THE LAND OF CANE AND CLOVER

Bluegrass Woodlands and the Griffith Farm (Harrison County, Kentucky): Challenges for Research and Restoration in a Eutrophic Landscape

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"Brothers: the fertile region of Kentucky is the land of cane and clover—spontaneously growing to feed the buffaloes, the elk and the deer; there the bear and beaver are always fat—the Indians from all the tribes have had a right from time immemorial, to hunt and kill unmolested these wild animals, and bring off their skins, to purchase themselves clothing—to buy blankets for their backs and rum to send down their throats, to drive away the cold and rejoice their hearts, after the fatigue of hunting and the toil of war [great applause from the crowd]. But

"Brothers, the long knives have overrun your country, and usurped your hunting grounds,—They have destroyed the cane—trodden down the clover—killed the deer and buffaloes, the bear and raccoon—They are building cabins and making roads on the ground of the Indian camp and warpath: The beaver has been chased from his dam and forced to leave the country [palpable emotion among the hearers].

“Brothers, the intruders on your lands exult in the success that has crowned their flagitious acts:—They are planting fruit trees and ploughing the land where not long since were the cane break and clover field. Were there a voice in the trees of the forest, or articulate sound in the gurgling waters, every part of this country would call upon you to chase away these ruthless invaders who are laying it waste:—Unless you rise in the majesty of your might and exterminate the whole race, you may bid adieu to the hunting ground of your fathers—to the delicious flesh of the animals with which it once abounded, and to the skins with which you were once enabled to purchase your clothing and your rum.”

Simon Girty’s speech of 1782, addressing assembled tribes before marching to attack Bryan Station, five miles north of Lexington; as reported in John Bradford’s “Notes on Kentucky” (1827); reprinted in J.W. Townsend (ed.). 1932. Bradford's Notes on Kentucky. Grabhorn Press, San Francisco.

Preface

This document is a provisional assembly of materials for a general guide to the Griffith Farm and Bluegrass Woodlands. Over the coming months and years, it will hopefully evolve in three directions: (1) to continue more or less with this format (see suggested table of contents), becoming the professional foundation for planning and assessment at the farm, and for educational use at the college level—ultimately a textbook on woodland ecology in the central Ohio Valley; (2) to turn this material into short simple handouts, class materials and popular booklets for schools and the general public; (3) to act as a framework for more technical scientific appendices or chapters that will be published as a series—or as a much grander academic tome in a decade or so.

Development of the document (or documents) will ideally involve collaboration with other interested people. In the immediate future (2008), I at least can begin to incorporate or append initial results from my various botanical mappings, old field studies and plantings at the farm. Also, it will be very beneficial to begin building large communal databases on vegetation at the farm and elsewhere in the region. Most of the ecological trends noted in this current document are illustrated only with data on numbers of species—they need to be explored further using real vegetation data, and ideally experimental results. Also, there are several obvious topics that remain to be incorporated, especially involving animals (mammals, birds, herps, selected inverts) and human cultural components (from native people to Virginians to recent farmers). And much more support is needed with maps from the farm, neighborhood and region, plus assorted photos for illustration.

The didactic needs in woodland ecology across this region are great, especially for our understanding of the major ecological gradients that exist (or used to exist) in native vegetation. Although I am sometimes considered eccentricly obsessed about these matters in Kentucky, it is clear to me that concepts of ecological gradients have not yet been applied nearly enough in this state. They will eventually transform professional approaches to native vegetation, and it is critical that teaching of ecology begins to incorporate them at all levels.

There are considerable difficulties to overcome before we can properly restore native woodland in the central Bluegrass. In particular, this document points to the overarching needs in propagation and initial trials with native plantings, plus the need to devolop systems of farm economy that can lead to effective reduction of invasive aliens. The problems with invasives are immense, but we do not yet a way, even at the Griffith Farm, to secure sufficient, sustainable financial support for even moderate reductions across the farm. These and other problems require us to assemble a cooperative, interdisciplinary group of people, at least to review plans and support development of each others' proposals. There are several people at UK and other institutions who could provide useful input but have yet been involved to a significant extent.

The Griffith Woods project is established with support of public and non-profit organizations that try to be community-based and science-based. Because we live in a democratic republic, it will be important to have transparent evaluations of our progress at the farm. Attached to back of this document is a summary table of conservation targets, suggested initial strategies, project priorities, and a potential format for reporting on progress. For a simple overview, **the major headings in bold** can be extracted from this table; the subheadings add more details. Note that it may eventually be reasonable to add native ungulates as an independent conservation target, especially elk and bison; these species would be treated as a highly managed component of the ecosystem, but some degree of free-ranging behavior could be studied, perhaps on the western (TNC) side of US 62, if fenced.

Table of Contents
[maps and photos are not yet assembled]
[material in brackets is still being developed at least for appendices]
[some botanical material for general education is attached as appendices]

[Classification and listing of species by functional life-forms and evolutionary taxonomy]
[Annotated lists of plant species from farm and region; tables comparing farm with regional norms; mapping of rare & unusual plants; priorities for propagation & recovery]
[Initial data from planting plans at farm: the native plant nursery; initial tree, shrub & cane plantings; recovery plans for running buffalo clover & other imperiled species; results from initial plantings (collection field, cane field, USDA fields); figures/tables showing growth & survival; associated vegetation data]
[Fauna: brief notes on selected taxonomic and ecological groups; conservation targets; lists with more detailed notes on mammals, birds, herptiles; annotated lists of selected invertebrates: lepidoptera, beetles, snails (?); potential relationships of fauna to conservation management.]

Cultural Features and Potentials: to be developed

Presettlement information (from archaic periods to contact)
Early settlement information (ca. 1770-1860)
Development of modern farmland (ca. 1870-1960)
Integration of cultural and natural features in the conserved landscape

Discussion: to be developed

Ecoregional role of the farm
Linkage with international interest in restoration of eutrophic woodlands
Fundamental questions of ecology & economy.

Summary: to be developed

Introduction

This document is a provisional assembly of materials for a general guide to the Griffith Farm and Bluegrass Woodlands. Over the coming months and years, it will hopefully evolve in three directions.
(1) To continue more or less with this format or a slightly expanded version (with zoological and cultural components), becoming the professional foundation for planning and assessment at the farm, and for educational use at the college level—ultimately a textbook on woodland ecology in the central Ohio Valley.
(2) To turn this material into short simple handouts, class materials and popular booklets for schools and the general public.
(3) To act as a framework for more technical scientific appendices or chapters that will be published as a series—or as a much grander academic tome in a decade or so.
The general layout of this document is designed to allow clear definition of targets for conservation at the farm and elsewhere in the region, but application of these definitions to planning at the farm is not addressed in any detail. Separate plans and proposals for the farm have been drafted and will continue to evolve on a parallel track to the scientific background emphasized here.

Although the definition of targets for planning conservation can initially appear to involve overwhelming potential complexity, an excellent simplifying approach has been devised by The Nature Conservancy and others. This can be summarized as a filtering process, down the levels of biological organization. For further detail, official Conservancy documents, websites and spreadsheets should be consulted to see the various kinds of tables, charts, and other technical products than can be generated from this process.

(i) First, define the region of interest based on natural features, for complete planning within the area, and for combining information about particular sites. For the larger sites, at least, then estimate the relative importance of each site as a representative of the region, based on its overall size, condition and context, and consider to what extent the more important sites can be conserved, using various strategies in land protection.

(ii) Second, define what types of natural habitat will still need relatively active restoration or further attention, in addition to any inclusion within the most obvious priorities for protected lands. A central question is: for each habitat type, how much do we want to maintain in a relatively natural condition, and where? Outline habitat types wisely, avoiding excessively technical subdivisions, and group them according to fundamental problems for management—for example, those that need restored hydrology, browsing or burning regimes.

(iii) Third, define what groups of species will still deserve special propagation or other micromanagement, even after their appropriate habitats are maintained on protected lands. Because so many species exist, only a few critical groups of imperiled or "indicator" species should be selected. A good indicator species would reflect the overall health of the habitats that it inhabits.

At each step in this filtering process, the threats to each target can be listed and ranked in importance. In addition to past problems for correction, common sources of current problems can be identified, including direct stresses within the system (e.g. continued logging, soil-erosion) or indirect influences from outside (e.g. polluted waters from upstream, climate change in general). A special class of threat needs particularly detailed attention—the diverse problems caused by invasive pathogens, pests or weeds that are already here or on the horizon.

Our Best Opportunity for Restoration of Central Bluegrass Woodland

The Region. Before settlement in 1770-1800, the natural ecosystem on plains of the Bluegrass Region was unique. With some of the most fertile upland soils of any temperate region in the world, its complex cover of deeper forest and thin grassy woodland was composed of species more typical of rich bottomlands elsewhere, including extensive canebreaks and much running buffalo clover, a species that is now endangered. This fertile region seems to have attracted concentrations of large herbivores, including bison and elk, which may have greatly influenced the vegetation, along with fires set by native peoples for thousands of years.

Simon Girty, an infamous character in Kentucky's pioneer history, urged Indians tribes in 1782 to resist Virginian settlement in this region with a speech that began: "Brothers: the fertile region of Kentucky is the land of cane and clover--spontaneously growing to feed the buffaloes, the elk and the deer...the intruders of your lands exult in the success that has crowned their flagitious acts—They are planting fruit trees and ploughing the land where not long since were the canebreak and clover field."

Because of intensive settlement on these fertile plains after the 1770s, and continuing development, natural vegetation has virtually disappeared from the Bluegrass plains. If we are to learn how this ecosystem functioned before settlement and how to restore some of its features into our future landscape, we must act now to save the best remnants. Lucy Braun, who wrote the classic book on Eastern Deciduous Forests in 1950, stated that the Inner Bluegrass is "the most anomalous vegetation area of eastern United States." There is, nevertheless, some similarity with the Nashville Basin, on similar bedrock, where woodlands have also been almost entirely converted to farmland or other developed land.

The Neighborhood. The Griffith Farm lies in a relatively rural area with limited residential development, except for moderate subdivisions, with several 5-20 acres lots, to the northeast and southwest. For a few miles to the east and west, as far as the Eden Shale Hills on either side, the land is generally farmed and it becomes increasing wooded into the hills. Some relatively extensive woods exist in these hills, with blocks of up to 1000 acres that lack developed roads in a few areas (Map ..).

It would be reasonable to explore the potential for conservation of farmland and woodland in a broad belt, perhaps 10 miles wide from east to west. This belt would be relatively narrow around the Griffith Farm but broaden into the hills. Such efforts, of course, would have to be voluntary and supported by the community. Several governmental programs, largely funded from the federal level, have allowed easements to be established for conserving farmland in Kentucky. It is possible that such efforts could be linked with the overall conservation program for the lower Licking River watershed, as promoted by various government agencies and The Nature Conservancy. They also could be part of a general regional planning within the central Bluegrass. However, although such regional planning has long been a dream of some, especially in non-profit organizations like "Bluegrass Tomorrow" and the "Bluegrass Conservancy", the relevant counties have not come together for substantial cooperation.

It remains to be seen if Harrison County can champion such efforts, and then perhaps plan together with its neighbors to the south in Scott County and Bourbon County. Although farmers often resist efforts to restrict their land uses, they might see benefits if there is associated support of farming from the community—as opposed to residential or other developments. Moreover, land values in conserved farmland, with limited subdivision, can rise if there is increasing demand for pleasant rural housing in restricted areas. The Griffith Farm, as a potential public place, could then function as a center for appropriate education and “passive” or “natural” recreation with this conserved neighborhood. While opportunities for residential development would be limited, the site would allow visitors to appreciate and enjoy the landscape, together with its varied natural or historical features.

The Site. Griffith Woods, on the old “Silver Lake Farm” in Harrison County, Kentucky, is considered the best remnant of presettlement savanna/woodland in the Bluegrass region. Covering about 170 acres, with room to double this area through restoration, the woods mostly consist of scattered ancient (150-300+ year old) chinquapin oaks, blue ashes, shagbark & shellbark hickories. Since the 1817, this farm has been owned by the Griffith family (or their cousins), who become protective of the ancient woodland-pasture; the 1956 will of H.F. Griffith provided that “no virgin timber is to be cut, destroyed or removed therefrom so long as the restrictions may be lawfully enforced.”

There is also a historically significant house, dating from ca. 1830, with four attached guest rooms, on the farm. Though it needs much restoration, there is consensus among preservationists that funds should be secured for this. The house could become an outstanding feature of public interest, a visitor center for the farm, and a center for the community’s interest in human and natural history. To quote Katherine Wilson’s notes on Harrison County houses: “The old mansion...was built for a tavern, and as such, housed many a distinguished personage as well as many an early planter, who stopped overnight en route to Cincinnati whence he was driving his sheep and cattle to be sold.”

Not only are such woods important for ecological understanding in Kentucky and eastern North America, but they also have potential to act as a global center for research into relationships of ungulates to woodland ecology. Such interactions have played a critical role in the region's unique ecology, given its prehistoric attraction for mammoths and mastodons, more recently elk and bison, and currently cattle and horses. Cane and other natural “herbage” in the woods, which provided excellent food for livestock in pioneer times, could be restored for rotational grazing in transitions to natural areas along streams and other wooded corridors. In Gilbert Imlay’s early book on the region, first published in 1792, he wrote about cane: “It is an evergreen, and is, perhaps, the most nourishing food for cattle upon earth. No other milk or butter has such flavour and richness as that which is produced from cows which feed upon cane. Horses which feed upon it work nearly as well as if they were fed upon corn, provided care is taken to give them once in three or four days a handful of salt."

The site is located in a central portion of the Conservancy's Licking River project area, and it can act as a base of operations for more broad-scale stewardship and community relations; for conducting research relevant to woodland restoration and overall conservation practices in the region; for demonstrating significant features and results; and for educating the public about the region's natural history and its conservation. To quote Dr. Lee Todd, president of the University of Kentucky: "Accomplishing this ambitious task will require an ongoing research effort welcomed enthusiastically by our ecologists and environmental scientists—and will create an outstanding educational resource to benefit students at all levels and the general public."

Broader Ecological Significance

Research and Education. While Griffith Woods—on the old Silver Lake Farm—is now well known as the best remnant of ancient woodland in the central Bluegrass region, its significance for basic research and public education has not been explored enough. In a nutshell, this site can become a regional center for understanding how hoofed animals—ungulates—of various kinds should be managed in woodland where we want to conserve a natural character. There is increasing evidence that, on exceptionally fertile soils like the phosphate-rich Bluegrass plains, original woodland in temperate climates developed for millions of years with much influence from large wild animals, and then in recent times it had additional influences from human beings, with cutting, burning and, eventually, livestock. Plants of Bluegrass woodlands that appear promoted by some degree of browsing include running buffalo clover—an endangered species, white snakeroot, ironweed, wild plum, pawpaw, coffee tree, buckeye, bur oak, walnut and hickory.

An important theory to be tested at Griffith Woods has arisen from several parts of the world where conservationists are reexamining remnants of woodland within fertile farmland, and trying to understand how to manage them. Such woodland can be subjected to various disturbances, not just storms, droughts and other climatic events, but also animals—from insects to ungulates (and formerly the extinct cousins of elephants that used to roam Kentucky). It is likely that herbivores in general had more intense effects on more fertile soils, due to the attraction of rich herbage, succulent saplings (especially maples, elms & ashes), fruits, nuts and other food. In recently opened up woodland, there would have been particularly dense forage, but after a period of browsing more resistant plants would have sprung up, especially those with prickles, thorns, bad tastes or poisons. Animals would then seek new openings in the woods, and the old trails and glades would grow back to denser forest, unless occupied by *Homo sapiens*.

