0.46	0.59	0.25	0.38	0.32	0.30	0.31	0.43	0.54	0.35	0.30	0.49	0.22
CSV				1	0.31	0.39	0.56	0.53	0.47	0.36	0.27	0.35	0.43	0.55	0.33	0.18	0.48	0.33
CPH					1	0.53	0.46	0.22	0.42	0.31	0.63	0.40	0.29	0.41	0.46	0.39	0.51	0.31
CK						1	0.50	0.31	0.49	0.41	0.37	0.36	0.39	0.53	0.49	0.27	0.61	0.40
DPH							1	0.30	0.50	0.53	0.27	0.45	0.47	0.64	0.49	0.42	0.65	0.25
DVS								1	0.36	0.46	0.17	0.26	0.37	0.38	0.21	0.12	0.36	0.33
HSF									1	0.52	0.27	0.55	0.40	0.48	0.61	0.30	0.53	0.32
HSS										1	0.11	0.43	0.53	0.62	0.53	0.35	0.63	0.18
IH											1	0.16	0.16	0.26	0.25	0.12	0.24	0.26
MCNF												1	0.37	0.49	0.54	0.49	0.52	0.21
SSF													1	0.66	0.37	0.19	0.61	0.24
SCN														1	0.48	0.30	0.79	0.23
TB															1	0.42	0.61	0.38
WP																1	0.38	0.16
WCH																	1	0.29
GRV																		1

n = 153; x = 0.403; sd = 0.136

TABLE 25. A matrix table of floodplain stands similarity co-efficients used to compile the ordinations in Figures 13 and 14.

Stand	BI	MFF	NFF	SCI
BI	1	0.23	0.19	0.21
MFF		1	0.56	0.32
NFF			1	0.41
SCI				1

$n = 6$; $\bar{x} = 0.32$; $sd = 0.143$

TABLE 26. A matrix table of old field succession similarity co-efficients used to compile the ordinations in Figures 13 and 14.

Stand	CSV	HCBK	JROF	MCOF	UP
CSV	1	0.17	0.79	0.80	0.31
HCBK		1	0.20	0.22	0.68
JROF			1	0.85	0.38
MCOF				1	0.41
UP					1

$n = 10$; $\bar{x} = 0.48$; $sd = 0.27$

TABLE 27. A matrix table of upland forest stand similarity co-efficients used to compile the ordinations in Figures 13 and 14.

Stand	BWU	GSC	GOS	JRMR	LR	SSC	SVW
BWU	1	0.62	0.34	0.56	0.59	0.45	0.54
GSC		1	0.28	0.39	0.58	0.31	0.42
GOS			1	0.36	0.38	0.29	0.38
JRMR				1	0.67	0.38	0.53
LR					1	0.41	0.60
SSC						1	0.51
SVW							1

$n = 21$; $\bar{x} = 0.457$; $sd = 0.12$

similarity co-efficients with many of the mixed woods stands. Conspicuous exceptions are the Indian Hill, Doyel Valley Slopes, and Wet Prong stands which occur on different substrates or landforms. Chicken Prong Hollow and Indian Hill are the most similar to each other indicating species similarities although the stands are located on opposite sides of the Green River.

The floodplain stands (Table 25) had the lowest average similarity co-efficient of the generalized stand groupings. The two floodplain stands located most closely together show the greatest similarity (New Ferry Floodplain and Mammoth Ferry Floodplain). The two island floodplain stands have less similarity to the shore floodplain stands than would be first expected. The periodic flooding and clearing of the island vegetation by floating snags and debris may account for this lack of similarity although the substrates are similar. The mean similarity in this small sample is 0.32 while for the mixed woods it is 0.40. In addition the standard deviation is less for the mixed woods stands than the floodplain stands indicating less variability although more tree species are involved. This indicates that the floodplain stands are normally more variable than they would appear at first examination.

Old field successional stands (Table 26) illustrate the contrast between old field areas which were stocked soon after the establishment of the Park and areas which were left alone to stock naturally. Hickory Cabin-Brooks Knob

and two of the plots included in Upland Stands are in areas where Virginia pine was planted to hasten forest canopy closure and increase protection for the residual soils. The remaining stands have been left alone, without forest management and have remarkable similarity (Joppa Ridge and Mammoth Cave Old Field have a similarity index of 0.85).

Table 27 presents similarity data for upland forest stands. The Great Onyx Successional stand, although it has canopy closure and young thrifty stems, is very much different from the remaining stands. In contrast the ridge/upland stands (Big Woods Upland, Joppa Ridge/Mammoth Ridge, and Lee Ridge) have similar values of similarity. It appears from these data and the stand table data that the Great Onyx stand is less mature and was a more greatly altered stand prior to Park establishment compared with the other stands in this group.

Mature Forests

Mixed Woods. The mixed woods of MCNP are characterized by several species sharing dominance. Indicator species of this forest type are northern red oak, white oak, tuliptree, sugar maple, red maple and formerly American chestnut. Densities of stands ranged from 250 trees per acre in one of the younger stands of the type to 90 trees per acre in Hunts Sink. Basal area per acre ranged in 20 stands sampled from 85 ft² per acre in Deer Park Hollow to 140 ft² in a section of Hunts Sink stand. These forests

are impressive with large stems and reaching heights approaching 125 feet. In Hunts Sink one tuliptree measured an incredible 180 feet tall.

Three stands with associated data are discussed as typical of the Mixed Woods. These stands are Salts Sink, Hunts Sink, and Crumps Knob. In the bottom of Hunts Sink (Fig. 21) spicebush is the principal cover. In a rather narrow band at the limestone outcrop just above the spicebush, sycamore and hackberry are found. Large tuliptrees and red maples (associated with a small creek) are dominant. In the saddle at the north side and on the southwest side of Hunts Sink a band of northern red oak and sugar maple contribute most of the basal area. Above these mesic bands white oak and pignut hickory are the important species. There are also snags and logs of American chestnut along this upper band. In the saddle, above the northern red oak-sugar maple band, black oak is common. On the plateau surrounding Hunts Sink, where it was not cleared for agriculture, bitternut hickory, mockernut hickory and white oak are the three most important species.

In Salts Sink (Fig. 22) a similar pattern occurs, although the sink itself is only about one-seventh the size of Hunts Sink and has fewer tree species. At the bottom and on the north slope large tuliptrees are common. On the south side of the sink northern red oak and white oak are the most important trees. White oak is the sole canopy species on the southeast slopes of the

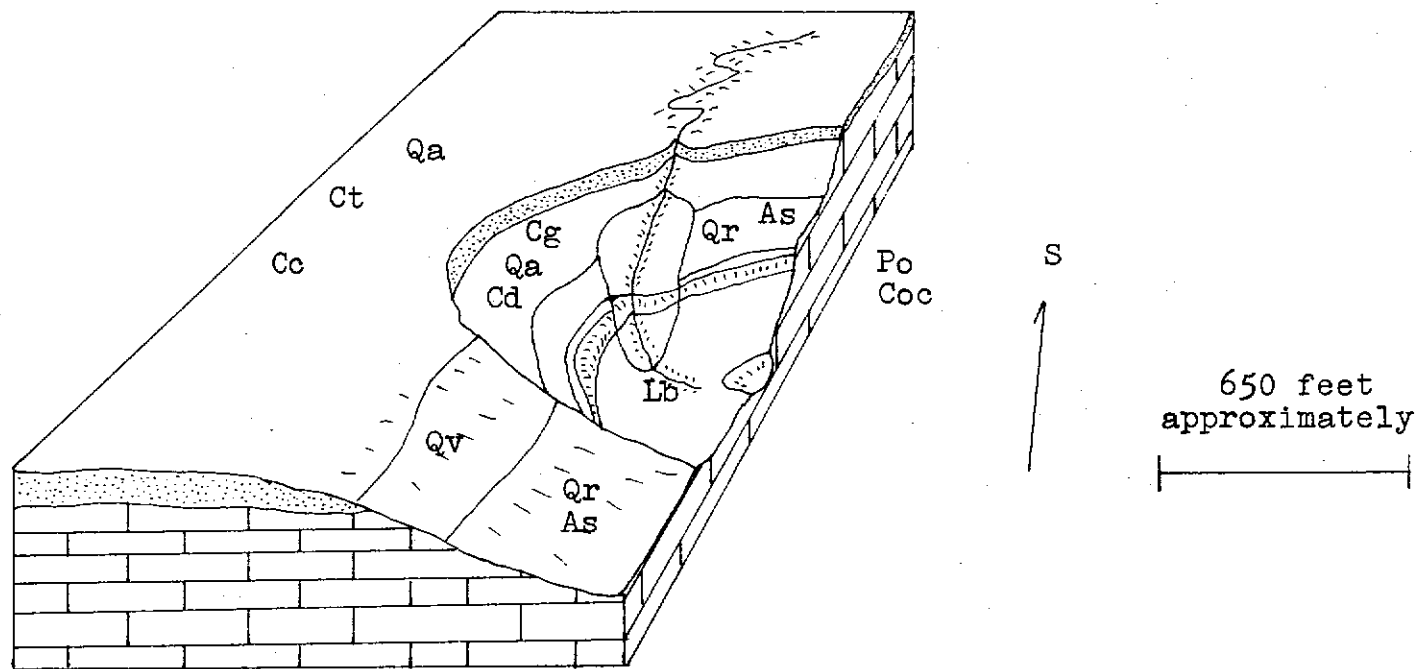


FIGURE 21. A block diagram of Hunts Sink, Mammoth Cave National Park, Kentucky illustrating the principal forest dominants related to elevation, aspect and sub-strate. Symbols follow Table 1H.

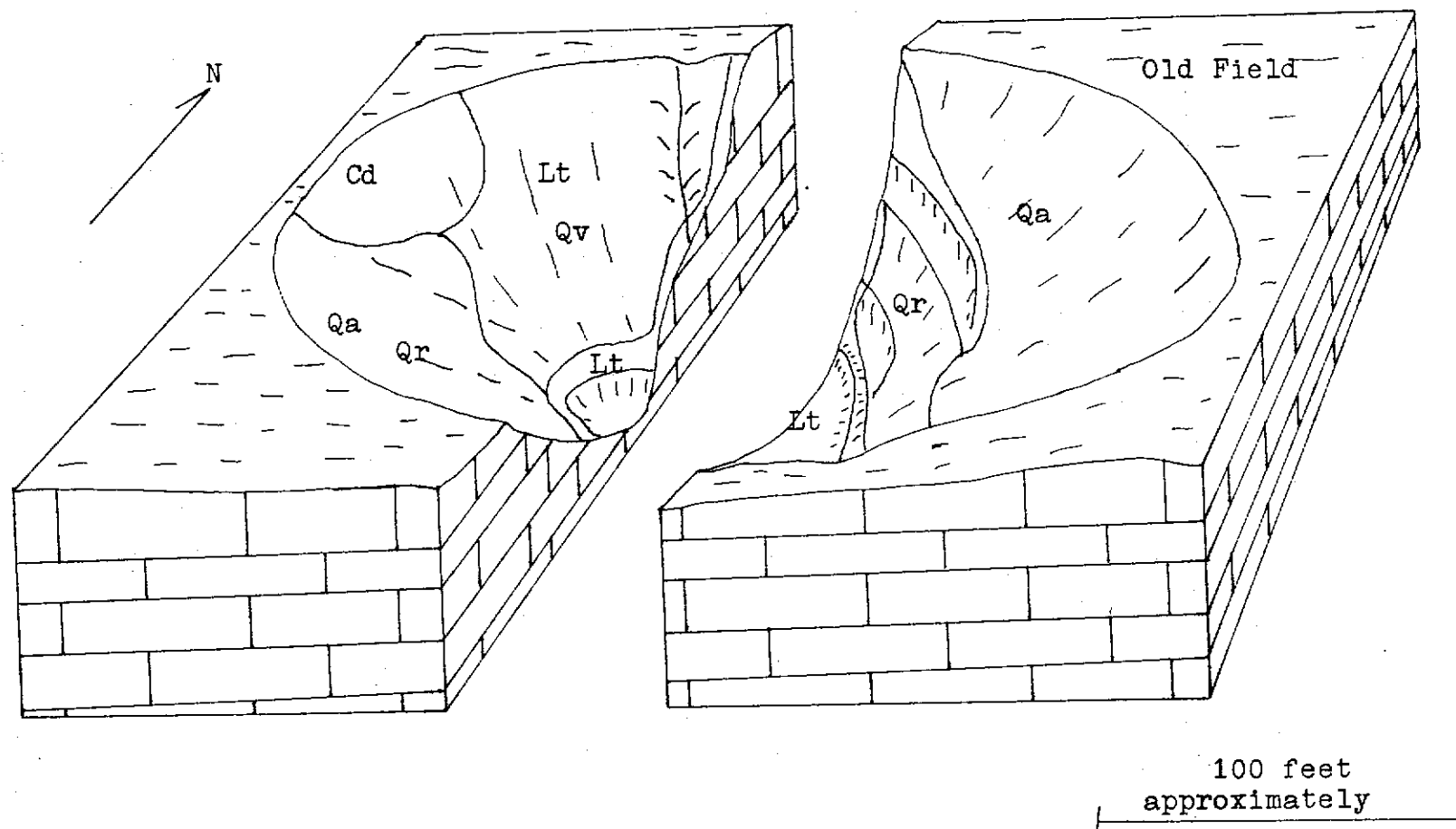


FIGURE 22. A block diagram of Salts Sink, Mammoth Cave National Park, Kentucky illustrating the principal forest dominants related to elevation, aspect and substrate. Symbols follow Table 1H.

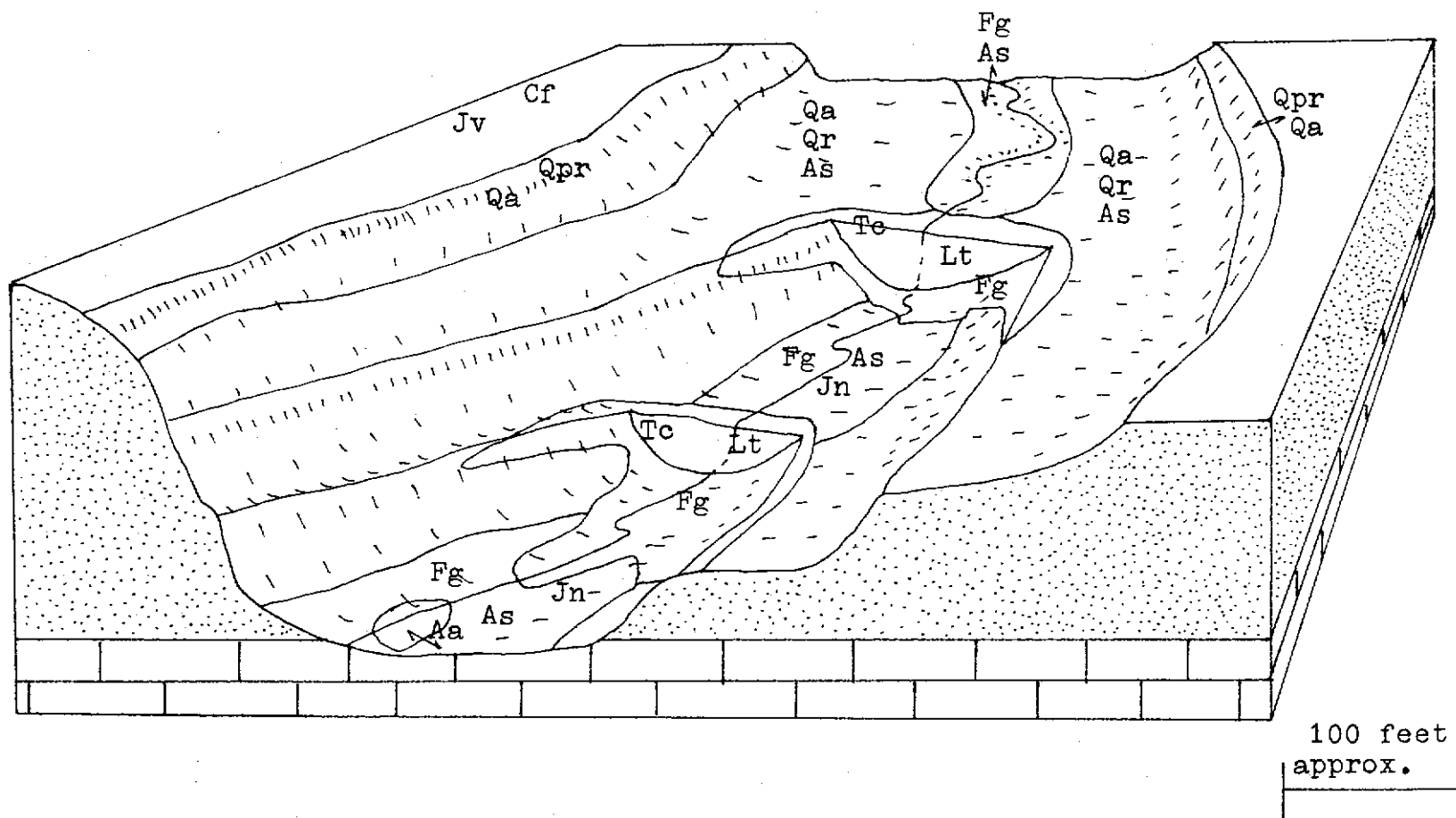


FIGURE 24. A block diagram of the sheltered coves of Mammoth Cave National Park, Kentucky illustrating the principal forest dominants related to elevation, aspect and substrate. Symbols follow Table 1H.

sink. There are also many snags of American chestnut on the west slope.

These two stands represent forest stands of intermediate composition between the more xeric forests and the more hydric forests of this association. The stand table (Table 9D) for Hunts Sink shows high Importance Values for black oak, white oak and tuliptree. The stand table (Table 15D) for Salts Sink shows tuliptree, white oak and northern red oak as the three leading species.

In contrast with stands associated with this intermediate grouping of species, Crumps Knob (Fig. 23) serves as an example of a more xeric array of tree species. This stand (Table 6D) is dominated by white oak, pignut hickory and chestnut oak. Crumps Knob is physiographically an outlier of the Western Coalfield Province lying south of the Green River. The flat upper plateau of Crumps Knob is underlain by Pennsylvanian sandstone. On this surface chestnut oak, snags of American chestnut and white oak completely dominate the forest community. Along the sandstone cliffs surrounding this upper plateau, northern red oak and red maple are important forest components. On the north-facing slopes and in small ravines a forest occurs which is closely related to the hemlock-beech-tuliptree segregate of the mixed mesophytic forest described by Braun (1950). In this community mountain laurel (Kalmia latifolia L.) and cucumber magnolia (Magnolia acuminata L.) are present in the shrub layers, and large tuliptrees and

American beech are common canopy species. Hemlock is absent from this forest community. Further down the slope, in the area underlain by limestone, white oak, black oak and pignut hickory are the important species. On the extensive limestone plateaus surrounding these outliers an eastern red cedar and black oak forest occupies much of the land formerly in agriculture.

Stands similar to Crumps Knob occur throughout the Park on Pennsylvanian sandstone substrate. Stands which include chestnut oak as an important component are: 1) Indian Hill Chestnut Oak Forest; 2) Hemlock Stands First Creek; and 3) Chicken Prong Hollow. Additional areas where this type of forest is found include Brooks Knob, and the sandstone plateaus between First, Second and Bylew Creeks.

These two sub-types (intermediate and xeric) of the Mixed Woods are still undergoing adjustment due to the chestnut blight which eliminated the American chestnut as a forest species during the 1930's in MCNP. This tree was an important member of these sub-types, and the sudden loss of canopy trees has allowed light intolerant tree species to increase in importance. In Hunts Sink the basal area of the chestnut logs on the ground exceeded all but two of the present living species. In addition, shrub-sized chestnut is common along the sandstone outcrops of the valleys and sinks in the Park.

The mesic stands of the Mixed Woods Association are found in the tributary valleys to the solution valleys

south of the Green River, and in the tributary valleys to the Green River north of the Green River. Two examples of this sub-type are Big Hollow and Big Woods. Both stands have American beech, tuliptree and white oak as the leading dominants. A third area where large American beech occur is in the north trending drainage from Sloans Crossing Turnout (Fig. 25).

While limited information is available to assess the pre-settlement forests in this region, the present day forests must be considered as modified versions of these old forests. Most of the slopes were never cleared for agriculture and have been in continuous forest. The principal disturbances include grazing farm animals before stock laws went into effect about 1920, and a limited forest products industry (white oak railroad ties) in the region before the National Park was established. After the Park was established, chestnut blight has been the principal cause of change in these sub-types of the Mixed Woods Association.

Beech, Tuliptree, Hemlock Sub-type. This relict Tertiary forest is confined to the sandstone hollows and cliffs associated with the upstream end of small water courses originating in Caseyville Sandstone of early Pennsylvanian (Pottsville) age. These areas offer much in the way of spectacular scenery, with tunnels in sandstone common, hanging gardens of vascular cryptograms and a pleasant coolness in the heat of summer (Fig. 26).



FIGURE 25. An area dominated by large American beech and tuliptree in the north trending drainage from Sloans Crossing



FIGURE 26. Hemlock-beech-tuliptree segregate of the Western Mesophytic Association

Problems in sampling these units result from the rugged topography and the isolation of mapping units which occupy a limited area. Each mapping unit is disjunct from another at the present time, appearing to be restricted by physiography and moisture availability. For this reason, the forest data were grouped into a single stand table (Table 22D).

Braun (1950) in her discussion of disjunct occurrences of species and communities (p. 484) describes the type of forest found in Wet Prong, First Creek, Second Creek, and Nolin River drainages in the northwest sections of the Park. Eastern white pine has been observed in MCNP according to Davies (1954) but Braun (1942) did not report it from any of the three counties in which the Park is located. I did not locate this species and a voucher specimen is not present in the Davies Herbarium at the University of Louisville.

Eastern hemlock is restricted to a band of sandstone (Fig. 24) near the "break" in the stream bed. Yellow birch is also common along the cliffs. Below the change in stream gradient magnolia (Magnolia acuminata and M. tripetala), American holly and large American beech are present. On the sandstone cliff wall herbaceous members of the community are present, including Tiarella cordifolia, Mitella diphylla and numerous Bryophytes. Additional herbaceous species include Iris cristata, and several

species from the family Orchidaceae including Goodyera pubescens which was found in no other association in the Park.

Two tree species of this association are of special interest. Sweetgum is frequently found in low density. Its presence emphasizes the relationship of this association to southern elements, and a part of the formerly more extensive Tertiary forest. The floristic affinities of other groups also support the contention that this association in MCNP represents an Appalachian outlier rather than a relict forest of Quaternary climatic effects in southern Kentucky. The second species, introduced into the area, the tree-of-Heaven (Ailanthus altissima (Mill.) Swingle), was found along Wet Prong just downstream from the area dominated by this association. In the hollows of Hill 759 northwest of Indian Hill at the western extreme of the Park a tree-of-Heaven 18 inches in diameter was located among a stand of several individuals.

American holly attains small tree size (3-5 inches dbh) in this association. It is also frequently seen invading old fields adjacent to the stream drainages. Magnolia tripetala and M. acuminata both occur as characteristic species.

The composite stand table (Table 22D) indicates that eastern hemlock and American beech contribute 35% of the Importance Value while chestnut oak contributes 18% in this sub-type of the Mixed Woods Association. The existence of

species at opposite extremes of a moisture spectrum in close proximity to one another is interesting. Figure 24 illustrates the banding of species characteristic of this sub-type. The presence of chestnut oak is limited to the well-drained uppermost level of sandstone in these hemlock areas. Frequently the areal extent of the individual beech-hemlock-tuliptree stand was less than 5 acres. This meant that sampling for basal area and species composition in these stands was difficult. In addition the variable radius sampling method often extends a "plot" beyond the restricted area of the hemlock.

Pteridophytes are numerous and several new species recently have been reported by Dr. Kenneth Nicely of Western Kentucky University.

Table 12E suggests that the hemlock areas have had relatively little disturbance within the life span of the large individual trees of these stands. High densities of smaller sugar maples indicate that maple will likely increase to the fourth most important species of this sub-type.

No seral stages of the beech, tuliptree, hemlock segregate of the Mixed Woods Association were identified. This sub-type has abrupt lines of demarcation from the other forest communities on the basis of species present and physiography so that it probably was not cut very extensively by the land owners of this region. However, this sub-type represents the most fragile forest of the

Mixed Woods Association in terms of its easy loss or disturbance by excessive visitation because of its limited areal extent in MCNP.

A community related to the relict Tertiary forest is present on Crumps and Brooks Knob south of the Green River. Both of these communities have several specimens of magnolia (Magnolia acuminata) as components of the canopy, however, eastern hemlock is absent as an arborescent species.

Floodplain Forest. The Green River, flowing from east to west through the Park with a normal pool level of 421 feet above sea level, bisects the floodplain forest. The river is backed up from behind Lock 6 Dam near Brownsville to Cave Island, a distance of 16 miles. Above this point to the eastern Park boundary at Tom Jones Crossing the river is free flowing. The Nolin River, a major tributary of the Green River, enters the Green about 1.5 miles downstream from Houchin Ferry, after flowing through the northwest corner of the Park for 5 miles. Associated with the floodplains of these rivers are well developed bottoms and terraces. The bottoms, behind a natural levee, are subject to annual flooding while the terraces are rarely flooded. On the larger floodplains, as at Turnhole Bend, old channels are evident with thicker lenses of clay in the upstream end of these old channels. In the bottoms small sinks are lined with alluvial deposits. These bottoms and terraces were intensively farmed before the Park was established.

Several large islands also support vegetation of the floodplain forest. The formation of these islands is related to riffles (or rapids) at their downstream end. First flood debris, then gravels and silts collect headward from the downstream riffle area. Headward erosion of the riffles would cause the island to be cut back at the downstream end while the upstream end is in the process of accumulating material carried by the river. Thus in the Green River, as it passes through the Park the islands would appear, in geologic time, to be moving upstream. This is in contrast to the islands in rivers which flow on glacial outwash material where bedrock is not exposed in the streambed (Lindsey et al. 1961). The relative stability of the Green River Islands is further emphasized by the nearly total absence of willow and cottonwood which are considered members of the earliest tree stratum on periodically inundated areas (Braun 1950, Hosner and Minckler 1963, Lindsey et al. 1961).

Each stand sampled was dominated by a different tree species and the degree of similarity between stands was low (Table 25). This variety in the floodplain stands is due to small variations in terrain elevation above the major rivers. The Mammoth Ferry floodplain (MFF) stand contained 16 species, including several species typical of more mesic forests (e.g., tuliptree, sugar maple and American beech). It has an elevational range in the sampled area of up to 20 feet above river pool level. Sand Dave Island (SCI), on

the other hand with two species contributing 90% of the importance value is flooded annually and is only 5-8 feet above river pool level at its highest point. Fast moving flood waters, often carrying large trees, are a powerful force in limiting the development of a complex forest community on the larger Green River Islands. The spring flood of 1974 (approximately 40 feet above pool level) was high enough to virtually eliminate the floodplain forest which had developed on Cave Island near the Mammoth Ferry floodplain stand. The forest along the shore was unchanged by this particular flood.

Woody reproduction is limited in areas which have a closed canopy. In addition, native cane, Johnson grass (Sorghum halepense (L.) Pers.), winged stem and ironweed are typical tall plants in the herb layer which further reduce light intensity at ground level.

In the parts of the floodplain which were cleared for agriculture the trees rarely exceed 18 inches dbh. However, in the Dennison Ferry area several sycamores with diameters in excess of 60 inches were measured, while one tree had a diameter of 73 inches. Figure 27 illustrates the rapid growth of floodplain trees. Tuliptrees are the most rapidly growing species, followed by black walnut, slippery elm and silver maple. The most rapidly growing tuliptree cored averaged just over 4 cm growth diameter per 5-year period of its total life span of 36 years.

There are two distinct successional communities. One

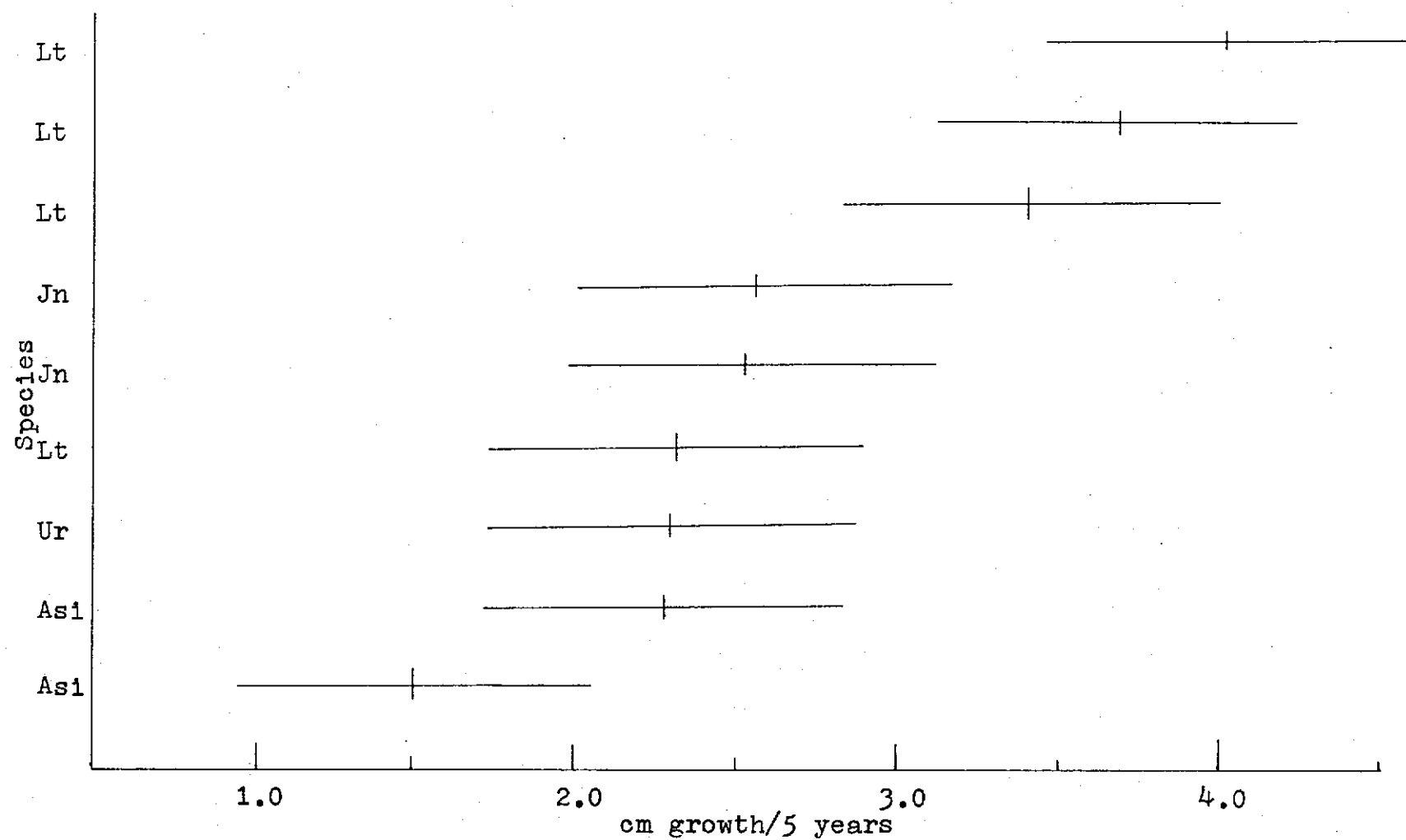


FIGURE 27. Confidence intervals (95% level) for tree ring growth of selected trees growing on the Green River floodplain. The species symbols are found in Table 1H.

is the community which is subject to annual flooding which represents an edaphic, physiographically controlled climax. This sub-type is dominated by sycamore and silver maple and is best developed along the levee and lower bottoms. Winged stem is an important herb in this sub-type.

The second community is found on somewhat higher sites. At present there are a few individuals of more mesic species but should the frequency or height of flooding continue to decrease, continued change in composition can be expected (Fig.28).

Upland Woods. Mature seral stages of the upland woods occupy a limited area in MCNP. The largest area, and perhaps the least modified stand, is on the level Pennsylvanian aged substrate in the Big Woods section of the Park. This stand (BWU) (Table 27D) is dominated by oaks (IV 49.90) and hickories (IV 30). South of the Green River the stand sampled on Lee Ridge in part of the original Mammoth Cave Tract (Table 32D) had four oak species and two hickory species contributing 51.8 IV and 17.4 IV, respectively. The Joppa Ridge, Mammoth Ridge stand (JRMR) is also similar to these typical stands with five oak species and a hickory species contributing 57.1 IV and 13 IV.