Well-designed, long-term research here should eventually examine the details of such ecological processes to see how predictable they can be. We need to experiment with livestock, at least in initial trials, to see if they can simulate the effects of wild animals. This will be challenging given the greatly changed nature of the woodland, now more than 200 years after Virginian settlement, and the need for careful cooperative planning. But this site is our best hope for such work in the region, and the potential benefits are great. In addition to using the research to conserve Bluegrass Woodlands in this region, we will be able to develop an international network of people interested in similar woodlands, and their animal uses, on fertile soils in other countries. From European lowlands, to Balkan and Himalayan valleys, to the plains of eastern China, there are woodlands that share significant features with our own. Through exchange of information and cooperative work, much can be gained for the world.

Towards a Sustainable Model. The farm is also important for the neighborhood. Its location, between Cynthiana, Paris and Georgetown, just 20 minutes from Interstate 75, could provide an attractive new venue for educational trips, tourism of various kinds, meetings and other events related to the central Bluegrass landscape and its relationships to other regions. The research, demonstration and education at the site can focus on several themes of great public interest. We really do not know currently how to manage a block of Bluegrass Woodland in a sustainable ecological *and* economic fashion.

It is not reasonable just to rely on government funding and private donation; we need to derive reasonable income from the farm. Most importantly, we need to investigate the potential for using livestock—or eventually tamed elk and buffalo—in a careful seasonal rotation to benefit the woodland and to provide income. Other income can come from timber management, hunting, native fruits and nuts, propagation of other native plants, and various fee-paying activities, including educational tours and special events. In doing this, we will be reinventing some of the original ways of the

Native Americans, as well as redesigning a future landscape. When the buildings are renovated as living museums, we can also focus on the history of farming in this landscape. If we can just break even—in a non-profit enterprise—that will be fine!

Many farmers and other landowners in the region will be interested in the extent to which livestock—including cattle, goats, sheep and horses—can be managed to browse on reestablished native forage, and to reduce palatable invasive aliens. Root-suckering native plants like cane, spindle, rough-leaf dogwood and slippery elm were probably feasted on by migrating buffaloes but are now uncommon in the region; aliens like bush honeysuckle, burning bush, buckthorn and white mulberry are filling the ecological vacuum since settlement. A wide spectrum of management can be investigated, for nature preserves with recovery of the original flora and fauna, for lands with multiple interests in preservation and utilization, and for more traditional farms enhanced by strips of native vegetation along streams and gullies to provide good water quality, seasonal forage and benefits for wildlife.

The Landscape

Descriptive Background

Regional Context. Many millions of years ago, the Bluegrass Region was pushed up by forces within the earth's crust, exposing a “dome” of bedrock that is older than anywhere else at the state's surface. These limestones and calcareous shales were deposited 440-450 million years ago (in the Ordovician era), and are teeming with fossils of various shellfish and coral-like organisms. This ancient, shallow seabed was fed by nutrients on western shelfs of the massive, volcanic mountainous subcontinent whose remnants today are the Blue Ridge Mountains. These rocks have weathered to produce some of the most fertile upland soils in North America, with a particularly high phosphate content in some karst plains, though less so in hilly sections with more shale and recent glacial deposits. In regions surrounding the Bluegrass, erosion has exposed successively younger rocks. The Kentucky River used to meander across the central Lexington Plain, but additional uplift (perhaps 10-20 million years ago) has led the river to entrench, partly along a fault line, forming the "Palisades" gorges. The Bluegrass Region extends northward into southern Ohio and Indiana, where it assumes a different character due to the old glacial deposits, which cover up the bedrock completely north of Hamilton County, Ohio.

The native forests, especially on more fertile soils, are distinct from all other regions. Characteristic trees include sugar maples (regular and black, bitternut hickory, Ohio buckeye, Kentucky coffee tree, hackberry, walnut (mostly black), elms (white, red), ashes (blue, white, green) and oaks (chinquapin, bur, shumard, shingle, northern red). The “rich herbage” and salt springs or “licks” in this region have attracted large populations of various grazing animals throughout the ages. Mastodons, mammoths and other extinct species roamed these plains as the last ice age waned, leaving concentrations of bones at some of the larger licks. Their disappearance may have been brought on by the hunting of early Native Americans. Later Indians probably used fire to maintain open grassy oak, ash and walnut woods and canebreaks, promoting deer, elk and, eventually, bison (“buffaloes”). The extensive upland canebreaks that existed before settlement may have been largely created and maintained by burning and browsing of the woods.

Bison appear to have been frequent in Kentucky only after Indians burned sufficient forest within the past thousand years or so. They followed an extensive network of animal trails, parts of which may have been extremely old. Some plants were probably associated with the trails and licks, e.g., Short's Goldenrod and Running Buffalo Clover. The trails were easily followed by humans, and some even turned into modern highways. Eventually, there were more permanent settlements during the mound-building Adena and Fort Ancient periods. However, it seems that Indian settlement declined 50-100 years before the first contacts with pioneers, perhaps due to diseases and other cultural disruptions that had spread earlier from the coastal colonies to “Kentucke”—this was an Indian word probably meaning something closer to “the land of cane and clover" than "the dark and bloody hunting ground.”

Due to its salt springs, rich soils and open woods, which were easily cleared, this was the first region of Kentucky to be intensively settled by Virginians. Early on it became the agricultural, financial and political “heart” of Kentucky. Much of the original wealth of Kentucky came from this productive farmland, and it is no accident that Lexington, in the Inner Bluegrass, has become the socioeconomic center of the state. At first, livestock feasted on the “rich herbage” in these woods, and amazing crop yields were obtained in the freshly plowed fields. Much land soon became converted to pasture for cattle, or, later, in more prosperous sections, for horses, with calcium and phosphate building the bones of champions. Sheep also had their day, especially in the hills, before disease took its toll.

The overgrazed native vegetation became largely replaced by grasses and legumes introduced from the Old World, beginning with English bluegrass and white clover in the richest woodland pastures. Within 50-100 years, 70-90% of each county had been replaced by farmland, and the remaining timber, mostly on steeper slopes along rivers and streams, became heavily harvested. Although this region had supported concentrated populations of game animals before settlement, bison, elk, bear, beaver and turkey soon disappeared, and for a time even white-tailed deer became rare. Since 1910-20, much farmland has been abandoned in the "Hills of the Bluegrass" (on Eden Shale), leading to recovery of much young forest, deer and other wildlife. However, within reverted forest, some original plant species may not return for a long time, due to soil erosion, other disturbances, and lack of seed. The Kentucky River, locked and dammed, has lost much of its natural quality, including most aquatic plants and mussels, but the Licking River is less changed. Demands for water supply from the larger streams will probably increase as the population increases and cities expand.

In addition to the lost large animals, several plants appear to have been particularly sensitive to the loss of natural habitat in this region, including Bladder-pod (*Lesquerella globosa*) and Marble-seed (*Onosmodium hispidissimum*) in drier woods, Running Buffalo Clover (*Trifolium stoloniferum*) and Giant Wood-lettuce (*Prenanthes crepidinea*) in moist grazed woods, False-indigo (*Baptisia australis*) along rocky river banks, and Tape-grass (*Vallisneria americana*) within the rivers.

Today, there are few sites in this region that are managed purely for their natural qualities, and these sites do not represent all the ecological subregions. They are mostly scattered along the Kentucky River and its tributary ravines, where the central Palisades section has been a major focus of effort by state government and The Nature Conservancy. Much forest and many rare plant species survive in the varied topography of this section. Also notable are Boone County Cliffs and Dinsmore Woods State Nature Preserves, on glacial deposits in the north, and, nearby in Grant County, the Lloyd Wildlife Preserve, which is a small but impressive old-growth forest managed by Kentucky Fish & Wildlife that deserves much more care and attention.

There are still opportunities to set aside large areas of less inhabited land in the Eden Shale Hills for eventual regrowth of the disappearing beech and white oak forests. However, there is an even more urgent need to protect and restore some of the native forests on the richer plains, especially more open savanna-like woodland with blue ash, burr oak and cane. Before settlement, such woodland was restricted, globally, to the Bluegrass Region, and, except for some larger remnants on old traditional farms, it is now virtually eradicated. [A small reprieve may have occurred during the Civil War.] Within these largely agricultural and suburban landscapes, we will need new approaches to conservation, perhaps working eventually with botanical gardens and zoological parks.

Geology.The Griffith Farm itself lies on the following Middle and Upper Ordovician strata (based on USGS Quadrangle Maps).

(1) Clays Ferry Formation: calcareous shale (50% or more) and limestone, weathers yellowish/greenish gray; the main block of this layer has a sharp contact with the underlying Lexington Limestone, and occurs to the west of this site; a finger of this bedrock extends along the ridge in the southern “savanna” field and along the central (NE-SW trending) ridge in the farm east of US 62. The section in this field has many small sinkholes, which suggest solution of the underlying Tanglewood Limestone and partial slumping of the Clays Ferry material. On broader ridges, damp conditions can develop, and there is some potential for shallow ponds; but the history of “Silver Lake” suggests that cracks to the underlying limestone can cause failure.

(2) Lexington Limestone: mostly limestone (partly phosphatic) and calcareous shale but composed of several distinct members, which are interbedded to some extent.
(2a) Tanglewood Limestone: limestone (slightly phosphatic), weathers brownish gray; this type of limestone covers much of the Inner Bluegrass Plains and interdigitates with more shaly strata in peripheral zones, as at this site. It covers most of the farm; an upper tongue of the Millersburg Member occurs within this limestone, generally at mid-slope. In general, this formation does not support ponds, except where these are dug into underlying shaly strata of the Millersburg Member. Small seeps and springs may be concentrated along such contacts.
(2b) Millersburg Member: limestone (70%) and calcareous shale, weathers yellowish brown or olive-gray; this unit covers some of the mid-slopes and lower slopes at the farm; it covers most the lower slopes in the small valleys that drain from the farm towards the Licking River. This formation contains two or more tongues of more argillaceous limestone and shale, which have been variously named. One (or more?) of these tongues may be partly considered a

tongue of the Clays Ferry Formation (see above). The upper one has been partly named the Strodes Creek Member (ostracodal limestone and up to 30-40% shale). Small ponds can be constructed on shaly strata along stream headwaters.

(3) Alluvium: silts, clay, sand and gravel, massive to poorly bedded. In some areas, silt is argillaceous, very pale orange to grayish brown, grading locally to clay. Elsewhere the alluvium is less argillaceous, brownish-red to reddish-brown. Sand and fine gravel-sized material is composed of particles of manganese/iron oxide [limonite], and locally includes some phosphatic material derived from the Tanglewood Limestone Member of the Lexington Limestone. Coarse gravel composed of limestone blocks and cobbles. “Unit merges with unmapped colluvium along valley sides” (USGS Centerville/1 & Paris East/2 Quads.)

Soils. The Griffith Farms lies mostly on the following soil series, based on the Harrison County Soil Survey (USDA Soil Conservation Service 1968) and other county surveys in area. Soil series in quotation marks were used in the Harrison survey but their usage may be largely changed in more recent surveys. Minor series, each covering less than 5% of the area are in brackets.

(1) Purer limestone soils, locally or slightly phosphatic.

(1a) “Loradale” silt loam: a typic argiudoll derived from slightly phosphatic limestone (Tanglewood Member) and lesser amounts of calcareous shale (plus some loess); on gentle upper slopes and broad ridges (0-12% slope); ca. 4-15 feet deep; pH ca. 6-6.5 in A horizon, 6.5-7 in B. This series name/concept is generally not applied in recent decades, becoming included perhaps in Shelbyville silt loam (a mollic hapludalf) or Lowell silt loam (a typic hapludalf), which may reflect general degradation of the original Loradale series, leaving less than 10 inches of mollic A horizon (Doug Hines, NRCS, pers. comm.). The original series may be viewed as an argillaceous relative of the strictly Inner Bluegrass Maury (typic paleudalf) and McAfee (mollic hapludalf) series, which are derived from purer Tanglewood Limestone. In general, it probably supported somewhat open, “intermediate” woodland before settlement; the damper/deeper soil variant of “savanna-woodland” with more bur oak seems to be loosely associated with this series in the Griffith Woods area, in contrast to the Faywood soil series (see below).

[(1b) Maury silt loam: a typic paleudalf; occurs nearby to south; apparently more deeply weathered ancient soil with little/no shaley influence but some loess; was probably typical of more open woodland variants.]

[(1c) McAfee silty clay loam: a mollic hapludalf; occurs nearby to south; was probably typical of intermediate/shady woodland/forest variants.]

[(1d) Fairmount rocky silty clay loam: a mollic hapludoll derived from limestone (locally phosphatic); on steeper slopes (6-50% slope); ca. 1-3 feet deep; pH 6.5-7.5. This series may occur downstream of the site, along steeper slopes of Edgewater Creek; it probably supported fairly dense calcareous forest, subxeric or mesic depending on aspect.

(2) More shaley limestone soils.

[(2a) Mercer silt loam: a typic fragiudalf derived from limestone and calcareous shale plus some loess; a minor series on gentle slopes and broad ridges that are less well drained (0-10% slope); ca. 4-10 feet deep; pH ca. 7-7.5 in A horizon, 5-6 in B. This series is a damp variant of Shelbyville or Lowell; it may have become included in modern surveys within the somewhat broader series, Nicholson.]

[(2b) Shelbyville silt loam: a mollic hapludalf derived from limestone and calcareous shale, or perhaps some ancient terrace deposits, plus some loess. This was not mapped in the original Harrison County survey, but in some other surveys this is a widely mapped series on well drained gentle slopes and broad ridges (2-12% slopes) with soils ca. 5-9 ft deep; pH 5-7. It appears to have been partly replaced "Loradale" (see above) and may even be intergradient with deeper variants of Lowell (or "Faywood" as initially conceived in Harrison County). Further complicating this situation is the recent mapping of degraded Shelbyville soils as the Sandview series in other counties. Pending further discussion with NRCS, the Shelbyville/Sandview concept may be retained for relatively deep soils on broader ridges, as part of the catena from Mercer/Nicholson to Shelbyville/Sandview to Lowell to Faywood to Cynthiana.]

(2c) "Faywood" silty clay loam: a typic hapludalf derived from limestone and calcareous shale plus some loess, such as the Clays Ferry Formation or Millersburg Member. In recent decades, the original broad concept of this widespread

series may be replaced by the following two series.
(i) Lowell silty clay loam (another typic hapludalf): on gentle slopes and broad ridges (2-20% slope); ca. 3-9 feet deep; pH ca. 6-6.5 in A horizon, 5-5.5 in B. This series replaces the Maury series in more shaley zones around the Inner Bluegrass. It probably supported variants of somewhat open/intermediate woodland/forest before settlement; indicators may be mayapple, shagbark hickory, locally white oak, tulip tree, etc.
(ii) Faywood silty clay loam (sensu stricto): on side slopes (2-40% slope); ca. 2-3 feet deep; pH ca. 6-6.5. This series replaces the McAfee series in more shaley zones around the Inner Bluegrass. It probably supported variants of somewhat open/intermediate woodland/forest before settlement, with much chinquapin oak and little/no burr oak--in contrast to Loradale soil series (see above).

[(2d) Cynthiana rocky clay (or rocky silty clay loam): a lithic hapludalf derived from limestone and calcareous shale; a minor series in the area on steeper slopes (12-60%); ca. 1-2 feet deep; pH ca. 6-7.5. It probably supported calcareous forest, submesic/mesic before settlement; as on Fairmount but less fertile; with indicators including occasional shagbark hickory, local white oak, tulip tree, etc.

(3) Floodplain/toe slope soils, derived from alluvium/colluvium of various strata.

(3a) Huntington silt loam: a fluventic hapludoll on alluvium derived from limestone and calcareous shale; on floodplains (0-4% slope); ca. 2-10 feet deep; pH ca. 6-7.5. Along smaller headwater streams with less well developed alluvium, a segregated series may be the Boonesboro silt, only 2-4 feet deep, but this is not mapped (yet) in Harrison County. Typical natural vegetation would be white/American elm, sycamore, boxelder, (and silver maple downstream near Licking River); also transitions to submesic/intermediate forest.