The similarity range for these three mature upland woods stands is between 0.56 and 0.67. In the less similar stands of this group (Sloans Crossing South, SCS, Good Spring Church, GSC, and others) dominant or sub-dominant

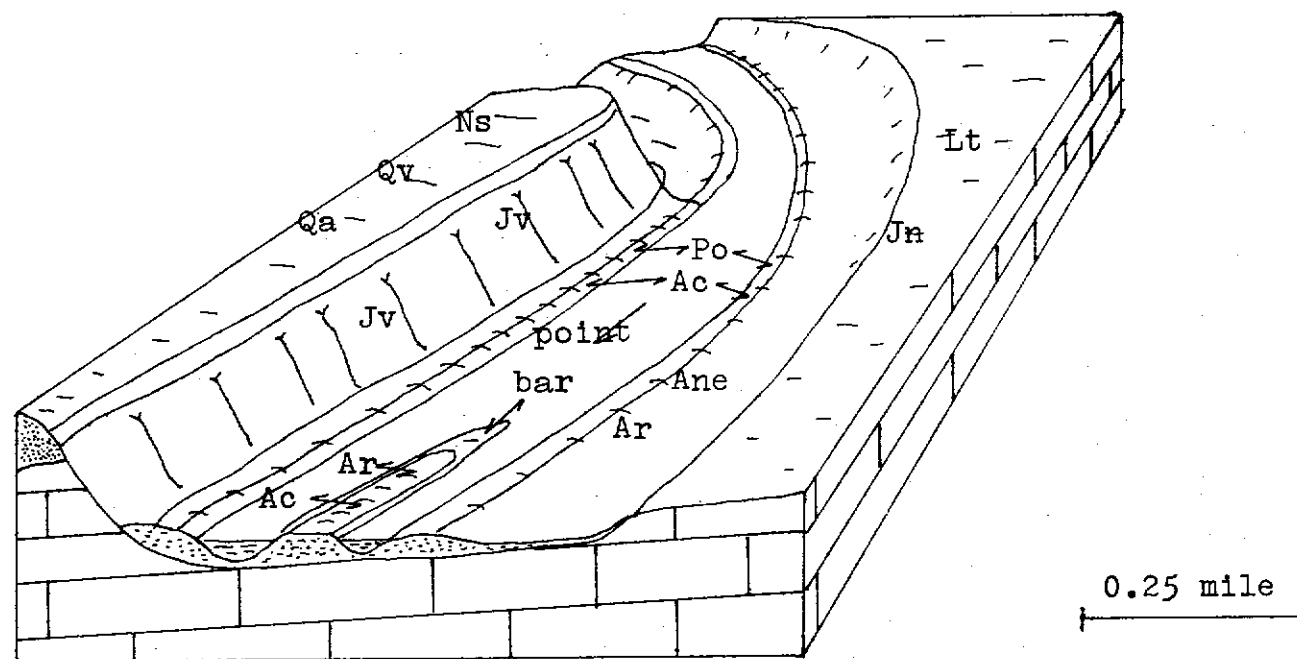


FIGURE 28. A block diagram of a major floodplain in Mammoth Cave National Park, Kentucky illustrating dominant tree species in relation to elevation, aspect and topography.

tree species included black gum, tuliptree and sourwood. These trees are among the first deciduous woody species to become important in the successional stages of the upland woods.

One area in MCNP (unsampled but visited) appeared to be similar to the "extremely xerophytic (an oak-hickory variant) community of rocky limestone slopes (in) the Ozarks" described by Braun (1950, p. 170). This area is located along the fire road leading to the east Park boundary from the Dennison Ferry Road a short distance above the Green River. Eastern red cedar was the dominant tree in this area, but oaks, dogwood and blackgum were also common on these thin soils.

Figure 29 shows the relationship of seven tree species in early, mid and late seral stages. Eastern red cedar is the earliest invader to reach tree size with American ash, black gum and tuliptree just beginning to appear. Eastern red cedar persists as a component of the tree stratum for a short period although it consistently appears in the herb stratum in each seral stage. By mid-seral stages eastern red cedar is not present as a part of the tree stratum in most locations while tuliptree has increased its importance. The late upland seral stages are dominated by black oak, northern red oak and white oak.

The physiognomy of these woods is less impressive than the mixed woods. Indeed, it may be this observation

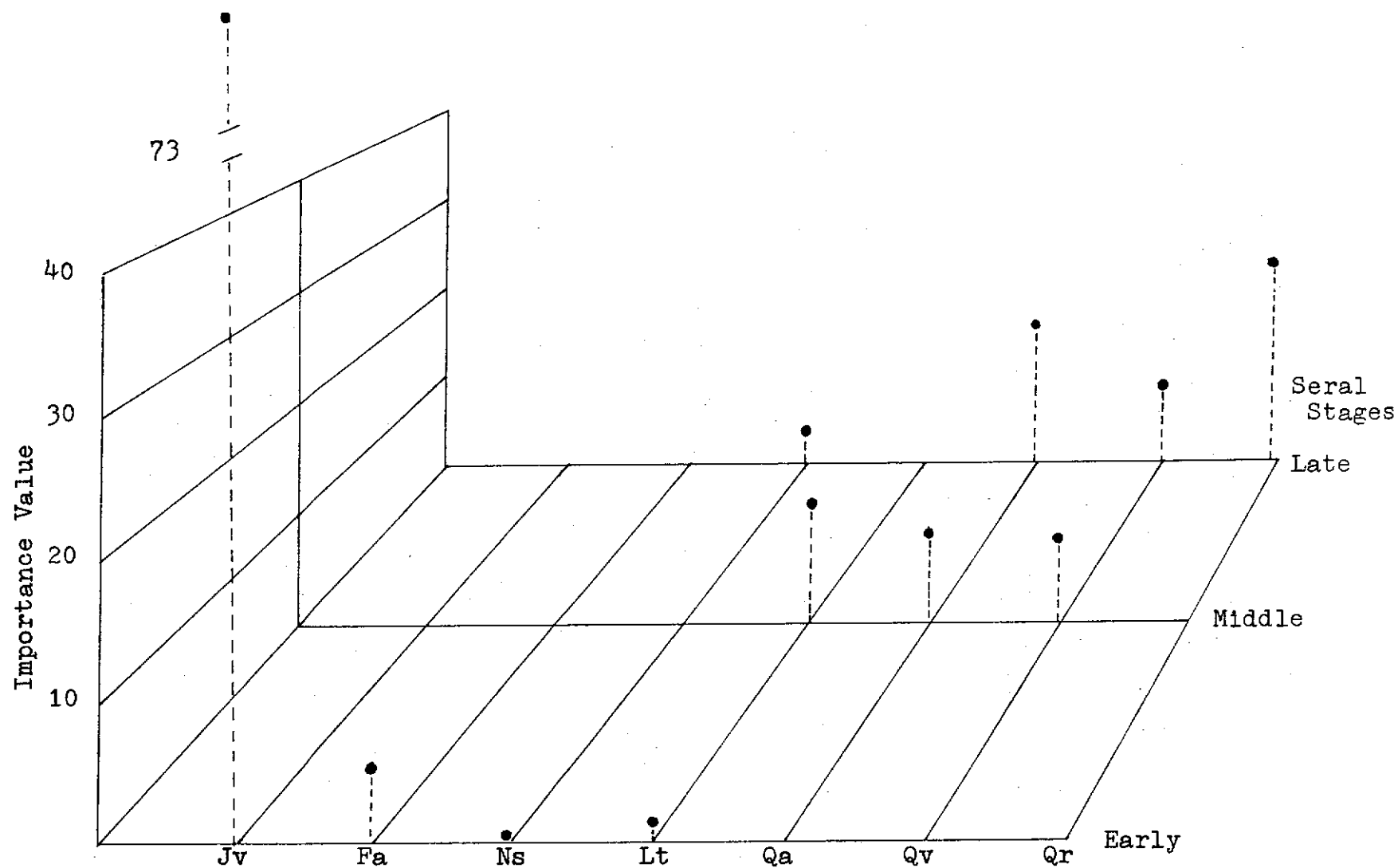


FIGURE 29. Successional relationships of seven tree species on the uplands of Mammoth Cave National Park, Kentucky. Species symbols are found in Table 1H.

which has led observers to suggest that these woods are relatively early representatives of successional stages. The canopy is approximately 80 to 90 feet high with the maximum diameter for trees approximately 24 inches dbh. Increment cores from larger trees (Fig. 30) growing on the plateau show from 60 to 100 rings. These trees grow at approximately one-half the rate of the floodplain trees.

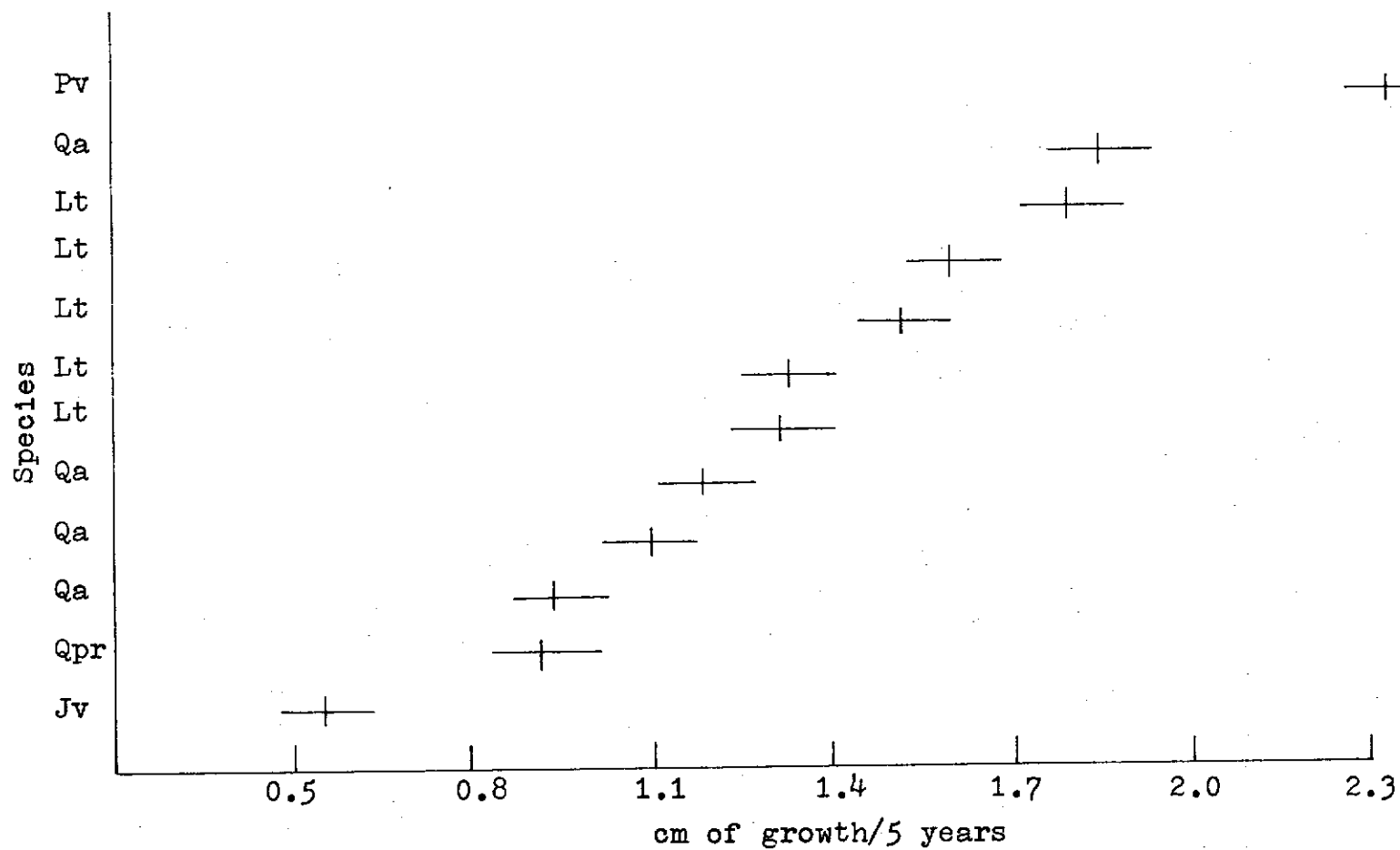


FIGURE 30. Confidence intervals (95% level) for tree ring growth of selected trees growing in upland woods. The species symbols are found in Table 1H.

Vegetation Maps and Analysis

Introduction

Seven major mapping units were used in the preparation of the MCNP vegetation maps (Appendix F). These major units were further divided into subunits characteristic of successional types on particular land forms (Plates 1-4). Appendix F is a key to air photo interpretation of the forest mapping units of south-central Kentucky with applicability throughout the Mississippian Plateaus and Western Coalfield.

Analysis

The most outstanding feature of the vegetation maps is the dominant relationship of topography to stand maturity. Large scale forest mapping units occurring on flat uplands or in solution valleys are rare. Cub Run Quadrangle Map (Plate 2) provides the most notable exception in the Big Woods area where approximately 400 acres of land were not clear cut for agriculture prior to the establishment of the Park. A second area where mature forests are evident is on the Mammoth Cave Quadrangle Map (Plate 3) in the original 500 acre Mammoth Cave Tract. Today this tract supports the majority of the visitor facilities in the Park but excellent examples of mixed woods vegetation remain.

The Mammoth Cave Quadrangle Map includes the largest percentage of the Park area. Other areas which are mapped

as mature mixed woods on this map are the major hollows north of the Green River (Wilson Cave Hollow, Big Hollow and Ugly Creek). South of the Green River solution topography dominates the mapping units with successional stages occurring throughout the former small farm tracts outside of the original Mammoth Cave Tract.

The Rhoda Quadrangle Map (Plate 4) and the Brownville Quadrangle Map (Plate 1) are dominated by forests mapped as part of the Mixed Woods occurring in the hollows or outliers of Pennsylvanian sandstone. Both of these plates have limited successional mapping units although bands of successional floodplain forests are evident. West of Turnhole Bend and south of the Green River a mosaic of successional and forest vegetation types occurs, controlled by landform and prior land use. Several areas of reforestation are evident north of Green River on the Rhoda Map where Virginia pine was planted as a conservation measure during the early years of USNPS administration (Ellsworth, 1936).

The small areas of hemlock dominated forests occur but were too small to be accurately mapped on Plates 1 and 4 or to be interpreted from the panchromatic photographs.

Soon after the Park was established Ellsworth (1936) prepared a vegetation map at 1:31,000 scale (approximately). He used on-site inspection techniques and surveyed individual mapping units (personal communication). A comparison of his map with the ones prepared during this

study indicates that the majority of the areas termed "non-re-stocking" in 1936 are still upland successional stands today. The "re-stocking" areas were areas where Virginia pine was planted (as noted above). Limited areas of American chestnut (Castanea dentata (Marsh.) Borkh.) were also mapped by Ellsworth along the slopes above the solution valleys south of the Green River. Today almost all of the chestnut has fallen to the ground with only a few shrub sized individuals still occurring in these areas.

DISCUSSION

The vegetation patterns of MCNP reflect the effects of human activity in the area. Each of the over 500 small units which were purchased by various governmental agencies had a different resource management before they were included in the National Park. Although the area is considered forested on the present day topographic maps (a change from the USGS map issues of the 1950's), forest composition has been altered extensively from the original vegetation. Records of the original vegetation do not appear to exist so reconstruction of the original vegetation and an interpretation of forest recovery rates must be based on contemporary data.

The general forest recovery in the Park is proceeding at different rates dependent on the substrate and type of prior management. The slowest recovery is on the abandoned farmlands of the Mammoth Cave Plateau and the Western Coalfield. The old field communities (Cedar Sink Valley Old Field, CSVO; Joppa Ridge Old Field, JROF; Mammoth Ridge Old Field, MROF) are located, in a cluster, some distance from the central core of stands in the two-dimensional ordination (Fig. 13). The average basal area per acre for these oldfield communities is 38.5 ft^2 which is well below the average basal area for the stands in the central core of ordination space. The area sampled

on Hickory Cabin and Brooks Knob (HCBK) which was restocked with Virginia pine when the Park was established (Ellsworth, 1936), has a basal area of 72.8 ft^2 per acre. Virginia pine contributed 69 percent and only 6 percent is contributed by eastern red cedar. Thus the re-stocking program with woody species which are not a major component of the native forest seems to: 1) accelerate the accumulation of biomass in the community and 2) retard recovery toward the deciduous forest typical of the region. The floodplains along the Green and Nolin Rivers were also intensively farmed. However, along this physiographic unit recovery has been rapid with a thrifty forest present 35 to 40 years after abandonment. The placement of the four floodplain areas into ordination space (Fig. 13) reflects the possible successional development of this forest. The Mammoth Ferry Floodplain Stand (MFF) is located in a section of the Mammoth Cave Tract and is an example of a late successional floodplain forest. The New Ferry Floodplain (NFF) and Boardcut Island (BI) stands are examples of less mature floodplain forests and lack the mesic species found in the Mammoth Ferry stand.

The slopes and hollows were apparently never completely deforested although some areas had more extensive selective cutting than others. Many of these stands now show an unusually high IV for tuliptree, which may be explained by the selective removal of valuable timber species in these areas (areas with tuliptree IV

over 10 include Big Hollow, Big Woods, Deer Park Hollow south slope of Hunts Sink, Salts Sink and Sloans Crossing North).

A summary successional diagram (Table 28) illustrates the probable sequence of dominant vegetation on the land forms of MCNP. Several points are illustrated:

- 1) There is a lack of successional data for the slopes;
- 2) A variety of plant species plays a role in the recovery of a forest vegetation in the Park;
- 3) The final hypothetical vegetation is a complex in which several woody genera may be important;
- 4) A "feedback loop" to illustrate secondary succession and the unusually high values for tuliptree in the slope communities is implied;
- 5) The planted stages may be by-passed on some substrates which were not restocked after the National Park Service began management of the land.

Considerable discussion has appeared (see particularly McIntosh, 1972, Langford and Buell, 1969, and others) concerning the meaning of a climax community. The vegetation of MCNP also reflects the utility of the gradient or continuum viewpoint with considerable variation in the vegetation due to local variation in environmental and historical factors. Whittaker (1965) pointed out that sharp boundaries, due to "competitive advantages," may occur along gradients but that these sharp boundaries are "of rare occurrence." These rapid transitions do occur in MCNP but

TABLE 28.

A succession diagram, showing dominant vegetation and physiognomy on land forms occurring in Mammoth Cave National Park, Kentucky.

Physiognomy	Abandoned Fields		Floodplains		Slopes	
	Solution Valleys	Plateau Farmlands	Bottom land Islands	Terraces	Mississippian Aged Bedrock	Pennsylvanian Aged Bedrock
Open land	Broomsedge grasses	Broomsedge grasses	Willow herb <u>Sorghum halepense</u> <u>Uniola latifolia</u> <u>Arundinaria gigantea</u>			
Young woodlands	Tuliptree Blackgum Winged sumac	Tuliptree Blackgum Dogwood Winged elm				
Evergreen forest		Virginia pine (planted)			Eastern red cedar	
Deciduous forest						
Early	Black locust (planted) Blackjack oak		Silver maple Sycamore Tuliptree Slippery elm		Tuliptree	
Typical	Northern red oak Southern red oak Black oak Pignut hickory		Sugar maple Red maple American beech		White oak Pignut hickory	Chestnut oak American beech Northern red oak Eastern hemlock Magnolia sp.
			Quercus-Liriodendron-Carya-Acer complex			

are usually related to fence boundaries, emphasizing the importance of historical factors in determining the present day vegetation. These historic factors comprise one continuum which is operating in MCNP.

A second continuum based on space and topographic gradients within more mature communities is suggested in Figure 17. This continuum appears to move toward the central core of the ordination from the floodplains and upland stands. Then in a very limited manner succession moves toward stands where American beech and sugar maple are important components. These beech-maple dominated areas are limited by topography and thus account for only a small number of the total stands sampled.

Sensitive vegetation within the boundaries of MCNP should be evaluated on the basis of:

- 1) Areal extent of suitable landform for their development;
- 2) Uniqueness with respect to the remaining regional natural vegetation;
- 3) Number of introduced or exotic species present in a particular area.

On this basis the hemlock areas associated with Pennsylvanian aged sandstone, the beech-maple stands in the larger hollows north of the Green River and the slope of the major solution valleys south of the Green River should receive careful attention. The majority of the exotic vegetation occurs along the roadway corridors (a coppice

of shrubbery adjacent to the forest is a more or less permanent feature of the wide mowed parkways along State Route 70) around old farmsteads, and the improved areas around Park Headquarters. Removal of introduced plants to the Park would be prohibitive, but reduction of habitat for the cosmopolitan roadside weeds is recommended to protect the mosaic of natural vegetation in the National Park.

The present day vegetation of MCNP serves as a basis to examine successional changes which occur in south-central Kentucky. In addition small areas within the Park boundaries reflect portions of the original vegetation mosaic of the area and serve as a basis for re-structuring this mosaic.

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APPENDIX

Appendix A

Theory and Practice of the Bitterlich
Variable-Radius Sampling Method

To determine if a tree is large enough to be included in a sample, both its diameter and the distance from the sampling point need to be determined. Thus, if the 33X diameter radius is used for the circle, a 2-foot diameter tree could be no more than 66 feet from the sampling point and be included. In practice, the procedure is simplified by using an angle gauge. As lines diverge with distance and visual perspective, a tree viewed from a distance appears smaller. A particular tree must be larger in diameter as its distance from the sampling point increases to be included in the sample. For this reason the forest attribute frequency, a measure of dispersion or distribution, cannot be measured by this method. Shanks (1954) suggested that the frequency tallied by this method reflects a vegetational contribution, rather than a frequency of botanical presence.

The size of the tree determines the size of the plot so that a constant or repeatable standard area is not sampled. To solve for the size of the angle and derive the 33:1 ratio the following relationships are presented. Assume that the tree radius is Δ and X (the plot

diameter ratio) will be solved for. The following illustration assumes that each individual tree tallied represents 10 ft^2 of basal area per acre for its species:

$$\begin{aligned}
 10 \text{ ft}^2 &= \text{BA of one tree/a} \quad \times 43560 \text{ ft}^2 \\
 10 \text{ ft}^2 &= \pi \Delta^2 / (X\Delta)^2 \quad \times 43560 \text{ ft}^2 \\
 10 \text{ ft}^2 &= \pi \Delta^2 / X^2 \Delta^2 \quad \times 43560 \text{ ft}^2 \\
 10 \text{ ft}^2 &= 43560 \text{ ft}^2 / X^2 \\
 X^2 &= 43560 \text{ ft}^2 / 10 \text{ ft}^2 \\
 X^2 &= 4356 \\
 X &= 66
 \end{aligned}$$

Where:

a = area/plot in square feet

43560 ft^2 = area in square feet of one acre

The number 66 represents a plot diameter in which the plot radius would equal 33X the tree diameter. The 104.18 minute angle selected for the angle gauge is based on $\sin 1:33 = 0.0303 = 104.18'$.

To have each tree tallied represent 5 ft^2 per acre, similar calculations derive a ratio of 1:46.7 and an angle of $74'$. In the field this five scale increases the number of individual trees tallied at each point, thereby giving a more accurate sample estimate when the areal extent of the forest type is limited, or when the average tree diameter is small.

The stand basal area (B_0) is determined by multiplying the scale factor (5, 10 etc.) times the total number of trees tallied (N) then dividing the number of points

sampled (n), as follows:

$$B_9 = 10N/n$$

If the basal area per species is required simply consider each species separately, as indicated below:

$$B_2 = 10N_{sp}/n$$

Density is determined by an estimate of the diameter of a tree to the nearest 4-inch size class. This assumes that enough individuals will be tallied so that the average basal area per size class can be used as a constant in a formula to derive density by species. Before the use of electronic calculators with at least three memory or storage registers this method required time-consuming calculation. In addition because an estimated size class value was in the original data, it was avoided by plant ecologists. Calculations today can be made with reasonable speed and the problem of estimate can be minimized through practice and occasional checking with a tape while in the field. Table 1A is included along with this equation for determining density for each size class species block.

$$D_5 = N_c k_f / np$$

Where:

D_5 = density per size class per species

N_c = number of trees counted in a size class

(independent variable)

k_f = BA in ft^2 of midpoint value of each 4-inch size class divided by factor used on angle gauge

np = number of points sampled.

The k_f value for the proper scale and size class midpoint is entered in one storage register, while the np is entered in a second register. To proceed with the calculations the N_c is entered into the calculator and multiplied by k_f (from Storage I) and the product is divided by np (from Storage II). This quotient is the value (D_5) for a particular size class of a particular species. Such D_5 values can be tabulated in a summing storage register so that the total density per acre (D_2) for the species is available.

TABLE 1A. Constants used in calculating density from size class grouping estimates in the Bitterlich method.

Size Class Midpoint in Inches	Basal Area in Square Feet	Bitterlich Scale	
		k_5	k_{10}
6	0.1963	25.4712	50.9424
10	0.5454	9.1676	18.3352
14	1.0690	4.6773	9.3545
18	1.7671	2.8245	5.6590
22	2.6398	1.8941	3.7882
26	3.6870	1.3561	2.7122
30	4.9087	1.0186	2.0372
34	6.3050	0.7930	1.5860
38	7.8758	0.6348	1.2697
42	9.6211	0.5197	1.0394
46	11.5410	0.4332	0.8665
50	13.0960	0.3818	0.7636

Appendix B

Location of Permanent Study Plots

Plot 1 is located in the old field northeast of the Mt. McKinley Pumphouse approximately 225 feet southwest by south of Mammoth Cave Ridge Road, about 600 feet northeast from a sink north of the Mt. McKinley Pumphouse. Stake 2 of Plot 1 is located 100 feet N 45 W from Stake 1 (Figure 1B).

Stake 1 of Plot 2 is located in the same field 225 feet S 45 W from Stake 2 of Plot 1. Stake 2 of this second plot is 100 feet N 45 W from Stake 1 (Figure 1B).

Plot 3 is also located in the same field 100 feet south of Stake 1, Plot 2. These Plots are located at approximately N $37^{\circ} 09' 42''$ and W $86^{\circ} 04' 30''$ (Figure 1B).

Plots 4 and 5 are located in an old field southwest of the northwest-trending access road to Good Spring Church. Plot 4 is 85 feet from the road starting at a blazed tuliptree along a bearing of S 35 W approximately 900 feet from the beginning of the access road. Stake 2 of Plot 4 is 100 feet N 57 W. Plot 5 is 100 feet from a blazed red maple along a bearing of S 35 W approximately 200 feet from the beginning of the access road. Stake 2 of Plot 5 is 100 feet south of Stake 1. These Plots are located at approximately N $37^{\circ} 12' 30''$ and W $86^{\circ} 09' 44''$ (Figure 1B).

Plots 6 and 7 are located in Hart County west of the access road to the Flint Ridge Ranger Station. Plot 6 is 700 feet from the Flint Ridge Road gate approximately 200 feet from the road on a bearing of N 80 W. Stake 2 of Plot 6 is 100 feet N 10 E from Stake 1. Plot 7 is 1100 feet from the gate and 100 feet N 80 W from Stake 1. These Plots are located at approximately W $86^{\circ} 04' 14''$ and N $37^{\circ} 12' 06''$ (Figure 2B).

Plots 8 and 9 are in an open area near the ESSA area set aside at the Great Onyx Cave Hotel site. Plot 8 is located at the top of a rise along a bearing of N 55 E from Point 737 on the access road, toward the Great Onyx Cave Pumping Station. Stake 2 is 100 feet north of Stake 1. Plot 9 is 150 feet north of Plot 8 in a west-trending draw. These Plots are located at approximately W $86^{\circ} 04' 27''$ and N $37^{\circ} 13' 08''$ (Figure 2B).

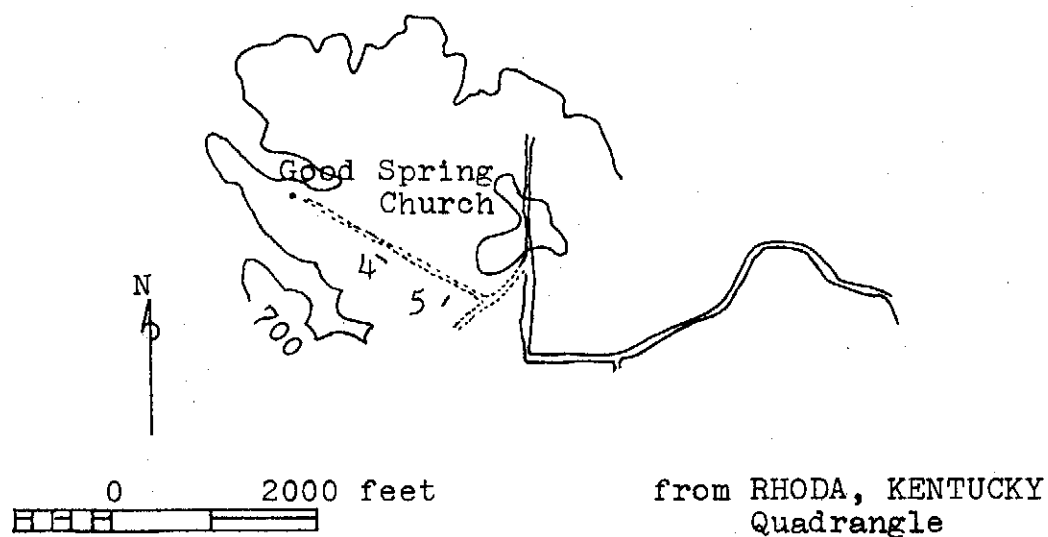
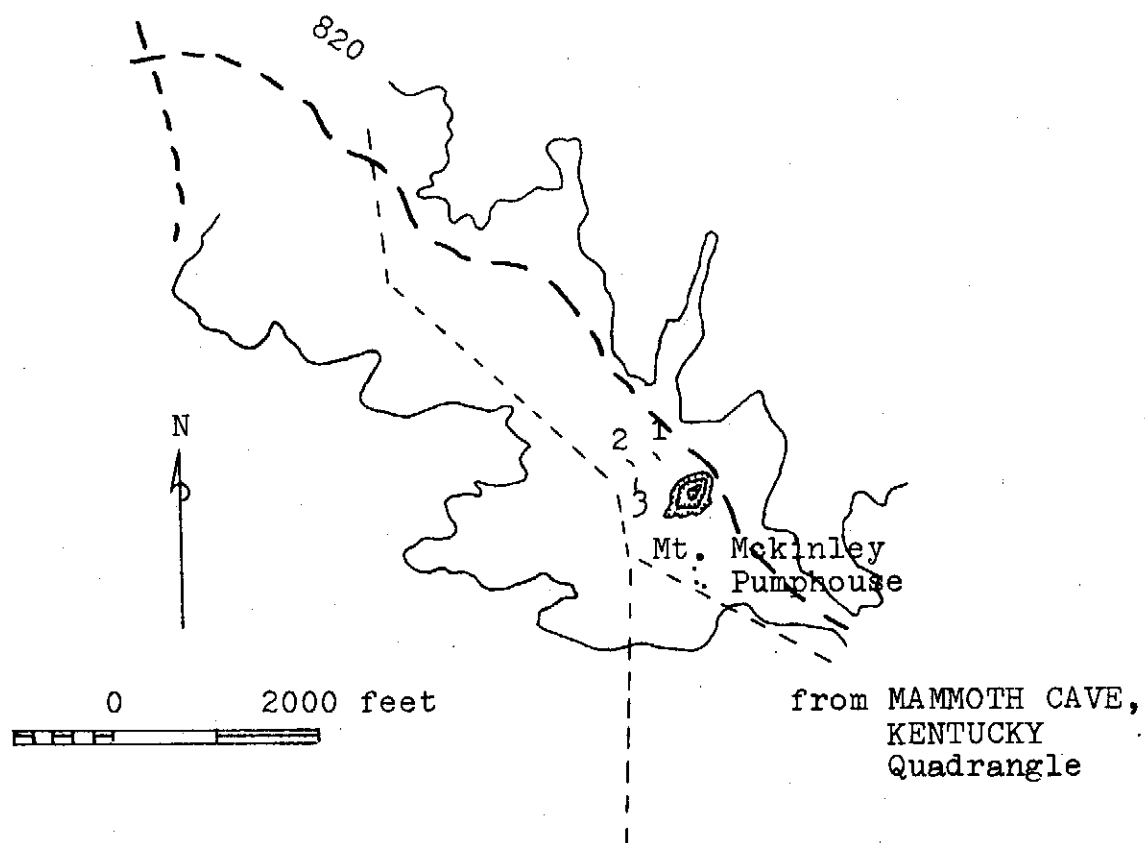


FIGURE 1B. Location of Permanent plots 1, 2, 3, 4 and 5.

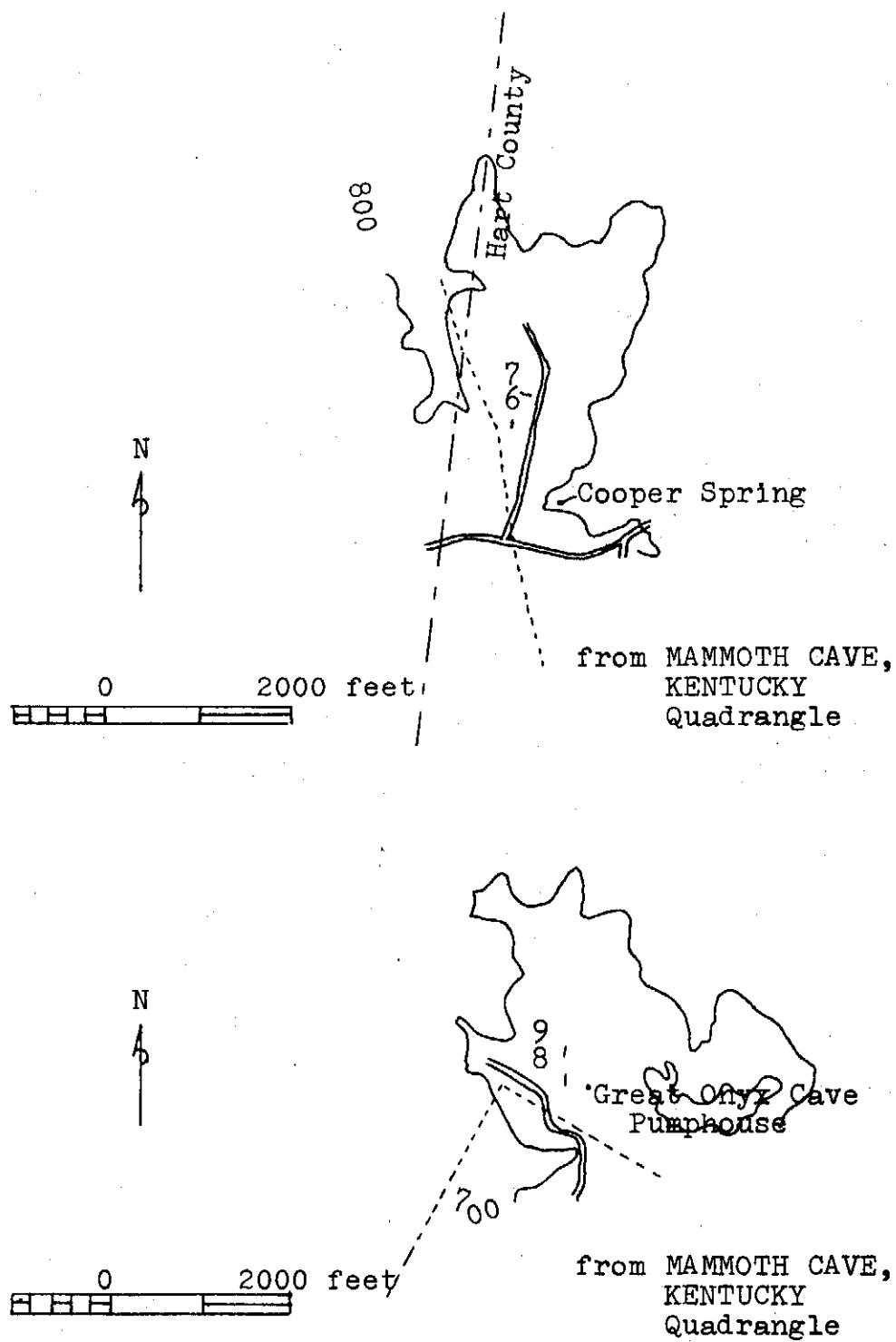


FIGURE 2B. Location of permanent plots 6,7,8, and 9.

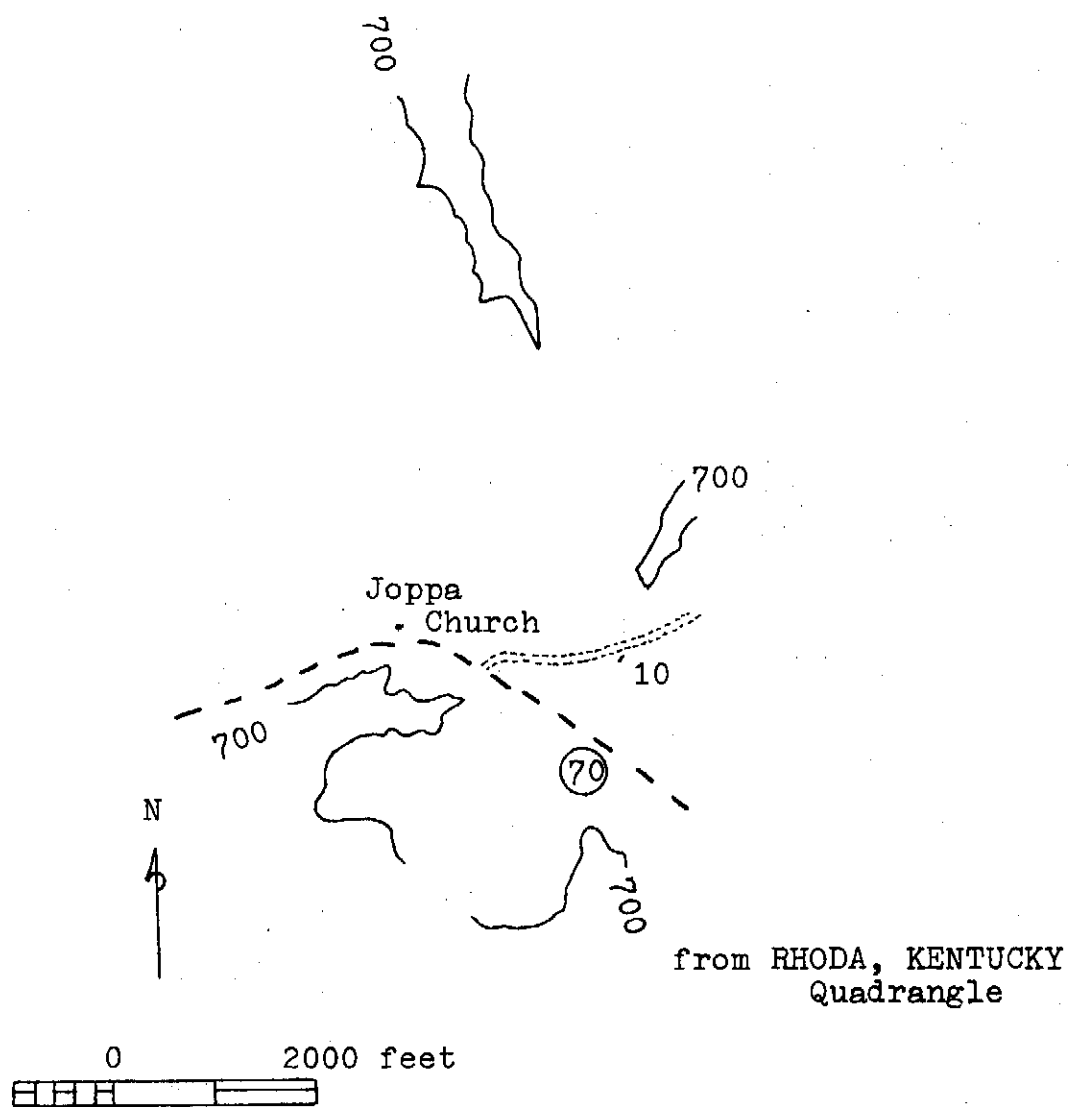


FIGURE 3B. Location of permanent plot 10.

Appendix C

Generalized Locations of Stands Sampled In This Study

The names of the stands follow the designations used in the text (Table 6) and in Appendixes D and E. Additional areas in the Park were visited but are not indicated on this map.

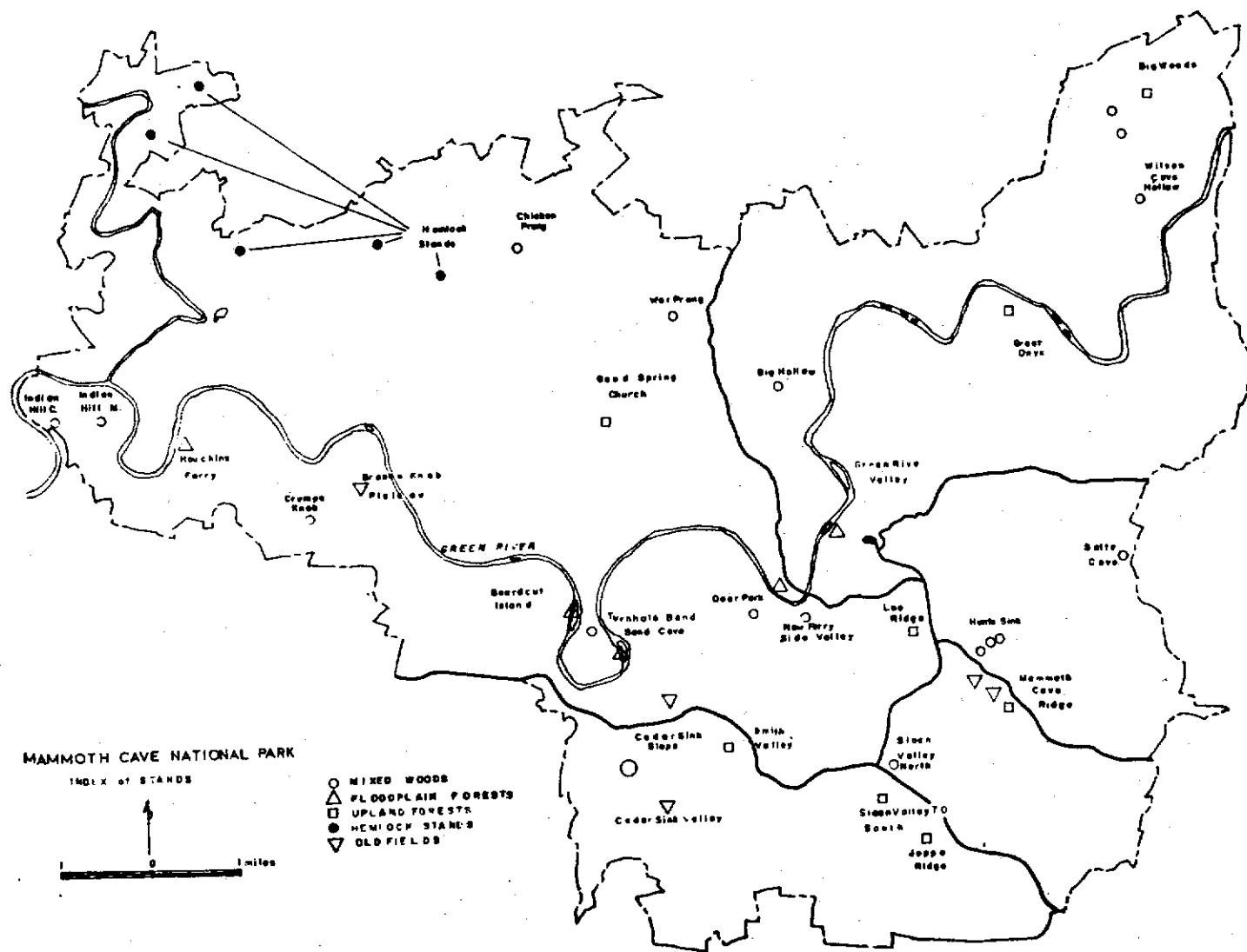


FIGURE 1C. Generalized locations of stands sampled in this study.

Appendix D

Attributes of Tree Species Over 4 inches dbh

Attributes of tree species over 4 inches dbh sampled in 39 stands during this study are included in this appendix. The tables are arranged alphabetically by forest association. The descriptive material in the body of the dissertation follows this same sequence of forest associations. The approximate locations of the stands from which these data were obtained are illustrated in Appendix C.

The attributes included are:

- 1) density per acre;
- 2) relative density;
- 3) basal area in ft^2 per acre;
- 4) relative basal area;
- 5) importance value, an average of the relative density and relative basal area; and
- 6) the average basal area per tree.

The inclusion of the long tables in Appendix D and E into the text would disrupt the discussion and present difficulties in interpretation for the reader. By grouping these tables together comparisons between stands of a particular forest association can be more easily seen.

Index of Tables

Appendix D

<u>Table Number</u>	<u>Stand Name</u>	<u>Stand Symbol</u>
1D	Big Hollow	BH
2D	Big Woods Slope	BWS
3D	Big Woods Ravine	BWR
4D	Cedar Sink Valley Slopes	CSVs
5D	Chicken Prong Hollow	CPH
6D	Crumps Knob	CK
7D	Deer Park Hollow	DPH
8D	Doyel Valley Slopes	DVS
9D	Hunts Sink Full	HSF
10D	Hunts Sink Upper	HSU
11D	Hunts Sink Lower	HSL
12D	Hunts Sink South Slope	HSS
13D	Indian Hill Chestnut	IH
14D	Mammoth Cave New Ferry	MCNF
15D	Salts Sink Full	SSF
16D	Salts Sink East facing	
17D	Salts Sink West facing	
18D	Sloans Crossing North	SCN
19D	Turnhole Bend North	TBN
20D	Wet Prong	WP
21D	Wilson Cave Hollow	WCH
22D	First Creek Hemlock	FCH
23D	Boardcut Island	BI
24D	Mammoth Ferry Floodplain	MFF
25D	New Ferry Floodplain	NFF
26D	Sand Cave Island	SCI
27D	Big Woods Upland	BWU
28D	Good Spring Church	GSC
29D	Great Onyx Succession	GOS
30D	Green River Valley	GVSL
31D	Joppa Ridge, Mammoth Ridge	JRMR
32D	Lee Ridge	LR
33D	Sloans Crossing South	SSC
34D	Smith Valley West	SVW
35D	Cedar Sink Valley	CSVO
36D	Hickory Cabin, Brooks Knob	HCBK
37D	Joppa Ridge Old Field	JROF
38D	Mammoth Cave Old Field	MCOF
39D	Upland Successional	US

TABLE 1D. Attributes¹ of tree species over 4 inches dbh in Big Hollow. Data are based on 20 points by Bitterlich variable-radius method. The sample location is shown on Figure 1C.

Species	D ₂	D ₃	B ₂	B ₃	V ₃	BA/ Tree
<i>Fagus grandifolia</i>	45	26	30	30	28	0.66
<i>Quercus alba</i>	23	13	18	18	16	0.78
<i>Liriodendron tulipifera</i>	17	9.8	10	10	10	0.60
<i>Acer saccharum</i>	21	12	7.5	7.6	9.8	0.37
<i>Acer rubrum</i>	17	10	6.0	6.1	8.0	0.35
<i>Carya glabra</i>	9.0	5.2	3.3	3.3	4.3	0.36
<i>Quercus rubra</i>	3.5	2.0	2.8	3.8	3.9	1.08
<i>Juglans nigra</i>	4.2	2.4	2.5	2.5	2.5	0.60
<i>Quercus muehlenbergii</i>	4.3	2.5	1.7	1.8	2.1	0.41
<i>Carya ovata</i>	3.7	2.2	2.0	2.0	2.1	0.53
<i>Nyssa sylvatica</i>	4.2	2.4	1.7	1.8	2.1	0.42
<i>Platanus occidentalis</i>	3.4	2.0	1.5	1.5	1.8	0.44
Other Species ²	17.78		10.25			0.55
Totals	173.08		97.25			0.56

¹D₂ symbolizes density per acre, D₃ is relative density, B₂ is basal area per acre, B₃ is relative basal area, and V₃ is importance value.

²Other species in decreasing order: *Fraxinus americana*, *Ulmus rubra*, *Quercus velutina*, *Carya cordiformis*, *Gymnocladus dioica*, *Fraxinus pennsylvanica*, *Juglans cinerea*, *Ulmus thomasi*, *Carya tomentosa*, *Carya ovalis*, *Sassafras albidum*, *Cornus florida*, *Carya sp.*, *Acer negundo*, *Tilia americana*.

TABLE 2D. Attributes¹ of tree species over 4 inches dbh in Big Woods (slopes). Data are based on a 3.6 acre sample (0.2 acre plots). The sample location is shown on Figure 1C.

Species	D ₂	D ₃	B ₂	B ₃	F ₁	F ₃	V ₃	BA/ Tree
Quercus alba	24	20	25	28	100	12	20	1.04
Quercus velutina	15	12	23	25	67	7.8	15	1.54
Liriodendron tulipifera	6.9	5.9	13	15	67	7.8	9.5	1.91
Carya tomentosa	14	12	5.1	5.8	89	10	9.4	0.36
Oxydendrum arboreum	13	11	2.3	2.6	72	8.4	7.4	0.17
Carya glabra	11	9.7	3.3	3.7	72	8.4	7.3	0.29
Nyssa sylvatica	6.9	5.9	5.7	6.4	72	8.4	6.9	0.82
Cornus florida	5.3	4.5	0.70	0.79	61	7.1	4.1	0.13
Acer rubrum	5.8	4.9	1.6	1.8	44	5.2	4.0	0.27
Quercus rubra	3.3	2.8	3.9	4.4	39	4.5	3.9	1.18
Carya ovata	4.2	3.5	1.3	1.5	44	5.2	3.4	0.31
Other Species ²	8.28		4.53					0.55
Totals	117.68		89.43					0.76

¹D₂ symbolizes density per acre, D₃ is relative density, B₂ is basal area per acre, B₃ is relative basal area, F₁ is frequency of occurrence, F₃ is relative occurrence, and V₃ is importance value.

²Other species in decreasing order: Quercus muehlenbergii, Ulmus rubra, Fagus grandifolia, Sassafras albidum, Ostrya virginiana, Juglans cinerea, Carya cordiformis, Quercus stellata, Fraxinus americana, Carya sp., Juglans nigra, Cercis canadensis.

TABLE 3D. Attributes¹ of tree species over 4 inches dbh in Big Woods (ravine). Data are based on a 1.0 acre sample (0.2 acre plots). The sample location is shown on Figure 1C.

Species	D ₂	D ₃	B ₂	B ₃	F ₁	F ₃	V ₃	BA/ Tree
Quercus alba	17	12	25	23	100	9.8	15	1.47
Liriodendron tulipifera	19	14	19	18	100	9.8	14	1.00
Fagus grandifolia	13	9.4	22	20	40	3.9	11	1.67
Oxydendrum arboreum	16	12	3.5	3.3	80	7.8	7.5	0.22
Carya glabra	12	8.6	4.5	4.1	100	9.8	7.5	0.37
Carya tomentosa	14	10	4.6	4.2	80	7.8	7.4	0.33
Quercus rubra	8	5.8	5.1	4.7	80	7.8	6.1	0.64
Acer saccharinum	7	5.0	4.3	4.0	80	7.8	5.6	0.61
Ulmus rubra	8	5.8	5.7	5.2	40	3.9	5.0	0.71
Nyssa sylvatica	7	5.0	6.4	5.9	40	3.9	5.0	0.91
Quercus velutina	4	2.9	5.7	5.2	60	5.9	4.7	1.42
Carya ovata	6	4.3	1.5	1.4	80	7.8	4.5	0.26
Other Species ²	8		1.46					0.18
Totals	139		108.76					0.78

¹D₂ symbolizes density per acre, D₃ is relative density, B₂ is basal area per acre, B₃ is relative basal area, F₁ is frequency of occurrence, F₃ is relative occurrence, V₃ is importance value.

²Other species in decreasing order: Cornus florida, Fraxinus americana, Cercis canadensis, Quercus coccinea, Carya sp.

TABLE 4D. Attributes¹ of tree species over 4 inches dbh on Cedar Sink Valley slopes. Data are based on 21 points by Bitterlich variable-radius method. The sample location is shown on Figure 1C.

Species	D ₂	D ₃	B ₂	B ₃	V ₃	BA/ Tree
<i>Quercus rubra</i>	40	20	30	29	25	0.75
<i>Quercus velutina</i>	23	12	20	19	15	0.86
<i>Cornus florida</i>	25	13	6.0	5.8	9.3	0.24
<i>Quercus alba</i>	13	6.7	8.1	7.9	7.3	0.62
<i>Oxydendrum arboreum</i>	16	8.3	4.8	4.7	6.5	0.29
<i>Carya tomentosa</i>	12	6.1	6.0	5.8	6.0	0.50
<i>Nyssa sylvatica</i>	14	7.3	3.8	3.7	5.5	0.27
<i>Carya glabra</i>	5.0	2.6	5.2	5.1	3.9	1.04
<i>Juniperus virginiana</i>	7.2	3.7	1.9	1.9	2.8	0.27
<i>Juglans nigra</i>	7.5	3.8	1.2	1.2	2.5	0.16
<i>Fagus grandifolia</i>	4.4	2.3	2.4	2.3	2.3	0.54
<i>Quercus stellata</i>	3.3	1.7	1.9	1.9	1.8	0.58
<i>Liriodendron tulipifera</i>	2.6	1.4	2.1	2.1	1.7	0.51
<i>Carya ovata</i>	4.9	2.5	0.95	0.93	1.7	0.20
Other Species ²	17.25		8.97			0.52
Totals	195.15		103.32			0.53

¹D₂ symbolizes density per acre, D₃ is relative density, B₂ is basal area per acre, B₃ is relative basal area, and V₃ is importance value.

²Other species in decreasing order: *Acer saccharum*, *Fraxinus americana*, *Carya cordiformis*, *Sassafras albidum*, *Quercus falcata*, *Cercis canadensis*, *Morus rubra*, *Ulmus alata*, *Acer rubrum*, *Populus alba*, *Quercus marilandica*, *Quercus prinus*.

TABLE 5D. Attributes¹ of tree species over 4 inches dbh in Chicken Prong Hollow. Data are based on 19 points by Bitterlich variable-radius method. The sample location is shown on Figure 1C.

Species	D ₂	D ₃	B ₂	B ₃	V ₃	BA/ Tree
<i>Quercus prinus</i>	71	38	26	28	33	0.36
<i>Quercus alba</i>	21	12	14	15	13	0.66
<i>Acer saccharum</i>	19	10	8.6	9.2	9.6	0.46
<i>Fagus grandifolia</i>	9.2	5.0	13	14	9.5	1.41
<i>Quercus rubra</i>	14	7.4	7.5	8.0	7.7	0.54
<i>Carya glabra</i>	13	7.1	4.7	5.0	6.1	0.35
<i>Quercus velutina</i>	8.8	4.7	5.5	5.9	5.3	0.63
<i>Fraxinus americana</i>	3.4	1.8	3.6	3.8	2.8	1.05
<i>Carya cordiformis</i>	5.1	2.7	1.8	1.9	2.3	0.35
Other Species ²	21.7		8.9			0.41
Totals	186.2		93.6			0.50

¹D₂ symbolizes density per acre, D₃ is relative density, B₂ is² basal area per acre, B₃ is relative basal area, and V₃ is importance value.

²Other species in decreasing order: *Liriodendron tulipifera*, *Acer rubrum*, *Carya tomentosa*, *Platanus occidentalis*, *Nyssa sylvatica*, *Ulmus americana*, *Sassafras albidum*, *Ulmus rubra*, *Cornus florida*, *Ostrya virginiana*, *Amelanchier arborea*, *Carya ovata*.

TABLE 6D. Attributes¹ of tree species over 4 inches dbh in Crumps Knob. Data are based on 15 points by Bitterlich variable-radius method. The sample location is shown on Figure 1C.

Species	D ₂	D ₃	B ₂	B ₃	V ₃	BA/ Tree
<i>Quercus alba</i>	28	13	21	19	16	0.74
<i>Carya glabra</i>	38	18	13	11	15	0.33
<i>Quercus prinus</i>	23	11	17	16	13	0.76
<i>Acer rubrum</i>	27	13	8.4	7.6	10	0.31
<i>Nyssa sylvatica</i>	25	12	8.1	7.3	9.7	0.32
<i>Liriodendron tulipifera</i>	11	5.2	13	12	8.4	1.17
<i>Quercus rubra</i>	14	6.6	5.9	5.4	6.0	0.42
<i>Acer saccharum</i>	8.0	3.8	3.4	3.1	3.4	0.43
<i>Quercus velutina</i>	3.6	1.7	5.6	5.1	3.4	1.56
<i>Carya ovalis</i>	6.8	3.2	3.1	2.8	3.0	0.46
<i>Carya ovata</i>	5.5	2.6	2.5	2.3	2.4	0.45
Other Species ²	19.96		10.18			0.51
Totals	209.86		111.18			0.53

¹D₂ symbolizes density per acre, D₃ is relative density, B₂ is basal area per acre, B₃ is relative basal area, and V₃² is importance value.

²Other species in decreasing order: *Carya tomentosa*, *Sassafras albidum*, *Juglans nigra*, *Fagus grandifolia*, *Fraxinus americana*, *Quercus falcata*, *Carya cordiformis*, *Ostrya virginiana*, *Quercus stellata*.

TABLE 7D. Attributes¹ of tree species over 4 inches dbh on Deer Park Hollow slopes along limestone outcrops. Data are based on a 0.7 acre sample (0.2 acre plots). The sample location is shown on Figure 1C.

Species	D ₂	D ₃	B ₂	B ₃	V ₃	BA/ Tree
<i>Quercus alba</i>	15	15	15	23	19	0.98
<i>Liriodendron tulipifera</i>	8	8	13	21	14	1.65
<i>Quercus rubra</i>	9	9	7.9	12	11	0.87
<i>Oxydendrum arboreum</i>	14	14	2.1	3.3	8.7	0.15
<i>Carya tomentosa</i>	7	7	4.7	7.4	7.2	0.67
<i>Acer saccharum</i>	8	8	3.7	5.8	6.9	0.46
<i>Nyssa sylvatica</i>	6	6	4.6	7.3	6.6	0.77
<i>Carya cordiformis</i>	6	6	3.5	5.5	5.8	0.59
<i>Cornus florida</i>	7	7	0.90	1.4	4.2	0.13
<i>Acer rubrum</i>	4	4	1.0	1.6	2.8	0.25
<i>Sassafras albidum</i>	2	2	1.9	3.0	2.5	0.91
<i>Fagus grandifolia</i>	3	3	1.1	1.7	2.4	0.37
Other Species ²	12		4.02			0.34
Totals 0.7 acres	101		63.42			0.63
Per Acre	144.8		90.60			

¹D₂ symbolizes density per acre, D₃ is relative density, B₂ is basal area per acre, B₃ is relative basal area, and V₃² is importance value.

²Other species in decreasing order: *Fraxinus americana*, *Ostrya virginiana*, *Carya glabra*, *Juglans nigra*, *Juglans cinerea*, *Quercus stellata*, *Carya ovata*.

TABLE 8D. Attributes¹ of tree species over 4 inches dbh on Doyel Valley slopes. Data are based on 20 points by Bitterlich variable-radius method. The sample location is shown on Figure 1C.

Species	D ₂	D ₃	B ₂	B ₃	V ₃	BA/ Tree
<i>Quercus velutina</i>	48	20	28	30	25	0.57
<i>Nyssa sylvatica</i>	57	24	15	16	20	0.27
<i>Quercus stellata</i>	19	8.1	10	11	9.4	0.52
<i>Cornus florida</i>	28	12	6.5	7.0	9.4	0.23
<i>Quercus alba</i>	16	6.9	8.0	8.6	7.7	0.49
<i>Quercus falcata</i>	18	7.7	4.8	5.1	6.4	0.26
<i>Juniperus virginiana</i>	14	5.9	2.8	3.0	4.4	0.20
<i>Diospyros virginiana</i>	11	4.7	3.0	3.2	4.0	0.27
<i>Quercus rubra</i>	10	4.3	2.8	3.0	3.6	0.27
<i>Quercus coccinea</i>	2.3	1.0	3.3	3.5	2.2	1.43
Other Species ²	19.53		9.3			0.48
Totals	242.83		93.5			0.39

¹D₂ symbolizes density per acre, D₃ is relative density, B₂ is basal area per acre, B₃ is relative basal area, and V₃ is importance value.

²Other species in decreasing order: *Carya glabra*, *Quercus marilandica*, *Oxydendrum arboreum*, *Sassafras albidum*, *Carya ovalis*, *Carya cordiformis*, *Liriodendron tulipifera*, *Quercus prinus*, *Acer saccharum*, *Juglans nigra*, *Fagus grandifolia*.

TABLE 9D. Attributes¹ of tree species over 4 inches dbh in the south sink of Hunts Sink. Data are based on a full census of 6.31 acres. The sample location is shown on Figure 1C.

Species	D ₂	D ₃	B ₂	B ₃	V ₃	BA/ Tree
<i>Quercus velutina</i>	31	5.5	85	18	12	2.75
<i>Quercus alba</i>	43	7.6	74	15	11	1.72
<i>Liriodendron tulipifera</i>	21	3.7	71	14	9.2	3.40
<i>Cornus florida</i>	85	15	12	2.4	8.7	0.14
<i>Carya glabra</i>	41	7.3	44	9.0	8.1	1.06
<i>Acer rubrum</i>	62	11	25	5.2	8.1	0.41
<i>Acer saccharum</i>	50	9.0	30	6.2	7.6	0.59
<i>Carya cordiformis</i>	43	7.6	23	4.8	6.2	0.55
<i>Carya ovata</i>	44	7.8	15	3.2	5.5	0.35
<i>Fraxinus pennsylvanica</i>	37	6.2	23	4.7	5.4	0.65
<i>Quercus rubra</i>	7	1.2	34	7.1	4.2	4.89
<i>Nyssa sylvatica</i>	28	5.0	8.9	1.8	3.4	0.32
Other Species ²	78		39.69			0.51
Totals 6.31 acres	570		484.59			0.85
Per Acre	90.5		77			

¹ D₂ symbolizes density per acre, D₃ is relative density, B₂ is basal area per acre, B₃ is relative basal area, and V₃² is importance value.

² Other species in decreasing order: *Celtis occidentalis*, *Ulmus rubra*, *Carya tomentosa*, *Sassafras albidum*, *Juglans nigra*, *Quercus falcata*, *Cercis canadensis*, *Quercus muehlenbergii*, *Platanus occidentalis*, *Ulmus americana*, *Juglans cinerea*, *Oxydendrum arboreum*.

TABLE 10D. Attributes¹ of tree species over 4 inches dbh in the north sink of Hunts Sink on the upper slopes. Data are based on a 0.3 acre sample (0.1 acre plots). The sample location is shown on Figure 1C.

Species	D ₂	D ₃	B ₂	B ₃	V ₃	BA/ Tree
<i>Quercus alba</i>	10	16	8.7	26	21	0.87
<i>Acer rubrum</i>	13	20	5.1	15	18	0.39
<i>Oxydendrum arboreum</i>	16	25	2.6	7.6	16	0.02
<i>Quercus falcata</i>	3	4.7	8.3	25	15	2.78
<i>Quercus velutina</i>	3	4.7	2.5	7.5	6.1	0.84
<i>Nyssa sylvatica</i>	6	9.4	0.95	2.8	6.1	0.16
<i>Carya tomentosa</i>	2	3.1	2.9	8.4	5.8	1.42
Other Species ²	11		2.89			0.26
Totals 0.3 acres	64		33.94			0.53
Per Acre	213		113.13			

¹D₂ symbolizes density per acre, D₃ is relative density, B₂ is basal area per acre, B₃ is relative basal area, and V₃² is importance value.

²Other species in decreasing order: *Cornus florida*, *Carya glabra*, *Quercus prinus*, *Liriodendron tulipifera*, *Quercus rubra*.

TABLE 11D. Attributes¹ of tree species over 4 inches dbh in the north sink of Hunts Sink on the lower slopes. Data are based on a 0.3 acre sample (0.1 acre plots). The sample location is shown on Figure 1C.

Species	D ₂	D ₃	B ₂	B ₃	V ₃	BA/ Tree
<i>Quercus rubra</i>	4	10	12	37	23	2.95
<i>Quercus alba</i>	11	28	4.8	15	21	0.44
<i>Carya tomentosa</i>	6	15	3.8	12	13	0.63
<i>Acer saccharum</i>	3	7.5	3.2	10	8.8	1.07
<i>Quercus muehlenbergii</i>	3	7.5	1.8	5.6	6.5	0.59
<i>Fraxinus pennsylvanica</i>	1	2.5	2.8	8.8	5.7	2.81
<i>Carya ovata</i>	2	5.0	1.1	3.3	4.2	0.52
<i>Nyssa sylvatica</i>	2	5.0	0.46	1.4	3.2	0.23
<i>Cornus florida</i>	2	5.0	0.26	0.81	2.9	0.13
<i>Carya glabra</i>	2	5.0	0.20	0.63	2.8	0.10
Other Species ²	4		1.67			0.42
Totals 0.3 acres	40		32.09			0.80
Per Acre	133		106.96			

¹D₂ symbolizes density per acre, D₃ is relative density, B₂ is basal area per acre, B₃ is relative basal area, and V₃ is importance value.

²Other species in decreasing order: *Fraxinus americana*, *Ulmus rubra*, *Ulmus alata*, *Liriodendron tulipifera*.

TABLE 12D. Attributes¹ of tree species over 4 inches dbh on the south slope of the north sink in Hunts Sink. Data are based on a 0.2 acre sample (0.1 acre plots). The sample location is shown on Figure 1C.