[(3b) Ashton silt loam: a mollic hapludalf on colluvium or alluvium derived from limestone and calcareous shale; a minor series in the area on toe slopes and terraces (0-10% slope); ca. 4-5+ feet deep; pH 5.5-7.5.   This may have been associated with somewhat open/intermediate woodland/forest; relatively damp/deep/fertile soils supported burr oak.]

[(3c) Wetter alluvial soils such as Egam or Dunning may be expected in small patches within this neighborhood; some of these had original mollic horizons, suggesting marshy vegetation before settlement, but they have been degraded in many areas.]

Targets for Conservation and Problems for Research

Regional Goal (at landscape level). A basic goal for the Griffith Farm should be to restore a parcel of the central Bluegrass uplands towards a simulation of presettlement ecosystems during the post-glacial era. There should be a special focus on the transition from Inner Bluegrass to Eden Shale foothills, as represented by this site, but other features of the Bluegrass Region may be incorporated after careful consideration. The site can promote research, demonstration and education about conservation in the region, including applications for watershed qualities in the lower Licking River system.

Target Definition (for technical detail and programatic context).
(a) The farm represents our best opportunity for restoration of a large area of native woodland in the central Bluegrass, and results here can be applied to other agricultural landscapes in the Central Ohio Valley.
(b) The site is also part of the Conservancy's Lower Licking River program (originally known as the "Lower Licking River Watershed Megasite"), which includes the whole watershed of the river from the Cave Run Dam downstream to its mouth in Covington.
(c) Another possible program involving Griffith Woods would be an effort to conserve rural lands as a "greenbelt" between central Harrison County and its major commuting partners to the south in Georgetown, Lexington and Paris (Map ..).

The "Inner Bluegrass" is sometimes defined to extend north or east of the Middle Ordovician limestones to the vicinity of Cynthiana (Harrison County), Paris (Bourbon County) and Winchester (Clark County). However, much of the land in these counties, including Griffith Woods, lies in the "Eastern Bluegrass", which is generally on lower Upper Ordovician bedrocks. This region is transitional, with interbedded strata, from the geology and soils of the Inner Bluegrass proper (with the Lexington Limestone and, below that, the High Bridge Group), and the Eden Shale Hills (with the Clays Ferry Formation, strictly defined). A compromise employed here is to call the expanded definition of the Inner Bluegrass, somewhat informally, the “central Bluegrass” instead. The geological shift to Upper Ordovician bedrock is relatively clear-cut in some places, as reflected in the soils and vegetation, but much less clear-cut in other places.

The appropriate Land Type Association is provisionally termed the “East-central Bluegrass Plains” with major soil series, Lowell & Faywood (typic hapludalfs) and locally Shelbyville (mollic hapludalf) or Loradale (typic argiudoll) or degraded variants; minor soils include Mercer/Nicholson (fragiudalfs) and Cynthiana & Eden (lithic hapludalfs). Ecological differences from the strictly defined “Inner Bluegrass Plains”, dominated by the Maury (typic paleudalf) and McAfee (mollic hapludalf) soil series, can be studied at the site in order to determine the extent to which features of that Land Type Association should be incorporated.

Differences in the natural vegetation of the Inner Bluegrass and the Eastern Bluegrass do not appear to have been pronounced. There were a few more inclusions of relatively infertile, acid soils, as indicated by local presence of trees such as shagbark hickory, white oak, tulip poplar and beech. Also, the more shaley Eastern Bluegrass may have been damper in places. And cane may have been more extensive in places, especially along the famous “Cane Ridge” that ran for 15-20 miles, and about 1-2 miles wide, from near Paris to near Mount Sterling.

Problems for Research. The following general questions can guide relevant work.
(1) How has the naturally high soil fertility of this region (on phosphatic limestone) influenced the pattern of ecosystems over the landscape, before and after settlement?
(2) What disturbance regimes existed before settlement due to consumers, fires and physical factors; and how can they be simulated in conservation and compatible land uses?
(3) What are the potential interactions between vegetation and hydrology in the region; and how can native vegetation be used to protect the Licking River and other watersheds?

In addition to purely academic interests in these questions, there will be interest in how results of these investigations can be applied to designing more sustainable land uses in the region. For example, if a system of managing livestock can be found that maintains woodland in a relatively natural condition, while also providing meat or other animals products, there could be further support from the community.

...Within the Interior Low Plateaus (Central Ohio Valley Section), the Bluegrass region contains unique conditions within the “Inner Bluegrass Plains” and the similar (but more shaley) “Eastern Bluegrass Plains”; these are on Middle to Upper Ordovician limestones and calcareous shales, with rolling uplands and extensive hapludalfs (or locally paleudalfs) that have high fertility, especially on phosphatic limestones. *More mapping and research of phosphate levels is needed; also, we need to know if the locally mollic soils were formed due to dense cane, wild rye, etc., in the woodland.*

...Subjects of great interest in the soils include: concentration of natural phosphate levels in the subsoil (in concretions with manganese, iron?); uptake of P by tree roots; need for high levels to benefit from P—and how is N-fixation controlled across the landcaspe; influence of farming, etc., on such processes...

...Key questions for the “deep ecology” of these submesic, eutrophic plains are: has the unusual upland fertility, and resultant ecosystem productivity, led to generally increased foraging on the vegetation from consumers (especially ungulates, eg bison overwintering in the cane, visiting “licks” and “Stamping Ground”); over evolutionary time, has this pressure led to special defenses in the flora; what effects might there be on mineral (especially N) cycling and redistribution over the landscape?

...Note special chemical or physical defenses of some trees (eg coffee tree, honey locust); special dispersal by ungulates (see also osage orange); associated clonal root-suckering and dioecy in several genera; also contrasts between related genera and families of trees in their defenses against ungulates (eg buckeye versus maple). These are ancient evolutionary divergences, 30+ million years old.

...What parallels are there elsewhere in the Temperate World: eg richer plains of Europe--note interglacial evidence for megafauna effects & Vera’s recent book; eg rich valleys from SE Europe to the Himalayas where distinct local walnut-buckeye woodland suggests similarities to Bluegrass woodlands; eg Sichuan Basin of China where openings with rhinoceros occurred a few millenia ago?

...Surely, an ancient association between megafauna and such woodland is relevant to conservation plans; well before increased fire and other disturbance from humans, ungulates must have had significant interactions. Although some are extinct we should attempt to use livestock for simulation of ancient effects. In some areas, we should experiment initially with ungulates and no fire; but we also need to consider potential effects of occasional lightning fires in dry years (perhaps with cane dieback for fuel).

...Extensive conversion to farmland in this landscape has caused severe challenges for conservation; within woodland remnants, there has been a general shift towards disturbance- or stress-adapted trees; compare also virtual disappearance of beech in Western Bluegrass.

The Habitats

From Historical Data to Practical Models

Historical Background. Several lines of evidence have been used to investigate the vegetation that occurred on more fertile plains and rolling uplands of the central Bluegrass Region during the 18th Century. These include interpretation of the paleoecological and archaeological context, historical accounts, early land surveys, early botany, current remnants, dendrochronology, and changes in land use after settlement. The evidence strongly suggests that this area was originally covered by woodland that was mostly continuous but that varied from deeply shady forest to savanna-like canelands and other openings. As detailed below (also in appendices), the most open vegetation, with only scattered trees and dominated instead by cane, other shrubby species, tall herbs or grasses, probably covered just 1-10% of the landscape. But these openings were spectacular features emphasized by many early writers.

This gradient was probably controlled by interacting patterns of disturbance from ungulates, human effects and, perhaps to a lesser extent, climatic events—occasional droughts or wet periods that stressed the trees. There is certainly considerable direct, indirect and circumstantial evidence that bison and other herbivores have had substantial local effects during the past 10,000 years and before.

Also, during the past 5000 years at least, there were probably substantial effects from human clearance for villages, campsites, trails and perhaps some burning in the woodland. However, there is little evidence that widespread burning occurred frequently. Based on historical records and recent experience, native vegetation does not appear to be particularly flammable, probably because of the relatively rapid decay of leaf litter in the woodland, and the restricted abundance of tall warm-season grasses. In contrast, on drier or less fertile soils in some adjacent regions, fire was clearly important in some areas. In warm or dry climatic periods, it is likely that fires were more frequent.

The most common woody species typical of relatively closed, shady (mesic) forest, covering about 30-40% of the landscape, were sugar (& black) maple and bitternut hickory, with minor amounts of northern red oak and basswood ("lin"), plus scattered ironwood (*Ostrya/Carpinus*) and spicebush in the understory. Trees typical of intermediate (submesic) woods, covering about 50% of the landscape, were Ohio buckeye, black walnut, hackberry, elms (white & red), ashes (white & blue), oaks (especially chinquapin & shumard) and shellbark hickory, with minor (but distinctive) amounts of mulberry and coffee tree, plus locally abundant pawpaw in the understory.These intermediate woods can be divided into a walnut/buckeye type and an ash/elm type, suggesting a secondary gradient related to palatability. Trees and shrubs typical of more open, brushy woodland, covering about 10% of the landscape, included bur oak, honey locust, black locust, cherry, plum, prickly ash and cane, which was dominant over several square miles on Cane Ridge and other areas.

After settlement, most native vegetation was cleared for farmland and much of the remaining woodland became thinned out for "woodland pastures". Within remnants, sugar maple, bitternut hickory and other species typical of deeper shade declined greatly. Some species of intermediate woodland also declined eventually, including buckeye and pawpaw. Oaks and ashes, with lesser amounts of shellbark hickory and white elm, were left in woodland-pastures, allowing them to grow 2-3 times faster and develop widely spreading branches. White elm, white ash, and to a lesser extent shellbark hickory and bur oak, are able to regenerate in modern farmland, but red elm, blue ash, chinquapin oak and perhaps shumard oak appear to prefer moderately shady, or perhaps less grazed, conditions for good regeneration. Black walnut, hackberry, cherry and black locust increased greatly in young successional woods. However, some species of more open conditions did not fare so well; honey locust, hawthorn, plum and other shrubby species have been reduced in farmland and are somewhat slow to recover. Almost all of the cane was converted to farmland and is rarely able to recover from remnants.

Gradient Models. Advances in the ecology of plant communities (or “vegetation science”) are dependent on concepts that recognize the intergrading nature of vegetation types, and avoid rigid classifications. The initial “continuum concept” was introduced by M.A. Curtis and others in Wisconsin and elsewhere in North America during the past 50 years, but it has yet to be widely used in Kentucky. Just as the study of plant evolution has been radically transformed for the better by the “cladistic” analysis of DNA data in relation to models of branching “family-trees”, the study of vegetation will eventually be transformed by applying models of ecological gradients to large amounts of data on species composition from plots sampled across whole regions.

Since we do yet have large databases in Kentucky, even for our local Bluegrass woodlands, deep scientific work in vegetation remains somewhat elusive. The concepts outlined below, focusing on three general gradients, are based on initial analyses of miscellaneous data (published elsewhere), and deserve a lot more scrutiny to develop the details. However, it has become clear to this author at least that these three gradients do reflect real patterns in the natural vegetation of eastern North America, and they can be readily applied and tested.

It is particularly important to apply these concepts where vegetation is managed for restoration of more natural conditions. Since change in some aspects of the vegetation can appear slow—in terms of our human urge for rapid results—it is critical that we arrive at a means to measure change in small increments, from one state of the vegetation to another. That is not really possible with a strict system of classification, and if we apply gradient concepts, we will want those gradients to reflect as much of the natural variation as possible in a few dimensions.

...to be developed: initial simple introductory diagram and illustration of the three gradients, with photos, etc.

The Base-related Gradient

General Description. During periods of post-glacial or inter-glacial climate on the uplands of Kentucky and surrounding states, the most extensive ecological gradient within the original vegetation appears to have been related to overall soil fertility (especially nitrogen and phosphorous) and base-status (calcium, magnesium, potassium, etc.). An "extensive ecological gradient" is defined here as one that spreads out the distributions of species in a more or less predictable sequence that is correlated with a suite of environmental factors. Unfortunately, we still understand little about this gradient—in terms of the original distribution of species along it, the ecological and physiological mechanisms that set it up, and the changes in it that have occurred during development of the modern landscape. Through broader surveys of the landscape and various experimental approaches, we need to develop more careful, controlled, comparisons of particular contexts and conditions in order to develop deeper scientific theory and sounder practice for management.

This gradient was undoubtedly complex, being controlled by several environmental factors, and the terms "base-related" or "pH-related" are merely initial simplistic labels. There was undoubtedly much independent variation in the major drivers of plant growth—nitrogen and phosphorous—and the various base levels. The availabilities of N (at least as nitrate) and P (as phosphates that can bind with calcium) tend to be highest between "medium" acid (pH 5.5) and circumneutral soils (pH 7) with more calcium. Soil pH itself probably has little general direct effect on vegetation, but it has many indirect effects by controlling solubilities of most ions, and by changes in the form of N (with nitrate shifting to ammonium at lower pH) or P (with various organic combinations). In addition to chemical complexity, there is at least a weak broad association on the landscape between more fertile soils and damper, lower sites. Moreover, because more fertile soils tend to have higher productivity, they tend to attract more herbivory, which can influence the vegetation in various ways. The arrival of human beings during the past 10,000 years or so has greatly amplified the concentrated disturbance from animals at the "base-rich" end of the gradient.

Figures 1-2 and Tables 1-3 illustrates some general compositional, structural and functional features of this gradient within Kentucky. This initial display is, however, based only on a preliminary analysis of vegetation and flora; much more work is needed to synthesize vegetation data from across states and regions, in order to develop deeper insights.

Compositional trends among large tree species are fairly well known (Figure 1), but the degree to which the whole vegetation and flora is involved in this gradient has not been generally appreciated. Compared to acid infertile soils (Table

1), base-rich soils are associated with much less frequent evergreen leaves in trees and shrubs, less frequent simple entire leaves and much more frequent compound leaves in large trees, more frequent lateral root-suckering ability in trees, occasional large trees with thorns or spines, much more frequent dioecy in large trees (with separate males and females), and, in several trees, unusually large fruits or nuts compared to their closest relatives.

There is a frequent misconception that dense herbaceous growth within woodland is indicative primarily of relatively open conditions, especially where there is a large component of grasses. However, base-rich soils tend to support relatively dense herbaceous vegetation (Figure 2), with grasses often dominant in moderately shady woodland. Within the whole native flora of Kentucky (Table 2), earlier-flowering graminoids of woodland (all C3 species) are much more frequent on base-rich soils. Other life-forms that are more frequent on base-rich soils (at least species of "intermedate" category D), include distichous woodland lilioids (Solomon's seals and the like), summer woodland perennials with large divided leaves (cohoshes, cicelies and the like), biennials and monocarpic perennials (biennial waterleaf, columbo and the like), and winter-annuals (corydalis, Miami mist and the like). Outside of woodlands, species of tall summer-fall perennial herbs (poke, goldenrod and the like) and tall annuals (amaranth, ragweed and the like) are also more frequent on base-rich soils.

In contrast, base-rich soils are associated with much less frequent species of later-flowering graminoids of medium-large size in woodland or grassland (all C4 species except for *Dichanthelium*). Other groups that decline greatly on base-rich soils include evergreen ferns, herbs or vines, mycotrophic plants, and, to a lesser extent, parasitic plants (Table 2). Although species of low shrubs and subshrubs are fairly frequent at both extremes of the base-related gradient (Table 2), they may decrease in abundance within woodland on more base-rich soils (Figure 2).

If the native flora is organized into major taxonomic groups, based largely on the latest analysis of DNA and other cryptic characters, there are some trends that could suggest deeper insights to plant evolution (Table 3). Groups with more frequency on acid infertile soils include: Lycophytes, Pteridophytes, Gymnosperms, Magnolioids and Ericoids. Groups with more frequency on base-rich soils include: Ranunculoids, Caryophylloids, Sapindoids, Solanoids and Aroids.