Species	D ₂	D ₃	B ₂	B ₃	V ₃	BA/ Tree
<i>Quercus alba</i>	7	27	11	38	33	1.51
<i>Liriodendron tulipifera</i>	1	3.8	11	40	22	11.24
<i>Nyssa sylvatica</i>	6	23	1.8	6.5	15	0.30
<i>Cornus florida</i>	3	12	0.36	1.3	6.4	0.12
<i>Acer saccharum</i>	2	7.7	1.2	4.1	5.9	0.58
<i>Carya cordiformis</i>	2	7.7	0.33	1.2	4.4	0.17
<i>Quercus rubra</i>	1	3.8	1.0	3.6	3.7	1.01
Other Species ²	4		1.34			0.34
Totals 0.2 acres	26		28.03			1.08
Per Acre	130		140.15			

¹D₂ symbolizes density per acre, D₃ is relative density, B₂ is basal area per acre, B₃ is relative basal area, and V₃ is importance value.

²Other species in decreasing order: *Fraxinus americana*, *Carya ovata*, *Oxydendrum arboreum*, *Fraxinus pennsylvanica*.

TABLE 13D. Attributes¹ of tree species over 4 inches dbh in the Indian Hill chestnut oak forest. Data are based on 9 points by Bitterlich variable-radius method. The sample location is shown on Figure 1C.

Species	D ₂	D ₃	B ₂	B ₃	V ₃	BA/ Tree
<i>Quercus prinus</i>	67	40	56	43	42	0.84
<i>Carya ovalis</i>	15	9.3	9.4	7.2	8.3	0.61
<i>Quercus velutina</i>	7.2	4.4	14	11	7.7	2.01
<i>Quercus alba</i>	6.8	4.2	9.4	7.2	5.7	1.38
<i>Oxydendrum arboreum</i>	13	7.6	3.8	2.9	5.2	0.29
<i>Acer rubrum</i>	10	6.3	5.0	3.8	5.1	0.48
<i>Carya glabra</i>	7.0	4.3	6.9	5.3	4.8	0.98
<i>Acer saccharum</i>	6.3	3.9	5.6	4.3	4.1	0.89
<i>Ilex opaca</i>	9.6	5.8	1.9	1.4	3.6	0.20
<i>Fagus grandifolia</i>	3.1	1.9	6.3	4.8	3.3	2.02
Other Species ²	19.55		11.96			0.61
Totals	164.55		130.26			0.79

¹D₂ symbolizes density per acre, D₃ is relative density, B₂ is basal area per acre, B₃ is relative basal area, and V₃ is importance value.

²Other species in decreasing order: *Nyssa sylvatica*, *Liquidambar styraciflua*, *Carya sp.*, *Quercus rubra*, *Carya cordiformis*, *Liriodendron tulipifera*, *Quercus muehlenbergii*.

TABLE 14D. Attributes¹ of tree species over 4 inches dbh in a side valley near Mammoth Cave New Ferry. Data are based on 5 points by Bitterlich variable-radius method.

The sample location is shown on Figure 1C.

Species	D ₂	D ₃	B ₂	B ₃	V ₃	BA/ Tree
<i>Quercus alba</i>	27	11	26	21	16	0.96
<i>Acer saccharum</i>	44	18	12	9.7	13	0.28
<i>Fraxinus americana</i>	29	12	14	11	12	0.48
<i>Cornus florida</i>	34	14	8	6.5	10	0.23
<i>Carya glabra</i>	22	9.0	12	9.7	9.3	0.56
<i>Sassafras albidum</i>	22	9.3	5	4.0	6.7	0.22
<i>Carya cordiformis</i>	16	6.6	7	5.6	3.8	0.44
<i>Quercus muehlenbergii</i>	6.9	2.9	5	4.0	3.5	0.73
<i>Carya tomentosa</i>	4.2	1.8	6	4.8	3.3	1.42
<i>Tilia americana</i>	8.8	3.7	3	2.4	3.0	0.34
<i>Quercus velutina</i>	4.5	1.9	5	4.0	3.0	1.10
<i>Liriodendron tulipifera</i>	3.0	1.2	5	4.0	2.6	1.69
<i>Fagus grandifolia</i>	4.6	1.9	4	3.2	2.6	0.87
<i>Carpinus caroliniana</i>	5.1	2.1	1	0.82	1.5	0.20
Other Species ²	4.16		4			0.96
Totals	235.26		117			0.50

¹D₂ symbolizes density per acre, D₃ is relative density, B₂ is basal area per acre, B₃ is relative basal area, and V₃ is importance value.

²Other species in decreasing order: *Carya ovata*, *Juglans nigra*, *Diospyros virginiana*.

TABLE 15D. Attributes¹ of tree species over 4 inches dbh in Salts Sink. Data are based on a full census of 0.94 acres. The sample location is shown on Figure 1C.

Species	D ₂	D ₃	B ₂	B ₃	V ₃	BA/ Tree
<i>Liriodendron tulipifera</i>	33	30	54	40	35	1.63
<i>Quercus alba</i>	30	27	47	35	31	1.56
<i>Quercus rubra</i>	7	6.3	15	11	8.7	2.13
<i>Cornus florida</i>	14	12	2.9	2.2	7.4	0.21
<i>Quercus velutina</i>	6	5.4	8.6	6.4	5.9	1.44
Other Species ²	20		6.95			0.35
Totals	110		134.45			1.21

¹D₂ symbolizes density per acre, D₃ is relative density, B₂ is basal area per acre, B₃ is relative basal area, and V₃ is importance value.

²Other species in decreasing order: *Sassafras albidum*, *Nyssa sylvatica*, *Acer rubrum*, *Carya glabra*.

TABLE 16D. Attributes¹ of tree species over 4 inches dbh on the east facing slope in Salts Sink. Data are based on a full census of 0.5 acres. The sample location is shown on Figure 1C.

Species	D ₂	D ₃	B ₂	B ₃	V ₃	BA/ Tree
Liriodendron tulipifera	19	29	30	40	34	1.55
Quercus alba	20	31	28	38	34	1.41
Quercus rubra	5	7.7	10	14	11	2.08
Cornus florida	9	14	2.3	3.0	8.4	0.25
Other Species ²	12		4.2			0.35
Totals	65		74.5			1.14

¹D₂ symbolizes density per acre, D₃ is relative density, B₂ is basal area per acre, B₃ is relative basal area, and V₃² is importance value.

²Other species in decreasing order: Nyssa sylvatica, Sassafras albidum, Quercus velutina.

TABLE 17D. Attributes¹ of tree species over 4 inches dbh on the west facing slope in Salts Sink. Data are based on a full census of 0.5 acres. The sample location is shown on Figure 1C.

Species	D ₂	D ₃	B ₂	B ₃	V ₃	BA/ Tree
<i>Liriodendron tulipifera</i>	14	30	24	41	36	1.74
<i>Quercus alba</i>	10	22	19	31	27	1.88
<i>Quercus velutina</i>	5	11	8.3	14	12	1.67
<i>Cornus florida</i>	5	11	0.70	1.2	6.0	0.14
<i>Quercus rubra</i>	2	4.4	4.5	7.5	5.9	2.26
<i>Sassafras albidum</i>	4	8.7	0.73	1.2	5.0	0.18
Other Species ²	6		2.5			0.42
Totals	46		59.73			1.30

¹D₂ symbolizes density per acre, D₃ is relative density, B₂ is basal area per acre, B₃ is relative basal area, and V₃ is importance value.

²Other species in decreasing order: *Nyssa sylvatica*, *Acer rubrum*, *Carya glabra*, *Fraxinus americana*.

TABLE 18D. Attributes¹ of tree species over 4 inches dbh in the north trending drainage from Sloans Crossing Turnout. Data are based on 20 points by Bitterlich variable-radius method. The sample location is shown on Figure 1C.

Species	D ₂	D ₃	B ₂	B ₃	V ₃	BA/ Tree
<i>Quercus alba</i>	55	27	35	31	29	0.63
<i>Liriodendron tulipifera</i>	20	9.5	22	19	14	1.11
<i>Quercus rubra</i>	21	10	15	13	12	0.67
<i>Cornus florida</i>	29	14	6.3	5.5	9.8	0.21
<i>Nyssa sylvatica</i>	17	8.2	4.8	4.2	6.2	0.28
<i>Carya glabra</i>	15	6.8	4.0	3.5	5.2	0.27
<i>Acer saccharum</i>	9.2	4.4	5.3	4.7	4.5	0.57
<i>Oxydendrum arboreum</i>	12	5.7	2.5	2.2	4.0	0.21
<i>Carya ovalis</i>	5.5	2.6	3.8	3.3	3.0	0.68
<i>Fraxinus americana</i>	5.3	2.6	3.8	3.3	2.9	0.71
Other Species ²	18.62		11.6			0.62
Totals	207.62		114.1			0.55

¹D₂ symbolizes density per acre, D₃ is relative density, B₂ is basal area per acre, B₃ is relative basal area, and V₃ is importance value.

²Other species in decreasing order: *Fagus grandifolia*, *Quercus velutina*, *Carya ovata*, *Quercus muehlenbergii*, *Carya cordiformis*, *Sassafras albidum*, *Juniperus virginiana*, *Diospyros virginiana*, *Tilia americana*, *Carya tomentosa*, *Juglans cinerea*, *Juglans nigra*, *Ulmus americana*.

TABLE 19D. Attributes¹ of tree species over 4 inches dbh in the forest north of the Green River, above the terraces, at Turnhole Bend. Data are based on 5 points by Bitterlich variable-radius method. The sample location is shown on Figure 1C.

Species	D ₂	D ₃	B ₂	B ₃	V ₃	BA/ Tree
<i>Quercus alba</i>	32	22	24	31	27	0.75
<i>Acer saccharum</i>	14	9.6	6	7.8	8.7	0.43
<i>Acer rubrum</i>	18	13	3	3.9	8.3	0.17
<i>Carya ovata</i>	14	9.7	5	6.5	8.1	0.36
<i>Carya cordiformis</i>	12	8.7	5	6.5	7.6	0.40
<i>Quercus velutina</i>	6.3	4.4	7	9.1	6.8	1.11
<i>Fraxinus americana</i>	11	7.4	4	5.2	6.3	0.38
<i>Carya glabra</i>	8.1	5.6	5	6.5	6.1	0.62
<i>Quercus rubra</i>	3.7	2.7	6	7.8	5.3	1.64
<i>Carya tomentosa</i>	2.4	1.7	3	5.2	3.4	1.23
<i>Fagus grandifolia</i>	1.4	1.0	3	3.9	2.5	2.14
Other Species ²	20.3		6			0.30
Totals	143.2		77			0.54

¹D₂ symbolizes density per acre, D₃ is relative density, B₂ is basal area per acre, B₃ is relative basal area, and V₃ is importance value.

²Other species in decreasing order: *Juglans nigra*, *Ulmus americana*, *Cornus florida*, *Quercus muehlenbergii*, *Tilia americana*, *Liriodendron tulipifera*.

TABLE 20D. Attributes¹ of tree species over 4 inches dbh in Wet Prong. Data are based on 8 points by Bitterlich variable-radius method. The sample location is shown on Figure 1C.

Species	D ₂	D ₃	B ₂	B ₃	V ₃	BA/ Tree
<i>Fagus grandifolia</i>	56	34	30	31	32	0.84
<i>Acer saccharum</i>	46	28	19	20	24	0.42
<i>Quercus alba</i>	20	12	17	17	15	0.86
<i>Fraxinus americana</i>	11	6.6	8.1	8.3	7.4	0.73
<i>Carya cordiformis</i>	10	6.0	3.7	3.8	4.9	0.36
<i>Quercus rubra</i>	3.8	2.3	5.0	5.1	3.7	1.33
<i>Liriodendron tulipifera</i>	5.0	3.0	3.7	3.8	3.4	0.75
Other Species ²	14.4		10.6			0.74
Totals	166.2		97.1			0.58

¹D₂ symbolizes density per acre, D₃ is relative density, B₂ is basal area per acre, B₃ is relative basal area, and V₃ is importance value.

²Other species in decreasing order: *Platanus occidentalis*, *Ulmus rubra*, *Ulmus americana*, *Sassafras albidum*, *Carya glabra*, *Ostrya virginiana*, *Carya ovata*.

TABLE 21D. Attributes¹ of tree species over 4 inches dbh in Wilson Cave Hollow. Data are based on 15 points by Bitterlich variable-radius method. The sample location is shown on Figure 1C.

Species	D ₂	D ₃	B ₂	B ₃	V ₃	BA/ Tree
<i>Quercus alba</i>	65	26	27	24	25	0.41
<i>Quercus rubra</i>	24	9.7	21	18	14	0.86
<i>Acer saccharum</i>	34	14	12	11	12	0.35
<i>Liriodendron tulipifera</i>	16	6.3	9.3	8.2	7.3	0.60
<i>Quercus velutina</i>	9.6	3.9	11	9.4	6.6	1.11
<i>Carya glabra</i>	22	8.9	4.6	4.1	6.5	0.21
<i>Nyssa sylvatica</i>	22	8.9	4.7	4.1	6.4	0.21
<i>Cornus florida</i>	17	6.9	3.3	2.9	4.9	0.20
<i>Carya ovata</i>	6.2	2.5	5.7	5.0	3.7	0.92
<i>Fraxinus americana</i>	7.1	2.9	3.0	2.7	2.8	0.43
Other Species ²	25.49		12.71			0.50
Totals	248.39		114.31			0.46

¹D₂ symbolizes density per acre, D₃ is relative density, B₂ is basal area per acre, B₃ is relative basal area, and V₃ is importance value.

²Other species in decreasing order: *Acer rubrum*, *Fagus grandifolia*, *Carya ovata*, *Juglans nigra*, *Sassafras albidum*, *Oxydendrum arboreum*, *Carya cordiformis*, *Carya tomentosa*, *Tilia americana*, *Quercus falcata*.

TABLE 22D. Attributes¹ of tree species over 4 inches dbh in the First Creek drainage hemlock stands. Data are based on 16 points by Bitterlich variable-radius method. The sample location is shown on Figure 1C.

Species	D ₂	D ₃	B ₂	B ₃	V ₃	BA/ Tree
<i>Tsuga canadensis</i>	49	22	20	20	21	0.41
<i>Quercus prinus</i>	42	18	16	17	18	0.39
<i>Fagus grandifolia</i>	25	11	16	16	14	0.63
<i>Acer saccharum</i>	17	7.4	7.3	7.6	7.5	0.44
<i>Liriodendron tulipifera</i>	9.2	4.1	6.7	6.9	5.5	0.72
<i>Quercus rubra</i>	10	4.5	6.0	6.2	5.3	0.59
<i>Carya glabra</i>	15	6.7	3.7	3.8	5.2	0.24
<i>Acer rubrum</i>	14	6.0	4.0	4.1	5.0	0.30
<i>Nyssa sylvatica</i>	8.5	3.7	1.7	1.7	2.7	0.20
<i>Oxydendrum arboreum</i>	7.4	3.3	1.7	1.7	2.5	0.23
<i>Quercus alba</i>	2.9	1.3	3.0	3.1	2.2	1.03
<i>Ilex opaca</i>	5.7	2.5	1.3	1.4	1.9	0.23
Other Species ²	22.06		9.52			0.43
Totals	227.76		96.92			0.43

¹D₂ symbolizes density per acre, D₃ is relative density, B₂ is basal area per acre, B₃ is relative basal area and V₃ is importance value.

²Other species in decreasing order: *Fraxinus americana*, *Carya ovata*, *Quercus velutina*, *Betula allegheniensis*, *Magnolia tripetala*, *Quercus muehlenbergii*, *Liquidambar styraciflua*, *Carya cordiformis*, *Ostrya virginiana*, *Carya tomentosa*, *Juglans nigra*, *Quercus falcata*, *Ulmus thomasi*, *Sassafras albidum*.

TABLE 23D. Attributes¹ of tree species over 4 inches dbh on Boardcut Island. Data are based on 10 points by Bitterlich variable-radius method. The sample location is shown on Figure 1C.

Species	D ₂	D ₃	B ₂	B ₃	V ₃	BA/ Tree
<i>Acer negundo</i>	155	77	47	47	54	0.30
<i>Acer saccharinum</i>	27	12	21	21	17	0.78
<i>Liriodendron tulipifera</i>	13	5.8	14	14	9.8	1.01
<i>Platanus occidentalis</i>	7.1	3.1	11	11	6.9	1.49
Other Species ²	26.62		6.5			0.24
Totals	228.72		99.5			0.44

¹D₂ symbolizes density per acre, D₃ is relative density, B₂ is basal area per acre, B₃ is relative basal area, and V₃² is importance value.

²Other species in decreasing order: *Acer saccharum*, *Fraxinus pennsylvanica*, *Juglans nigra*, *Acer rubrum*, *Ulmus rubra*.

TABLE 24D. Attributes¹ of tree species over 4 inches dbh on Mammoth Ferry floodplain. Data are based on a 1.4 acre sample (0.2 acre plots). The sample location is shown on Figure 1C.

Species	D ₂	D ₃	B ₂	B ₃	V ₃	BA/ Tree
<i>Platanus occidentalis</i>	16	12	67	54	33	4.06
<i>Ulmus rubra</i>	34	26	17	13	19	0.49
<i>Acer saccharinum</i>	25	19	9	7	13	0.35
<i>Fagus grandifolia</i>	14	10	15	12	22	1.08
<i>Ostrya virginiana</i>	11	8	1	0.8	4	0.09
Other Species ²	32.4		22.4			0.69
Totals	132.4		131.4			0.99

¹D₂ symbolizes density per acre, D₃ is relative density, B₂ is basal area per acre, B₃ is relative basal area, and V₃ is importance value.

²Other species in decreasing order: *Carya ovata*, *Liriodendron tulipifera*, *Celtis occidentalis*, *Fraxinus pennsylvanica*, *Carpinus caroliniana*, *Acer negundo*, *Acer saccharum*, *Ulmus alata*, *Fraxinus americana*, *Oxydendrum arboreum*, *Quercus muehlenbergii*.

TABLE 25D. Attributes¹ of tree species over 4 inches dbh on New Ferry floodplain. Data are based on a 0.6 acre sample (0.1 acre plots). The sample location is shown on Figure 1C.

Species	D ₂	D ₃	B ₂	B ₃	V ₃	BA/ Tree
<i>Fraxinus pennsylvanica</i>	35	26	25	28	27	0.71
<i>Platanus occidentalis</i>	26	23	39	44	34	1.50
<i>Ulmus rubra</i>	32	28	13	15	21	0.41
Other Species ²	21		12.2			0.58
Totals 0.6 acres	114		89.2			0.78
Per Acre	190		148.6			

¹D₂ symbolizes density per acre, D₃ is relative density, B₂ is basal area per acre, B₃ is relative basal area, and V₃ is importance value.

²Other species in decreasing order: *Acer saccharinum*, *Acer negundo*.

TABLE 26D. Attributes¹ of tree species over 4 inches dbh on Sand Cave Island. Data are based on 5 points by Bitterlich variable-radius method. The sample location is shown on Figure 1C.

Species	D ₂	D ₃	B ₂	B ₃	V ₃	BA/ Tree
Acer saccharinum	85	52	46	47	50	0.54
Platanus occidentalis	58	36	44	45	40	0.77
Other Species ²	19.3		8			0.41
Totals	162.3		98			0.60

¹D₂ symbolizes density per acre, D₃ is relative density, B₂ is basal area per acre, B₃ is relative basal area, and V₃ is importance value.

²Other species in decreasing order: Acer negundo, Ulmus alata, Acer rubrum.

TABLE 27D. Attributes¹ of tree species over 4 inches dbh in Big Woods (upland). Data are based on a 4.6 acre sample (0.2 acre plots). The sample location is shown on Figure 1C.

Species	D ₂	D ₃	B ₂	B ₃	F ₁	F ₃	V ₃	BA/ Tree
Quercus alba	34	26	21	26	96	12	22	0.61
Quercus velutina	23	17	24	30	91	12	20	1.05
Carya glabra	15	11	6.4	7.9	87	11	10	0.43
Carya tomentosa	11	8.5	5.5	6.9	78	10	8.4	0.50
Quercus rubra	10	7.6	5.7	7.1	65	8.8	7.9	0.57
Oxydendrum arboreum	8.5	6.5	1.4	1.8	56	7.2	5.2	0.17
Cornus florida	7.0	5.3	0.84	1.0	70	8.9	5.1	0.12
Nyssa sylvatica	5.0	3.8	3.7	4.6	43	5.5	4.7	0.74
Quercus stellata	4.3	3.3	3.5	4.3	43	5.5	4.4	0.80
Acer rubrum	3.9	3.0	0.56	0.69	48	6.1	3.3	0.14
Other Species ²	9.33		7.56					0.81
Totals	131.03		80.16					0.61

¹D₂ symbolizes density per acre, D₃ is relative density, B₂ is basal area per acre, B₃ is relative basal area, F₁ is frequency of occurrence, F₃ is relative occurrence, and V₃ is importance value.

²Other species in decreasing order: Liriodendron tulipifera, Carya ovata, Juglans nigra, Fraxinus americana, Juglans cinerea, Cercis canadensis, Quercus falcata.

TABLE 28D. Attributes¹ of tree species over 4 inches dbh in the forest surrounding the Good Spring Church successional study area. Data are based on 9 points by Bitterlich variable-radius method. The sample location is shown on Figure 1C.

Species	D ₂	D ₃	B ₂	B ₃	V ₃	BA/ Tree
<i>Quercus alba</i>	60	25	37	31	28	0.61
<i>Acer rubrum</i>	52	21	17	14	18	0.33
<i>Carya glabra</i>	47	19	11	9.0	14	0.23
<i>Quercus rubra</i>	15	6.1	18	15	10	1.20
<i>Quercus velutina</i>	15	6.1	14	12	9.0	0.93
<i>Nyssa sylvatica</i>	14	5.7	5.5	4.7	5.2	0.40
<i>Liriodendron tulipifera</i>	8.5	3.5	5.0	4.3	3.9	0.59
Other Species ²	31.84		11.6			0.36
Totals	243.34		119.1			0.49

¹D₂ symbolizes density per acre, D₃ is relative density, B₂ is basal area per acre, B₃ is relative basal area, and V₃ is importance value.

²Other species in decreasing order: *Carya ovalis*, *Cornus florida*, *Ulmus rubra*, *Fraxinus americana*, *Carya cordiformis*, *Carya tomentosa*, *Acer saccharum*, *Carya ovata*, *Sassafras albidum*, *Fagus grandifolia*, *Juglans nigra*, *Quercus stellata*.

TABLE 29D. Attributes¹ of tree species over 4 inches dbh in the forest surrounding the Great Onyx succession site. Data are based on 5 points by Bitterlich variable-radius method. The sample location is shown on Figure 1C.

Species	D ₂	D ₃	B ₂	B ₃	V ₃	BA/ Tree
<i>Pinus virginiana</i>	62	20	30	28	24	0.48
<i>Liriodendron tulipifera</i>	50	16	10	9.3	12	0.20
<i>Cornus florida</i>	46	14	9	8.3	11	0.20
<i>Quercus velutina</i>	24	7.5	11	10	8.4	0.46
<i>Quercus alba</i>	18	5.7	11	10	8.0	0.60
<i>Carya tomentosa</i>	24	7.5	6	5.6	6.6	0.25
<i>Quercus falcata</i>	10	3.1	10	9.3	6.3	0.99
<i>Ulmus alata</i>	17	5.4	4	3.7	4.6	0.23
<i>Acer rubrum</i>	13	4.1	4	3.7	3.9	0.31
<i>Platanus occidentalis</i>	18	5.7	5	4.6	3.3	0.28
<i>Carya glabra</i>	10	3.2	2	1.9	2.1	0.20
Other Species ²	26.43		6			0.23
Totals	318.43		108			0.34

¹D₂ symbolizes density per acre, D₃ is relative density, B₂ is basal area per acre, B₃ is relative basal area, and V₃ is importance value.

²Other species in decreasing order: *Carya cordiformis*, *Celtis occidentalis*, *Juglans nigra*, *Diospyros virginiana*, *Quercus marilandica*, *Quercus stellata*.

TABLE 30D. Attributes¹ of tree species over 4 inches dbh on the slopes of the Green River Valley along south facing limestone outcrops. Data are based on 9 points by Bitterlich variable-radius method. The sample location is shown on Figure 1C.

Species	D ₂	D ₃	B ₂	B ₃	V ₃	BA/ Tree
<i>Juniperus virginiana</i>	138	36	37.7	34	35	0.27
<i>Quercus alba</i>	43	11	18.7	17	14	0.31
<i>Quercus velutina</i>	47	12	14.5	13	13	0.30
<i>Acer rubra</i>	48	12	14.4	12	12	0.35
<i>Quercus prinus</i>	21	5.6	7.4	6.5	6	0.23
<i>Quercus marilandica</i>	25	6.5	5.8	5.2	5.8	0.19
<i>Cornus florida</i>	15	3.8	2.8	2.6	3.2	0.29
Other Species ²	44.4		9.9			0.22
Totals	381.4		111.2			0.29

¹D₂ symbolizes density per acre, D₃ is relative density, B₂ is basal area per acre, B₃ is relative basal area, and V₃ is importance value.

²Other species in decreasing order: *Carya ovata*, *Carya glabra*, *Carya ovalis*, *Ulmus alata*, *Ostrya virginiana*, *Fagus grandifolia*.

TABLE 31D. Attributes¹ of tree species over 4 inches dbh in upland forest on Joppa Ridge and Mammoth Cave Ridge. Data are based on 15 points by Bitterlich variable-radius method. The sample location is shown on Figure 1C.

Species	D ₂	D ₃	B ₂	B ₃	V ₃	BA/ Tree
<i>Quercus velutina</i>	55	23	19	22	22	0.34
<i>Quercus rubra</i>	53	22	17	19	21	0.32
<i>Carya glabra</i>	34	14	11	12	13	0.32
<i>Cornus florida</i>	31	13	3.4	7.2	10	0.11
<i>Quercus falcata</i>	21	8.8	9.3	11	9.7	0.44
<i>Quercus alba</i>	14	5.9	8.0	9.1	7.5	0.56
<i>Quercus stellata</i>	7.4	3.1	6.0	6.8	4.9	0.81
<i>Quercus rubra</i>	3.6	1.5	2.0	2.2	1.7	0.55
Other Species ²	21.4		10.2			0.48
Totals	240.4		85.9			0.36

¹D₂ symbolizes density per acre, D₃ is relative density, B₂ is basal area per acre, B₃ is relative basal area, and V₃² is importance value.

²Other species in decreasing order: *Liriodendron tulipifera*, *Oxydendrum arboreum*, *Carya ovalis*, *Quercus falcata*, *Carya tomentosa*, *Fagus grandifolia*, *Nyssa sylvatica*, *Quercus marilandica*, *Carya cordiformis*.

TABLE 32D. Attributes¹ of tree species over 4 inches dbh on Lee Ridge. Data are based on 15 points by Bitterlich variable-radius method. The sample location is shown on Figure 1C.

Species	D ₂	D ₃	B ₂	B ₃	V ₃	BA/ Tree
<i>Quercus rubra</i>	55	23	17	20	22	0.30
<i>Quercus alba</i>	30	13	18	21	17	0.72
<i>Carya glabra</i>	26	11	8.7	11	11	0.40
<i>Cornus florida</i>	32	14	6.3	7.6	11	0.20
<i>Quercus velutina</i>	18	7.4	6.6	8.0	7.7	0.38
<i>Nyssa sylvatica</i>	19	8.0	4	4.9	6.5	0.26
<i>Carya ovata</i>	13	5.6	6	7.3	6.4	0.46
<i>Quercus stellata</i>	6.9	2.9	6	7.3	5.1	0.87
<i>Acer rubrum</i>	13	5.3	2.7	3.3	4.3	0.22
Other Species ²	23.52		7.6			0.32
Totals	236.42		82.9			0.35

¹D₂ symbolizes density per acre, D₃ is relative density, B₂ is basal area per acre, B₃ is relative basal area, and V₃ is importance value.

²Other species in decreasing order: *Carya tomentosa*, *Carya cordiformis*, *Carya ovata*, *Fraxinus americana*, *Liriodendron tulipifera*, *Prunus serotina*, *Oxydendrum arboreum*, *Quercus muehlenbergii*, *Quercus prinus*.

TABLE 33D. Attributes¹ of tree species over 4 inches dbh in a valley south of Sloans Crossing. Data are based on 12 points by Bitterlich variable-radius method. The sample location is shown on Figure 1C.

Species	D ₂	D ₃	B ₂	B ₃	V ₃	BA/ Tree
<i>Nyssa sylvatica</i>	65	25	15	18	21	0.30
<i>Oxydendrum arboreum</i>	62	23	14	16	19	0.22
<i>Quercus stellata</i>	25	9.6	12	13	11	0.46
<i>Quercus velutina</i>	25	9.3	13	12	10	0.54
<i>Quercus alba</i>	20	7.5	7.1	8.0	7.8	0.36
<i>Quercus rubra</i>	12	4.5	7.1	8.0	6.3	0.59
<i>Quercus falcata</i>	9.7	3.7	5.4	6.1	4.9	0.56
<i>Cornus florida</i>	15	5.6	2.9	3.3	4.5	0.20
<i>Quercus marilandica</i>	7.8	2.9	5.0	5.7	4.3	0.64
Other Species ²	24.07		8.39			0.35
Totals	265.57		89.89			0.34

¹D₂ symbolizes density per acre, D₃ is relative density, B₂ is basal area per acre, B₃ is relative basal area, and V₃ is importance value.

²Other species in decreasing order: *Carya tomentosa*, *Quercus muehlenbergii*, *Carya ovalis*, *Sassafras albidum*, *Carya cordiformis*, *Carya glabra*, *Quercus macrocarpa*, *Quercus coccinea*, *Liriodendron tulipifera*, *Platanus occidentalis*.

TABLE 34D. Attributes¹ of tree species over 4 inches dbh in Smith Valley west of Joppa Church. Data are based on 20 points by Bitterlich variable-radius method. The sample location is shown on Figure 1C.

Species	D ₂	D ₃	B ₂	B ₃	V ₃	BA/ Tree
<i>Quercus velutina</i>	31	14	17	19	16	0.54
<i>Cornus florida</i>	40	18	8.5	9.5	14	0.21
<i>Quercus alba</i>	22	9.8	10	11	10	0.46
<i>Nyssa sylvatica</i>	24	11	7.8	8.7	9.8	0.32
<i>Quercus rubra</i>	16	7.3	8.5	9.5	8.4	0.52
<i>Quercus coccinea</i>	4.9	2.2	5.8	6.4	4.3	1.16
<i>Carya glabra</i>	8.0	3.6	4.3	4.8	4.2	0.53
<i>Quercus stellata</i>	8.5	3.8	4.0	4.5	4.1	0.47
<i>Acer saccharinum</i>	10	4.5	3.0	3.4	3.9	0.30
<i>Juniperus virginiana</i>	9.4	4.2	2.8	3.1	3.6	0.29
<i>Fagus grandifolia</i>	5.7	2.6	2.8	3.1	2.8	0.48
<i>Quercus falcata</i>	3.7	1.7	3.3	3.6	2.6	0.89
<i>Juglans nigra</i>	4.3	1.9	1.3	1.4	1.7	0.29
<i>Liriodendron tulipifera</i>	1.4	0.62	2.3	2.5	1.6	1.63
<i>Quercus muehlenbergii</i>	5.6	2.5	0.25	0.28	1.4	0.05
<i>Sassafras albidum</i>	3.8	1.7	0.75	0.84	1.3	0.20
Other Species ²	14.13		6.60			0.47
Totals	212.43		89.0			0.42

¹D₂ symbolizes density per acre, D₃ is relative density, B₂ is basal area per acre, B₃ is relative basal area, and V₃ is importance value.

²Other species in decreasing order: *Carya cordiformis*, *Fraxinus americana*, *Carya ovalis*, *Acer rubrum*, *Carya tomentosa*, *Carya ovata*, *Tilia americana*, *Fraxinus pennsylvanica*, *Liquidambar styraciflua*.

TABLE 35D. Attributes¹ of tree species over 4 inches dbh in Cedar Sink Valley.
Data are based on a 1.0 acre sample (0.2 acre plots). The sample location is shown
on Figure 1C.

Species	D ₂	D ₃	B ₂	B ₃	F ₁	F ₃	V ₃	BA/ Tree
Juniperus virginiana	145	77	36	75	100	29	60	0.25
Juglans nigra	17	9.0	3.7	7.7	60	18	11	0.22
Salix nigra	7	3.7	4.2	8.6	20	5.9	6.1	1.23
Cornus florida	7	3.7	1.2	2.5	20	5.9	4.0	0.66
Prunus serotina	4	2.1	0.98	2.0	20	5.9	3.3	0.25
Carya cordiformis	2	1.1	0.80	1.6	20	5.9	2.9	0.40
Ulmus rubra	2	1.1	0.26	0.54	20	5.9	2.5	0.13
Other Species ²	4		1.09					0.27
Totals	188		48.23					0.26

¹D₂ symbolizes density per acre, D₃ is relative density, B₂ is basal area per acre, B₃ is relative basal area, F₁ is frequency of occurrence, F₃ is relative occurrence, and V₃ is importance value.

²Other species in decreasing order: Pinus virginiana, Liriodendron tulipifera, Gleditsia triacanthos, Nyssa sylvatica.

TABLE 36D. Attributes¹ of tree species over 4 inches dbh on Hickory Cabin and Brooks Knob Plateau. Data are based on 15 points by Bitterlich variable-radius method. The sample location is shown on Figure 1C.

Species	D ₂	D ₃	B ₂	B ₃	V ₃	BA/ Tree
<i>Pinus virginiana</i>	110	56	50	69	62	0.46
<i>Cornus florida</i>	33	17	7.0	9.6	13	0.21
<i>Juniperus virginiana</i>	23	12	4.3	5.9	8.7	0.19
<i>Nyssa sylvatica</i>	6.8	3.4	2.7	3.7	3.5	0.39
<i>Sassafras albidum</i>	8.5	4.3	1.7	2.3	3.3	0.20
Other Species ²	16.41		7.06			0.43
Totals	197.71		72.76			0.37

¹D₂ symbolizes density per acre, D₃ is relative density, B₂ is basal area per acre, B₃ is relative basal area, and V₃ is importance value.

²Other species in decreasing order: *Liriodendron tulipifera*, *Carya glabra*, *Carya ovata*, *Carya tomentosa*, *Fraxinus americana*, *Ulmus alata*, *Oxydendrum arboreum*, *Quercus velutina*.

TABLE 37D. Attributes¹ of tree species over 4 inches dbh in an old field succession on Joppa Ridge. Data are based on 15 points by Bitterlich variable-radius method. The sample location is shown on Figure 1C.

Species	D ₂	D ₃	B ₂	B ₃	V ₃	BA/ Tree
<i>Juniperus virginiana</i>	150	81	23	75	78	0.15
<i>Nyssa sylvatica</i>	13	6.7	2.0	6.5	6.6	0.16
<i>Fraxinus americana</i>	7.4	4.0	1.3	4.1	4.0	0.17
Other Species ²	15.92		4.55			0.29
Totals	186.32		30.85			0.17

¹D₂ symbolizes density per acre, D₃ is relative density, B₂ is basal area per acre, B₃ is relative basal area, and V₃ is importance value.

²Other species in decreasing order: *Quercus stellata*, *Oxydendrum arboreum*, *Liriodendron tulipifera*, *Carya glabra*, *Cornus florida*, *Carya tomentosa*, *Quercus velutina*, *Acer rubrum*.

TABLE 38D. Attributes¹ of tree species over 4 inches dbh in an old field succession on Mammoth Cave Ridge. Data are based on 20 points by Bitterlich variable-radius method. The sample location is shown on Figure 1C.

Species	D ₂	D ₃	B ₂	B ₃	V ₃	BA/ Tree
<i>Juniperus virginiana</i>	164	76	26	71	74	0.16
<i>Fraxinus americana</i>	8.5	3.9	2.5	6.8	5.4	0.29
<i>Acer rubrum</i>	10	4.7	1.5	4.1	4.4	0.15
<i>Liriodendron tulipifera</i>	3.6	1.6	2.5	6.8	4.2	0.70
<i>Cornus florida</i>	10	4.7	0.75	2.0	3.4	0.07
Other Species ²	20.40		3.25			0.16
Totals	216.50		36.50			0.17

¹D₂ symbolizes density per acre, D₃ is relative density, B₂ is basal area per acre, B₃ is relative basal area, and V₃ is importance value.

²Other species in decreasing order: *Quercus marilandica*, *Diospyros virginiana*, *Nyssa sylvatica*, *Oxydendrum arboreum*, *Ulmus alata*.

TABLE 39D. Attributes¹ of tree species over 2 inches dbh in seven upland successional permanent plots. Data are based on 7, 0.1 acre plots. The sample locations are shown on Figure 1C.

Species	D ₂	D ₃	B ₂	B ₃	V ₃	BA/ Tree
<i>Pinus virginiana</i>	60	34	9.1	41	37	0.1519
<i>Juniperus virginiana</i>	45	26	5.8	28	27	0.1281
<i>Cornus florida</i>	22	13	1.1	6.2	9.6	0.0496
<i>Liriodendron tulipifera</i>	13	7.5	1.7	7.9	7.7	0.1298
<i>Nyssa sylvatica</i>	11	6.3	1.2	6.0	6.2	0.1132
<i>Diospyros virginiana</i>	6	3.5	0.42	2.2	2.8	0.0704
Other Species ²	18		2.7			0.1479
Totals 0.7 acre	175		22.02			0.1257

¹D₂ symbolizes density per acre, D₃ is relative density, B₂ is basal area per acre, B₃ is relative basal area, and V₃ is importance value.

²Other species in decreasing order: *Acer rubra*, *Fraxinus americana*, *Quercus stellata*, *Ulmus alata*, *Carya glabra*, *Sassafras albidum*, *Carya tomentosa*, *Robinia pseudoacacia*, *Rhus copallinum*.

Appendix E

Size Class Density per Acre Tables

Reference data for size class densities per acre of stands sampled by the Bitterlich variable-radius method are found in Appendix E. These data are arranged alphabetically by forest association.

These size class density tables aid in assessing the changes occurring in the tree populations in a particular stand.

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Appendix E

<u>Table Number</u>	<u>Stand Name</u>	<u>Stand Symbol</u>
1E	Big Hollow	BH
2E	Cedar Sink Valley Slopes	CSVS
3E	Chicken Prong Hollow	CPH
4E	Crumps Knob	CK
5E	Doyel Valley Slopes	DVS
6E	Indian Hill Chestnut	IH
7E	Mammoth Cave New Ferry	MCNF
8E	Salts Sink Full	SSF
9E	Sloans Crossing North	SCN
10E	Wet Prong	WP
11E	Wilson Cave Hollow	WCH
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24E	Mammoth Cave Old Field	MCOF

TABLE 1E. Size class densities per acre of tree species comprising 80% I.V. in Big Hollow (+ equals ≤ 0.1 tree per acre). Data are based on 20 points by Bitterlich variable-radius method.

Species	Size Class Midpoint								
	6	10	14	18	22	26	30	34	38
<i>Fagus grandifolia</i>	29	8	5	2	1				
<i>Quercus alba</i>	4	10	7	1	0.3	0.1			
<i>Liriodendron tulipifera</i>	9	5	2	1	0.4	0.1	0.1	0.1	+
<i>Acer saccharum</i>	15	4	0.5	0.4	0.9	+		+	
<i>Acer rubrum</i>	13	3	0.7	0.6					
<i>Carya glabra</i>	6	2	0.5	0.3					
<i>Quercus rubra</i>		1	1	0.6	+		+		
<i>Juglans nigra</i>		2	1		1				
<i>Quercus muehlenbergii</i>	3	1	0.2	0.1					
18 Minor Species ¹	16	8	5						
Totals	95	44	22.9	6	3.6	0.2	0.1	0.1	

¹Minor species in decreasing order: *Carya ovata*, *Nyssa sylvatica*, *Platanus occidentalis*, *Fraxinus americana*, *Ulmus rubra*, *Quercus velutina*, *Carya cordiformis*, *Gymnocladus dioica*, *Fraxinus pennsylvanica*, *Juglans cinerea*, *Ulmus thomasi*, *Carya tomentosa*, *Carya ovalis*, *Sassafras albidum*, *Cornus florida*, *Carya* sp., *Acer negundo*, *Tilia americana*.

TABLE 2E. Size class densities per acre of tree species comprising 80% I.V. of the Cedar Sink Valley slopes. Data are based on 21 points by Bitterlich variable-radius method.

Species	Size Class Midpoint						
	6	10	14	18	22	26	30
<i>Quercus rubra</i>	13	12	10	4	0.8	0.3	
<i>Quercus velutina</i>	2	11	6	2	1	0.1	
<i>Cornus florida</i>	22	3					
<i>Quercus alba</i>	4	7	2	0.8			
<i>Oxydendrum arboreum</i>	13	2	0.7				
<i>Carya tomentosa</i>	7	2	2	0.8	0.1		
<i>Nyssa sylvatica</i>	13	0.9					
<i>Carya glabra</i>		3	2	0.4			
<i>Juniperus virginiana</i>	6	0.9	0.2				
<i>Juglans nigra</i>	5	3					
16 Minor Species ¹	19	8	8.6	0.5	0.3		0.5
Totals	104	52.8	31.5	8.5	2.2	0.4	0.5

¹ Minor species in decreasing order: *Fagus grandifolia*, *Quercus stellata*, *Liriodendron tulipifera*, *Carya ovata*, *Acer saccharum*, *Fraxinus americana*, *Carya cordiformis*, *Sassafras albidum*, *Quercus falcata*, *Cercis canadensis*, *Morus rubra*, *Ulmus alata*, *Acer rubrum*, *Populus alba*, *Quercus marilandica*, *Quercus prinus*.

TABLE 3E. Size class densities per acre of tree species comprising 80% I.V. in Chicken Prong Hollow. Data are based on 19 points by Bitterlich variable-radius method.

Species	Size Class Midpoint						
	6	10	14	18	22	26	30
<i>Quercus prinus</i>	44	23	3	0.2	0.1		
<i>Quercus alba</i>	9	8	3	0.3	0.4	0.4	0.1
<i>Acer saccharum</i>	10	6	2	0.1			
<i>Fagus grandifolia</i>	4	3	2	0.1		0.1	0.2
<i>Quercus rubra</i>	8	3	2	0.1			
<i>Carya glabra</i>	8	4	0.5	0.1			
<i>Quercus velutina</i>	1	5	2		0.2		
14 Minor Species ¹	22	9	2.5	0.1			
Totals	106	61	17	1	0.7	0.5	0.3

¹Minor species in decreasing order: *Fraxinus americana*, *Carya cordiformis*, *Liriodendron tulipifera*, *Acer rubrum*, *Carya tomentosa*, *Platanus occidentalis*, *Nyssa sylvatica*, *Ulmus americana*, *Sassafras albidum*, *Ulmus rubra*, *Cornus florida*, *Ostrya virginiana*, *Amelanchier arborea*, *Carya ovata*.

TABLE 4E. Size class densities per acre of tree species comprising 80% I.V. of Crumps Knob. Data are based on 15 points by Bitterlich variable-radius method.

Species	Size Class Midpoint						
	6	10	14	18	22	26	30
<i>Quercus alba</i>	10	7	8	2	0.6	0.3	
<i>Carya glabra</i>	27	10	1	0.3			
<i>Quercus prinus</i>	6	7	8	1	0.2	0.1	0.1
<i>Acer rubrum</i>	22	4	1				
<i>Nyssa sylvatica</i>	19	5	1				
<i>Liriodendron tulipifera</i>		5	5	0.7	0.4	0.3	
<i>Quercus rubra</i>	9	3	0.9	0.4	0.1	0.2	0.1
<i>Acer saccharum</i>	5	2	0.6	0.4			
12 Minor Species ¹	22	14	4.5	2.4	0.4		
Totals	120	57	30	7.2	1.7	0.9	0.2

¹Minor species in decreasing order: *Quercus velutina*, *Carya ovalis*, *Carya ovata*, *Carya tomentosa*, *Sassafras albidum*, *Juglans nigra*, *Fagus grandifolia*, *Fraxinus americana*, *Quercus falcata*, *Carya cordiformis*, *Ostrya virginiana*, *Quercus stellata*.

TABLE 5E. Size class densities per acre of tree species comprising 80% I.V. of Doyel Valley slopes. Data are based on 20 points by Bitterlich variable-radius method.

Species	Size Class Midpoint						
	6	10	14	18	22	26	30
<i>Quercus velutina</i>	23	13	9	2	2	0.1	
<i>Nyssa sylvatica</i>	50	6	2				
<i>Quercus stellata</i>	11	4	3	1	0.2		
<i>Cornus florida</i>	27	1					
<i>Quercus alba</i>	9	4	3	0.3	0.2		
<i>Quercus falcata</i>	8	0.9	2	0.4	0.1		
<i>Juniperus virginiana</i>	14						
14 Minor Species ¹	31	6.1	3	1.3		0.1	0.1
Totals	173	35	22	5	2.5	0.2	0.1

¹ Minor species in decreasing order: *Diospyros virginiana*, *Quercus rubra*, *Quercus coccinea*, *Carya glabra*, *Quercus marilandica*, *Oxydendrum arboreum*, *Sassafras albidum*, *Carya ovalis*, *Carya cordiformis*, *Liriodendron tulipifera*, *Quercus prinus*, *Acer saccharum*, *Juglans nigra*, *Fagus grandifolia*.

TABLE 6E. Size class densities per acre of tree species comprising 80% I.V. of Indian Hill chestnut oak forest. Data are based on 9 points by Bitterlich variable-radius method.

Species	Size Class Midpoint							
	6	10	14	18	22	26	30	34
<i>Quercus prinus</i>	22	21	13	6	3	0.8	0.4	0.4
<i>Carya ovalis</i>	6	5	3	1				
<i>Quercus velutina</i>			4	2	0.9	0.3	0.4	0.2
<i>Quercus alba</i>		2	2	0.7	1.2	0.2		0.1
<i>Oxydendrum arboreum</i>	10	2	0.6					
<i>Acer rubrum</i>	6	2	1	0.4		0.2		
<i>Carya glabra</i>		3	2	1		0.2		
<i>Acer saccharum</i>		6	0.6					
9 Minor Species ¹	16	9	2.8	2.9	0.1	0.3	0.5	0.1
Totals	60	50	29	14	5.2	2	1.3	0.8

¹Minor species in decreasing order: *Illex opaca*, *Fagus grandifolia*, *Nyssa sylvatica*, *Liquidambar styraciflua*, *Carya* sp., *Quercus rubra*, *Carya cordiformis*, *Liriodendron tulipifera*, *Quercus muehlenbergii*.

TABLE 7E. Size class densities per acre of tree species comprising 80% I.V. in a side valley near Mammoth Cave New Ferry. Data are based on 5 points by Bitterlich variable-radius method.

Species	Size Class Midpoint						
	6	10	14	18	22	26	30
<i>Quercus alba</i>	10	4	7	2	3	0.8	
<i>Acer saccharum</i>	41	2	0.9				
<i>Fraxinus americana</i>	15	6	7		0.4	0.3	
<i>Cornus florida</i>	31	4					
<i>Carya glabra</i>	10	6	5	1			
<i>Sassafras albidum</i>	20	2					
<i>Carya cordiformis</i>	10	2	4				
<i>Quercus muehlenbergii</i>	5			1	0.4	0.3	
<i>Carya tomentosa</i>			3	1	0.3		
<i>Tilia americana</i>	5	4					
<i>Quercus velutina</i>		2	2	0.6		0.3	
6 Minor Species ¹	6	8	4.1	1.4		1	0.6
Totals	153	40	33	7	4.1	2.7	0.6

¹Minor species in decreasing order: *Liriodendron tulipifera*, *Fagus grandifolia*, *Carpinus caroliniana*, *Carya ovalis*, *Juglans nigra*, *Diospyros virginiana*.

TABLE 8E. Salts Sink size class table. Data are based on a full census of 0.94 acres.

Species	Size Class Midpoint							
	6	10	14	18	22	26	30	34
<i>Liriodendron tulipifera</i>		8	10	6	5	3		1
<i>Quercus alba</i>	8	7	3	3	3	3	2	1
<i>Quercus rubra</i>		2	2			2	1	
<i>Cornus florida</i>	13	1						
<i>Quercus velutina</i>	2	2	1					1
<i>Sassafras albidum</i>	5	3	1					
<i>Nyssa sylvatica</i>	5	2	1					
<i>Acer rubrum</i>	1	1						
<i>Carya glabra</i>	1							
<i>Fraxinus americana</i>	1							
Totals	36	26	18	9	8	8	3	3

TABLE 9E. Size class densities per acre of tree species comprising 80% I.V. in north trending drainage from Sloans Crossing Turnout (+ equals <0.1 tree per acre). Data are based on 20 points by Bitterlich variable-radius method.

Species	Size Class Midpoint						
	6	10	14	18	22	26	30
<i>Quercus alba</i>	22	18	12	3	0.7	0.3	0.1
<i>Liriodendron tulipifera</i>	3	8	4	3	1	0.6	0.2
<i>Quercus rubra</i>	8	7	5	2	0.4	0.1	
<i>Nyssa sylvatica</i>	14	2	0.7				
<i>Carya glabra</i>	9	3	2	0.6	+		
<i>Acer saccharum</i>	4	4	0.9	0.6	0.2		
<i>Oxydendrum arboreum</i>	11	0.5					
15 Minor Species ¹	16	8					
Totals	87	50.5	24.6	9.2	2.3	1	0.3

¹Minor species in decreasing order: *Carya ovalis*, *Fraxinus americana*, *Fagus grandifolia*, *Quercus velutina*, *Carya ovata*, *Quercus muehlenbergii*, *Carya cordiformis*, *Sassafras albidum*, *Juniperus virginiana*, *Diospyros virginiana*, *Tilia americana*, *Carya tomentosa*, *Juglans cinerea*, *Juglans nigra*, *Ulmus americana*.

TABLE 10E. Size class densities per acre of tree species comprising 80% I.V. in Wet Prong. Data are based on 8 points by Bitterlich variable-radius method.

Species	Size Class Midpoint							
	6	10	14	18	22	26	30	34
<i>Fagus grandifolia</i>	25	28	9	2	4	0.3	2	0.4
<i>Acer saccharum</i>	51	32	7	2				
<i>Quercus alba</i>	13	9	11	3	2	2	0.3	
<i>Fraxinus americana</i>		16	5	1.4				
<i>Carya cordiformis</i>	13	7	1					
<i>Quercus rubra</i>			5	3				
8 Minor Species ¹	6	20	8	3.6				
Totals	108	112	46	15	6	2.3	2.3	0.4

¹Minor species in decreasing order: *Liriodendron tulipifera*, *Platanus occidentalis*, *Ulmus rubra*, *Ulmus americana*, *Sassafras albidum*, *Carya glabra*, *Ostrya virginiana*, *Carya ovata*.

TABLE 11E. Size class densities per acre of tree species comprising 80% I.V. in Wilson Cave Hollow (+ equals <0.1 tree per acre). Data are based on 15 points by Bitterlich variable-radius method.

Species	Size Class Midpoint								
	6	10	14	18	22	26	30	34	38
Quercus alba	42	16	4	1	0.5	0.3	+	+	
Quercus rubra	3	9	9	2	0.1	0.2			
Acer saccharum	20	6	7	0.6	0.2				
Liriodendron tulipifera	8	4	3	0.2	0.1	0.2	0.1		
Quercus velutina		5	2	2	0.6	0.4			+
Nyssa sylvatica	20	1							
Cornus florida	17								
Carya glabra	15	4	3	0.4	0.1	0.2	0.1		+
Carya ovata		3	2	0.9					
Fraxinus americana	5	1	0.6		0.1				
10 Minor Species ¹	20	12	2	2	1				
Totals	150	61	32.6	9.1	2.7	1.3	0.2		

¹ Minor species in decreasing order: *Acer rubrum*, *Fagus grandifolia*, *Carya ovalis*, *Juglans nigra*, *Sassafras albidum*, *Oxydendrum arboreum*, *Carya cordiformis*, *Carya tomentosa*, *Tilia americana*, *Quercus falcata*.

TABLE 12E. Size class densities per acre of tree species comprising 80% I.V. of the hemlock stands in First Creek drainage. Data are based on 16 points by Bitterlich variable-radius method.

Species	Size Class Midpoint					
	6	10	14	18	22	26
<i>Tsuga canadensis</i>	34	10	3	1	0.5	
<i>Quercus prinus</i>	22	13	4	2	0.3	
<i>Fagus grandifolia</i>	14	6	4	1	0.3	0.5
<i>Acer saccharum</i>	8	7	0.6	0.2		0.2
<i>Liriodendron tulipifera</i>	3	3	2	0.5	0.3	0.1
<i>Quercus rubra</i>	5	3	1	0.7		
<i>Carya glabra</i>	12	3		0.2		
<i>Acer rubrum</i>	10	3	0.3			
18 Minor Species ¹	35	8	5.1	1.4		
Totals	143	56	20	7	1.4	0.8

¹ Minor species in decreasing order: *Nyssa sylvatica*, *Oxydendron arboreum*, *Quercus alba*, *Illex opaca*, *Fraxinus americana*, *Carya ovata*, *Quercus velutina*, *Betula lutea*, *Magnolia tripetala*, *Quercus muehlenbergii*, *Liquidambar styraciflua*, *Carya cordiformis*, *Ostrya virginiana*, *Carya tomentosa*, *Juglans nigra*, *Quercus falcata*, *Ulmus thomasi*, *Sassafras albidum*.

TABLE 13E. Size class densities per acre of tree species comprising 80% I.V. on Boardcut Island. Data are based on 10 points by Bitterlich variable-radius method.

Species	Size Class Midpoint						
	6	10	14	18	22	26	30
<i>Acer negundo</i>	122	27	6			0.1	
<i>Acer saccharinum</i>	12	5	5	2	0.4	1	0.3
<i>Liriodendron tulipifera</i>	3	5	3	2	0.4	0.1	0.1
6 Minor Species ¹	17	12.9	1.4	3	0.1	0.1	0.3
Totals	154	49.9	15.4	7	0.9	1.3	0.7

¹Minor species in decreasing order: *Platanus occidentalis*, *Acer saccharum*, *Fraxinus pennsylvanica*, *Juglans nigra*, *Acer rubrum*, *Ulmus rubra*.

TABLE 14E. Size class table Mammoth Ferry floodplain. Data are based on a 1.4 acre sample (0.2 acre plots).

Species	Size Class Midpoint									
	6	10	14	18	22	26	30	34	38	50
<i>Platanus occidentalis</i>	2	1	1	3		3	5	2	2	2
<i>Ulmus rubra</i>	14	6	4	1	1	1	1			
<i>Acer saccharinum</i>	6	6	1	1		1				
<i>Fagus grandifolia</i>	2				1		1	2		
<i>Ostrya virginiana</i>	1	1								
<i>Carya ovata</i>	1	2	2		1					
<i>Liriodendron tulipifera</i>	3	1	2	1						
<i>Celtis occidentalis</i>	2									
<i>Fraxinus pennsylvanica</i>	2						1			
<i>Carpinus caroliniana</i>	1	1	1							
<i>Acer negundo</i>		1	2							
<i>Acer saccharum</i>	1	1								
<i>Ulmus alata</i>				1						
<i>Fraxinus americana</i>	1									
<i>Oxydendrum arboreum</i>		1								
<i>Quercus muehlenbergii</i>	1									
Totals	37	21	13	7	3	5	8	4	2	2

TABLE 15E. Size class densities per acre of tree species on Sand Cave Island.
Data are based on 5 points by Bitterlich variable-radius method.

Species	Size Class Midpoint							
	6	10	14	18	22	26	30	34
Acer saccharinum	7	18	12	6	2	2		
Platanus occidentalis	3	12	15	7	3	3		1
Acer negundo		4	1					
Ulmus alata	1		1					
Acer rubrum	1							
Totals	12	34	29	13	5	5		1

TABLE 16E. Size class densities per acre of tree species comprising 80% I.V. of Good Spring Church successional forest. Data are based on 9 points by Bitterlich variable-radius method.

Species	Size Class Midpoint						
	6	10	14	18	22	26	30
<i>Quercus alba</i>	23	20	14	3	0.6		
<i>Acer rubrum</i>	40	9	2	0.6	0.2		
<i>Carya glabra</i>	42	3	1				
<i>Quercus rubra</i>	3	2	5	3	1	0.3	
<i>Quercus velutina</i>		7	6	2	0.4		
<i>Nyssa sylvatica</i>	8	4	0.5	0.6	0.2		
<i>Liriodendron tulipifera</i>		1	3	0.6			0.1
12 Minor Species ¹	17	7	0.5	0.2	0.6		
Totals	133	53	32	10	3	0.3	0.1

¹Minor species in decreasing order: *Carya ovalis*, *Cornus florida*, *Ulmus rubra*, *Fraxinus americana*, *Carya cordiformis*, *Carya tomentosa*, *Acer saccharum*, *Carya ovata*, *Fagus grandifolia*, *Juglans nigra*, *Quercus stellata*, *Sassafras albidum*.

TABLE 17E. Size class densities per acre of tree species comprising 80% I.V. of the forest surrounding Great Onyx succession site. Data are based on 5 points by Bitterlich variable-radius method.

Species	Size Class Midpoint						
	6	10	14	18	22	26	30
<i>Pinus virginiana</i>	31	22	9	0.6			
<i>Liriodendron tulipifera</i>	41	7	0.9		0.4	0.3	
<i>Cornus florida</i>	46						
<i>Quercus velutina</i>	10	11	3				
<i>Quercus alba</i>	10	4	3	1	0.4		0.2
<i>Carya tomentosa</i>	20	4					
<i>Quercus falcata</i>		5	4	0.6		0.3	
<i>Ulmus alata</i>	15	2					
9 Minor Species ¹	61	4	2.1				
Totals	234	59	22	2.2	0.8	0.6	0.2

¹Minor species in decreasing order: *Acer rubrum*, *Platanus occidentalis*, *Carya glabra*, *Carya cordiformis*, *Celtis occidentalis*, *Juglans nigra*, *Diospyros virginiana*, *Quercus marilandica*, *Quercus stellata*.

TABLE 18E. Size class densities per acre of tree species comprising 80% I.V. of Joppa Ridge and Mammoth Cave Ridge upland forest. Data are based on 15 points by Bitterlich variable-radius method.

Species	Size Class Midpoint					
	6	10	14	18	22	26
<i>Quercus velutina</i>	41	9	5	0.6		
<i>Quercus rubra</i>	39	10	3	0.4		
<i>Carya glabra</i>	25	7	2	0.6		
<i>Cornus florida</i>	31	0.6				
<i>Quercus falcata</i>	12	7	2	0.4	0.1	
<i>Quercus alba</i>	7	4	2	0.4	0.5	0.1
<i>Quercus stellata</i>	3	1	2	0.4	0.2	
10 Minor Species ¹	13.5	6.4	4.3	0.2	0.2	0.1
Totals	171.5	45	20.3	3	1	0.2

¹Minor species in decreasing order: *Acer rubrum*, *Liriodendron tulipifera*, *Oxydendrum arboreum*, *Carya ovalis*, *Quercus coccinea*, *Carya tomentosa*, *Fagus grandifolia*, *Nyssa sylvatica*, *Quercus marilandica*, *Carya cordiformis*.

TABLE 19E. Size class densities per acre of tree species comprising 80% I.V. of Lee Ridge upland forest. Data are based on 15 points by Bitterlich variable-radius method.

Species	Size Class Midpoint						
	6	10	14	18	22	26	30
<i>Quercus rubra</i>	42	10	3				
<i>Quercus alba</i>	17	5	5	3	0.4		0.1
<i>Carya glabra</i>	19	6	1	0.2			
<i>Cornus florida</i>	32						
<i>Quercus velutina</i>	10	6	1				
<i>Nyssa sylvatica</i>	19						
<i>Carya ovalis</i>	3	0.6					
<i>Quercus stellata</i>	2	2	2	0.9	0.2		
10 Minor Species ¹	34	6.4	3	1.4	0.2		
Totals	178	36	15	5.5	0.8		0.1

¹Minor species in decreasing order: *Acer rubrum*, *Carya tomentosa*, *Carya cordiformis*, *Carya ovata*, *Fraxinus americana*, *Liriodendron tulipifera*, *Prunus serotina*, *Oxydendrum arboreum*, *Quercus muehlenbergii*, *Quercus prinus*.

TABLE 20E. Size class densities per acre of tree species comprising 80% I.V. of valley south of Sloans Crossing. Data are based on 12 points by Bitterlich variable-radius method.

Species	Size Class Midpoint						
	6	10	14	18	22	26	30
<i>Nyssa sylvatica</i>	59	4	2				
<i>Oxydendrum arboreum</i>	57	5					
<i>Quercus stellata</i>	13	9	3		0.3		
<i>Quercus velutina</i>	15	5	3	0.7	0.3	0.2	
<i>Quercus alba</i>	17	0.8	2	0.2	0.2	0.1	
<i>Quercus rubra</i>	6	3	2	0.2	0.2	0.1	0.1
<i>Quercus falcata</i>	4	4	1		0.1	0.1	0.2
<i>Cornus florida</i>	15						
<i>Quercus marilandica</i>	4	2	2	0.5			
<i>Carya tomentosa</i>	6	0.8	0.4	0.2			
<i>Quercus muehlenbergii</i>	4						
8 Minor Species ¹	8	5					
Totals	208	38.6	15.4	1.8	1.1	0.5	0.3

¹Minor species in decreasing order: *Carya ovalis*, *Sassafras albidum*, *Carya cordiformis*, *Carya glabra*, *Quercus macrocarpa*, *Quercus coccinea*, *Liriodendron tulipifera*, *Platanus occidentalis*.

TABLE 21E. Size class densities per acre of tree species comprising 80% I.V. in Smith Valley west of Joppa Church. Data are based on 20 points by Bitterlich variable-radius method.

Species	Size Class Midpoint						
	6	10	14	18	22	26	30
<i>Quercus velutina</i>	17	7	6	0.8	0.2	0.3	
<i>Cornus florida</i>	39	0.5					
<i>Quercus alba</i>	13	6	3	0.4	0.2	0.1	
<i>Nyssa sylvatica</i>	18	6	0.7	0.3			
<i>Quercus rubra</i>	9	4	4	0.1			
<i>Quercus coccinea</i>		1	2	1	0.2		0.1
<i>Carya glabra</i>	5	0.5	2	0.1			
<i>Quercus stellata</i>		3	0.7	0.1		0.1	
<i>Acer saccharum</i>	8	1	1		0.1		
<i>Juniperus virginiana</i>	6	2	0.2				
<i>Fagus grandifolia</i>	4	1	0.5	0.4	0.1		
14 Minor Species ¹	24	7	3.9	1.3			
Totals	143	39	24	4.5	1	0.5	0.1

¹Minor species in decreasing order: *Quercus falcata*, *Juglans nigra*, *Liriodendron tulipifera*, *Quercus muehlenbergii*, *Sassafras albidum*, *Carya cordiformis*, *Fraxinus americana*, *Carya ovalis*, *Acer rubrum*, *Carya tomentosa*, *Carya ovata*, *Tilia americana*, *Fraxinus pennsylvanica*, *Liquidambar styraciflua*.

TABLE 22E. Size class densities per acre of tree species comprising 95% I.V. of Hickory Cabin and Brooks Knob Plateau. Data are based on 15 points by Bitterlich variable-radius method.

Species	Size Class Midpoint				
	6	10	14	18	22
<i>Pinus virginiana</i>	80	31			
<i>Cornus florida</i>	32	1			
<i>Juniperus virginiana</i>	20	2			
<i>Nyssa sylvatica</i>	7				
<i>Sassafras albidum</i>	8				
<i>Liriodendron tulipifera</i>	2	0.6	0.9	0.4	0.1
<i>Carya glabra</i>	3				
6 Minor Species ¹	7	2.7			
Totals	159	37.3	0.9	0.4	0.1

¹Minor species in decreasing order: *Carya ovata*, *Carya tomentosa*, *Fraxinus americana*, *Ulmus alata*, *Oxydendrum arboreum*, *Quercus velutina*.

TABLE 23E. Size class densities per acre of tree species comprising 95% I.V. of Joppa Ridge old field succession. Data are based on 15 points by Bitterlich variable-radius method.

Species	Size Class Midpoint		
	6	10	14
<i>Juniperus virginiana</i>	143	7	
<i>Nyssa sylvatica</i>	12	0.6	
<i>Fraxinus americana</i>	7	0.6	
<i>Quercus stellata</i>	2	2	
<i>Oxydendrum arboreum</i>	5		
<i>Liriodendron tulipifera</i>		0.6	0.6
<i>Carya glabra</i>		1.2	
4 Minor Species ¹	3	1	0.3
Totals	172	13	0.9

¹Minor species in decreasing order: *Cornus florida*, *Carya tomentosa*, *Quercus velutina*, *Acer rubrum*.

TABLE 24E. Size class densities per acre of tree species comprising 90% I.V. of Mammoth Cave Ridge old field succession. Data are based on 20 points by Bitterlich variable-radius method.

Species	Size Class Midpoint		
	6	10	14
<i>Juniperus virginiana</i>	151	13	
<i>Fraxinus americana</i>	8		
<i>Acer rubrum</i>	10		
<i>Liriodendron tulipifera</i>	2	0.6	1
<i>Cornus florida</i>	10		
<i>Quercus marilandica</i>	5		
4 Minor Species ¹	14		
Totals	200	13.6	1

¹Minor species in decreasing order: *Diospyros virginiana*, *Nyssa sylvatica*, *Oxydendrum arboreum*, *Ulmus alata*.