Local Expression. Conservation of nature, however defined, is generally more challenging on base-rich soils. Not only have we had much more clearance and disturbance from various agricultural or residential developments, and the land is relatively expensive, there have been many losses of native species and many gains of aliens. In more rugged terrain, there are still some relatively extensive areas of woodland, such as along the Palisades of the Kentucky River, but these are not typical of what formerly occurred in the gentler landscapes that have been largely converted to farms, towns or suburbs. Even in the best areas of the Palisades, there are some serious threats from some alien plants, especially the bush-honeysuckles, purple winter-creeper and garlic-mustard. If we are to restore some semblance of native vegetation on the gentler landscapes, we should investigate what occurred here before Virginian settlement, how it has changed since then, and how it might be managed to restore naturalistic processes and native composition.

The central Bluegrass region exemplifies the base-rich end of the gradient better than any other section of the state. Elsewhere in unglaciated eastern North America, it is similar in some respects to parts of the Nashville Basin where small remnants of native woodland have been described on deeper soils. To the north, on glaciated lands, it is somewhat similar to parts of Ohio, Indiana and Illinois, but there are virtually no extensive remnants there other than scattered small woodlots. The vegetation and flora of woodland remnants in these regions are mostly composed of species typical of base-rich soils or transitions to medium acid soils. Smaller areas of highly base-rich conditions are of course found widely in many parts of these regions, but they are usually concentrated on alluvial lowlands, in various kinds of “hollow” or “cove” within the hills, and along limestone rock outcrops. In many respects, uplands of the central Bluegrass were unique in their woodlands because they resembled mesic alluvial terraces, with local abundance of plants like bitternut hickory, nettles, black walnut, wild ryes, cane and peavine in the original woodlands.

About 240 native vascular plants have been found at the Griffith Farm or nearby, within a few miles on similar topography. An additional 70-260 species may have occurred in the neighborhood before Virginian settlement, judging from scattered floristic records and circumstantial evidence for the whole region. This total pool of about potential 500 native species for gentler lands of the central Bluegrass is dominated by species typical of “base-rich” soils (category E) or transitional to medium acid (“intermediate” category D). Only about 7% of the farm’s species are typically centered on “medium-acid” soils in the state. These are mostly rare or uncommon at the farm, with the exception of broom-sedge and perhaps the other grasses in some old fields: dissected grape-fern, common spleenwort, Christmas fern, tulip poplar, woodland geranium, wild strawberry, northern dewberry, orange milkweed, common lobelia, common Solomon’s seal, early and common ladies-tresses, small hairy early-panic, meadow late-panic, single lens-grass, and broom-sedge. In the larger potential pool of 500 species, this proportion is increased to about 9%, with the assumption of scattered trees like beech, white oak, post oak, northern red oak, black oak, sassafras and persimmon, as well as associated shrubs and herbs. Such species were certainly not common in gentler parts of the central Bluegrass before settlement. None of the species in this pool are typical of “highly acid” soils or even transitions to “medium acid” soils.

Natural areas or potential natural areas in more rugged sections of the central Bluegrass or in transitions to peripheral hills tend to have larger proportions of species typical of “medium acid” soils. Along the Palisades of the Kentucky River, these species generally amount to 10-20% of the flora. In some areas they are locally more frequent, especially in subxeric hills on shaley or gravelly soils, where white oak was formerly dominant, and on mesic sandy terraces along the river, where beech was formerly dominant.

Significance for Restoration. Given that several features of the original vegetation on these base-rich soils have been drastically changed since Virginian settlement, restoration cannot proceed properly until these problems have been understood and appropriate trials or experiments formulated to address them. Apparent changes in the disturbance regime raise fundamental questions about the vegetation, as discussed further below.

There are several indications that the native vegetation and flora was to some extent coevolved with high levels of consumption by generalist herbivores, especially larger ones. There are concentrations of trees with root-suckering ability, protective thorns and large mammal-dispersed fruits. There are concentrations of annual and biennial herbs, often in environmental contexts that could have been enhanced by megafauna, for example along trails through woodlands and in meadow-like situations on lowlands. This theme is developed further below, with special reference to the endangered runing buffalo-clover, which generally behaves as a short-lived perennial that runs into woodland paths on damp fertile soils.

In contrast, there are few indications from the historical record, modern remnants, or recent trials, to suggest that fire was a frequent important force in the original vegetation. Warm-season grasses that are well-known to be promoted by fire in Kentucky are much less frequent in the vegetation and flora on base-rich soils. There are relatively few species typical of base-rich soils or transitions to medium acid that are known to have depended generally on fire before settlement. Nevertheless, closer examination of many species is needed to explore this theme. It is certainly likely that native people used fire at least locally along trails and around campsites or villages, and some of the weedy species associated with those places might well have benefitted.

The loss of many native species is especially acute within some life-forms. This theme is developed further in subsequent sections, suggesting clear priorities for propagation and recovery of selected species. The gain of several seriously invasive aliens is also a concentrated problem for certain groups of native plants, especially those disturbance-adapted annuals, biennials, short creeping perennials or others that were probably associated with the disturbances of larger animals and native people. A comprehensive package of plans for adaptive management and experimental research is needed to address these problems. It is unlikely that idealistic goals to restore completely native vegetation and naturalistic processes are realistic, but let us see how far we can go.

The Water-related Gradient

While the base-related gradient is only fully expressed by comparing sites across broad regions, there is a much better known gradient related to mesic versus xeric conditions (Figure 1). This water-related gradient is largely independent of the base-related gradient, though dampness and fertility are often weakly correlated over the landscape. The water-related gradient is better known because most within natural areas that have been intensively surveyed, it is more or less predominant where topography includes clear contrasts between lowlands or riparian zones, versus uplands or rocky ridges. There are, however, some important subtleties in the overall expression of dryness and wetness over whole landscapes, and their association with various disturbance regimes.

When one focuses on a landscape with relatively homogeneous conditions along the base-related gradient, as in the central Bluegrass, it is generally possible to discern at least two further gradients in the vegetation (Figures 2a-d). If one considers the full diversity of vegetation types, following the kind of comprehensive review conducted for the National Vegetation Classification, it appears that dryness and wetness should be considered as somewhat independent factors. There are certainly many areas, especially on topography with low relief, where conditions are relatively wet in the winter and spring, then dry in the summer and fall. Such sites must be contrasted with truly "mesic" sites, especially on cool slopes and well-drained stream terraces, where moisture-levels averaged through time may be similar, but where stress from dryness or wetness varies much less and remains relatively low during most of the year. On top of this pattern, there is clearly some general association in the modern landscape between areas of low relief and disturbance from farming or other human activities. And even in the pre-human landscape, it seems likely that larger animal herds concentrated more often on areas of lower relief, and that fires burned more often over broader plains without the interruptions of damper valleys and rock outcrops.

Although succession towards mesic conditions, due to changes in vegetation and soil, is often slow or non-existent, there are some broad parallels that can be drawn between trends of increasing dryness, at least in late summer-fall, and trends of increasing disturbance or openness. For example, trees and shrubs with ring-porous wood, growing wide vessels in the early season then narrow vessels in the late season, are concentated in dry high relief and disturbed low relief sections of the gradients (Figure 2f). [However, red-cedar, which lacks vessels completely, reverses this trend somewhat at dry extremes.] Trees and shrubs with hairy leaves show similar trends, but more so in vegetation typical of disturbed low relief than dry high relief—for example, one of the hairiest trees is swamp white oak, typical of seasonal wetlands on high terraces (Figure 2g). Trees with thorns or toxins, and those with fleshy bird-dispersed fruit, as also associated with dryness and openness (Figures 2h,i).

Among grasses and sedges, species with C4 photosynthesis are largely associated with seasonally dry conditions, from marshy margins to old fields to rocky glades (Figure 2j). A few C4 species also occur locally in scoured riparian edges (at the lower left corner of Figure 2); these special habitats do not fit neatly into the two-dimensional scheme. Many other trends in various plant groups can be explored further using this model of ecological gradients.

Within the largely farmed landscapes of the central and eastern Bluegrass, the recognized soil series tend to subdivide the land most finely on alluvial terraces, and least finely on rugged uplands (Figure 2e). Within a typical area like the Griffith Farm, most of the land is classified into just a few soil series typical of uplands with relatively deep well-drained soils. There is little obvious expression of water-related gradients, other that the clear distinction of narrow riparian zones, scattered small springs or damp swales, and scattered patches of thinner soil with erosion or rare rock outcrops. Excluding these minor sites, the predominant gradient within the soil series on these uplands generally ranges between more sloping ground with shallower soils to less sloping ground with deeper soils. In some cases, gentler slopes and flats are more prone to waterlogging in the winter and spring, especially if there is dense clay in the subsoil. However, the mapping of these seasonally damp spots is challenging and generally not well-developed in details.

Some general associations between these slope-related shifts in upland soils and the original natural vegetation types could probably be ascertained after more detailed analysis. However, there has of course been much disturbance within woodland remnants, generally pushing the vegetation towards more openness. Also, at least in old trampled woodland-pastures, disturbances have led towards additional stresses associated with hot sunny conditions and degratation of the soil. There has undoubtedly been much rescrambling of the original relationships between disturbance and soil. It remains for us to examine the existing gradients of disturbance, to explore their causes and origins, and to extract concepts, theories and practices that may guide our restoration.

The Openness-related Gradient

Overall Concept. The concept of forest succession has dominated much plant ecology, but it has often been applied in ways that are too simplistic. While succession from old fields towards high forests in the modern landscape may have many parallels with some disturbance-related processes in the original woodland, it is dangerous to assume that a similar one-dimensional trend occurred after the much more local disturbances that occurred before settlement. Moreover, even today, it is common to find regenerating patches of woodland in the central Bluegrass that are not moving beyond the "intermediate" condition dominated by walnut, hackberry, ash or elm (position 2 in the tables). In some cases, this lack of final succession is simply due to lack of seed for the species of deeper woodland, especially sugar maple or black maple and the many slowly-dispersed herbs.

In other cases, even with seed sources present, intensive browsing by deer, cattle or other animals seems to be holding back the maples, and keeping tree saplings in general less dense or vigorous. At some sites with intense browsing, seedlings and saplings of more resistant tree species do accumulate, such the "stinking" Ohio buckeye. There is evidence that buckeyes were locally dominant in the original woodland. However, with little use by people before or after settlement, buckeyes were not favored in yards, fencerows or woodland-pastures, and their density is now relatively low. These large-seeded trees are not dispersed rapidly from remnants back into the largely deforested landscape.

While it will take much more careful observation and experimentation to uncover the details of dynamics within various wooded situations, there is still of course a moderately predictable, broad gradient that can be described from woodland with deep shade, to grassland and bare ground. Rather than call this gradient “successional”, or even “disturbance-related”, it seems best to call it simply “openness-related.” With this term, the gradient can include parallel trends from mesic conditions to various kinds of xeric or hydric conditions. For our purposes in most of the central Bluegrass region, xeric and hydric conditions can generally be excluded from detailed consideration, but it is useful to understand the common environmental factors that have selected certain traits in the vegetation. In the opposing direction, “biomass-related” might be another appropriate descriptor, at least if attention is confined to uniform soil conditions.

Divisions of current and original vegetation. On the modern landscape, six broadly defined habitat divisions can be outlined in the openness-related gradient.
(1) Deeply shaded woodland (with sugar maple and bitternut hickory).
(2) Intermediate woodland (with walnut and hackberry, or locally oaks, ashes and elms).
(3) Young woods or woodland mixed with grassland (with locust, cherry, or locally some woodland-pasture).
(4) Shrubby-brushy old fields and edges (grape, poke-berry, black-berry, coral-berry, also common aliens).
(5) Perennial grasslands (with fescue and bluegrass, also native invaders like goldenrod and ironweed).
(6) Situations with much bare ground (annual cropland, recent plowings, shorelines, rock outcrops, asphalt).
With this broad definition, the gradient concept can generally be applied to historical and modern data.

Species can usually be assigned with some confidence to one of these divisions as a typical habitat along the gradient, while recognizing that most species extend commonly into adjacent divisions. Species with longer life-spans, especially some trees, present a problem, because conditions for their regeneration may be significantly different from the typical habitat of large mature individuals. In general, the assignment in these cases attempts to find a middle ground, but uncertain interpretations do remain.

Based on species of witness tree in surveys at the time of settlement, only about 20-35% of the original landscape was covered by species typical of deeper woodland (Table 4). Most of the land, about 55-65%, appears to have been covered by species typicalk of “intermediate” woodland. Another 10-15% of the trees were oaks, black locust, cherry or other trees typical of division 3 along the gradient, which can be interpreted in various ways. Since the surveyors did not reliably distinguish oak species, and since some of the oak species were undoubtedly concentrated in intermediate or deeper woods, probably less than 10% was truly young woods or open woodland. However, oaks do generally benefit from at least small temporary openings. Only 0-7% of the land can be assigned to the brushy transitional division 4, and this depends largely on the assumption that honey locust indicates such vegetation. Honey locust does generally need open grassy or brushy vegetation for establishment, and more so than black locust, which suckers vigorously at edges rather than dispersing far into openings. However, as with the oaks, much of the locust blazed in the surveys had probably grown up along with local succession in the woodland.

Witness trees from surveys of various tracts of the Griffith family during 1818-1876 indicate a very similar division of species along the openness-related gradient (Table 4). However, these trees were of course mostly located in fencerows and other boundaries. From an analysis of historical trends in this region, it is clear that the clearance of woodland continued at a steady rate from 1770-90 to the 1860-80, when less than 1% of survey corners referred to witness-trees. In the modern landscape, some local regrowth of woodland had been allowed, but generally no more than 10%, including young brushy transition. The Griffith Farm, with about 25% in woods, is highly unusual on the gentler lands that prevail in this region.

Distributions of common, rare and alien flora. The 800-900 native species of vascular plant in the central Bluegrass and adjacent Eden Shale Hills are distributed fairly evenly along the habitat classes from deep shade to bare ground (Table 5). Although brushland, grassland and raw substrate covered only 1-10% of the landscape before Virginian settlement, about half of the flora consists of species that are typical of those habitats. Native species that are more or less widely scattered over the landscape today have a similar range of typical habitat, as illustrated at the Griffith Farm (row e in Table 5). However, these generally more common species are somewhat concentrated in “intermediate” woodland, and they include relatively few species typical of deeper woods. Less common native species also have a broad distribution along the gradient, but with concentrations at the extremes. Many species are now largely restricted to ravines and hills with deeper woodland and unusual rocky habitats, but some of these appear to have been much more common before settlement, based on historical records and circumstantial evidence (rows b in Table 5). Also, there are many uncommon species that are more or less restricted to open habitats in lowlands or wetlands that were probably much more frequent before settlement (row d).

In contrast, species are regional rare to globally imperiled are concentrated in thin or young woods, shrubby-brushy transitions and grassland (rows f and g in Table 5). Few are typical of extreme habitats along the gradient. The globally imperiled species that was probably most common in the original woodland, running buffalo clover, occurs typically along trails in heavily browsed woodland. Regionally rare species, as opposed to globally imperiled, are concentrated in more open grassy habitats, but these are mostly typical of subhydric-xeric or subhydric-hydric sites in peripheral ravines, hills and wetlands, rather than the mesic-submesic soils that prevail in the central Bluegrass.

Alien species increase in numbers along the gradient from deep shade to bare ground (row i in Table 5). However, the relatively few seriously problematic species for restoration of woodland or grassland are of course concentrated within those habitats. Although several alien species extend to various degrees into woodland, the only frequent aliens that have their typical habitat within intermediate or deep woodland are garlic mustard and, more locally, periwinkle. Bush-honeysuckle and purple winter-creeper are also very common within intermediate or deep woodland, but they are most abundant in slightly more open woods, younger thickets and edges. Some other aliens with a broad range of habitats can prosper in deeper shade, but have not yet become widespread on uplands of the region. The most seriously threatening of these is probably the Japanese “stilt-grass” (*Microstegium vimineum*).