Appendix F

Elimination Key to Forest Formations and Their Associations
on Air Photos at Mammoth Cave National Park, Kentucky

The following key is designed to aid in the identification and classification of the major forest communities found in south-central Kentucky.

This key is based on interpretation of 1:20,000 scale panchromatic photographs taken while leaves are present on the trees. (The majority of the photographs used in this study were taken during October).

A simple stereoscope is adequate for interpretation, although a mirror stereoscope will permit more rapid examination of stereopairs.

Appendix F

TABLE 1F. Elimination key to forest formations and their associations on air photos at Mammoth Cave National Park, Kentucky (scale 1:20,000).

1.	Upland plateaus.....	2
2.	Closed canopy absent, old field succession, many dark trees (eastern red cedar).....	old fields
2.	Closed canopy present.....	3
3.	Light-dark pattern, irregular height	white oak, pignut, upland forest
3.	Darker regular height and texture	blackjack and scarlet oak
1.	Valleys and bottoms.....	4
4.	Bottoms along major rivers.....	5
5.	Band of tall trees along river	sycamore, silver maple
5.	Light, delicate texture band adjacent to above	box elder, slippery elm and green ash
4.	Valleys.....	6
6.	Sinks and solution valley slopes south of Green River.....	7
7.	Sinks	northern red oak, tuliptree, sugar maple
7.	Solution valley slopes.....	8

TABLE 1F (continued).

-
-
- | | | |
|----|--|---|
| 8. | Dense, irregular texture, light dark
pattern
.white oak, black oak, southern red oak | |
| 8. | Toe of slope, scattered dark trees
among lighter crowns
.....eastern red cedar, hardwoods | |
| 6. | Valleys north of Green River..... | 9 |
| 9. | Upstream end of valley, dense canopy,
medium grey tone
...n. red oak, sugar maple, American beech ¹ | |
| 9. | Downstream end of valley
.....walnut, butternut, Kentucky coffeetree | |
-
-

¹Hemlock-tuliptree-beech segregate of the Mixed Mesophytic Forest cannot be identified on the panchromatic 1:20,000 photographs.

Appendix G

Annotated Species List

This list includes species collected from Mammoth Cave National Park during this study and by Davies (1954) who collected in the late 1940's. Nomenclature follows Gleason and Cronquist (1963) for herbs and shrubs and Little (1953) for trees except for Carya ovalis (Wang.) Sarg. which follows Gleason and Cronquist (1963). Davies, in his original study, followed Fernald (1950). Where these authorities are in conflict Gleason and Cronquist were followed. Additional workers in the Park include Henry Lix who also collected during the late 1940's and Kenneth Nicely currently at Western Kentucky University.

One asterisk indicates a report from Davies but not collected during this study; two asterisks indicate a first report from this study and three asterisks indicate that a species was observed but material was not collected. Flowering dates, based on collected material, are approximate for MCNP. Collections by Faller are deposited in the Indiana State University Herbarium, collections by Lix in the Mammoth Cave National Park Herbarium and the National Herbarium, collections by Davies are deposited in the Davies Herbarium, University of Louisville. Earlier collections by Braun are not included in this list because

her location information only refers to the Kentucky counties of Barren and Edmonson.

The following table is a summary of the collections by Davies and Faller.

TABLE 1G. Summary of vascular plant collections made at Mammoth Cave National Park by Faller and Davies.

	Families	Genera	Species
Faller	72	205	311
Davies	106	390	674
Additions by Faller	1	8	77

Acanthaceae

Justica americana (L.) Vahl. Water-willow. Eastern U.S. Common on the upstream end of Green River Islands. July.**

Ruellia strepens L. Smooth ruellia.*

Aceraceae

Acer negundo L. Box-elder. Eastern U.S. Distributed along the Green River floodplain in the first bottoms. April.

Acer rubrum L. Red maple. Eastern U.S. Found locally in wetter upland sites. The largest observed in Hunts Sink has a dbh of 44 inches. March.

Acer saccharinum L. Silver maple.*

Acer saccharum Marsh. Sugar maple. Eastern U.S. Common throughout the Park with well developed stands occurring in the sandstone valleys north of the Green River. April.

Aizoaceae

Mollugo verticillata L. Carpet-weed.*

Alismataceae

Sagittaria rigida Pursh.*

Amaranthaceae

Amaranthus retroflexus L. Pig weed.*

Amaranthus spinosus L. Thorny amaranth.*

Amaryllidaceae

Agave virginica L. False aloe.*

Hymenocallis occidentalis (Le Conte) Kunth Spider Lily.*

Hypoxis hirsuta (L.) Coville.*

Narcissus pseudo-narcissus L. Daffodil. Old homesteads. March.***

Anacardiaceae

Rhus copallinum L. Dwarf sumac. Eastern U.S.
Thickets in old fields with a narrow coppice common
between mowed road shoulder and old fields. May,
June.

Rhus radicans L. Poison ivy.*

Rhus typhina L. Staghorn sumac.*

Annonaceae

Asimina triloba (L.) Dunal. Pawpaw.*

Apocynaceae

Apocynum cannabinum L. Hemp dogbane.*

Vinca minor L. Periwinkle. Europe. Common in the
unattended cemeteries. April.

Aquifoliaceae

Ilex opaca Ait. American holly.*

Araceae

Arisaema triphyllum (L.) Schott. var triphyllum.
Jack-in-the-pulpit. Eastern U.S. Rich woods
associated with sheltered areas. April, May.

Arisaema triphyllum (L.) Schott. var pusillum Peck.
Jack-in-the-pulpit.

Araliaceae

Aralia racemosa L. American spikenard.*

Aralia spinosa L. Hercules'-club.*

Panax quinquefolium L. Ginseng. Eastern U.S.
Uncommon, but found in most forest types in Park.

Aristolochiaceae

Aristolochia durior Hill. Dutchman's pipe.*

Aristolochia serpentaria L. Virginia snake root.*

Aristolochia tomentosa Sims. Pipe-vine. Eastern U.S. Common vine of the Green River floodplain.**

Asarum canadense L. Wild ginger.*

Asclepidaceae

Asclepias exaltata L. Poke milkweed. Eastern U.S. Old fields. July.

Asclepias quadrifolia Jacq.*

Asclepias syriaca L. Common milkweed. Eastern U.S. Old fields and roadsides. June.

Asclepias tuberosa L. Butterfly-weed. Eastern U.S. Roadsides and old fields. More common in sandstone region north of Green River. July.

Asclepias variegata L. White milkweed. Eastern U.S. Sheltered cove forests north of Green River. May, June.

Asclepias verticillata L. Horsetail milkweed.*

Gonolobus gonocarpos (Walt.) Perry.*

Balsaminaceae

Impatiens biflora Walt. Spotted touch-me-not. Eastern U.S. Common on floodplain and islands.

Impatiens pallida Nutt. Pale touch-me-not.*

Berberidaceae

Berberis thunbergii DC. Japanese barberry.*

Caulophyllum thalictroides (L.) Michx. Blue cohosh. N. eastern U.S. Uncommon in most areas. Largest populations in drainages north of Green River. April, May.

Jeffersonia diphylla (L.) Pers. Twinleaf.*

Podophyllum peltatum L. Mayapple. Eastern U.S. Common throughout the Park. April, May.

Betulaceae

Alnus maritima (Marsh.) Nutt. (Alnus glutinosa [L.] Gaertn. in Davies, 1954).

Betula lenta L. Sweet birch. N. eastern U.S. In hemlock areas in sandstone coves north of Green River.**

Betula lutea Michx. f. Yellow birch.*

Betula nigra L. River-birch. Eastern U.S. Occasional on floodplain.

Carpinus caroliniana Walt. Blue beech.*

Corylus americana Walt. Eastern U.S. Common in old fields and drier forests south of the Green River. March.

Ostrya virginiana (Mill.) K. Koch. Ironwood.*

Bignoniaceae

Bignonia capreolata L. Cross-vine (Anisostichus in Gleason and Cronquist, 1963).*

Campsis radicans (L.) Sem. Trumpet-creeper. S. eastern U.S. Old homesites. July, August.

Boraginaceae

Cynoglossum virginianum L. Wild comfrey. Eastern U.S. Late secondary succession woods. May.

Hackelia virginiana (L.) Johnst. Eastern U.S. Old growth stands. Hunts Sink. June.**

Lithospermum canescens (Michx.) Lehm. Hoary puccoon. disturbed sites along roadsides. April.

Lithospermum latifolium Michx. Gromwell.*

Mertensia virginica (L.) Pers. Bluebells. Common. Old fields. April.

Myosotis verna Nutt. Forget-me-not.*

Symphytum officinale L. Comfrey. Eurasia.
(Doubtful identification.)

Cactaceae

Opuntia compressa (Salisb.) Macbr. Prickly pear.*

Caesalpiniaceae

Cassia fasciculata Michx. Partridge-pea.*

Cassia marilandica L.*

Cassia nictitans L. Wild sensitive plant. Eastern U.S. Common. Old fields in limestone areas south of Green River. July, August, September.

Cercis canadensis L. Redbud. Eastern U.S. Along roadways or openings in forests. Not found in deep shade. April.

Gleditsia tricanthos L. Honey locust.*

Gymnocladus dioica (L.) K. Koch. Kentucky coffeetree.

Campanulaceae

Campanula americana L. Tall bellflower. Eastern U.S. In old growth stands along smaller streams. September.

Triodanis perfoliata (L.) Niewl. Venus' looking glass. North Americana. First Creek Drainage. June (Specularia in Davies, 1954).

Caprifoliaceae

Lonicera japonica Thunb. Japanese honeysuckle. Eastern Asia. Largely successional species. June.

Lonicera sempervirens L. Trumpet honeysuckle.*

Sambucus canadensis L. Common elder.*

Symphoricarpos orbiculatus Moench. Coralberry. Central and eastern U.S. Old fields.

Triosteum perfoliatum L. Horse-gentian.*

Viburnum acerifolium L. Maple-leaved viburnum.
Eastern U.S. Common on sandstone substrate north of
Green River. May.

Viburnum prunifolium L. Blackhaw.*

Caryophyllaceae

Arenaria patula Michx.*

Cerastium viscosum L. Eurasia. Old fields,
limestone substrate. June.

Dianthus armeria L. Deptford pink. Europe. Old
fields. June.

Paronychia canadensis (L.) Wood.*

Paronychia fastigata (Raf.) Fern.*

Saponaria officinalis L. Bouncing bet.*

Silene rotundifolia Nutt.*

Silene stellata (L.) Ait. f. Starry campion.*

Silene virginica L. Firepink. Eastern U.S. Appears
to follow limestone outcrops. April, May.

Stellaria media (L.) Cyrill. Old world. Sandstone
outliers south of Green River. April, May.**

Stellaria pubera Michx. Eastern U.S. Old growth
forests. Hunts Sink. April.

Celastraceae

Celastrus scandens L. Bittersweet.*

Euonymus americanus L. Strawberry-bush.*

Euonymus atropurpureus Jacq. Wahoo. Eastern U.S.
along abandoned roadsides. Uncommon.

Chenopodiaceae

Chenopodium ambrosiodes L. Mexican tea.*

Commelinaceae

Commelina communis L.*

Commelina virginica L.*

Tradescantia subaspera Ker.*

Tradescantia virginiana L.*

Compositae

Achillea millefolium L. Yarrow. Circumboreal.
Common. Old field species. May, June.

Ambrosia artemisiifolia L. Common ragweed.*

Antennaria plantaginifolia (L.) Richards. Eastern
N.A. Common in roadsides and late successional
forests on sandstone. April.

Antennaria solitaria Rydb.*

Anthemis cotula L. Dog-fennel.*

Arctium minus (Hill) Bernh. Common burdock.*

Artemisia annua L. Annual wormwood.*

Aster divaricatus L.*

Aster dumosus L. Bushy aster. Eastern U.S. Common
in disturbed areas. September, October.

Aster lateriflorus (L.) Britt. Eastern U.S.
Roadsides. September.**

Aster linariifolius L.*

Aster patens Ait.*

Aster pilosus Willd. Eastern U.S. Roadsides.
August, September, October.

Aster sagittifolius Willd. Eastern U.S. Old growth
woods. September.**

Aster sericeus Vent. Silky aster.*

Aster shortii Lindl. S. eastern U.S. Old fields and
young oak-hickory woods. September, October.

Aster solidagineus Michx. S. eastern U.S. Old fields. July. (Sericocarpus linifolius [L.] BSP. in Davies, 1954.)

Aster undulatus L.*

Aster vinimeus Lam. Eastern U.S. Old fields. October.**

Astranthium integrifolium (Michx.) Nutt. Daisy.*

Bidens aristosa (Mich.) Britt. Central U.S. Scattered woods. October.**

Bidens bipinnata L. Spanish needles.*

Bidens comosa (Gray) Wieg.*

Bidens polylepsis Blake. Central U.S. Upland woods. September.**

Chrysanthemum leucanthemum L. White chrysanthemum. Eurasia. Common in old fields. May, June.

Cichorium intybus L. Chichory.*

Cirsium altissimum (L.) Spreng. Tall thistle.*

Cirsium discolor (Muhl.) Spreng. Field thistle.*

Cirsium virginianum (L.) Michx.*

Coreopsis auriculata L.*

Coreopsis lanciolata L. S. eastern U.S. Roadsides. May, June.**

Coreopsis major Walt. S. eastern U.S. Oak-hickory woods. May.

Coreopsis pubescens Ell. S. eastern U.S. Old fields. June.**

Coreopsis tripteris L. Tall tickseed. Eastern N.A. Upland old field savanna. June.

Echinacea pallida Nutt. Pale coneflower. Eastern N.A. May be calciophile. Roadsides. June.

Echinacea purpurea (L.) Moench. Purple coneflower.*

Eclipta alba (L.) Hassk.*

Elephantopus carolinianus Willd. Elephant's foot.*

Erechtites hieracifolia (L.) Raf. Fireweed.*

Erigeron annuus (L.) Pers. Whitetop. Northern U.S.
Old fields. Common. June.

Erigeron philadelphicus L.*

Erigeron pulchellus Michx. Eastern U.S. Roadsides.
May.

Erigeron pusillus Nutt. (not in Gleason and
Cronquist, 1963).*

Erigeron strigosus Muhl. Daisy fleabane. U.S.
Sandstone coves north of Green River. June.

Eupatorium altissimum L. Tall throughwort.*

Eupatorium aromaticum L.*

Eupatorium coelestinum L. Mist-flower. S. eastern
U.S. Old fields and roadsides. August.

Eupatorium hyssopifolium L. Eastern U.S. Old fields
and roadsides. North of Green River. August.**

Eupatorium perfoliatum L. Boneset.*

Eupatorium pilosum Walt. (not in Gleason and
Cronquist, 1963).*

Eupatorium purpureum L. Joe-Pye weed.*

Eupatorium rotundifolium L. S. eastern U.S. Old
fields. August.

Eupatorium rugosum Houtt. White snakeroot. Eastern
U.S. Old fields. Alluvium and roadsides. August,
September.

Eupatorium serotinum Michx. Late boneset. S.
eastern U.S. Oak woodlands. August, September,
October.

Eupatorium sessilifolium L. Upland boneset.*

Galinsoga siliata (Raf.) Blake. Peruvian daisy.*

Gnaphalium obtusifolium L. Sweet everlasting.
Eastern U.S. Old fields. September, October.

Gnaphalium purpureum L. Early cudweed.*

Helenium autumnale L.*

Helenium flexuosum Raf. Eastern U.S. Old fields.
July. (H. nudiflorum Nutt. in Davies, 1954.)

Helianthus divaricatus L. Eastern U.S. Roadsides.
North of Green River. July.

Helianthus hirsutus Raf. S. eastern U.S. Oak forests.
July, August.**

Helianthus microcephalus T. & G. Eastern U.S.
Roadsides. September.

Helianthus mollis Lam.*

Helianthus strumosus L. Eastern U.S. Oak forests and
roadsides. September.**

Heliopsis helianthoides (L.) Sweet.*

Hieracium aurantiacum L. Orange hawkweed. Europe.
Black gum, white oak woods. South of Green River.
May, June.**

Hieracium gronovii L. Eastern U.S. Old fields.
August, September, October.

Hieracium marianum Willd.*

Hieracium pilosella L. Europe. Old field.
October.**

Hieracium scabrum Michx. Rough hawkweed. Eastern
U.S. Mixed oak forests. July.

Hieracium venosum L. Eastern U.S. Old fields,
cemeteries. May.

Krigia biflora (Walt.) Blake.*

Krigia dandelion (L.) Nutt.*

Kuhnia eupatorioides L. False boneset. Eastern U.S.
Old field. August.**

Lactuca floridana (L.) Gaertn. S. eastern U.S.
Wilson Cave Hollow. September.

Liatris scabra (Greene) K. Schum.*

Liatris scariosa (L.) Willd.*

Liatris squarrosa (L.) Michx. Eastern U.S. Old
field. September, October.**

Parthenium integrifolium L. American feverfew.*

Polymnia canadensis L. Leaf cup.*

Polymnia uvedalia L.*

Prenanthes altissima L.*

Prenanthes trifoliolata (Cass.) Fern.*

Pyrrhopappus carolinianus (Walt.) DC. S. eastern
U.S. July, August.

Ratibida pinnata (Vent.) Barnh. Drooping coneflower.
Eastern U.S. Oak forest. June.

Rudbeckia fulgida Ait. Orange coneflower.*

Rudbeckia hirta L. Black-eyed susan. Central and
eastern U.S. Roadsides and old fields. June, July,
August.

Rudbeckia laciniata L. Goldenglow.*

Rudbeckia spathulata Michx. (R. fulgida in Gleason
and Cronquist, 1963).*

Rudbeckia triloba L. Brown-eyed susan.*

Senecio aureus L. Golden ragwort. Central and
eastern U.S. Oak-hickory woods. April, May.**

Senecio obovatus Muhl. S. eastern U.S. Chestnut oak
woods. April, May.

Senecio pauperculus Michx. Eastern U.S. Mixed
woods. May.**

Senecio smallii Britt.*

Senecio visosus L. European. Old field. May, June.**

Serinia oppositifolia (Raf.) Ktze. (Krigia oppositifolia in Gleason and Cronquist, 1963).*

Silphium integrifolium Michx. Rosin-weed. Central U.S. Roadsides, old fields. July, August.**

Silphium terebinthinaceum Jacq. Prairie-dock.*

Silphium trifoliatum L. S. central U.S. Abandoned roadsides. July, August.

Solidago bicolor L. White goldenrod.*

Solidago caesia L. Woodland goldenrod. Eastern U.S. Roadsides, oak forests. August, September.**

Solidago canadensis L. Tall goldenrod. North America. Old fields. October.

Solidago erecta Pursh.*

Solidago flexicaulis L.*

Solidago gattingeri Chapm.*

Solidago juncea Ait. Early goldenrod. Eastern U.S. Old fields. July, August.

Solidago nemoralis Ait. Field goldenrod. Eastern U.S. Old fields, roadsides. September, October.

Solidago odora Ait.*

Solidago puberula Nutt. Eastern U.S. Old fields. October.**

Solidago rugosa Mill. Roughleaved goldenrod. Eastern U.S. Roadsides, oak woodlands. September.**

Solidago sphacelata Raf.*

Solidago ulmifolia Muhl. Elm leaved goldenrod.*

Sonchus asper (L.) Hill. Spiny sow-thistle.*

Taraxacum laevigatum (Willd.) DC. Red-seeded dandelion. Eurasia. Roadside. April to fall.**

Taraxacum officinale Weber. Common dandelion. Eurasia. Roadsides. April to fall.

Tragopogon major Jacq. Goatsbeard.*

Verbesina alternifolia (L.) Britt. Yellow ironweed. Eastern U.S. Islands and floodplains. August.

Verbesina helianthoides Michx.*

Verbesina virginica L. White crownbeard. S. eastern U.S. Valleys north of Green River. October.**

Vernonia altissima Nutt. Central U.S. Roadsides. August.

Convolvulaceae

Convolvulus sepium L. Hedge-bindweed. N.A. and Eurasia. Old fields; islands of Green River. June.

Cuscuta gronovii Willd. Dodder.*

Ipomoea pandurata (L.) Mey. Wild sweet-potatoe.*

Ipomoea purpurea (L.) Roth. Common morning-glory.*

Cornaceae

Cornus florida L. Flowering dogweed. Eastern U.S. Common throughout the Park. April.

Nyssa sylvatica Marsh. Black gum. Common in upland old fields and young forests. June, July.

Crassulaceae

Sedum pulchellum Michx. S. eastern U.S. Old growth in wet locations.

Sedum ternatum Michx. Wild stonecrop. Eastern U.S. Old growth in wet locations. April.

Cruciferae

Arabis laevigata (Muhl.) Poir. Smooth rockcress. N. eastern U.S. Mixed forest. Sandstone outcrops. April.

Arabis virginica (L.) Poir. S. eastern U.S. Roadside weed. April.**

Barbarea vulgaris R. Br. Common wintercress.*

Brassica nigra (L.) Koch. Black mustard.*

Capsella bursa-pastoris (L.) Medic. Shepherd's purse.*

Cardamine bulbosa (Schreb.) BSP.*

Cardamine douglassii (Torr.) Britt.*

Cardamine hirsuta L. Old world. Roadside and lawn weed. April.**

Cardamine parviflora L.*

Cardamine pennsylvanica Muhl. Western U.S. Upland oak forest. April, May.**

Dentaria heterophylla Nutt. S. eastern U.S. Mixed woods. March, April.

Dentaria laciniata Muhl. Toothwort. Eastern U.S. Mixed woods. March, April.

Dentaria multifida Muhl.*

Draba brachycarpa Nutt.*

Draba verna L. Whitlow-grass. Europe. Roadside and lawn weed. April.

Iodanthus pinnatifidus (Michx.) Steud.*

Lepidium campestre (L.) R. Br. Field peppergrass.*

Lepidium ruderales L. Pepper-grass. Europe. Old fields, Doyel Valley. May, June.**

Lepidium virginicum L. Common peppergrass.*

Lesquerella globosa (Desv.) Wats. Calcareous rocks, local Kentucky, Tennessee. Roadside weed. June.**

Cyperaceae

Carex cephalophora Muhl.*

Carex convoluta Mack. (C. rosea Schk. in Gleason and Cronquist, 1963).*

Carex crinita Lam.*

Carex eburnea Boott.*

Carex pennsylvanica Lam. Eastern U.S. Hickory woods. Sandstone. April.

Carex plantaginea Lam. Eastern U.S. Hemlock areas north of Green River. April.

Carex platyphylla Carey.*

Cyperus flavescens L.*

Cyperus strigosus L.*

Cyperus virens Michx. (not in Gleason and Cronquist, 1963).*

Dulichium arundinaceum (L.) Britt.*

Eleocharis obtusa (Willd.) Schultes. Blunt spike rush. (E. ovata [Roth] R. & S. in Gleason and Cronquist, 1963).*

Rhynchospora corniculata (Lam.) Gray.*

Scirpus rubricosus Fern. (S. cyperinus [L.] Kunth. in Gleason and Cronquist, 1963).*

Dioscoreaceae

Dioscorea quaternata (Walt.) Gmel. Wild yam. Chiefly Appalachian region. Old growth, more common north of Green River. May.

Dipsacaceae

Dipsacus sylvestris Huds. Teasel.*

Ebenaceae

Diospyros virginiana L. Persimmon. S. eastern U.S. Uplands.

Equisetaceae

Equisetum arvense L. Field horsetail. Cosmopolitan. Stream bottoms. April, May.

Equisetum hyemale L. Tall scouring-rush.*

Ericaceae

Chimaphila maculata (L.) Pursh. Spotted wintergreen. Circumboreal. Common. Oak tuliptree woods. June

Eubotrys recurva (Buckl.) Britt. Eastern U.S. Cedar Sink Valley. May, June.**

Gaylussacia baccata (Wang.) K. Koch. Black huckleberry. Eastern U.S.**

Kalmia latifolia L. Eastern U.S. Mountain laurel. Hemlock areas and sandstone outliers south of Green River. June.

Monotropa hypopithys L. Pinesap.*

Monotropa uniflora L. Indian pipe.*

Oxydendrum arboreum (L.) DC. Sourwood. S. eastern U.S. Old fields. Common. June, July.

Vaccinium arboreum Marsh. Farkleberry. S. eastern U.S. Black oak forests. June.

Vaccinium stamineum L. Deerberry. S. eastern U.S. Black oak forests, juniper woodlands. June.

Vaccinium uliginosum L. Bog-bilberry. Circumboreal. Juniper woodlands. June.**

Vaccinium vacillans Torr. Hill blueberry.*

Euphorbiaceae

Acalypha virginica L.*

Croton capitatus Michx. Southern midwest. First report in Park at deer pens. Introduced with feed. July.**

Croton monanthogynus Michx.*

Euphorbia corollata L. Flowering spurge. Eastern U.S. Doyel Valley, wet sites. July, August.

Euphorbia maculata L. Wartweed.*

Tragia cordata Michx.*

Fabaceae

Amphicarpa bracteata (L.) Fern. Hog-peanut.*

Coronilla varia L. Europe. Roadsides.**

Desmodium canadense (L.) DC. Eastern N.A. Oak woods. August.**

Desmodium cuspidatum (Muhl.) Loud.*

Desmodium glutinosum (Muhl.) Wood.*

Desmodium nudiflorum (L.) DC. Eastern U.S. Common. July, August.

Desmodium paniculatum (L.) DC.*

Desmodium pauciflorum (Nutt.) DC.*

Desmodium rotundifolium DC. Eastern U.S. Barrens and successional woods. August.**

Lespedeza hirta (L.) Hornem.*

Lespedeza intermedia (Wats.) Britt. Eastern U.S. Roadsides. August.

Lespedeza procumbens Michx. Trailing bush-clover. Eastern U.S. Old fields. August.**

Lespedeza striata (Thunb.) H. & A. Japanese clover.*

Lespedeza virginica (L.) Britt. Slender bush-clover. Eastern U.S. Old fields.**

Medicago sativa L. Alfalfa.*

Melilotus alba Desr. White sweet clover. Eurasia.
First Creek Drainage. June.

Melilotus officinalis (L.) Lam. Yellow sweet clover.*

Psoralea psoralioides (Walt.) Cory.*

Pueraria lobata (Willd.) Ohwi. Kudzu-vine.*

Robina hispida L. Bristly locust. S. eastern U.S.
Flint Ridge roadside. May.**

Robina pseudoacacia L. Black locust. S. eastern U.S.
Planted by Louisville and Nashville Railroad Co.
Escape in Doyel Valley and elsewhere south of Green
River.

Strophyostyles umbellata (Muhl.) Britt. Successional
forests. August.

Stylosanthes biflora (L.) BSP. Pencil-flower.*

Tephrosia virginiana (L.) Pers. Goat's-rue.*

Trifolium agarium L. Yellow hop-clover. Eurasia.
Old fields. May, June.**

Trifolium hybridum L. Alsike clover. Eurasia.
Upland old fields. June.**

Trifolium pratens L. Red clover.*

Trifolium procumbens L. Low hop-clover. Eurasia.
Common roadside weed. June.

Trifolium reflexum L. Buffalo clover.*

Vicia caroliniana Walt. Carolina vetch.*

Fagaceae

Castanea dentata (Marsh.) Borkh. American chestnut.
Eastern U.S. As a shrub present along sandstone
outcrops. More common south of the Green River. No
flowering material seen.

Fagus grandifolia Ehrh. American beech. Eastern U.S. Ravines and second terraces. April.

Quercus alba L. White oak. Eastern U.S. Upper slopes and uplands.

Quercus bicolor Willd. Swamp white oak.*

Quercus coccinea Muenchh. Scarlet oak. Eastern U.S. Dry south facing slopes.

Quercus falcata Michx. Southern red oak. S. eastern U.S. Old field succession. April, May.**

Quercus imbricaria Michx. Shingle oak.*

Quercus macrocarpa Michx. Bur oak.*

Quercus marilandica Muenchh. Blackjack oak. Southern U.S. Old field succession. April, May.

Quercus muehlenbergii Engelm. Chinquapin oak. Eastern U.S. Oak forests. Moist sites. April, May. (Q. prinoides var. acuminata [Michx.] Gl. in Gleason and Cronquist, 1963).

Quercus nigra L. Water-oak.*

Quercus palustris Muenchh. Pin oak.*

Quercus phellos L. Willow oak. Coastal plain. S. eastern U.S. Old field succession.**

Quercus prinus L. Chestnut oak. Sandstone outcrops, particularly Caseyville Formation. S. eastern U.S.

Quercus rubra L. Northern red oak. Eastern U.S. Mesic lower slopes. Common.

Quercus stellata Wang. Post oak. S. eastern U.S. Dry uplands.

Quercus velutina Lam. Black oak. Eastern U.S. Dry upper slopes. Common.

Fumariaceae

Corydalis flavula (Raf.) DC. Pale corydalis.
Eastern U.S. Floodplain of Green River. Common.

Dicentra canadensis (Goldie) Walp. Squirrel corn.*

Dicentra cucullaria (L.) Bernh. Dutchman's breeches.*

Gentianaceae

Centaurium pulchellum (Sw.) Druce. Centaury.
Europe. Mowed areas around cemeteries. May.**

Gentiana andrewsii Griseb. Closed gentian.*

Gentiana puberula Michx. Downy gentian.*

Gentiana villosa L. Sampson-snakeroot.*

Obolaria virginica L. Pennywort. S. eastern U.S.
Oak, tuliptree woods. Common. April, May.

Sabatia angularis (L.) Pursh. Rose-gentian. Eastern
U.S. Old fields and roadsides. Common July-
October.

Swertia caroliniensis (Walt.) Ktze. American
columbo.*

Geraniaceae

Geranium carolinianum L.*

Geranium dissectum L. Eurasia. Dry forest. May,
June.**

Geranium maculatum L. Cranesbill. S. eastern U.S.
Mesic forests. May, June.

Geranium molle L.*

Gramineae

Agrostis alba L. Redtop. (A. stolonifera L. in
Gleason and Cronquist, 1963).*

Agrostis hyemalis (Walt.) BSP. Common tickle grass.*

Agrostis perennans (Walt.) Tuckerm. Autumn bent
grass.*

- Andropogon elliotii Chapm.*
- Andropogon gerardi Vitman Big bluestem.*
- Andropogon scoparius Michx. Little bluestem.*
- Andropogon ternarius Michx.*
- Andropogon virginicus L. Broom-sedge. S. eastern U.S. Old fields, uplands. Common. August, September.
- Aristida dichotoma Michx.*
- Aristida oligantha Michx.*
- Arundinaria gigantea (Walt.) Chapm. Cane. S. eastern U.S. First bottoms of floodplains and seeps in ravines.
- Bromus commutatus Schrad. Hairy chess. (B. racemosus L. in Gleason and Cronquist, 1963).*
- Bromus japonicus Thunb.*
- Bromus purgans L. Canada brome.*
- Dactylis glomerata L. Orchard grass.*
- Danthonia spicata (L.) Beauv. Oat grass.*
- Digitaria ischaemum (Schreb.) Muhl. Smooth crab grass.*
- Digitaria sanguinalis (L.) Scop. Common crab grass.*
- Echinochloa crusgalli (L.) Beauv. Barnyard grass.*
- Elymus villosus Muhl. Slender wild rye.*
- Elymus virginicus L. Eastern and midwestern N.A. Islands and floodplains. June, July.
- Eragrostis frankii C. A. Meyer.*
- Eragrostis pectinacea (Michx.) Nees.*
- Eragrostis spectabilis (Pursh) Steud.*
- Erianthus alopecuroides (L.) Ell. Plume grass. S. eastern U.S. Uplands. September.

- Festuca obtusa Biehler Nodding fescue.*
- Glyceria striata (Lam.) Hitchc.*
- Hordeum pusillum Nutt. Small wild barley.*
- Hystrix patula Moench Bottlebrush grass.*
- Leersia oryzoides (L.) Sw. Cut grass.*
- Leptochloa filiformis (Lam.) Beauv. Sprangle-top grass.*
- Melica mutica Walt.*
- Muhlenbergia frondosa (Poir.) Fern.*
- Muhlenbergia mexicana (L.) Trin.*
- Muhlenbergia schreberi J. F. Gmel. Nimble will.*
- Panicum boscii Poir. Eastern U.S. Upland forests. June.
- Panicum capillare L. Witch grass.*
- Panicum dichotomiflorum Michx. Fall panicum.*
- Panicum gattingeri Nash. (P. capillare L. in Gleason and Cronquist, 1963).*
- Panicum latifolium L. N. eastern N.A. Upland forests. June.
- Panicum polyanthes Schult. S. eastern U.S. Upland forests. June.
- Panicum sphaerocarpon Ell.*
- Panicum stipitatum Nash.*
- Panicum virgatum L. Switch grass. Eastern and midwestern N.A. Uplands and old fields. August.
- Paspalum pubiflorum var. glabrum Vasey. S. eastern U.S. Uplands. Common. September.
- Phleum pratense L. Timothy.*

Poa compressa L. Canada blue grass.*

Poa pratensis L. Kentucky blue grass.*

Setaria glauca (L.) Beauv. Yellow foxtail.*

Sorghastrum nutans (L.) Nash. Indian grass. N.A.
Flint Ridge road.