Distributions of life-forms and functional traits. The various general life-forms or functional groups of native plants within the region are segregated to a considerable degree along the openness-related gradient (Table 6). Groups concentrated in intermediate or deep woodland include relatively shade-tolerant, understory-concentrated large tree species, and, in general, high woody vines. Other groups are mostly perennial herbs and graminoids: determinate spring-flowering herbs*, various short spring-summer herbs (including some rosette-plants*), large-leaved summer-flowering herbs** (such as sweet cicely), simple broad-leaved summer woodland herbs* (such as white snakeroot), distichous-leaved lilioid monocots** (such as Solomon’s seal), taller woodland graminoids* (mostly twist-leaved grasses like the wild-ryes), and small-tussock graminoids (mostly sedges). In addition, there are concentrations of early summer biennials**, in general (such as biennial waterleaf), and some winter annuals (such as Miami mist). However, several of these groups (those marked with asterisks) are poorly represented in current woodland remnants, and appear to have declined greatly since settlement.

Groups concentrated in thin or young woods and shrubby-brushy habitats include relatively shade-intolerant, canopy-concentrated large trees, small tree species* in general, and shrubs* in general. Others include low perennial vines (such as moonseed), tall summer-fall perennial herbs* (such as poke, taller goldenrods and wingstems), late-summer biennials (such as meadow thistle), and some annual vines (such as hog-peanut in the original woodland). Athough these life-forms are still securely represented by at least a few native species, some (marked with asterisks) have declined greatly, in general, or have a high proportion of rare species or serious threats from aliens.

In grassland, there are concentrations of medium-sized graminoids, both tussock-forming and running. The few "tall running graminoids" (mostly sedges and allies) are clustered on damper ground. There is also a considerable number of summer- or fall-flowering perennial herbs*, usually with relatively narrow or divided leaves (such as tick-trefoil, bergamot and old field asters). This group of herbs includes several common species of old fields and pastures in the modern landscape. However, patches or zones of native grassland were probably also associated with unusually dry or damp habitats before settlement. On such sites, this group of herbs appear so have dwindled greatly due to declines in habitat, with losses of rare species (such as tall gromwell) and increases in aliens (especially fescue). At the open extremes, where bare soil is often exposed by plowing, burning, flooding or rock outcrops, there are concentrations of all sizes of annual herbs and graminoids. These annuals generally survive fairly well in the modern landscape, though there is much competition from aliens, and a few have become endangered, especially on rocky soils. Several strictly aquatic species* have also declined greatly, based on historical records.

Further Dynamic Complexity: potential regeneration cycles and herbivorous filtering?

The Need to Develop Concepts. The simple three-gradient model outlined above is of course insufficient for exploring the many varied processes within natural vegetation, let alone its highly modified and fragmented descendants in the modern landscapes. During the past 50 years or so, there have been several major efforts to guide human understanding of the great dynamic complexities within vegetation. For particular vegetation types, early generalizations about plant succession across regions have generally been replaced by a focus on the local disturbance regime and how different species respond to various disturbances. Within woodland, this focus has often led to new generalizations about "intolerant" versus "tolerant" tree species, or other categories of behavior. But within woodland, we also have a great variety of structural forms among woody and herbaceous species. The relationships of dynamic processes to the "stratification" of these forms, or other patterns in spatial arrangements, remain rather poorly understood.

In recent decades, D. Tilman and others have developed theories and experiments to examine how the gross diversity of plants depends on general gradients of resources, and the effects on those resourses by disturbances and competition between plants (for example: Plant Strategies and the Dynamics and Structure of Plant Comunities, 1988, Princeton University Press). P. Grime has focused on the most obvious ecological characteristics of plant species in relation to generalized gradients in resources, disturbance and competition, and he has provided an initial means to place each species within a three-cornered diagram, with "competitors", stress-tolerators" and "ruderals" (disturbance-adapted) at the poles (Plant Strategies, Vegetation Processes, and Ecosystem Properties, 2001, Wiley). P.J. Grubb's concept of the "regeneration niche" provided a global framework for investigation of the ways in which many species depend on more or less restricted conditions for their establishment from seed, but then persist as adults in mixtures with other species that appear, at first sight, to occupy the same general "niche" for growth and survival (Biological Review, 1977, 52:107-145; see also his chapter in "Tropical Rainforest Research – Current Issues, 1996, Springer). Another theme developed in much theoretical work is that the consumers of plants—from microbial pathogens to invertebrate pests to larger herbivores—have quite specific interactions with many species of plant, allowing them under some conditions to act as controlling agents for part of the diversity among plant species. While general models of plant-animal interaction can be developed along these lines, following, for example, R.M.C. May (Stability and Complexity in Model Ecosystems, 1973, Princeton University Press), they remain very difficult to apply simply because there are so many species.

Can such themes be combined into accessible concepts and practical applications? With an affirmative view, F.W.M. Vera has recently renewed interest in the potential role of large free-ranging herbivores in temperate forest, woodland, savanna, scrub, and associated networks of grassy trails. His controversial book (Grazing Ecology and Forest History, 2000, CABI Publishing), based on an extremely thorough literature review, has been criticized for some misinterpretations and excessive extrapolations, but it has led to a deeper general examination of how large herbivores may have interacted with woodland. The general concept emerging from the book is that regeneration cycles of various plant species, caused by various disturbances, back and forth between closed and open conditions, could well be enhanced or modified by large herbivores. With most examples coming from succession of open grassy extreme towards higher forest, Vera shows how free-ranging ungulates can lead to selection of thicket-forming shrubs and herbs, often thorny or unpalatable, and that this “mantle” of protective vegetation can allow tree seedlings to disperse into it and regenerate. More tenuously, he advances the concept that, after high forest is established, eventual gaps, if sufficiently large and productive, could allow large herbivores to redirect their foraging, and perhaps establish new grassy trails through the woods. A shifting network of animal trails is envisaged around the mosaic of various dynamic phases in the woodland.

A theme that is not developed much in Vera’s book, though implied by the context of many cited examples, is that his concept would be more likely to apply on productive, fertile (eutrophic) plains than on infertile (dystrophic) hills. Many observations suggest that herbivory is often enhanced on productive sites, especially if available nutrients in the soil increase after major disturbances of the tree canopy. Moreover, large herbivores can increase mineral cycling within ecosystems, potentially enhancing previous gradients of fertility. Vera’s concept could also be broadened to include fairly stable patterns of herbivorous effects on the landscape. For example, animal trails in some areas might tend to stay in the same general location due to topographic features, strong local gradients in nutrition, connections between mineral licks, or other factors influencing diurnal or seasonal movements. As indicated by historical records, bison, perhaps with associated elk and deer, may have developed such patterns in the Bluegrass region during the 18th century.

If Vera’s concept is applied to Bluegrass woodlands, Figure .. is an attempt to develop the expected compositional details and other corollaries. Even if a dynamic regeneration cycle is not a significant aspect, this diagram does provide a hypothetical framework for exploring the somewhat independent dimensions of ‘closed-versus-open’ vegetation, and ‘unbrowsed-versus-browsed’ composition. It displays the initially estimated average positions for each woody species along these two dimensions, based on compositional trends and eco-morphological clues. It focuses attention on dynamic processes within typical woodland on upland soils, rather than broader spatial gradients caused by patterns in soil moisture, topography and geology.

There is some circumstantial evidence that a “browsing-related gradient”, from palatable to resistant species, did exist in the original woodland, based on provisional analysis of witness-tree data. Within “intermediate” woodland, as defined here, there seem to have been areas dominated by the relatively palatable ashes and elms, which contrasted with areas domimnated by the less palatable walnuts and bucketes. Similar results may be gleaned from data on scattered woodland remnants in the modern landscape. But these trends will remain speculative until larger databases are accumulated and controlled comparisons or experiments are performed.

Potential Relationships with Seed Biology: production, dispersal, germination and establishment.

[To be developed in consultation with Baskins, literature review, etc.]

...In addition to traits of mature plants, there are undoubtedly many aspects of reproductive biology that have strong relationships with the openness-related gradient and its dynamic complexities. A general survey of fruit and seed types is needed for full analysis, but some trends among species are obvious (Table 7). Among species where the common method of seed dispersal is indicated by morphology, there is a general overlappping sequence in the frequency of groups from wooded habitats to open habitats: from samaroid wind-dispersal seeds (such as maples, ashes, elms); to squirrel-dispersed nuts (such as oaks and hickories); to bird-dispersed seeds (such as hackberry and blackberry); to larger vertebrate-dispersed fleshy fruits (such as pawpaw and honey-locust); to plumed wind-dispersed seeds (such as sycamore and goldenrods); to super-plumed wind-dispersed seeds (such as willows and thistles). Another obvious mechanism, on hairs of mammals, appears bimodal with clusters among species of intermediate woodland (such as avens, sanicles and bedstraws) and those of disturbed or otherwise exposed soil (such as bur-marigolds and cockle-bur); tick-trefoils are partly in the gap.

...The diagram applying Vera’s concepts (Figure ..) also incorporates an emerging theme from multivariate analysis of eco-morphological characteristics, suggesting that three common ‘strategies’ can be broadly outlined for plant species. Among woody plants of temperate regions, these strategies appear loosely associated with major mechanisms of seed dispersal and regeneration.

(a) With fleshy fruit dispersed in animal guts, partly matching Grime’s ‘ruderal’ strategy, but modified to address long-

distance dispersal into openings and the value of holding dominance within those openings.
(b) With large nutty fruit dispersed by caching of animals, partly matching Grime's 'stress-tolerant' strategy, but modified to address interactions with animals and regeneration in dense ground vegetation.
(c) With small seed dispersed by wind, partly matching Grime's 'competitor' strategy, but modified to address the frequent thinning within dense, wind-blown, monospecific stands.

Potential Relationship with Natural Defenses: morphological and chemical.
[To be developed with review of chemical defenses in plants, especially species in Bluegrass woodland.]
...Table .. will list families of plants in rank order from shade-concentrated to open-concentrated (with display of distribution); in parallel columns each family will be summarized in terms of its apparent general resistance to browsing versus palatability, and in terms of its secondary chemistry.

Potential Relationships with Life-history and Flowering.
[To be developed in some aspects; perhaps with reference to special local interest in dioecy...]

Targets for Conservation and Problems for Research

Ecological Goal (at habitat level). It can be generally agreed that the goal is to restore the associations of vegetation with topography that probably occurred on this site during the post-glacial era, and to simulate gradients of disturbance regime, including wild or domesticated ungulates. While the associated patterns of presettlement vegetation, herbivores, soils and topography may never be precisely replicated, comparisons should be set up for scientific insight into these patterns and their potential persistence in the future. This research should be applied to nature conservation and compatible land uses in the region.

Target Definition (for technical detail and programatic context). For practical discussion, mapping, planning, management and assessment, we need to break the potential variation in vegetation down to a few meaningful units. It is reasonable to propose just three general classes of habitat for initial discussion of Bluegrass woodlands, dividing the openness-related gradient into deeper woodland, transitional woodland, and more open brushy or grassy vegetation. Such division recognizes that at least three general groups of loosely associated species were locally dominant in the original vegetation: (a) sugar maple, bitternut hickory and associates in deeper shade; (b) buckeyes, walnuts, elms and ashes in intermediate woodland; (c) locusts, bur oak, cane and other sun-loving species in edges and openings. The exact definition of units could be adjusted depending on the application, and it will be wise to keep in mind that at least six subdivisions along the gradient can be readily recognized in terms of composition, structure and function.

Further complexity in patterns and process of the vegetation will need to be addressed in details of management and research, but a simple initial approach can be retained. Within any one of the broadly defined divisions of the overall openness-related gradient, there are probably important differences caused by deer browsing, cattle grazing, past farming activities, and other disturbances. In some woodland, it does seem reasonable to apply Vera's concepts for regeneration cycles and herbivorous filtering (Figure ..), and the definition of targets could well be adjusted in accord the the goals of management.

In technical terms, the following three intergrading types of terrestrial community could be given priority for restoration on the residual upland soils prevalent at this site. Mere land protection is clearly inadequate for these types, since special disturbance regimes need to be developed, and many species will need to be reintroduced. All three of these types are considered globally endangered (G1) in the National Vegetation Classification (see www.NatureServe.org).

(a) Mesic eutrophic woodland (JC Class 05.E), typified by dominance of sugar or black maple, and locally abundant bitternut hickory; with minor associates such as white ash, slippery elm, tulip tree, hornbeam and spicebush. Ground vegetation probably included species such as mayapple, wild hyacinth, twinleaf, bloodroot, wild ginger, wood-chickweed and wood nettle. This is equivalent to a calcareous variant of "Deep Soil Mesophytic Forest" of KSNPC or to "Inner Bluegrass Sugar Maple / Black Maple - Bitternut Hickory Forest" (CEGL-004411) of the NVC.

(b) Submesic eutrophic woodland (JC Class 07.E) typified by stinking ("Ohio") buckeye, black walnut, hackberry, elms, ashes, coffee tree and pawpaw, plus scattered oaks and hickories, and with much intergradation to (a) or (b).

Although this type appears to have had a fairly closed canopy, some of it was probably much influenced by ungulates; for example, sugar maple dominance may have been held back, leaving less palatable buckeye in the understory. Ground vegetation appears to have included much wild rye, running buffalo clover and white snake root. This type is more or less equivalent to “Bluegrass Mesophytic Cane Forest” of KSNPC or to “Black Walnut - Ohio Buckeye - Kentucky Coffeetree / Giant Cane - (Common Pawpaw) Forest” (CEGL-004437) of the NVC, but these concepts will need revision. Provisional analysis of early land surveys suggests that a segregate of this type, with abundant ash (probably white and blue) and locally elm (probably white and red) was also widespread, perhaps on sites with more moisture stress or less ungulate influence.

(c) Canebrakes and associated open eutrophic woodland (JC Classes 08.E & 10.E), as indicated by savanna-like remnants of ancient bur oaks and other trees in woodland-pasture, and by historical evidence, including locust thickets, other clonal brushy phases, and meadow-like areas with larger animal trails and native american sites. There is much uncertainty about the potential native ground vegetation, but this will be investigated using various native plants in more experimental sections of the farm; pea-vine (*Amphicarpaea bracteata*) and perhaps tall nettle (*Urtica gracilis*) were associates of cane. This type is more or less equivalent to “Bluegrass savanna-woodland” of Ky. State Nature Preserves Commission or to “Blue Ash - Bur Oak - Chinquapin Oak / Giant Cane / Wild Rye species Woodland” and associated cane-dominated vegetation (CEGL-004436 & 3835) of the NVC. However, these concepts need revision in the light of further historical evidence.

In riparian zones or wetter ground, there is a minor type to be investigated, mapped and nurtured at appropriate locations: streamside forest typified by white (“American”) elm, sycamore, boxelder, green ash and associated wetland patches (CEGL-004690, etc.). Such vegetation is widely distributed in the region (with global ranking of G4). True wetland species would have been generally absent at the Griffith Farm, but many wetland species are now rare in the region and appear to have declined greatly. It might be reasonable to establish small wetlands at the farm in order to support some of these species, perhaps simulating the kind of beaver-ponds that probably did occur before settlement.

On drier ground, there are transitions on drier slopes to subxeric forest typified by chinquapin oak, shumard oak, blue ash, shagbark hickory and perhaps white oak, with more open disturbed variants (especially CEGL-007808, with a global rank of G3). Such fine distinctions may not deserve much attention during initial planning of the farm. This drier woodland may not be globally imperiled, but, if converted with browsing or burning to more open grassland, the resulting vegetation could be considered endangered or virtually disappeared (as detailed in sections on species below). There are a few regionally or globally rare species typical of such habitats in the region, but it is unknown if they could have occurred on land like the Griffith Farm. At Broadwell Corner, the old road cuts through Eden Shale, and a small exhibit of more xeric grassland or shrubland could be designed there for initial displays and trials.