Sorghum halepense (L.) Pers. Johnson grass.*

Sphenopholis intermedia Rydb. Wedge grass.*

Sporobolus vaginiflorus (Torr.) Wood.*

Trioda flava (L.) Smyth. Purpletop. Eastern U.S.
Old fields and roadsides. Common.

Uniola latifolia Michx. Spike grass. S. eastern U.S.
Along small stream beds, floodplains. September,
October.

Hamamelidaceae

Hamamelis virginiana L. Witch hazel.***

Liquidambar styraciflua L. Sweet gum.***

Hippocastanaceae

Aesculus glabra Willd. Ohio-buckeye.*

Hydrophyllaceae

Hydrophyllum canadense L. Eastern U.S. Floodplains
and islands. July.

Phacelia bipinnatifida Michx. S. eastern U.S. Mixed
forests. May.

Hypericaceae

Ascyrum hypericoides L. St. Andrew's cross. Eastern
U.S. Upland forests. Dry sites. July, August.

Hypericum canadense L. Canadian St. John's-wort.
Northern U.S. Eaton Valley. First report. June.**

Hypericum denticulatum Walt. S. eastern U.S. Old fields. June, July.

Hypericum dolabriforme Vent. S. eastern U.S. Old fields. June, July.

Hypericum drummondii (Grev. and Hook) T. & G. S. eastern U.S. Oak woodlands. July.

Hypericum frondosum Michx. S. eastern U.S. Buffalo Ferry Road. July, August.**

Hypericum mutilum L. Dwarf St. John's-wort. Eastern U.S. Old fields. June, July.

Hypericum perforatum L. Common St. John's-wort.*

Hypericum punctatum Lam. Spotted St. John's-wort.*

Iridaceae

Belamcanda chinensis (L.) DC. Blackberry-lily.*

Iris cristata Ait. Crested iris. S. eastern U.S. Wet Prong, sandstone cove. April, May.

Sisyrinchium albidum Raf. Blue-eyed grass. Northern U.S. Eaton Valley. April.

Sisyrinchium angustifolium Mill.*

Juglandaceae

Carya cordiformis (Wang.) K. Koch Bitternut hickory. Eastern N.A. Upland woods. Common. May.

Carya glabra (Mill.) Sweet. Pignut hickory. Eastern U.S. Upland woods. Common. May.

Carya illinoensis (Wang.) K. Koch Pecan.*

Carya laciniosa (Michx.) Loud. Shellbark hickory.*

Carya ovalis (Wang.) Sarg. Sweet pignut hickory.***

Carya ovata (Mill.) Sweet. Shagbark hickory. Eastern U.S. Upper slopes.

Carya tomentosa (Poir.) Nutt. Mockernut. Eastern N.A. Upland woods, old fields. Common. May.

Juglans cinerea L. Butternut. Eastern N.A. Mesic ravines. Uncommon. April.

Juglans nigra L. Black walnut. Eastern N.A. First terrace and ravines. Common. April.

Juncaceae

Juncus acuminatus Michx.*

Luzula echinata (Small) F. J. Herm. (not in Gleason and Cronquist, 1963).*

Labiatae

Blephilia ciliata (L.) Benth. Wood mint. Eastern U.S. Eaton Valley. June.

Collinsonia canadensis L. Richweed.*

Glechoma hederacea L. Ground-ivy. Eurasia. Alluvial soil. Weedy species. May, June.

Hedeoma pulegioides (L.) Pers. American pennyroyal.*

Isanthus brachiatus (L.) BSP. False pennyroyal.

Lycopus americanus Muhl. Water horehound.*

Lycopus uniflorus Michx.*

Lycopus virginicus L.*

Meehania cordata (Nutt.) Britt.*

Mentha piperita L. Peppermint.*

Monarda bradurniana Beck. S. eastern U.S. Blackgum, white oak woods. May, June.**

Monarda clinopodia L. S. eastern U.S. Mixed forests. May, June.

Monarda fistulosa L. Wild bergamot. Eastern N.A. Eaton Valley. Common. June.

Monarda russeliana Sims. Southern U.S. Upland woods. June.**

- Perilla frutescens (L.) Britt. Beefsteak plant.*
- Physostegia virginiana (L.) Benth. False dragonhead.*
- Prunella vulgaris L. Europe. Roadsides. July
- Pycnanthemum flexuosum (Walt.) BSP. Mountain mint.*
- Pycnanthemum incanum (L.) Michx. Northern U.S.
Trails and roadsides. Weedy. Common. July, August.
- Salvia lyrata L. Cancer-weed. S. eastern U.S. Old
fields and roadsides. Common. May, June.
- Scutellaria elliptica Muhl. Hairy skullcap.*
- Scutellaria incana Biehler Downy skullcap.*
- Scutellaria lateriflora L.*
- Scutellaria nervosa Pursh. Eastern U.S. Mixed forests.
June.**
- Scutellaria parvula Michx.*
- Synandra hispidula (Michx.) Baill.*
- Teucrium canadense L. Wood-sage.*
- Trichostema dichotomum L. Bluecurls.*
- Trichostema setaceum Houtt. Eastern U.S. Old fields.
Common. September, October (not in Gleason and
Cronquist, 1963).

Lauraceae

- Lindera benzoin (L.) Blume. Spice bush. Eastern U.S.
Alluvial soils. Common. March, April.
- Sassafras albidum (Nutt.) Nees Sassafras.*

Lemnaceae

- Spirodela polyrhiza (L.) Schleid. Duckweed.*

Liliaceae

- Allium canadense L. Wild garlic.*
- Allium tricoccum Ait. Wild leek.*

- Asparagus officinalis L. Garden asparagus.*
- Chamaelirium luteum (L.) Gray. Blazing star.
Eastern U.S. Mixed woods. June.
- Erythronium albidum Nutt. Trout lily.*
- Erythronium americanum Ker. Trout lily. Eastern N.A.
Beech maple woods. April.
- Hemerocallis fulva L. Day lily.*
- Lilium canadense L. Wild yellow lily.*
- Lilium philadelphicum L. Wood lily.*
- Medeola virginiana L. Indian cucumber-root. Eastern
N.A. Relict forests. May, June.
- Nothoscordum bivalve (L.) Britt. False garlic.*
- Ornithogalum umbellatum L. Star-of-Bethlehem.*
- Polygonatum biflorum (Walt.) Ell. Small Solomon's-
seal.*
- Smilacina racemosa (L.) Desf. False Solomon's-seal.*
- Smilacina stellata (L.) Desf. Northern N.A. Oak
forests. May.**
- Smilax bona-nox L. Fringed greenbrier.*
- Smilax ecirrhata (Engelm.) S. Wats.*
- Smilax glauca Walt. Sawbrier.*
- Smilax herbacea L. Carrion flower. Eastern N.A.
Relict forests. May, June.
- Smilax rotundifolia L.*
- Smilax tamnoides Fern. (S. hispida Muhl. in Gleason
and Cronquist, 1963).*
- Trillium gleasoni Fern. N. eastern U.S. Mixed
forests. April. (T. flexipes in Davies, 1954).
- Trillium recurvatum Beck Purple trillium.*

Trillium sessile L.*

Uvularia perfoliata L. Eastern U.S. Rich woods.
April, May.

Uvularia sessilifolia L. Eastern N.A. Oak-hickory
forest. April, May.**

Linaceae

Linum medium (Planch.) Britt. Eastern U.S. Old
fields. July.

Linum virginianum L.*

Lobeliaceae

Lobelia cardinalis L. Cardinal flower. Eastern N.A.
Alluvium, mixed woods. September.

Lobelia inflata L. Indian-tobacco. Eastern U.S.
Successional forests. Low pH soils. August.

Lobelia puberula Michx. Downy lobelia. S. eastern
U.S. Old fields. August, September.

Lobelia spicata Lam. Spiked lobelia.*

Lobelia syphilitica L. Blue cardinal flower.
Eastern and midwestern U.S. Alluvium, mixed woods.
September.

Lycopodiaceae

Lycopodium lucidulum Michx.*

Lythraceae

Cuphea petiolata (L.) Koehne Blue waxweed.*

Magnoliaceae

Liriodendron tulipifera L. Tuliptree. Eastern U.S.
Throughout the Park. Best development in sinks. May.

Magnolia acuminata L. Cucumber tree. S. eastern
U.S. Relict forests. May.

Magnolia macrophylla Michx. Bigleaf magnolia.*

Magnolia tripetala L. Umbrella magnolia. S. eastern
U.S. Relict forests. May.

Malvaceae

Hibiscus militaris Cav. Rose-mallow.*

Hibiscus moscheutos L. Rose-mallow.*

Sida spinosa L.*

Melastomataceae

Rhexia mariana L.*

Rhexia virginica L.*

Menispermaceae

Menispermum canadense L. Moonseed.*

Moraceae

Maclura pomifera (Raf.) Schneid. Osage-orange.*

Morus rubra L. Red mulberry.*

Oleaceae

Fraxinus americana L. American ash. Eastern N.A.
Mixed woods and upland depressions.

Fraxinus nigra Marsh. Black ash.*

Fraxinus pennsylvanica Marsh. Green ash. Eastern
N.A. Floodplains and seeps.

Fraxinus quadrangulata Michx. Blue ash.*

Onagraceae

Gaura filipes Spach.*

Ludwigia alternifolia L. Seed-box.*

Ludwigia palustris (L.) Ell. False loosestrife.*

Oenothera fruticosa L. Sundrops.*

Oenothera rhombipetala Nutt.*

Oenothera tetragona Roth. Sundrops.*

Ophioglossaceae

Botrychium dissectum Spreng. Grape fern.*

Botrychium virginianum (L.) Sw. Rattlesnake fern.
Eastern N.A. Oak forests. May, June.

Ophioglossum engelmanni Prantl. Adder's-tongue.*

Orchidaceae

Apelctrum hyemale (Muhl.) Torr. Puttyroot.*

Corallorhiza odontorhiza (Willd.) Nutt. Late
coralroot.*

Corallorhiza wisteriana Conrad. Wister's coralroot.
Southern U.S. Old fields. April, May.

Cypripedium calceolus L. Yellow lady-slipper.*

Goodyera pubescens (Willd.) R. Br. Rattlesnake-
plantain.*

Hexalectris spicata (Walt.) Barnh. Crested coralroot.*

Liparis lilifolia (L.) L. C. Richard Twayblade.*

Orchis spectabilis L. Showy orchis.*

Spiranthes cernua (L.) Rich. Nodding ladies'
tresses. Eastern N.A. Old fields. October.**

Spiranthes ovalis Lindl.*

Spiranthes tuberosa Raf.*

Spiranthes vernalis Engelm. & Gray Eastern U.S.
Old fields. July.

Tipularia discolor (Pursh) Nutt. Crane-fly orchid.*

Orobanchaceae

Conopholis americana (L.) Wallr. Squaw-root.
Eastern N.A. Dry oak forests. April.**

Epifagus virginiana (L.) Bart. Beech-drops. Eastern
U.S. Mixed mesic woods. September.

Osmundaceae

Osmunda cinnamomea L. Cinnamon fern.*

Osmunda regalis L. Royal fern.*

Oxalidaceae

Oxalis grandis Small.*

Oxalis stricta L. Upright yellow wood-sorrel. N.A.
Old fields. May, June.

Oxalis violacea L. Violet wood-sorrel. Eastern U.S.
Cemeteries. April, May.

Papaveraceae

Sanguinaria canadensis L. Bloodroot. Eastern U.S.
Mixed forests. April.

Stylophorum diphyllum (Michx.) Nutt. Celandine.
poppy.*

Passifloraceae

Passiflora incarnata L. Maypops.*

Passiflora lutea L.*

Phytolaccaceae

Phytolacca americana L. Pokeweed.*

Pinaceae

Juniperus virginiana L. Eastern red cedar.*

Pinus echinata Mill. Shortleaf pine. S. eastern
U.S. Uplands, NW section of the Park. Uncommon.
April.

Pinus strobus L. Eastern white pine.*

Pinus virginiana Mill. Virginia pine. S. eastern U.S. Old field succession, dry sites. April.

Tsuga canadensis (L.) Carr. Eastern hemlock. Eastern U.S. Relict forests.

Plantaginaceae

Plantago aristata Michx. Buckhorn. Eastern U.S. Old fields. May.

Plantago lanceolata L. English plantain.*

Plantago media L. Eurasia. Old fields. May.**

Plantago rugelii Decne. Common plantain.*

Plantago virginica L.*

Platanaceae

Platanus occidentalis L. Sycamore.***

Polemoniaceae

Phlox amoena Sims. S. eastern U.S. Mixed forest. April.**

Phlox bifida Beck. Sand phlox. S. eastern U.S. Mixed forest. April, May.**

Phlox divaricata L. Blue phlox. Eastern N.A. Mixed woods. April, May.

Phlox glaberrima L. Smooth phlox.*

Phlox maculata L. Sweet-william phlox.*

Phlox paniculata L. Garden phlox.*

Polemonium reptans L.*

Polygalaceae

Polygala sanguinea L. Eastern U.S. Old fields. July, August.

Polygala verticillata L.*

Polygonaceae

Polygonum convolvulus L. Black bindweed.*

Polygonum cristatum Engelm. & Gray (not in Gleason and Cronquist, 1963).*

Polygonum douglasii Greene. N. eastern U.S.
Alluvium, mixed woods. September.**

Polygonum persicaria L. Lady's thumb.*

Polygonum punctatum Ell. Water smartweed.*

Polygonum scandens L. False buckwheat.*

Polygonum virginianum L. Virginia knotweed.
Eastern U.S. Alluvium, floodplain. August,
September.**

Rumex acetosella L. Red sorrel.*

Rumex crispus L. Curly dock.*

Polypodiaceae

Adiantum pedatum L. Maidenhair fern.*

Asplenium montanum Willd. Mountain spleenwort.*

Asplenium pinnatifidum Nutt.

Asplenium platyneuron (L.) Oakes Ebony spleenwort.*

Asplenium resiliens Kunze. Black spleenwort. S.
central U.S. Old fields, open oak woods. Common.

Asplenium trichomanes L. Maidenhair spleenwort.*

Asplenium trudelli Wherry. X.*

Athyrium filix-femina L. Lady fern.*

Athyrium pycnocarpon (Spreng.) Tidest. Glade fern.*

Athyrium thelypteroides (Michx.) Desv. Silvery
spleenwort.*

- Camptosorus rhizophyllus (L.) Link Walking fern.*
- Cheilanthes lanosa (Michx.) D.C. Eat. Lip fern.*
- Cystopteris bulbifera (L.) Bernh. Bladder fern.*
- Cystopteris fragilis (L.) Bernh.*
- Dennstaedtia punctilobula (Michx.) Moore Hay-scented fern.*
- Dryopteris goldiana (Hook.) Gray Goldie's fern.*
- Dryopteris marginalis (L.) Gray Marginal wood fern.*
- Dryopteris noveboracensis (L.) Gray New York fern. (Referred to Thelypteris in Gleason and Cronquist, 1963).*
- Dryopteris spinulosa (O. F. Muell.) Watt. Spinulose wood fern. (D. austriaca (Jacq.) Woyнар. in Gleason and Cronquist, 1963).*
- Onoclea sensibilis L. Sensitive fern. Eastern N.A. Mixed forests. Moist soils.
- Pellaea atropurpurea (L.) Link Cliff-brake.*
- Polypodium polypodioides (L.) Watt. Resurrection fern.*
- Polypodium virginianum L. (P. vulgare L. in Gleason and Cronquist, 1963).*
- Polystichum acrostichoides (Michx.) Schott. Christmas fern. Eastern N.A. Common. Woods.
- Pteridium aquilinum (L.) Kuhn Bracken fern.*
- Thelypteris hexagonoptera (Michx.) Weatherby. Broad beech-fern. Circumboreal. Mixed woods.
- Woodsia obtusa (Spreng.) Torr. Cliff fern.*

Portulacaceae

- Claytonia virginica L. Spring beauty. Eastern U.S. Woods. Common. April.

Portulaca oleracea L. Purslane.*

Primulaceae

Anagallis arvensis L. Pimpernel.*

Dodecatheon meadia L. Shooting-star.*

Lysimachia lanceolata Walt. Loosestrife. S. eastern U.S. Old fields. June, July.

Lysimachia quadrifolia L. Whorled loosestrife. Chiefly Ozark region. Roadsides. June.

Samolus parviflorus Raf. Brookweed. (not in Gleason and Cronquist, 1963).*

Ranunculaceae

Actaea pachypoda Ell. White baneberry. (A. alba (L.) Mill. in Gleason and Cronquist, 1963).*

Anemone quinquefolia L. Eastern N.A. Mixed woods. April.**

Anemone virginiana L. Tall anemone. Eastern N.A. Roadsides and old fields. July.

Anemonella thalictroides (L.) Spach. Rue anemone. Eastern U.S. Mixed woods. May.

Aquilegia canadensis L. Columbine.*

Clematis glaucophylla Small Leather flower.*

Clematis viorna L. Leather flower.*

Delphinium tricornis Michx. Dwarf larkspur.*

Hepatica acutiloba DC. Eastern N.A. Relict forests and mixed woods. March, April.

Hydrastis canadensis L. Goldenseal. Eastern U.S. Drainages north of Green River. Uncommon. April.

Isopyrum bitermum (Raf.) T. & G. False rue anemone. Eastern N.A. Mixed woods. April.

Ranunculus abortivus L. Small-flowered crowfoot.*

Ranunculus fascicularis Muhl. Tufted buttercup.*

Ranunculus hispidus Michx. Bristly buttercup.
Eastern U.S. Oak woods. May.

Ranunculus recurvatus Poir.*

Ranunculus sardous Crantz. Europe. Oak woods.
April.**

Ranunculus septentrionalis Poir. Marsh buttercup.
Eastern N.A. Mixed woods. May.

Thalictrum dioicum L. Early meadow-rue.*

Thalictrum polygamum Muhl. N. eastern N.A. Relict
forests. May, June.**

Thalictrum revolutum DC. Waxy meadow-rue.

Rhamnaceae

Ceanothus americanus L. New Jersey tea. Eastern
N.A. Old fields. May, June.

Rhamnus carolinianus Walt. Carolina buckthorn.
S. eastern U.S. Dry oak forests. May.

Rosaceae

Agrimonia parviflora Ait.*

Agrimonia pubescens Wallr. S. eastern U.S.
Roadsides, old fields. July, August.**

Agrimonia rostellata Wallr. S. eastern U.S. Dry
oak woods. August.

Amelanchier arborea (Michx. F.) Fern. Shadbush.
Eastern U.S. Upland woods. Common. April.

Aruncus dioicus (Walt.) Fern. Goat's-beard.*

Duchesnea indica (Andr.) Focke. Indian strawberry.*

Fragaria virginiana Duch. Wild strawberry.
Throughout U.S. Old fields, dry oak woods. April.

Geum vernum (Raf.) T. & G. Spring avens. N. eastern
U.S. Relict forests, mesic forests. April, May.**

Geum virginianum L.*

Gillenia stipulata (Muhl.) Trel. Indian physic.
S. eastern U.S. Roadsides. Dry oak woods. June.

Physocarpus opulifolius (L.) Maxim. Ninebark.
Northern U.S. Dry oak, mixed woods.**

Potentilla recta L. Europe. Roadsides and old
fields. May.

Potentilla simplex Michx. Common cinquefoil.
Eastern N.A. Dry oak forests. May, June.

Prunus americana Marsh. Wild plum.*

Prunus serotina Ehrh. Wild black cherry. Eastern
N.A. Upland forests. Common.

Rosa carolina L. Carolina rose. Eastern U.S.
Uplands, old fields, homesites. May, June.

Rosa setigera Michx. Prairie-rose.*

Rosa virginiana Mill. (doubtful identification).

Rubus flagellaris Willd. Dewberry.*

Rubus occidentalis L. Black raspberry.*

Rubus pensylvanicus Poir. N. eastern N.A. Old fields.
May (R. frondosus Bigel. in Davies, 1954).

Waldsteinia fragarioides (Michx.) Tratt. Barren
strawberry.*

Rubiaceae

Cephalanthus occidentalis L. Buttonbush. Eastern
N.A. Floodplains and islands. July.

Diodia teres Walt. Rough buttonweed.*

Diodia virginiana L.*

Galium asprellum Michx. Rough bedstraw. N. eastern
N.A. Relict forests. June.**

Galium circaeazans Michx. Eastern N.A. Mixed old
growth woods. June.

Galium obtusum Bigel. N. eastern N.A. Mixed woods.
June.**

Galium triflorum Michx. Sweet-scented bedstraw.
Circumboreal. Alluvium, islands. June, July.

Houstonia caerulea L. Eastern U.S. Old fields, dry oak forests. April, May, June.

Houstonia lanceolata (Poir.) Britt.*

Houstonia longifolia Gaertn. Eastern N.A. Mixed woods. June.**

Houstonia purpurea L. S. eastern U.S. Roadsides. May.

Houstonia pusilla Schoepf. S. eastern U.S. Oak woods. April.

Mitchella repens L. Partridge-berry. Eastern N.A. Relict forests. June.

Rutaceae

Ptelea trifoliata L. Hop-tree.*

Salicaceae

Populus alba L. White poplar.*

Salix gracilis Fern. (S. petiolaris Sm. in Gleason and Cronquist, 1963).*

Salix humilis Marsh. Upland-willow.*

Salix interior Rowlee Sandbar-willow.*

Salix nigra L.*

Salix sericea Marsh. Silky willow.*

Santalaceae

Comandra richardsiana Fern. Bastard toad-flax. (C. umbellata [L.] Nutt. in Gleason and Cronquist, 1963).*

Saururaceae

Saururus cernuus L. Lizard-tail.**

Saxifragaceae

Astilbe biternata (Vent.) Britt. False goat's beard. Appalachian Mts. Relict forests. June.**

Boykinia aconitifolia Nutt. Appalachian Mts. Relict forests, sandstone substrate. April.**

Heuchera americana L.*

Heuchera parviflora Bartl. S. eastern U.S. Mixed woods. May, June.

Heuchera villosa Michx. S. central U.S. Relict forests, sandstone substrate. May, June.**

Hydrangea aborescens L.*

Mitella diphylla L. Bishop's cap. N. eastern U.S. Mixed woods. April, May.

Penthorum sedoides L. Dutch stonecrop. (Referred to the Crassulaceae in Gleason and Cronquist, 1963).*

Saxifraga virginensis Michx. Eastern N.A. Mixed woods. April, May.

Tiarella cordifolia L. Foam-flower. Eastern N.A. Relict forests and mixed woods. April, May.

Scrophulariaceae

Aureolaria flava (L.) Farw. (Gerardia flava in Davies, 1954).*

Aureolaria virginica (L.) Pennell. Eastern U.S. Roadsides. Common. July.

Buchnera americana L. Bluehearts.*

Chelone obliqua L.*

Gerardia tenuifolia Vahl. Eastern U.S. Old fields, roadsides. Common. August-October.

Leucospora multifida (Michx.) Nutt. Southern U.S. Old fields. June, July.**

Linaria vulgaris Hill. Butter-and-eggs.*

Mimulus alatus Ait.*

Paulownia tomentosa (Thunb.) Steud. Empress-tree. China. Maple Springs CCC Camp. July.**

Pedicularis canadensis L. Eastern N.A. Mixed woods. April, May.

Penstemon calycosus Small.*

Penstemon pallidus Small Eastern U.S. Mixed woods.
May, June.**

Scrophularia marilandica L.*

Seymeria macrophylla Nutt. (Referred to Dasistoma in
Gleason and Cronquist, 1963.)*

Verbascum blattaria L. Moth-mullein.*

Verbascum thapsus L.*

Veronica arvensis L.*

Veronicastrum virginicum (L.) Farw. Culver's root.*

Simarubaceae

Ailanthus altissima (Mill.) Swingle. Tree-of-
heaven.***

Solanaceae

Datura stramonium L. Jimson-weed.*

Physalis heterophylla Nees.*

Physalis longifolia Nutt. Eastern U.S. Roadsides and
old fields. Common.**

Solanum carolinense L. Horse-nettle. S. eastern
U.S. Floodplains and islands. Grass dominated areas.
June, July.

Solanum nigrum L. Black nightshade.*

Sparganiaceae

Sparganium androcladum (Engelm.) Morong.*

Staphyleaceae

Staphylea trifolia L. Bladder-nut.*

Tiliaceae

Tilia americana L. Basswood. Eastern N.A. Mixed
woods. April, May.**

Typhaceae

Typha latifolia L. Cat-tail.*

Ulmaceae

Celtis occidentalis L. Hackberry. Eastern N.A.
Sink hole alluvium, first terrace and floodplains.

Planera aquatica (Walt.) J. F. Gmel. Planer-tree.*

Ulmus alata Michx. Winged elm. S. eastern U.S.
Old fields, early secondary succession.

Ulmus americana L. American elm. Eastern and
central U.S. Alluvium. Uncommon.

Ulmus rubra Muhl. Slippery elm. Eastern U.S.
Depressional sites, alluvium along streams.

Ulmus thomasi Sarg. Rock elm. N. eastern U.S.
Historic Entrance trail. Uncommon to rare.**

Umbelliferae

Angelica venenosa (Greenway) Fern.*

Cryptotaenia canadensis (L.) DC. Honewort.*

Daucus carota L. Queen Ann's lace.*

Erigenia bulbosa (Michx.) Nutt. Salt and pepper.
Eastern U.S. Mixed woods. Common on old Mammoth
Cave property. March, April.

Eryngium yuccifolium Michx. Rattlesnake-master.*

Osmorhiza claytoni (Michx.) Clarke.*

Oxypolis rigidior (L.) C. and R.*

Sanicula canadensis L. Black snakeroot. Eastern U.S.
Mixed woods. May, June.

Sanicula marilandica L.*

Taenidia integerrima (L.) Drude.*

Thaspium pinnatifidum (Buckl.) Gray Meadow-parsnip.*

Zizia aptera (Gray) Fern. Golden alexanders.
Northern U.S. Mixed woods. April, May, June.

Urticaceae

Boehmeria cylindrica (L.) Sw. False nettle. Eastern
N.A. Mixed woods. August, September.

Laportea canadensis (L.) Wedd. Wood-nettle. Eastern N.A. Floodplain alluvium. July, August.**

Parietaria pensylvanica Muhl. Pellitory.*

Pilea pumila (L.) Gray Clearweed.*

Valerianaceae

Valeriana pauciflora Michx.*

Verbenaceae

Verbena canadensis (L.) Britt.*

Verbena simplex Lehm. Eastern U.S. Old fields. Common. May, June.

Verbena stricta Vent.*

Verbena urticifolia L.*

Violaceae

Hybanthus concolor (T. F. Forst.) Spreng. Green violet. (Referred to Cubelium in Gleason and Cronquist, 1963.)*

Viola affinis LeConte. Eastern U.S. Floodplains. April.**

Viola conspersa Reichenb. American dog-violet.*

Viola cucullata Ait. Blue marsh-violet.*

Viola eriocarpa Schw. Smooth yellow violet. Eastern N.A. Mixed woods. June.**

Viola hirsutula Brainerd. S. eastern U.S. Mixed woods. April.

Viola incognita Brainerd.*

Viola kitaibeliana Fern. (not in Gleason and Cronquist, 1963).*

Viola lanceolata L.*

Viola papilionacea Pursh. Meadow-violet. Eastern U.S. Old fields. April.

Viola pedata L. Bird-foot violet. Eastern U.S. Roadsides, old fields. April.

Viola pensylvanica Michx.*

Viola sagittata Ait. Arrowleaf violet.*

Viola sororia Willd. Woolly blue violet.*

Viola striata Ait. S. eastern U.S. Mixed woods.
April, May.

Viola triloba Schwein.*

Vitaceae

Parthenocissus quinquefolia (L.) Planch. Virginia
creeper.*

Vitis aestivalis Michx. Summer-grape.*

Vitis cinerea Engelm. S. eastern U.S. Upland oak
woods.**

Vitis vulpina L. Forest-grape.*

Appendix H

TABLE 1H. Key to species symbols. Nomenclature follows Gleason and Cronquist (1963).

Symbol	Scientific Name	Common Name
Ane	<i>Acer negundo</i> L.	Boxelder
Ar	<i>Acer rubrum</i> L.	Red Maple
Asi	<i>Acer saccharinum</i> L.	Silver Maple
As	<i>Acer saccharum</i> Marsh.	Sugar Maple
Ag	<i>Aesculus glabra</i> Willd.	Ohio Buckeye
Aa	<i>Ailanthus altissima</i> (Mill.) Swingle	Tree-of-heaven (<i>Ailanthus</i>)
Am	<i>Amelanchier arborea</i> (Michx. f.) Fern.	Serviceberry
At	<i>Asimina triloba</i> (L.) Dunal	Pawpaw
Bl	<i>Betula lutea</i> Michx. f.	Yellow Birch
Bn	<i>Betula nigra</i> L.	River Birch
Ccar	<i>Carpinus caroliniana</i> Walt.	American Hornbeam
Ccor	<i>Carya cordiformis</i> (Wang.) K. Koch	Bitternut Hickory
Cg	<i>Carya glabra</i> (Mill.) Sweet	Pignut Hickory
Cov	<i>Carya ovata</i> (Mill.) K. Koch	Shagbark Hickory
Col	<i>Carya ovalis</i> (Wang.) Sarg.	Red Hickory
Ct	<i>Carya tomentosa</i> Nutt.	Mockernut Hickory
Cd	<i>Castanea dentata</i> (Marsh.) Borkh.	American Chestnut
Coc	<i>Celtis occidentalis</i> L.	Hackberry
Ccan	<i>Cercis canadensis</i> var. <i>canadensis</i>	Eastern Redbud
Cf	<i>Cornus florida</i> L.	Flowering Dogwood
Cr	<i>Crataegus</i> sp.	Hawthorn
Dv	<i>Diospyros virginiana</i> var. <i>virginiana</i>	Common Persimmon

TABLE 1H (continued).

Symbol	Scientific Name	Common Name
Fg	<i>Fagus grandifolia</i> Ehrh.	American Beech
Fa	<i>Fraxinus americana</i> L.	White Ash
Fp	<i>Fraxinus pennsylvanica</i> Marsh.	Green Ash
Fq	<i>Fraxinus quadrangulata</i> Michx.	Blue Ash
Gt	<i>Gleditsia triacanthos</i> L.	Honey Locust
Gd	<i>Gymnocladus dioica</i> (L.) K. Koch	Kentucky Coffeetree
Io	<i>Illex opaca</i> Ait.	American Holly
Jc	<i>Juglans cinerea</i> L.	Butternut
Jn	<i>Juglans nigra</i> L.	Black Walnut
Jv	<i>Juniperus virginiana</i> L.	Eastern Red Cedar
Lb	<i>Lindera benzoin</i> (L.) Blume	Spice Bush
Ls	<i>Liquidambar styraciflua</i> L.	Sweet Gum
Lt	<i>Liriodendron tulipifera</i> L.	Yellow Poplar (Tuliptree)
Mt	<i>Magnolia tripetala</i> L.	Umbrella Magnolia
Mr	<i>Morus rubra</i> L.	Red Mulberry
Ns	<i>Nyssa sylvatica</i> var. <i>sylvatica</i>	Black Tupelo (Black Gum)
Ov	<i>Ostrya virginiana</i> (Mill.) K. Koch	Eastern Hophornbeam
Oa	<i>Oxydendrum arboreum</i> (L.) DC	Sourwood
Pv	<i>Pinus virginiana</i> Mill.	Virginia Pine
Po	<i>Platanus occidentalis</i> L.	American Sycamore
Pd	<i>Populus deltoides</i> Bartr.	Eastern Cottonwood
Pa	<i>Populus alba</i> L.	White Poplar
Ps	<i>Prunus serotina</i> var. <i>serotina</i>	Black Cherry
Qa	<i>Quercus alba</i> L.	White Oak
Qc	<i>Quercus coccinea</i> Muenchh.	Scarlet Oak

TABLE 1H (continued).