Problems for Research. [...initial notes to be developed cooperatively with colleagues...]
Based on general interests and uncertainties about these targets, general questions for associated research can be stated as follows, with the first being most prominent in the short-term.
(1) How do disturbance-regimes influence temporal and spatial patterns in the vegetation, soil processes, and overall ecological dynamics; can results help interpret historical patterns and redesign naturalistic systems?
(2) How has interaction and coevolution among consumers and plants been influenced by the highly productive soils of this landscape and similar areas elsewhere?
(3) How can research on such disturbance regimes and interactions between them guide design and management of restored areas for native biodiversity and reduction of alien species?

From further considerations of Question 1, with review of relevant literature (as covered in other documents), initial experiments at the Griffith Farm could reasonably be proposed to test the following basic hypotheses.
(a) Browsing and burning are expected to have different effects within Bluegrass woodlands. Browsing is expected to shift composition along the ‘browsing-resistance’ gradient, while burning—if possible—should shift vegetation towards more open conditions (Figure ..). Burning is expected to be relatively difficult, especially in the spring, but may be more effective in oak litter. Browsing is expected to increase nitrogen levels in the soil, while burning may reduce it.
(b) The best current season for disturbance, in terms of promoting native composition, is expected to be August to September, when native species tend to be dormant and several aliens are exposed. But after more cane is established, browsing or burning later in the winter may also become useful, especially to prepare bare ground for running buffalo clover, the most endangered species typical of these woodlands. Intense spring browsing is expected to be damaging to native vegetation.

Factorial experiments could be conducted with well-replicated 15 x 15 m plots subjected to various treatments. Browsing could be conducted with a small group of goats and sheep, contained within portable electrified fences for short intense periods that still allow some differences between plant species in their responses. Burning should probably be conducted under the driest possible conditions in order to ensure clear results. Selected plantings could be designed within the experimental plots, since many species have been eradicated from these woodlands. Analysis of the growth and survival of plantings would provide sounder conclusions than just comparison of different species within existing vegetation. Species should be selected to represent different ecological groups: woody and herbaceous; shade-loving versus sun-loving; and browsing-resistant versus sensitive. Such plantings could have special interest for potential reduction of alien plants, as noted further below in sections on species (especially under "simple broad-leaved summer woodland perennials"). There would also be special interest in plantings designed across trails, in order to investigate the local effects of mowing, trampling and manuring (see also below "short spring-summer perennials" and running buffalo clover).

Large sections of the Griffith Farm, and a few other sites with Bluegrass woodlands, could become assigned for free-ranging livestock, or eventually elk and bison. Exclosures in various dynamic woodland phases could be designed to begin addressing the following questions, both critical to general theories of interaction between ungulates and woodlands, as advanced by Vera .
(a) Do free-ranging ungulates, or other herbivores, have significant effects in succession from openings towards more shady woodland?
(b) Do they prolong or extend openings after removal of tree canopy within more shady forest?
Ideally, such research would be developed using a broad network of sites in the region, experimental plantings, and integration with more detailed research on experimental blocks.

The Species

A Functional Approach to Conservation Targets

Life-forms and Functional Features. A classification of life-forms is adopted that will contribute to analysis of functional features in woodlands of the central Bluegrass, as compared to other vegetation in eastern North America. This will also lead to better understanding of the challenges for restoration, and the development of management plans. As indicated above in the summary of ecological gradients, the native vegetation of highly fertile areas like the central Bluegrass is unusual in several structural features, as follows.

(1) There is a distinctive suite of characteristic trees and shrubs that includes almost no evergreens, relatively frequent compound leaves, or leaves with broad-to-cordate bases, frequent lateral root-suckering ability, several species with well-developed thorns or unusual toxicity, frequent fruits or nuts with large size, and frequent dioecy. These features are probably promoted, through natural selection, by high soil fertility and productivity, together with intense competition and, in some cases, herbivory. But much more theoretical and experimental work is needed to understand the ecological function of these features.

(2) This is a relatively high diversity or local abundance of small spring perennials and larger summer perennials in woodlands. These features are more pronounced within less disturbed mesic woodlands, especially on steeper slopes with rocky soils.

(3) There is a relatively high diversity or local abundance of winter annuals and biennials in woodlands (mostly non-gramnioids), as well as woodland graminoid perennials (twist-leaved grasses and tussock sedges). These features are especially pronounced within somewhat disturbed, often browsed or successional, submesic woodlands on gentler slopes with deep soils. These species may be promoted by high rates of litter composition, high soil fertility, and well-lit conditions within these deciduous woodlands during the winter, combined with frequent disturbance by herbivores.

(4) There are relatively few grassland species, but there is a high potential for local abundance of several tall native perennial, biennial or annual herbs in openings. Such potential has, of course, often been transformed into exotic tall annual crops such as hemp and tobacco, and a diversity of vigorous alien weeds.

Table 1 summarizes information presented in the notes above under each functional group. Several groups are identified within which most species need special attention for propagation and recovery in restored natural areas. These groups (with priority A or B) include small trees & large shrubs, most woodland perennials that flower in spring to early summer, and later flowering woodland perennials with compound or lobed leaves. Groups with moderate proportions or limited selections of needy species (priority C) include large trees, vines (at least the herbaceous hog-peanut), most summer or fall perennials, biennials, winter annuals, woodland perennial graminoids, and—only in wetlands—tall running graminoids. Groups with little or no needy species (D or E) include summer annuals and remaining graminoid groups, about half of which are short tussock sedges and similar species.

Alien species are concentrated within some functional groups, presenting additional problems for restoration, but much less common within other groups. Aliens outnumber natives greatly (by factors of 2-3) among short spring-summer perennials (mostly as low creeping species), among biennials and winter annuals, among tillering tussock graminoids, and among creeping annual graminoids. Aliens are much less frequent than natives, with no widespread seriously invasive species, among large trees, summer woodland perennials, tall fall perennials, woodland perennial graminoids, and short tussock graminoids (mostly sedges).

Evolutionary Groups and Floristic Trends. As detailed above, eighteen groups of species are broadly defined here based on recent advances in understanding of evolutionary trends. In general, the species within each group share a common ancestor unique to them, or in a few cases, they include clusters of closely related groups with parallel evolution. A practical taxonomy is sought here, rather than strict adherence to cladistic principles.

The numbers of species in some groups represent a relatively high proportion of the total native flora in Kentucky (Table 2): 31-36% in Ranunculoids, Fagoids, Solanoids and their allies. Other groups have a low representation: 10-14% in Gymnosperms, Ericoids, Gentianoids, Lilioids, Graminoids and their allies. As indicated above in the presentation of ecological gradients, these differences are part of broad trends related to soil fertility and acidity.

The 377 native species attributed to the central Bluegrass are divisible into approximately equal common (115), scattered (105) and restricted (124) classes, plus a small number (17) in the imperiled classes (Table 2). Much uncertainty remains in the extent to which species now largely restricted to ravines, or other peripheral habitats, were more widespread before settlement. Groups with relatively large proportions of common species include the Rosoids, Asteroids and Graminoids (with allies); this reflects their high frequency in grasslands and open woodlands—but they do not have particularly high proportions of the Kentucky flora. Groups with relatively low proportions of common species include Ferns, Magnolioids, Ranunculoids, Lamioids and Aroids; these groups are concentrated in remnants of deeper woods, riparian corridors and wetlands.

The rarest species within each group (Table 3), either imperiled (endangered or threatened) or already extinct within the region, have been detailed in preceding sections. About 16 species can be listed with some certainty, and another 13 based on more circumstantial evidence. In Kentucky, most of these rare species are at the edge of northern or mid-western ranges; few of them extend further south or east than central Tennessee, and none have largely southern ranges. About half have extensive global ranges (G4 to G5 in Natural Heritage terms), but the others are more restricted. A few are globally threatened or endangered, with ranges largely restricted to the Ohio Valley: water-stitchwort, bladder-pod, running buffalo-clover, and Short's goldenrod.

These rare species belong to diverse taxonomic groups, but with some concentration (10 of 29) among "eurosoids" (Salicoids, Sapindoids, Rosoids), few monocots and virtually no graminoids. There is also a wide range of functional groups, but with some clustering among smaller annuals (5 winter or medium summer species), early summer perennials (4 species), late summer grassland perennials (5 species), and especially tall late summer perennials (6 species). The only woody plant is white walnut. The smaller annuals and early summer perennials are mostly typical of submesic woodlands, often grading into subxeric or subhydric sites, and usually with some degree of disturbance. Most of the late summer grassland perennials are typical of peripheral subxeric to xeric hills, and taprooted. The tall late summer perennials are typical of submesic to subhydric meadows, thickets or open woods, especially on floodplain terraces. Overall, there is a wide range of indicated hydrology: 8 species of hydric and subhydric; 14 of mesic and submesic; 7 of xeric and subxeric. There also a wide range along the disturbance-related gradient, but with relatively few at the extremes of shade and openness (Table _).

The numbers of widespread alien species in each group vary greatly, as percentages of the total native species (Table 2). Two groups have much higher percentages of aliens: the Sapindoids and allies (mostly with mustards & cresses in

Brassicaceae), and especially the Caryophylloids and allies (mostly with Caryophyllaceae). The Lamioids and Asteroids also have high numbers of aliens, but not exceptional as percentages. No aliens occur among Ferns, Gymnosperms, Magnolioids and Fagoids; and relatively few occur among Ranunculoids. These groups are dominated by relatively "primitive" plants or woody plants.

Targets for Conservation and Problems for Research

Biological Goal (at species level). The Griffith Woods project can become a center for conservation of genetic diversity in the native flora and fauna of the central Bluegrass uplands, with a special focus on species that deserve recovery or propagation for ecological and economic purposes. The site will act as a source of plant propagules for restoration or research at the site and elsewhere in the region. It will include a living collection with documented native provenances from the central Bluegrass region, and with careful consideration to genetic issues (e.g. potential pollution of local genotypes).

Target Definition (for technical detail and programatic context). In order to guide conservation plans and associated research, it is important to summarize important trends among groups of species that have similar ecological features and threats.

(a) **Small trees & large shrubs**. These have a high proportion of conservative or rare species that need special attention for propagation and recovery. The numbers of alien species in these groups are moderate, but a few aliens are particularly abundant, especially Amur bush-honeysuckle. Some native species were probably abundant over large areas in the original vegetation (e.g. **spicebush**, **pawpaw**, **cane**). Many species can sucker laterally from roots, which may allow efficient techniques in propagation and management. This suckering, as well as other features, contributes to the special character of native woody vegetation on the unusually fertile soils of this region.

(b) **Early or short perennials of woodland (mostly flowering in Mar-May); from earlier determinates to later running species**. These have a high proportion of conservative species that need special attention for propagation and recovery. Within the later-flowering subgroups, there are high proportions of alien species, some of which are highly invasive (e.g. false strawberry, gill-over-the-ground). The **running buffalo clover** is a globally endangered species in the stoloniferous subgroup, associated with trails or other disturbed ground where the aliens often occur. In the natural condition, woodlands of the Bluegrass region have a distinctively high local abundance and diversity of species in these groups.

(c) **Larger perennials of woodland (flowering in May-Jul); especially those with large compound/lobed leaves, distichous monocots and graminoids**. The large-leaved and monocot groups have high proportions of conservative or rare species for attention in propagation and recovery, but almost no aliens. Though generally not so rare, several **simple broad-leaved species** also deserve attention, including competitive species like **wood-nettle** and **white-snake root**, which may help reduce the alien biennials and annuals. As in the earlier flowering groups (b), Bluegrass woodlands have distinctive abundance and diversity of species in these groups.

(d) **Biennials and winter annuals of woodland**. These include moderately high proportions of conservative or rare species that need special attention for propagation and recovery. There are high proportions of alien species within these groups, including highly invasive species (e.g. garlic mustard, common henbit, common chickweed). Even relatively common natives like **Miami mist**, **corn-salad** and **woodland chervil** deserve propagation for general woodland restoration and suppression of aliens. The **bladder-pod** is a globally endangered biennial typical of thin rocky woods, but potentially also prospering on deeper soils. [Rare winter-annuals on damp or seeping ground might have included false mermaid-weed and water-stitchwort.] Bluegrass Woodlands have distinctively high abundance and diversity of species in these groups.

(e) **Tall late summer-fall perennials.** These occur mostly in open woodlands and thickets on low ground that has been virtually all converted to farmland. They have a cluster of regionally rare or locally extinct species, including **tall nettle**, **prairie mimosa**, **broad-leaved scurf-pea**, **giant wood-lettuce** and **Michigan lily**. **Cane** could also be affiliated ecologically with this group, although somewhat woody in its growth. Although not highly diverse, this component is another distinctive feature of Bluegrass Woodlands.

Some selected species in other functional groups do deserve attention for restoration of woodland or other native vegetation across the region, but on the whole their groups have not fared as badly as the five outlined above. Some other woody species obviously deserve propagation, especially some of the **larger trees with nuts**, including the disease-ridden **white walnut**. Several smaller shrubs and perennial vines have special botanical or horticultural interest, but **cane** clearly stands out as a top priority.

A few **summer annuals of woodlands** deserve special pattention, especially the annual vine **hog-peanut**, with unusual cleistogamous subterranean flowers, which was widespread and locally abundant before settlement and rooting by hogs. The **summer-fall grassland perennials** do have several rare species (e.g. **tall gromwell**), and probably significant problems with aliens. However, most of the less common species in this group are typical of drier ground in peripheral hills, or in marshy transitions, where special restoration using different sets of recommended species may be more appropriate than typical woodland restoration.

Graminoids in general (grasses, sedges and similar plants) do not have particularly high proportion of rare species, and alien species are relatively infrequent, except in the tillering group dominated by bluegrass and fescue, which do not pose long-term threats to most native vegetation. The **woodland perennials** tend to be more rare or restricted, and could be associated with broad-leaved species under item (c) above. Large-scale propagation of selected woodland grasses will be useful for general restoration, emphasizing **woodland bluegrass** and **woodland fescue**, as well as the more widespread **wild-ryes**. It will probably also be useful eventually to investigate the potential for mass-propagation of **some woodland sedges**, challenging though that may be.

...Further notes to be developed for nursery, etc....

...The globally threatened plant species to be prioritized for recovery at this site is running buffalo clover (*Trifolium stoloniferum*). Recovery will also be tried, experimentally, for the globally endangered Lesquereaux's bladderpod (*Lesquerella globosa*), which is mostly restricted to rocky woods in the region but can also occur on deeper soils with disturbance. Other globally or regionally rare species for recovery trials include giant wood-lettuce (*Prenanthes crepidinea*), broad-leaved scurf-pea (*Orbexilum onobrychis*), hairy false gromwell (*Onosmodium molle* ssp.

hispidissimum), and false mermaid-weed (*Floerkea proserpinacoides*).

...Plant species to be promoted in propagation for regional use include the ancient woodland-pasture trees, shrubby species largely eliminated from the landscape but useful for restoration (such as cane, pawpaw, roughleaf dogwood, plums, prairie rose), grasses and herbs typical of open woodlands and forests (such as wild ryes, wood fescue, wood bluegrass, Miami mist, wild hyacinth, pea-vine, biennial waterleaf, wood-nettle, false rue-anemone, wild ginger).

...Animal species to be focussed on for management and recovery will need more research and discussion. They may range from bison and elk, to moths and other insects that specialize on cane, to dung-beetles and native earthworms.

General Research Questions: to be developed as part of regional program...
(1) How do typical plant species in these woodlands interact with disturbance regimes, especially consumption and trampling of ungulates?
(2) How does the dispersal ecology of various plant species influence interactions with disturbance regimes and recovery into restored habitats?
(3) What is the physiological basis of palatability and nutritional quality for ungulates in different plant species?

...There will also need to be detailed research on selected animal species, including any introduced to the site, such as wild ungulates and moths that specialize on cane. Another important topic may be the general relationship of soil biota to different vegetation types and management practices.

...At the genetic level, other important associated research should be conducted to address the general question: what genetic variation exists within native species, and are there geographic relationships with physical or biological factors in the environment? Such research should become truly regional and may not need an operational basis at this site. However, its results should be applied to the selection of genotypes for restoration programs demonstrated here.

Table 1. Base-related trends in some ecomorphological features of Kentucky's native trees and shrubs, as indicated

by the distribution of typical positions for each species along the base-related gradient.

Ecomorphological Features	**Percentages of species (with listed trees) at their typical positions along the gradient**				
	A: highly acid	**B: intermediate**	**C: medium acid**	**D: intermediate**	**E: base-rich**
Percent of all with evergreen leaves **Large and small trees with evergreen leaves**	**29%** **pitch pine** **hemlock** **rhododendron**	**5%** **virginia pine** **shortleaf pine**	**3%** **holly** **(white pine)**	**3%** **red cedar** **(white cedar)**	**0**
Percent of large trees with entire simple leaves	**21%**	**44%**	**19%**	**6%**	**5%**
Percent of large trees with compound leaves	**0**	**11%**	**12%**	**32%**	**50%**
Percent of all trees with lateral spread **Large trees with lateral spread (by root-suckering or layering)**	**10%**	**14%**	**13%** **persimmon** **sassafras**	**19%** **black locust** **black willow** **slippery elm** **(white cedar)**	**30%** **coffee-tree** **honey locust** **?rock elm** **(?osage orange)**
Large trees with thorns or spines				**black locust** **(water locust)**	**honey locust** **(osage orange)**
Percent of trees with ring-porous wood	**20%**	**27%**	**38%**	**46%**	**68%**
Percent of large trees with dioecy	**0**	**0**	**23%**	**22%**	**32%**
Trees with unusually large fruit (compared to related species)		**chestnut**	**persimmon** **crabapple**	**shellbark hick.** **sweet buckeye** **pawpaw**	**bur oak** **black walnut** **coffee-tree** **(osage orange)** **(goose-plum)**
Total large trees	**7**	**9**	**26**	**32**	**19**
Total small trees	**3**	**5**	**18**	**17**	**9**

Total large shrubs	**9**	**19**	**16**	**6**	**9**
Total small shrubs	**5**	**6**	**10**	**11**	**7**
Combined totals	**25**	**39**	**67**	**64**	**45**

See Table 3 for definitions of assignments to base-related positions (A to E). See notes below for definition of large trees, small trees, large shrubs and small shrubs. Details of ecomorphological features are as follows.

Percent of all with evergreen leaves. Included all trees and typical shrubs; excluding vines, subshrubs, briars and cane.
Large and small trees with evergreen leaves. All known native species; rare or local species are in parentheses.
Percent of large trees with entire simple leaves. Excluding needle-leaved gymnosperms.
Percent of large trees with compound leaves. Trends are absent among smaller trees and shrubs.
Percent of all trees with lateral spread. These are large and small trees with frequent root-suckering or layering.
Large trees with lateral spread. Rare, local or adventive species are in parentheses. Trends are absent among shrubs.
Large trees with thorns or spines. Trends are absent among smaller trees and shrubs.
Percent of trees with ring-porous wood. These are large and small trees with at least "semi-ring-porous" wood; the numbers of ring-porous decline from large trees (60%) to small trees (17%) to large shrubs (3%) and small shrubs (5%).
Percent of large trees with dioecy. Included here are "polygamo-dioecious" species: with sexes mostly on separate trees but with some perfect flowers in some cases. Trends are weak or absent in smaller trees and shrubs.
Trees with unusually large fruit. Among Kentucky's native species, these are large or small trees with the largest fruit within their genus (if more than one species), or the largest within their family (if one species per genus), or the largest within their order (if one species per family). Excluded are species with normal types of bird-dispersed or wind-dispersed seeds.

Table 2. Base-related trends in some functional groups or life-forms among Kentucky's native herbs and vines, as indicated by the distribution of typical positions for each species along the base-related gradient.

Functional Groups	Percentages of native species at their typical positions along the base-related gradient				
	A: highly acid	B: intermediate	C: medium acid	D: intermediate	E: base-rich
Evergreen ferns, herbs and vines (54)	16%	2.4%	1.4%	1.5%	3.5%
Mycotrophic plants (51)	8.9%	3.4%	3.4%	0.7%	0.5%
Parasitic plants (28)	2.4%	2.0%	2.0%	1.3%	2.0%

Larger warm-season graminoids (49)	**1.6%**	**5.1%**	**2.4%**	**1.8%**	**1.5%**
Later woodland graminoids (28)	**1.6%**	**2.4%**	**1.6%**	**1.0%**	**0.5%**
Vines (82)	**0.8%**	**0.7%**	**4.9%**	**5.8%**	**2.5%**
Earlier woodland graminoids (28)	**0**	**0**	**0.8%**	**2.7%**	**2.0%**
Distichous woodland lilioid perennials (21)	**0**	**1.0%**	**1.0%**	**1.3%**	**1.0%**
Tall summer-fall perennials (66)	**0**	**1.0%**	**3.0%**	**5.2%**	**3.5%**
Tall annuals (15)	**0**	**0**	**0.3%**	**1.6%**	**1.0%**
Summer woodland perennials w/large divided leaves (37)	**0**	**1.0%**	**1.7%**	**1.9%**	**4.5%**
Biennials and monocarpic perennials (51)	**0.8%**	**0.7%**	**1.0%**	**4.1%**	**6.4%**
Winter-annuals (34)	**0%**	**0%**	**1.1%**	**2.4%**	**5.9%**
Total species	**123**	**294**	**708**	**678**	**202**

See Table 3 for definitions of assignments to base-related positions (A to E). See notes below for definition of functional or life-form groups. Woody species are excluded here except in the "vine" groups and a few in the parasitic plants. Numbers of species within each group are provided in parentheses in left column. All percentages are based on the total numbers of all woody and herbaceous native species at each position along the gradient (A to E); these totals are provided in the bottom row. Details of ecomorphological features are as follows.

Evergreen ferns, herbs and vines (including woody vines). These are species with tough evergreen leaves usually evident above the litter, excluding the many species with only basal tufts of leaves that are protected near ground level. Nevertheless, some assigments are tentative, and species of rock outcrops deserve may deserve distinction; sandstone species are mostly A, limestone B.
Mycotrophic plants. Partially or (in a few cases) completely dependent on fungi for nutrition; most species are in Orchidaceae. Further refinement of concepts is needed including distinction from mycorrhizae.

Parasitic plants (including woody Santalaceae). Partially or completely dependent on host plants for nutrition; most species are in Orobanchaceae.
Larger warm-season graminoids. Excluded are those in "small" groups ca. 0.1-0.2 (0.4) m tall, which are mostly typical of wetlands; also excluded are "woodland" species (*Muhlenbergia* spp.). The remainder included here are C4 species in Cyperaceae and Poaceae that are typical of open sunny sites.
Later woodland graminoids. Comprises C3 panic-grasses (*Dichanthelium* spp.) plus a few C4 muhly-grasses (*Muhlenbergia* spp.).
Vines. Similar trends (with peaks in C or B) occur among woody types, herbaceous perennials and annuals; all are combined here.
Earlier woodland graminoids. These all have C3 photosynthesis.
Distichous woodland lilioid perennials. This small group could be affiliated with some woodland graminoids or herbs.
Tall summer-fall perennials. Plants reaching ca. 1-3 m; trends are similar for running and non-running subgroups.
Tall annuals. Plants reaching ca. 1-3 m; note also success of tall annual crops on base-rich soils: okra, hemp, tobacco, corn (maize).
Summer woodland perennials with large divided leaves. Trends are similar for early and late flowering subgroups.
Biennials and monocarpic perennials. Trends are similar for early and late flowering subgroups.
Winter-annuals. Trends are similar for subgroups of woodlands, old fields and rocky glades.

Table 3. Distribution of the Kentucky Flora with respect to Soil Fertility; see explanation below.

Major Plant Groups (monophyletic + additions)	Number of Species	Typical Soil Distribution					Basophily	Spread
		A	B	C	D	E	(D+E)/(A+B)	(A+B+D+E)/C
Lycophytes	14	9	1	3	0	1	(0.1)	(3.7)
Pteridophytes	67	13	11	22	10	11	0.9	2.0
Gymnosperms	10	2	4	1	3	0	(0.5)	(9.0)
Magnolioids (+Nymph., Schis.)	26	4	4	13	5	0	(0.6)	(1.0)
Ranunculoids (+Cerat., Prot.)	64	2	3	18	31	10	8.2	2.3
Caryophylloids	60	4	3	17	27	9	5.1	2.5
Geranioids+ (Sax., Vit., Myrt.)	84	8	7	37	25	7	2.1	1.3
Salicoids (+Bux., Santal.)	104	7	21	29	34	13	1.7	2.7
Sapindoids	75	3	6	12	36	18	6.0	5.3
Rosoids	197	5	44	69	67	12	1.6	1.9
Fagoids	49	6	4	17	15	7	(2.2)	(1.9)
Ericoids+ (Corn.)	84	22	15	25	15	7	0.6	2.4

Gentianoids	66	5	7	25	24	5	2.4	2.0
Lamioids	152	4	20	57	43	28	3.0	1.7
Solanoids+ (Hydroph., Borag.)	45	0	0	14	21	10	(31/0)	2.2
Asteroids	318	6	42	127	126	17	3.0	1.5
Aroids (+Acor.)	48	0	2	19	22	5	(13.5)	(1.5)
Lilioids+ (Asparag.)	113	11	21	43	25	13	1.2	1.6
Graminoids	429	12	79	160	149	29	2.0	1.7
TOTALS	2005	123	294	708	678	202	2.11	1.83

Major plant groups are adapted from the Angiosperm Phylogeny Group's website; all groups are estimated to be monophyletic except for those groups indicated by "+". See notes in text for details of each group within the central Bluegrass region. Broad soil preferences were assigned to each native species or variety that is clearly recognized in Kentucky (based on the Atlas).

The five classes are defined as follows.

A Association with low pH (ca. 4-5) and low overall fertility; this is indicated by concentration on relatively acid shales and sandstones in the Knobs and Appalachian regions, coupled with virtual absence in the Bluegrass region or other calcareous regions; typical upland oaks include *Quercus montana* and *Q. coccinea*; *Castanea dentata* was formerly frequent; Ericaceae are common.

B Transitional or uncertain assignment between A and B.

C Association with average pH (ca. 5-6) and average overall fertility; this is indicated by widely scattered distribution over the state, including parts of the Bluegrass, or other calcareous regions, as well as the Knobs and Appalachian hills; typical upland oaks include *Q. alba*, *Q. velutina*, *Q. stellata* and *Q. falcata*.

D Transitional or uncertain assignment between C and E; widespread species that are common on farmland or alluvial soils with relatively high fertility are generally assigned here.

E Association with high pH (ca. 6-7) and generally medium to high overall fertility; this is indicated by higher frequency in the Bluegrass or other calcareous regions, compared to the Knobs and Appalachian hills (excluding more fertile valleys and other unusual sites); typical upland oaks include *Q. muhlenbergii*, *Q. shumardii*, *Q. macrocarpa*, and perhaps *Q. imbricaria*.

Indices of "basophily" and "spread" (right columns) are in parentheses for totals of less than 50.

Table 4. Distribution of original and current woodland along the openness-related gradient.

Groups of witness trees	Typical position on openness-related gradient					
	1	**2**	**3**	**4**	**5**	**6**
Witness trees in surveys for land grants during 1774-1788 in the central and eastern Bluegrass						
(1) Upper North Fk. Licking Rv. watershed (Maso. Flem.)	19%	69%	18%	0	0	0
(2) Lower South Fk. Licking Rv. watershed (Harr. Pend.)	15%	66%	12%	7%	0	0
(3) Mill Creek watershed (Harr.)	26%	55%	15%	3%	1%	0
(4) Townsend Creek watershed (Bour. Harr.)	23%	66%	9%	2%	0	0
(5) Stoner Creek watershed (Bour. Clar.)	34%	50%	12%	4%	0	0
(6) Hinkston Creek watershed (Bour. Nich. Mont. Bath)	38%	59%	3%	0	0	0
(7) Inner Bluegrass: mostly plains of Elkhorn Creek	29%	54%	10%	7%	0	0
Witness trees at Griffith Farm: 1817-1845 (-1876)						
(7) Upper elevation: broad ridges and rolling uplands	25%	66%	9%	0	0	0
(8) Lower elevation: side slopes and stream gullies	37%	56%	7%	0	0	0
Approximate current distribution in Griffith Farm	5%	20%	10%	5%	50%	10%
Approximate current distribution in central Bluegrass	< 1%	5%	5%	5%	70%	15%

Witness Trees. These are data from the original surveys on unsettled land for grants from the state of Virginia (copies at the Musuem of Kentucky History). In the Licking River watershed, counties covered by each sample are indicated in parentheses: Bourbon, Clark, Harrison, Mason, Montgomery, Nicholas and Pendleton. In the Kentucky River watershed, the “Inner Bluegrass” sample mostly covers Fayette, Franklin, Jessamine, Scott and Woodford.

All surveys within the relevant watersheds were compiled, except for those where location and composition show that the survey was mostly in the Eden Shale Hills, with much white oak, black oak, beech, poplar or dogwood. Total witness tree numbers for each area ranges from 81 to 243. Because surveyors did not consistently identify the species of oak, all oaks here are assigned a position of 3 along the gradient. However, observation of modern woodland remnants indicates that oak species range from 1 to 4. Because chinquapin oak, with a score of 2, may have been the most common oak, the assignment of 3 rather than 2 for oaks may exaggerate the indicated degree of disturbance, but it does allow more fine distinction between samples.

(1) On the waters of North Fork of Licking River during 1784-88; tributaries include North East Fk Licking (?), Lees Creek.
(2) On the waters of South Fork of Licking River, excluding named tributaries with separate samples (see below), mostly during 1784-88; these are typically located between the Ruddell's Mill area (forks of Stoner and Hinkston Fork) and the lowlands north of Cynthiana.
(3) On the waters of Hinkston's Mill Seat Creek (and nearby?) during 1784-88; this creek is now known as Mill Creek, to the northwest of Cynthiana; but possible confusion among mill creeks may need further checking.
(4) On the waters of Townsend's Run (and nearby?) during 1784-88; this is now known as Townsend Creek; further checking of crrek names is needed in this area.
(5) On the waters of Stoner's Fork of Licking River (called Gists Creek in 1775-76), during 1775-76 & 1784-88; tributaries include "the west branch that heads opposite Four Mile Creek", Grassy Creek.
(6) On the waters of Hinkston's Fork of Licking River, during 1775-76 & 1784-88; tributaries include Cooper's Run, Strode's Fork, Steel's Run (a north branch).
(7) Surveys during 1774-75 in the Inner Bluegrass and some transitions; mostly in the Plains of Elkhorn Creek; original survey nos. include 8, 40, 59, 76, 3921, 3926, 3927, 3973, etc.; thanks to Neal Hammon for initial transcription and summary.

(8) and (9). Trees noted at corners of various land surveys for the Griffith family during 1817-1876 (85% before 1845); thanks are due to Sharon Buford for collecting copies of these surveys. The number of tree records is only 73, and it is possible that there is some duplication. The sample includes some tracts up to 5 miles from the main Griffith Farm. The division into trees from higher versus lower elevation is provisional; further geographic analysis will be invaluable.

Table 5. Distributions of rare versus widespread species along the openness-related gradient.