Symbol	Scientific Name	Common Name
Qf	<i>Quercus falcata</i> var. <i>falcata</i>	Southern Red Oak
Qma	<i>Quercus macrocarpa</i> Michx.	Bur Oak
Qmar	<i>Quercus marilandica</i> Muenchh.	Blackjack Oak
Qmu	<i>Quercus muehlenbergii</i> Engelm.	Chinquapin Oak (Yellow Oak)
Qpr	<i>Quercus prinus</i> L.	Chestnut Oak
Qr	<i>Quercus rubra</i> L.	Northern Red Oak
Qst	<i>Quercus stellata</i> var. <i>stellata</i>	Post Oak
Qv	<i>Quercus velutina</i> Lam.	Black Oak
Rc	<i>Rhus copallinum</i> L.	Shining Sumac
Rp	<i>Robinia pseudoacacia</i> L.	Black Locust
Sn	<i>Salix nigra</i> L.	Willow
Sa	<i>Sassafras albidum</i> (Nutt.) Nees	Sassafras
Ta	<i>Tilia americana</i> L.	American Basswood
Tc	<i>Tsuga canadensis</i> (L.) Carr.	Eastern Hemlock
Ual	<i>Ulmus alata</i> Michx.	Winged Elm
Ua	<i>Ulmus americana</i> var. <i>americana</i>	American Elm
Ur	<i>Ulmus rubra</i> Muhl.	Slippery Elm
Ut	<i>Ulmus thomasi</i> Sarg.	Rock Elm

Appendix I

TABLE 11. Field key to the common hickories of Mammoth Cave National Park.

Species	Leaflets	Twig	Bark	Bud Scales	Fruit
<u>Carya ovata</u> (shagbark)	5	stout	shaggy		thick husk
<u>C. glabra</u> (pignut)	5-9	slender	tight rounded		pear shaped thin
<u>C. cordiformis</u> (bitternut)	7-11	slender	ridged shallow furrowed	yellow in pairs	thin
<u>C. ovalis</u> (sweet pignut)	7 glabrous	slender	scaly to shaggy	not yellow not paired	thin
<u>C. tomentosa</u> (mockernut)	7-9	stout	shallow furrowed anastomosing	over $\frac{1}{2}$ inch	thick husk

0.1 acre PERMANENT PLOT 1

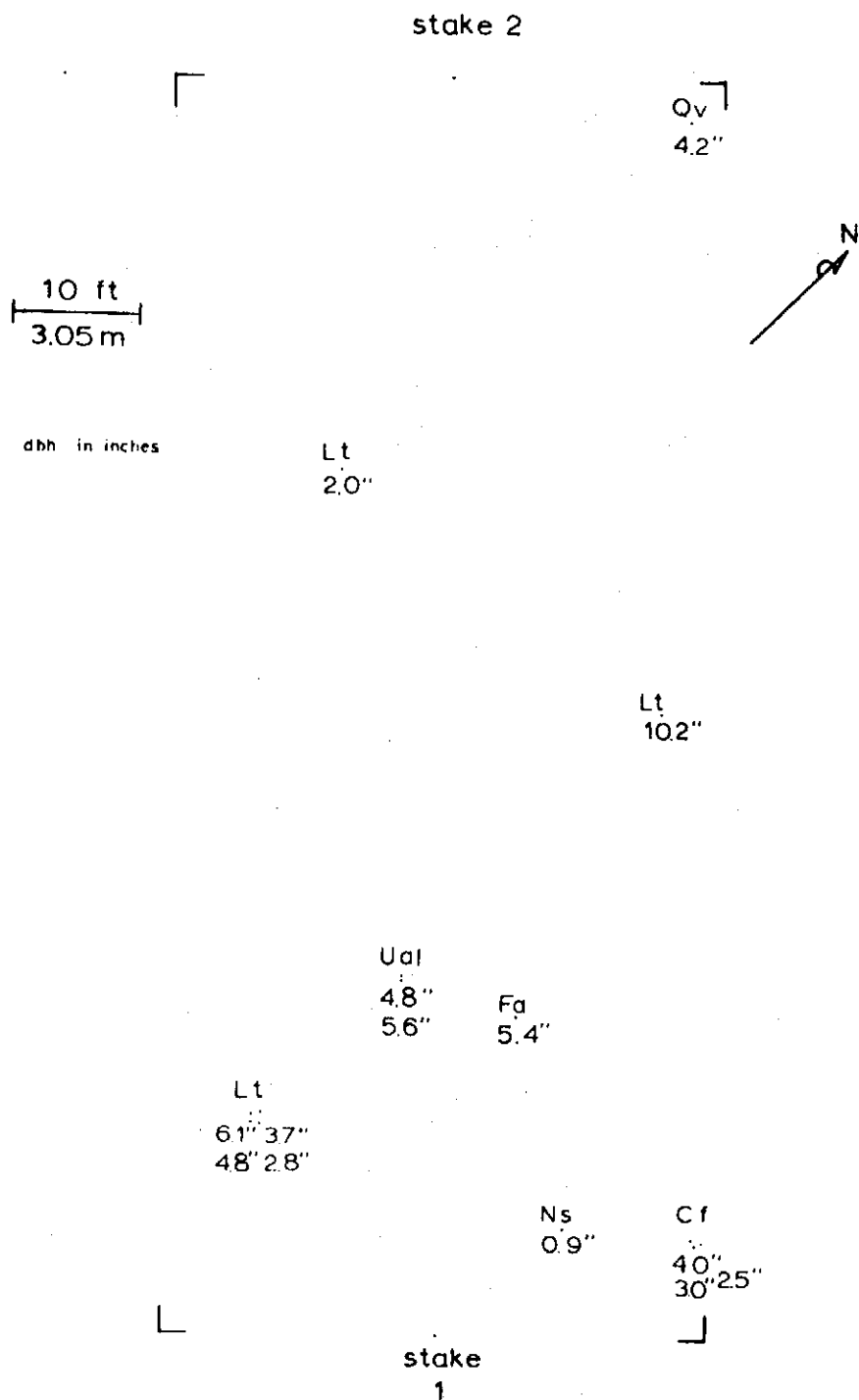


PLATE 5. Permanent vegetation Plot 1. See Appendix B for location. Symbols follow Table III.

0.1 acre PERMANENT PLOT 2

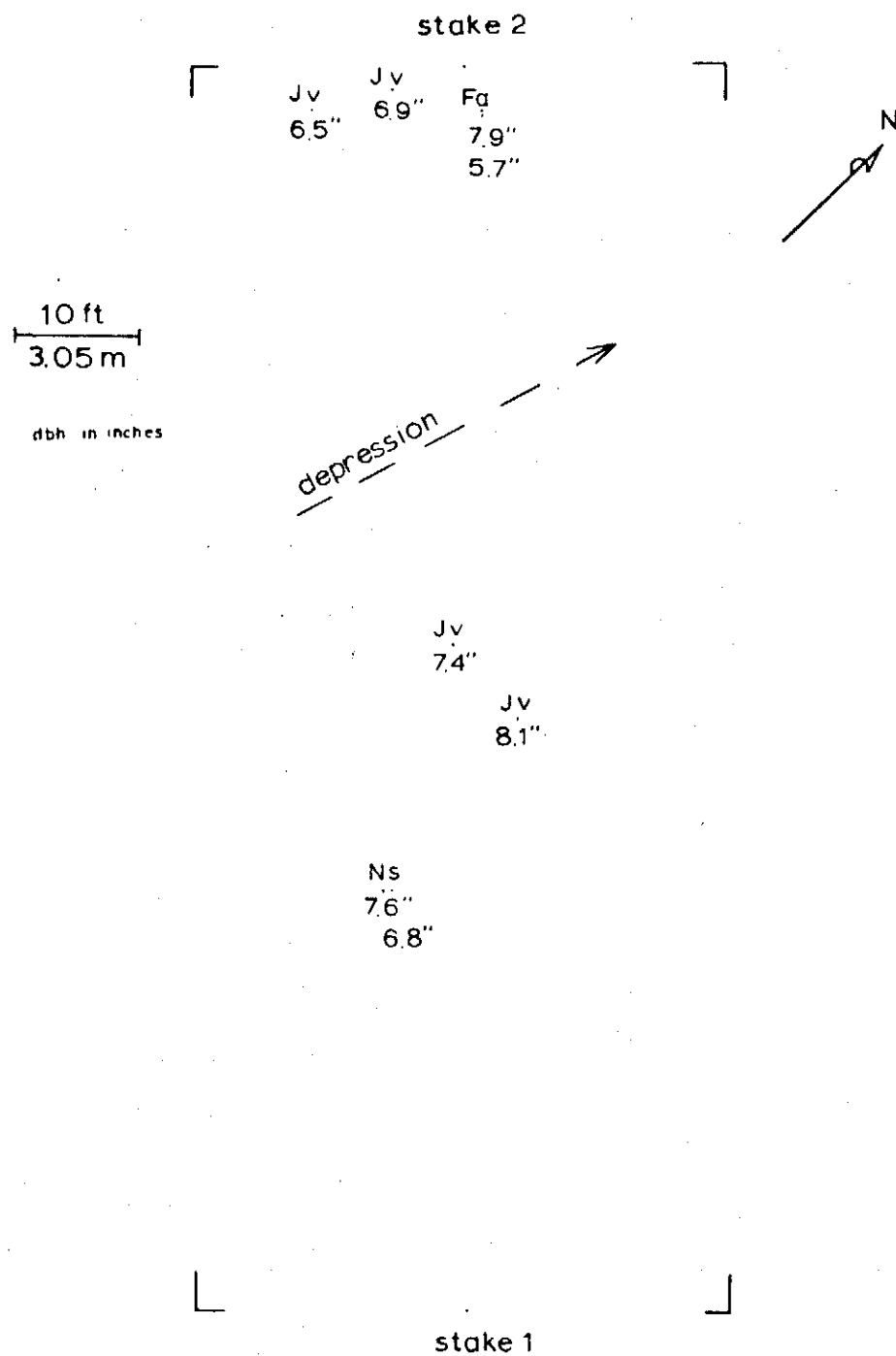


PLATE 6. Permanent vegetation Plot 2. See Appendix B for location. Symbols follow table 1H.

O.1acre PERMANENT PLOT 3

stake 2

10 ft
3.05m

dbh in inches

Lt
2.0"

Ns

5.8"



stake 1

PLATE 7. Permanent vegetation Plot 3. See Appendix B for location. Symbols follow Table III.

0.1acre PERMANENT PLOT 4
stake 2

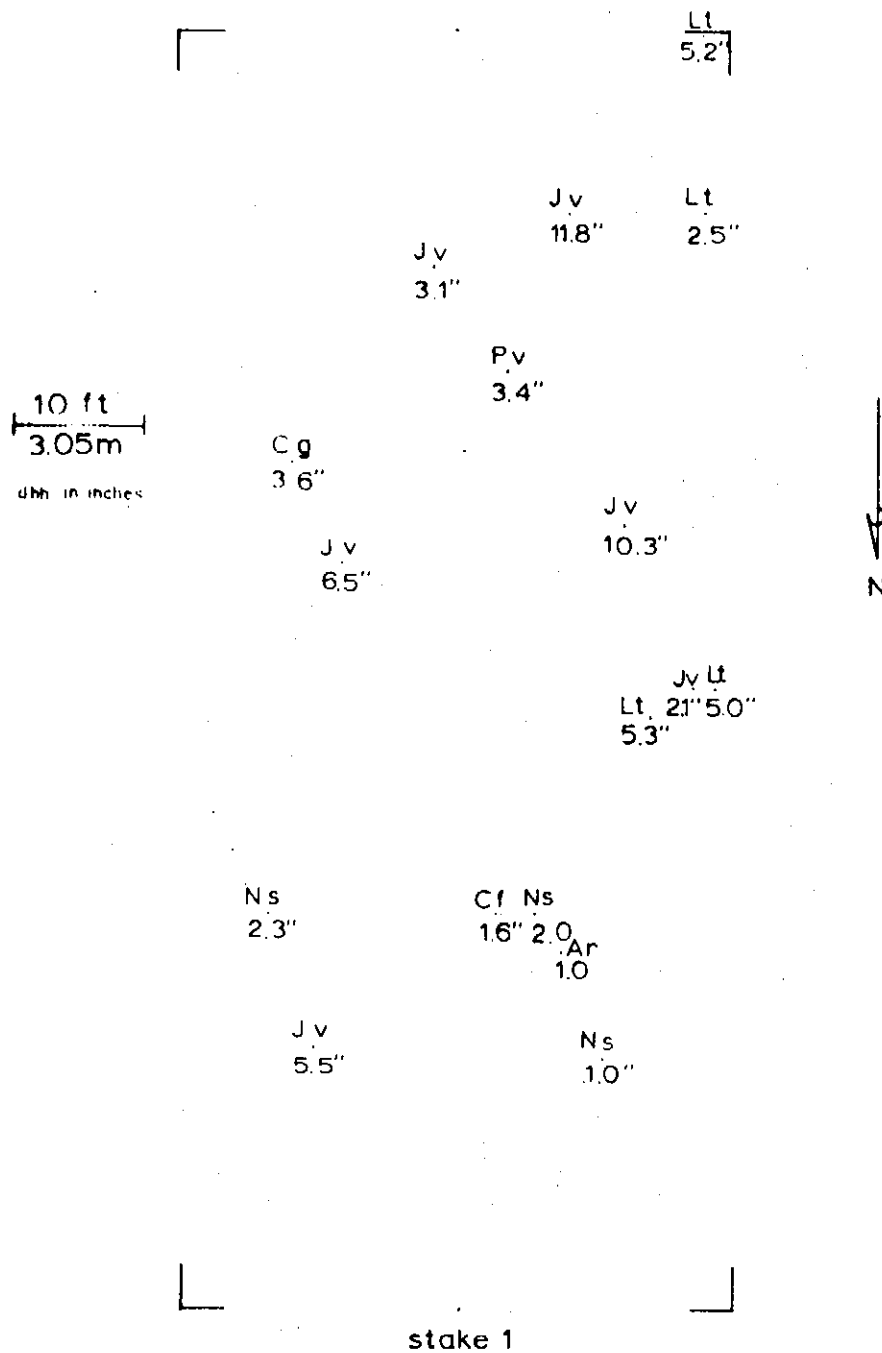


PLATE 8. Permanent vegetation Plot 4. See Appendix B for location. Symbols follow Table 1H.

0.1acre PERMANENT PLOT 5

stake 2

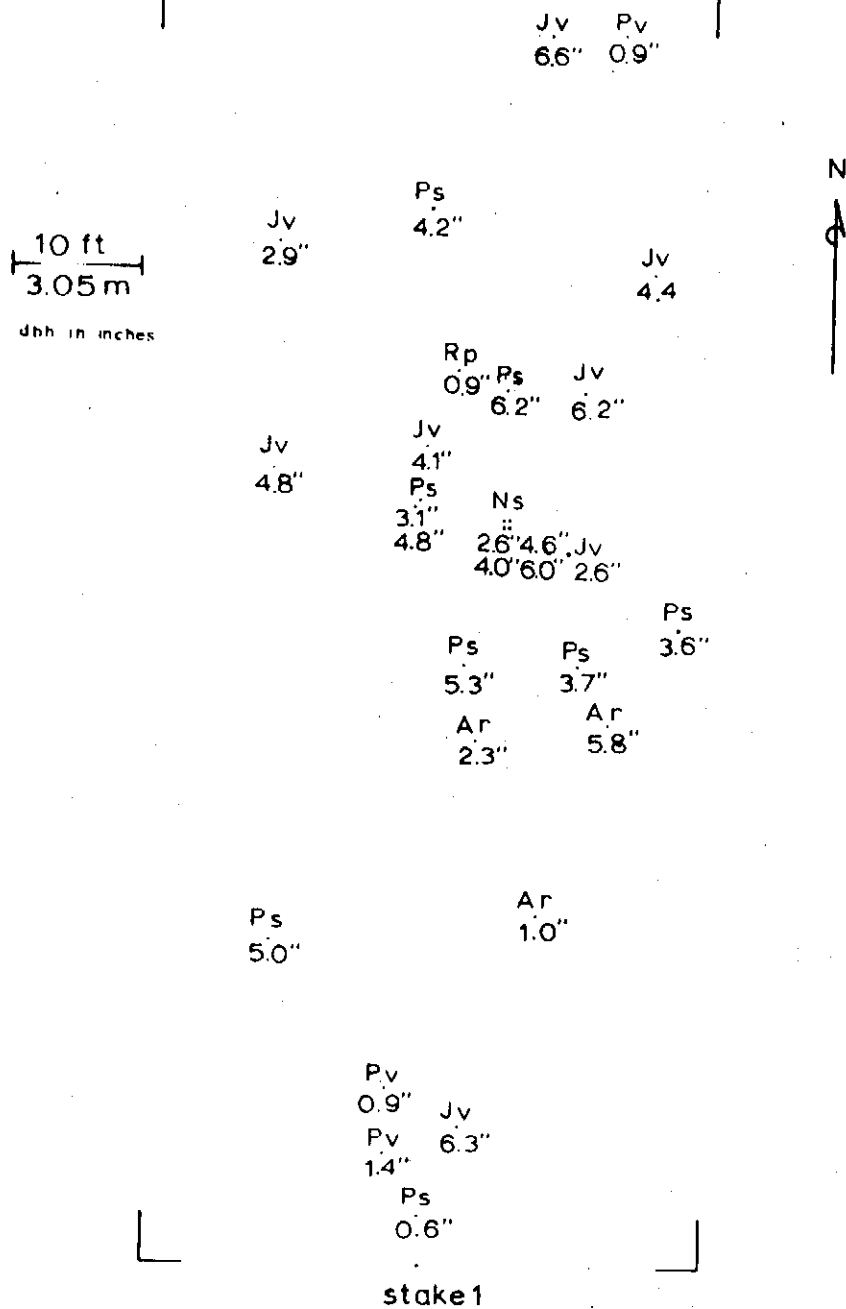


PLATE 9. Permanent vegetation Plot 5. See Appendix B for location. Symbols follow Table III.

0.1 acre PERMANENT PLOT 6

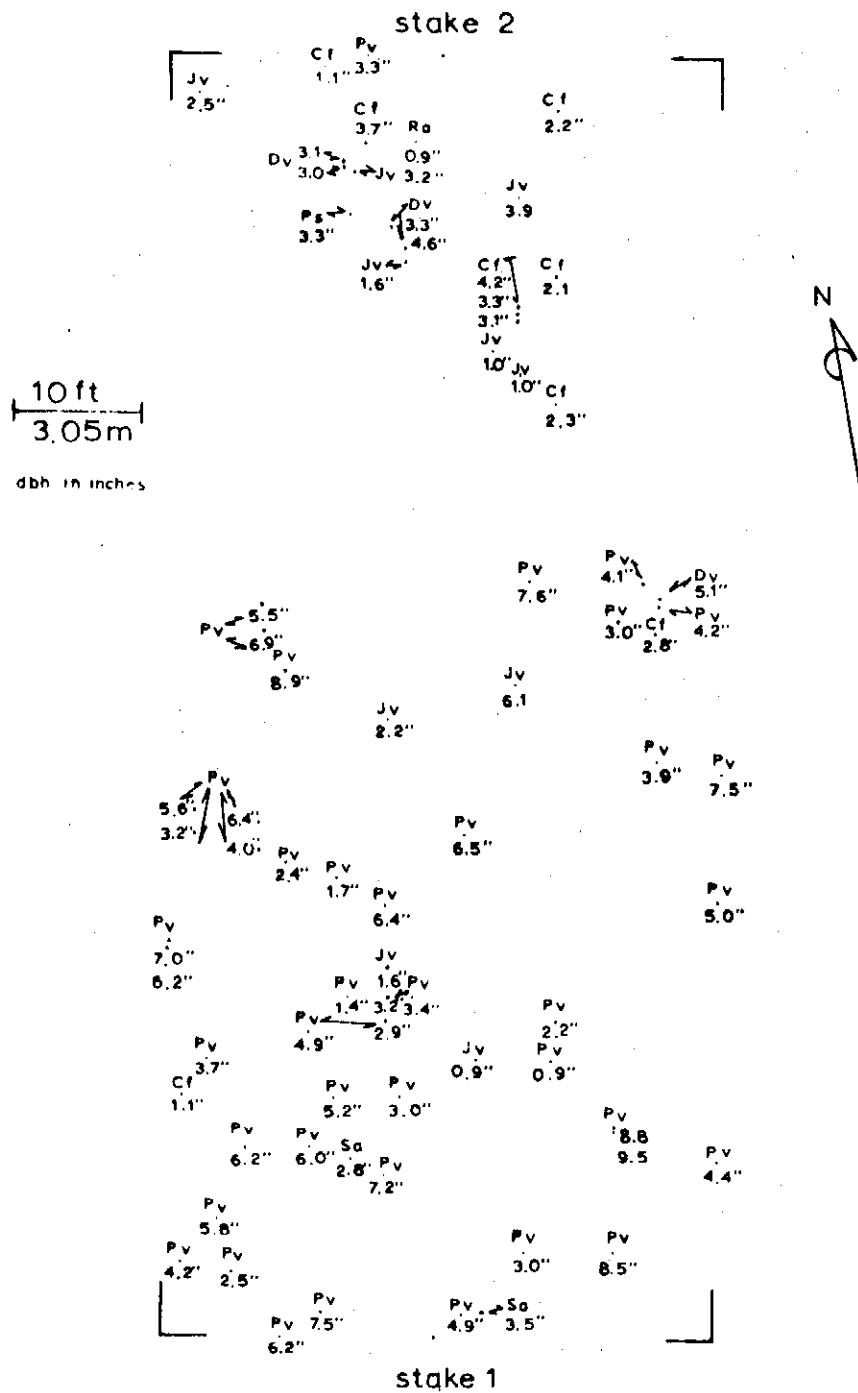


PLATE 10. Permanent vegetation Plot 6. See Appendix B for location. Symbols follow Table 1H.

0.1 acre PERMANENT PLOT 7

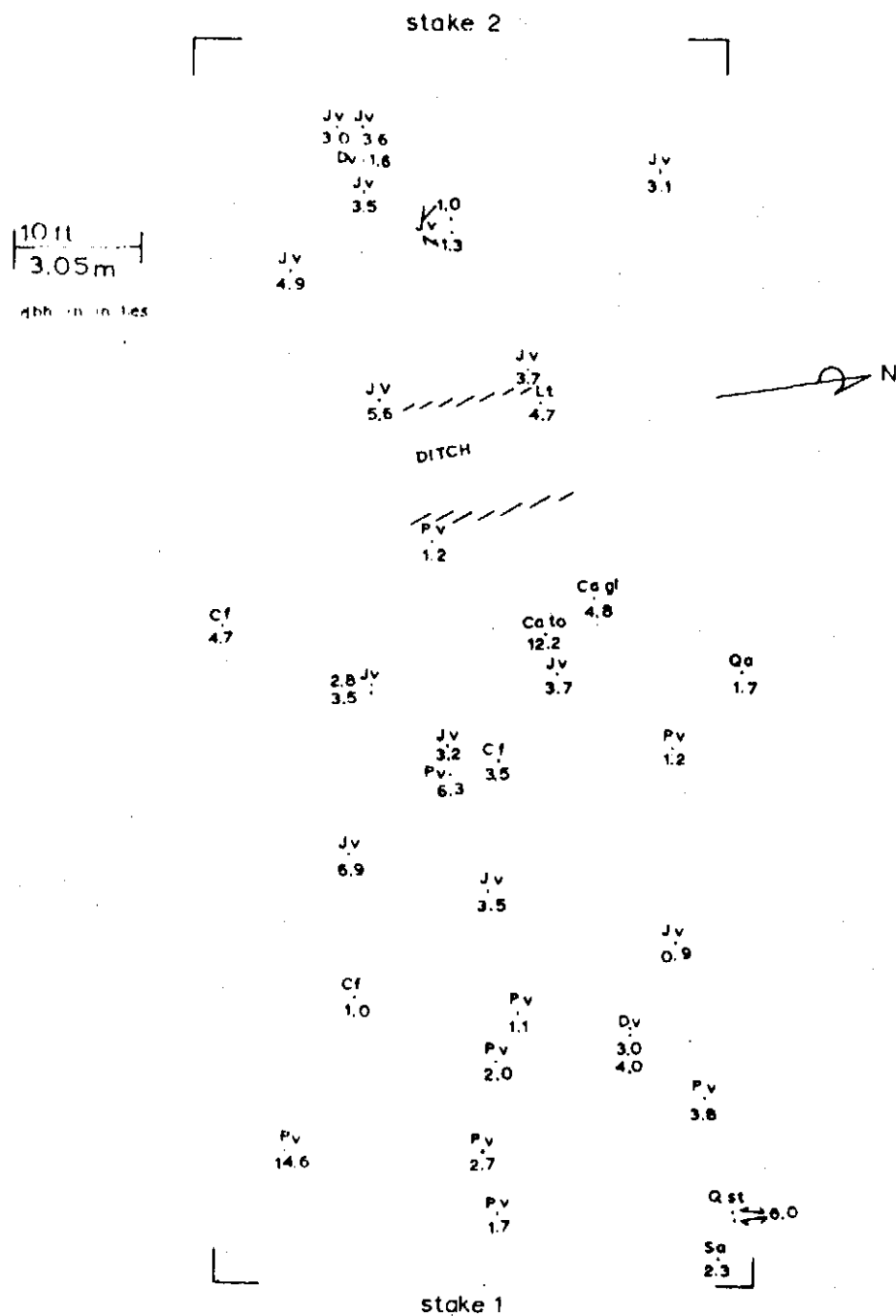


PLATE 11. Permanent vegetation Plot 7. See Appendix B for location. Symbols follow Table III.

0.1 acre PERMANENT PLOT 8
stake 2

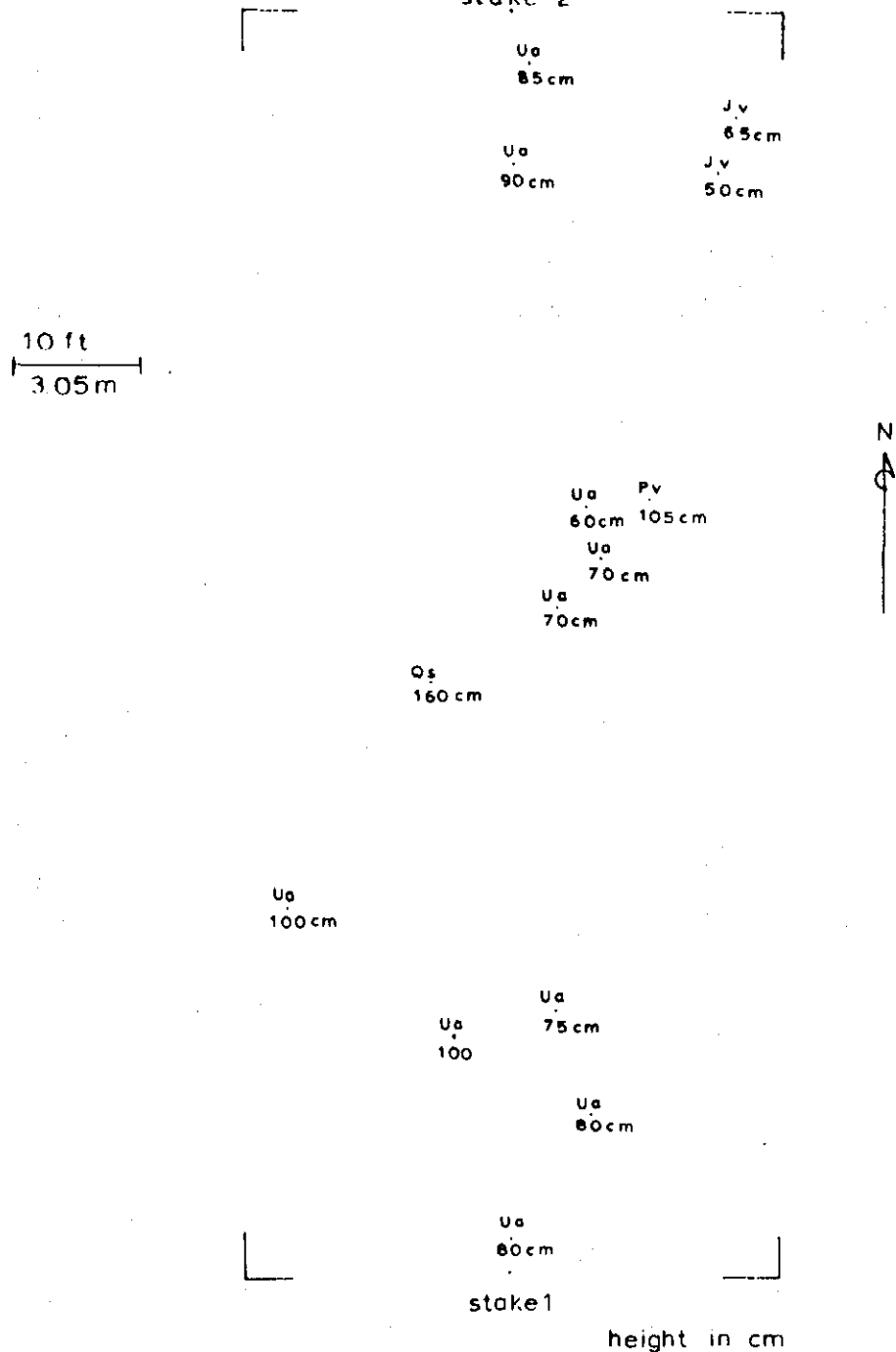


PLATE 12. Permanent vegetation Plot 8. See Appendix B for location. Symbols follow Table III.

0.1 acre PERMANENT PLOT 9

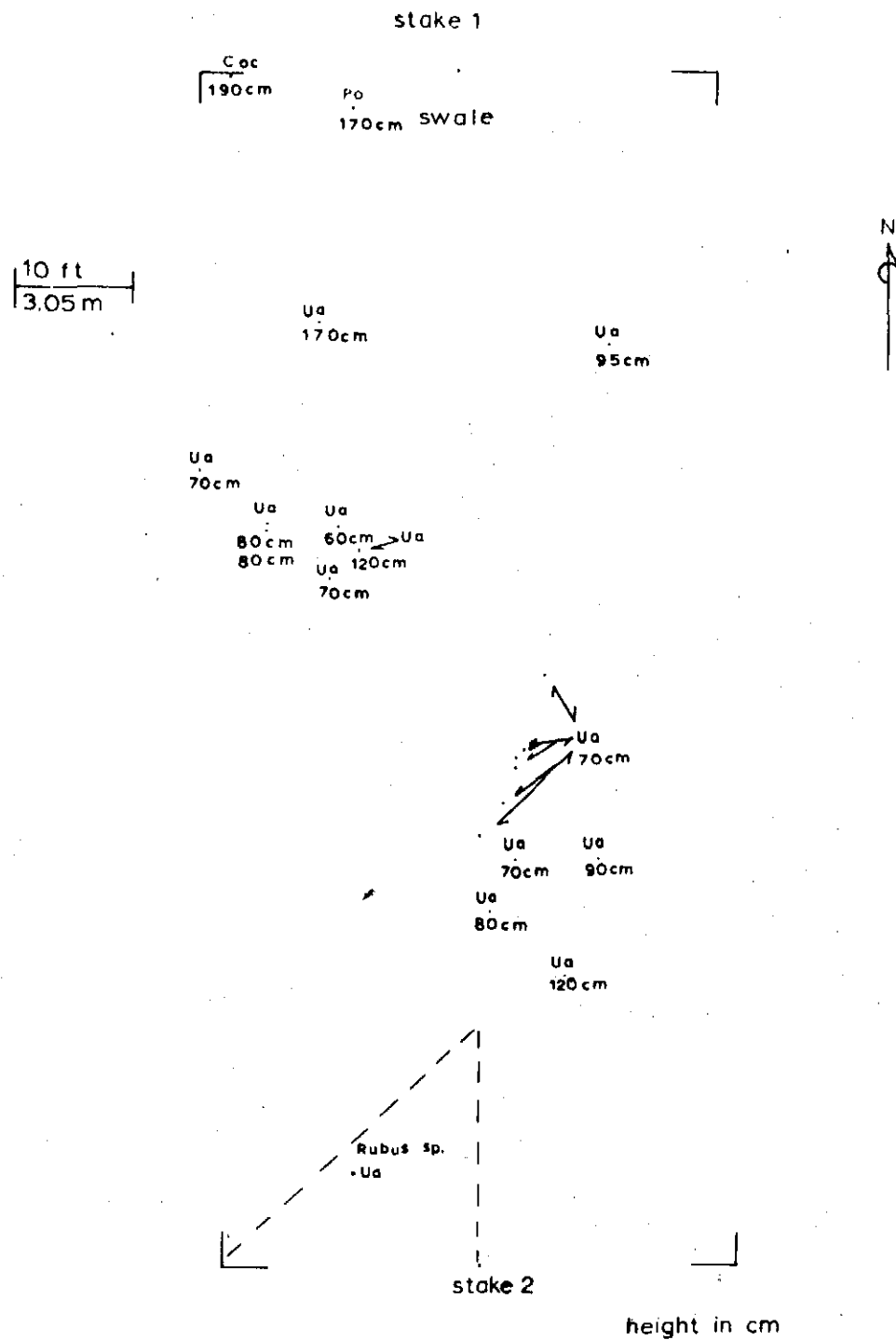


PLATE 13. Permanent vegetation Plot 9. See Appendix B for location. Symbols follow Table 1H.