Groups of species	Typical position on openness-related gradient					
	1	**2**	**3**	**4**	**5**	**6**
Numbers of native species in the central Bluegrass region and adjacent Eden Shale Hills						
Total numbers of native species in region	**122**	**154**	**134**	**171**	**148**	**138**

(a) Upland species restricted to ravines and hills that may have been slightly more widespread (209)	47	45	26	37	28	26
(b) Upland species that are less restricted and that probably were much more widespread (69)	25	12	11	11	4	6
(c) Lowland species restricted to wetlands and river valleys that may have been slightly more widespread (45)	1	6	4	6	10	18
(d) Lowland species that are less restricted and that probably were much more widespread (16)	0	1	0	3	1	11
(e) Species known from the Griffith Farm or within 5 miles in similar habitat, excluding the river corridor (242)	15	64	31	40	51	41
(f) Globally rare or imperiled species (G2-G3G4)	1	2	3	4	1	1
(g) Regionally imperiled or disappeared (G4-G5)	2	2	3	2	6	1
Numbers of alien species in the central Bluegrass						
(h) Most threatening alien species in woodland or grassland	0	1	10	3	7	0
(i) Moderately or locally threatening species	0	1	6	8	14	10
(j) Other naturalized aliens in the central Bluegrass flora	0	0	5	21	24	66
(k) Alien species at the Griffith Farm or nearby	0	1	14	17	27	54

Table 6. Distribution of functional groups of native species along the openness-related gradient.

Functional Groups of Species	Typical position on openness-related gradient					
	1	**2**	**3**	**4**	**5**	**6**
DE: Determinate Spring Woodland Perennials	23	12	4	0	0	0

DL: Distichous Monocots (1/2/3)	3	2	1	0	0	0
LL: Large-leaved Summer Woodland Perennials (3/4/6)	5	4	3	1	0	0
EB: Early Summer Biennials (2/1/6)	4	2	1	2	0	0
RE: Rosette Perennials (14/2/12): pending subdivision	10	4	3	4	3	4
SE: Short Spring-summer Perennials (9/8/14)	15	14	5	2	3	2
LT2: Understory-concentrated Large Trees (16/2/4)	6	14	2	0	0	0
SL: Simple Broad-leaved Sum. Woodl. Perennials (7/5/19)	6	13	6	6	0	0
V1-2: High Woody Vines (5/1/4)	0	5	3	2	0	0
WG: Taller Woodland Graminoids (6/2/9)	2	8	2	4	1	0
STG: Small Tussock Graminoids (12/0/6)	5	5	2	0	5	1
LT1: Canopy-concentrated Large Trees (16/1/6)	2	4	10	7	0	0
ST: Small Trees (11/2/7)	1	2	8	9	0	0
V3-4: Low Perennial Vines (5/2/7)	0	2	3	8	1	0
ST2-4: Shrubs (6/6/9): with subshrubs, briars, cane	2	2	1	14	2	0
TL: Tall Summer-fall Perennials (18/4/17)	2	1	6	21	9	0
LB: Late Summer Biennials (9/2/2)	0	0	1	6	4	2
WA: Winter Annuals (10/3/6)	0	6	2	1	1	9
V5: Annual Vines (4/3/6)	0	1	1	4	2	5
GL: Summer-fall Grassland Perennials (19/8/28)	0	5	5	12	27	6
MTG: Medium Tussock Graminoids (13/0/9)	0	1	2	3	11	0
TRG: Tall Running Graminoids (6/1/3)	0	1	0	2	8	0
MTG: Medium (& Small) Running Graminoids (8/2/6)	0	2	2	0	8	2

TA: Tall Summer Annuals (8/3/4)	1	0	0	2	0	12
MA: Medium Summer Annuals (18/0/7)	0	3	2	0	4	17
SA: Short Summer Annuals (1/4/5)	0	0	0	1	0	9
AG: Annual Graminoids (5/5/4): creeping, short and tall	0	0	0	0	2	12
AQ: Aquatic Plants (2/2/16)	0	0	0	0	2	18

Explanation: see text.

Table 7. Distribution of functional characters in species along the openness-related gradient.

Functional Groups of Species **Totals for local/declined/restricted, inc. wetlands**	Typical position on openness-related gradient					
	1	**2**	**3**	**4**	**5**	**6**
Samaroid Wind-dispersed Seeds (15/5/3): blowing around	6	12	3	2	0	0
Squirrel-dispersed Nuts (11/2/7): or cached by some birds	4	7	5	4	0	0
Bird-dispersed Seeds (24/8/19): or sometimes other animals	5	8	15	19	3	1
Larger Vertebrate-dispersed Fleshy Fruits (8/1/4): varied	0	2	3	4	3	1
Plumed Wind-dispersed Seeds (21/4/28): blowing further	4	9	7	15	15	2
Super-plumed Wind-dispersed Seeds (10/2/3): blowing up	0	0	2	4	9	1
Hair-dispersed Seeds (14/5/11)	2	11	6	1	3	7
to be continued...						

Table 8. Functional groups of species in the central Bluegrass region: numbers of species, degrees of restriction, and overall priorities for recovery; see explanation below.

Functional Groups of Species	**Approx. no. of species**	**Restricted proportion**	**Overall priority**	**Common aliens: natives**
LT: Large Trees	30 (14/16)	1 (1/1)	C	4:21
ST: Small Trees & Shrubs	30 (11/10/9)	6 (7/6/5)	B	8:10*
V: Vines & Subshrubs	27 (6/4/7/7/3)	3	C	8:16*
DE: Determinate Spring Woodland Perennials	25 (16/9)	9 (9/8)	A	3:5*
SE: Short Spring-Summer Perennials	22 (11/7/2)	9 (10/6/5)	A	11:3**
RE: Rosette Spring-Summer Perennials	10 (3/7)	5 (10/3)	B	2:5*
DL: Distichous Woodland Perennials	5	10	A	0:1
LL: Large-leaved Summer Woodland Perennials	8	8	A	0:1
SL: Simple Broad-leaved Sum. Woodl. Perennials	15 (8/6/1)	7 (6/7/10)	C	1:5
GL: Summer-Fall Grassland Perennials	22 (9/9/4)	6 (8/3/8)	C	6:9*
TL: Tall Summer-Fall Perennials	25 (15/10)	5 (4/5)	C	2:12
EB: Early Summer Biennials	5	6	C	22:6**
LB: Late Summer Biennials	10	4	C	13:6**
WA: Winter Annuals (with uncertain species)	15 (7/9)	3 (2/3)	C	22:11**
S/M/TA: Summer Annuals (small/medium/tall)	29 (8/13/8)	3 (5/2/4)	D	20:19*
WG: Woodland Perennial Graminoids	9	6	C	0:4
TRG: Tall Running Graminoids	7	6	C	3:3*

MRG: Medium (and Small) Running Graminoids	7	2	E	4:6*
RTG: Tillering Tussock Graminoids	2?	5?	E	7:2**
TTG: Tall Tussock Graminoids	9 (5/4)	3 (4/2)	E	1:6
MTG: Medium (and Small) Tussock Graminoids	23	4	E	2:9
EAG: Erect (and Creeping) Annual Graminoids	10 (10/0)	2	E	11:8*
AQ: Aquatic Plants	12	6	D	3:5*

Explanation of Columns

Abbreviations. These are developed for general use in text, tables and databases. The “small tussock graminoid” and “small running graminoid” classes are combined with the “medium” classes since numbers of species are small.

Approximate number of native species. This is the approximate number of species that could have been more widespread in the central Bluegrass before settlement, based on current remnants and historical clues; parentheses indicate subgroups. The total number of species is about 350; this will correspond to the sum of rows (b), (d) and (e) in Table 2 (excluding the more conservative species of ravines and wetlands in rows a and c). See appended notes for lists of widespread species by life-form and taxonomic group.

[Note: editing, cross-referencing and checking is still in progress...].

Restricted proportion. This is measured in tenths, as the approximate proportion of native species that are likely to have been more widespread but which now appear more or less “conservative” in the modern landscape (absent from most good woodlots or old fields). Parentheses indicate subgroups.

Overall priority for conservation (including propagation). A = most native species need attention; B = most species in a subgroup need attention; C = selected conservative/rare species need attention, perhaps few but including at least one formerly abundant species; D = few species need attention; E = no species need attention.

Common aliens:natives ratio. These are the numbers of widespread common species. Single asterisks (*) indicate groups with approximately equal numbers of alien and native species, or with at least one widespread seriously invasive alien. Double asterisks (**) indicate groups where aliens greatly outnumber natives, generally by factors of about ×2-3.

Table 9. Evolutionary groups of species in the central Bluegrass: representation of Kentucky Flora; numbers of abundant versus rare species; numbers of natives versus aliens.

Evolutionary Groups	Percent of KY Flora	Natives				Aliens		
		A	B	C	D	a	b	%N

Ferns and allies	19 (67)	0	4	8	1	0	0	0
Gymnosperms	10 (10)	0	1	0	0	0	0	0
Magnolioids and allies	23 (26)	0	1	5	0	0	0	0
Ranunculoids and allies	36 (64)	5	5	10	3	0	3	13
Caryophylloids and allies	18 (60)	4	3	3	1	10	11	191
Geranioids and allies	15 (84)	3	4	6	0	0	4	31
Salicoids and allies	22 (104)	7	5	11	0	1	4	22
Sapindoids and allies	25 (75)	6	6	4	3	2	20	116
Rosoids and allies	16 (197)	14	11	4	3	6	6	38
Fagoids and allies	31 (49)	5	5	4	1	0	0	0
Ericoids and allies	08 (84)	1	2	4	0	0	3	43
Gentianoids and allies	14 (66)	4	3	2	0	1	1	22
Lamioids and allies	24 (152)	9	7	21	0	8	9	46
Solanoids and allies	36 (45)	6	6	3	1	2	2	25
Asteroids and allies	18 (318)	28	10	19	1	8	11	33
Aroids and allies	23 (48)	0	3	7	1	0	3	27
Lilioids and allies	12 (113)	2	6	5	1	2	2	29
Graminoids and allies	14 (429)	21	23	15	1	7	6	22
TOTALS	17 (2005)	115	105	124	17	47	85	37

Percent of Kentucky Flora. These are numbers in the local native flora (A+B+C+D) expressed as percentages of the whole known native flora in Kentucky.

Natives. This is the distribution of native species in the generally farmed landscape of the central Bluegrass, with respect to the following classes; “widespread” species, as generally referred to elsewhere in this document (row e of Table 5 plus a few additions), are divided into classes A and B; “largely restricted” or “more conservative” species are placed in class C (rows b plus d of Table 5), but this generally excludes highly conservative species that are restricted to peripheral habitats and probably did not occur more widely before settlement (row a and other in totals of Table 5). If there are

reasonable clues from historical records and circumstantial evidence, a few of these most conservative species are included, but only in the “imperiled” or “locally extinct” class D.
A: widespread to common; expected in most good extensive woodland remnants or old fields.
B: widely scattered but not common; expected in better woodland remnants, diverse old fields, wetlands.
C: concentrated in or near adjacent hills, ravines, stream corridors or wetlands; rare to absent elsewhere.
D: probably imperiled or extinct within the Bluegrass region, as suggested by old records and biogeography.

Aliens.
a: widely scattered and at least locally abundant.
b: widely scattered but not generally abundant.
%N: totals (a+b) as percentages of native species (A+B+C+D).

Table 10. Regionally imperiled or locally extinct vascular plants known from the central Bluegrass region (excluding ravines along rivers).

Common Name	Latin Name	TAX	LIF	HAB	GLO
Rich Woodfern	*Dryopteris carthusiana*	FER	RE1	1m	10
Marsh Marigold	*Caltha palustris*	MAG	AQ2	5h	10
Northern Anemone	*Anemone canadensis*	RAN	SE3	5sh	10
?Mid-western Meadow-rue	*Thalictrum dasycarpum*	RAN	LL1	3sh	?8
Water-stitchwort	*Stellaria fontinalis*	CAR	WA1	1sh	4
?Woodland Mercury	*Acalypha deamii*	SAL	MA1	2m	?7
?Mid-western Woodland Spurge	*Euphorbia obtusata*	SAL	MA1	2m	9
Glade-mallow	*Malvastrum hispidum*	SAP	MA2	6x	?6
Bladder-pod	*Physaria globosa*	SAP	EB2	4sx	?3
False Mermaid-weed	*Floerkea proserpinacoides*	SAP	WA1	2m	8
?Tall-nettle	*Urtica gracilis*	ROS	TL2	3m	10

Prairie Mimosa	*Desmanthus illinoensis*	ROS	TL1	4sm	10
?Broad-leaved Scurf-pea	*Orbexilum onobrychis*	ROS	TL2	4sm	7
Running Buffalo-clover	*Trifolium stoloniferum*	ROS	SE2	3m	5
White Walnut	*Juglans cinerea*	FAG	LT1	2m	?7
Broad-leaved Meadow Loosestrife	*Lysimachia hybrida*	ERI	GL2	5sh	?8
?White Gentian	*Gentiana alba*	GEN	GL1	5sx	8
?Purple Milkweed	*Asclepias purpurascens*	GEN	GL1	4sm	10
?Glade Savory	*Calamintha glabella*	LAM	SE2	4sx	?6
Eastern Tall Gromwell	*Onosmodium hispidissimum*	SOL	GL1	5sx	9
Eulophus	*Perideridia americana*	AST	DE2a	3sx	7
?Short's Goldenrod	*Solidago shortii*	AST	GL2	5x	3
?Hastate Indian-plantain	*Hasteola suaveolens*	AST	TL2	4m	?6
Giant Wood-lettuce	*Prenanthes crepidinea*	AST	TL1	3m	7
?Tape-grass	*Vallisneria americana*	ARO	AQ3	6h	10
Michigan Lily	*Lilium michiganense*	LIL	TL1	3m	8
?Showy Orchid	*Galearis spectabilis*	LIL	RE2	1m	9
Southern Swamp Ladies' Tresses	*Spiranthes odorata*	LIL	MRG1	4h	8
?Northern Head-sedge	*Carex vesicaria*	GRA	MTG1	5sh	10

Explanation. These are species that are known from less than 10 localities within the region, and no more than one reasonably secure population. They do not include species that are known only from ravines along rivers, or from other peripheral habitats, but they do include some that have extended (at least before settlement) along larger tributary streams well into the generally farmed landscape. Question marks at left margin indicate species with little or no definitive record but with potential to have occurred here during the warm post-glacial era, based on circumstantial evidence and biogeography. Several other regionally rare species with more dubious rationale, known only from peripheral regions or habitats, are excluded from the table but deserve note: *Magnolia acuminata*, *Ranunculus fascicularis*, *Sida hermaphrodita*, *Filipendula rubra*, *Desmodium cuspidatum*, *Astragalus canadensis*, *Fraxinus nigra*, *Pedicularis lanceolata*, *Echinacea purpurea*, *Silphium terebinthinaceum*, *Prenanthes racemosa*, *Cypripedium pubescens*, *Bouteloua curtipendula*.
TAX. Taxonomic group (based on evolutionary model); abbreviation are first letters of names (Table 1).
LIF. Life-form (functional groups); abbreviations follow Table 2; see also notes in previous sections.

HAB. Typical habitat. Numbers 1-6 indicate divisions of the openness-related gradient, from deep shade to bare substrate. Letters indicate divisions of the water-related gradient: h = hydric, sh = subhydric, m = mesic, sm = seubmesic; x = xeric, sx = subxeric.

GLO. Global abundance versus rarity with 10-point scale, allowing uncertain intermediate classes: 10 = widespread across much of continent (G5 in Natural Heritage system); 8 = widespread across large region (e.g. biome, G4); 6 = restricted to small region (e.g. mountain range, G3); 4 = threatened (10s-100s of sites, G2); 2 = endangered (<10 good sites, G1). These are updated estimates, based on general floristic mapping in Kentucky, but several assignments are tentative, as indicated by question marks (?).