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Major professor
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THE EFFECTS OF CONTROLLED-BURN MANAGEMENT ON THE ECOLOGY OF FOREST-OPENINGS VEGETATION IN SOUTHERN ILLINOIS

By

Alicia Suzanne Biagi

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ABSTRACT

THE EFFECTS OF CONTROLLED-BURN MANAGEMENT ON THE ECOLOGY OF FOREST-OPENINGS VEGETATION IN SOUTHERN ILLINOIS

By

Alicia Suzanne Biagi

Nine southern Illinois forest-openings examined for classification purposes in 1988 by A. Heikens of Southern Illinois University-Carbondale were re-examined in 1993 to determine the effect of interim fire management on vegetation composition and structure in three zones: opening, opening-forest transition, and adjacent forest. Site boundaries were mapped in 1994 and the vegetation strata of the three zones were compared. Forest-openings ranged from 450 to 7825 m^2 in area.

In all sites, the ground layer was a forest-prairie mixture with a high percentage of annuals, unusual matrix species and a dominant overstory species which varied by site. At sites which had been fire-managed more than once, openings were characterized by *Brickellia eupatoriodes* and *Silphium terebinthinaceum*; these herbs were useful as indicator species.

Vegetation of the burned and unburned forest-openings displayed unexpected similarities in herb life-form, life history, and proportion of grasses, forbs, legumes and exotics. However, management maintained the three vegetation zones; increased herb species diversity, richness and cover; and decreased woody species richness and density in the opening. Thus, fire-management can be recommended as a means of retarding the replacement of herbaceous communities by woody species in the region investigated.

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INTRODUCTION

Forest-openings (remnant grassland communities) occur throughout the Midwest in the ecotonal region between the tallgrass prairie and the eastern deciduous forest. Forest-openings, also known as savanna remnants, are considered to be a subclass of temperate zone savanna, of which only 0.02% remains (Nuzzo 1986). Savanna remnants (specifically the barrens subclass) are currently the most endangered terrestrial community in the Midwest (White 1984a,b).

Savanna decline has resulted from dramatic increases in development and agriculture and the absence of natural fire since c. 1850 (Nuzzo 1986). Historically, fire maintained openings by eliminating woody saplings (Wright and Bailey 1982) and favoring graminoid species (Gibson 1988). Fires were iginited by lightning strikes, Native Americans, and early Euro-American settlers (Wright and Bailey 1982). Due to a growing interest in these unique communities since the early 1960's increasing efforts have been made to study forest-openings and to reintroduce fire (Seastedt and Ramundo 1990).

In 1988, 22 forest-openings in southern Illinois were sampled and classified into seven types according to vegetation and substrate characteristics, such as the presence of certain herb indicator species and the percent cover of exposed surface rock (Heikens 1991). At the time of the 1988 study, several sites were noted to appear stable, while several others appeared to be undergoing woody encroachment. Therefore, management recommendations were proposed (Heikens 1991). In the ensuing five years, respective land stewards introduced fire via prescribed burn treatments and the mechanical removal of young woody growth at about half of these sites.

In 1993, nine of the original 22 sites were resampled, four of which were managed. Sites were chosen on the basis of permit availability, proximity, management history (treated and control sites) and availability of permanent plots. Vegetation composition was then compared between years (1988 and 1993) in the nine sites. Managed and unmanaged sites (1993) were also compared. Forest-opening perimeters were mapped in 1994 to determine opening size and shape and to document site dimensions for future reference. Also in 1994, north-south transects were sampled for herb and woody species structure and composition. This allowed the comparison of opening vegetation and adjacent forest-interior communities. In this way, species unique to the openings, and often uncommon in southern Illinois, were determined to inhabit several of the sites.

OBJECTIVES

The principal research goal was to determine the changes in managed and unmanaged forest-openings over time, and to evaluate management efficacy in maintaining the structure and composition of forest-opening communities. To achieve this goal, specific project objectives included the following:

1. describe forest-opening herbaceous vegetation composition (in terms of species richness, percent cover, and relative importance)

   -describe herb composition categorically (1993) by grouping herb species by life history, habitat preference, life form, and family,

   -develop vascular plant species lists for all nine sites (encompassing the opening and surrounding 15 m of forest vegetation),

2. determine similarities and differences in composition for managed and unmanaged sites,

   -compare managed sites (1993) with earlier unmanaged condition (1988) using species richness, percent cover, relative importance, and percent similarity,

   -compare managed sites with unmanaged counterparts (1993) (as above),

3. document vegetation distribution,

   -elucidate spatial patterns in the occurrence of herbaceous growth from the opening to the forest interior using species richness, percent cover, relative importance, life form and diversity,

   -elucidate spatial patterns in woody seedlings, shrubs and saplings, and trees from the opening to the forest interior using species richness, density, relative importance and shade tolerance,

-map the open area of each site,

4. determine soil influences,

-compare soil characteristics (i.e., moisture, texture, nutrients, pH, organic matter, depth) between years (1988 and 1993),

-elucidate trends in soil moisture and depth from the opening to the forest-interior (1994),

5. define climatic variables (i.e., temperature, precipitation) in 1988, 1993 and the average (1910-1993) for southern Illinois, and

6. develop management recommendations for each site based on the size of the opening, the stage of woody succession and information from the literature review.

LITERATURE REVIEW: The Ecological Dynamics of the Grassland-Forest Interface

Grasslands

The grassland biome is ubiquitous. Covering 24% of the vegetated land surface worldwide (Harlan 1956), they exist on every continent, from the dense bamboo thickets of the tropics to the arctic plains (Risser et al. 1981). Grasslands are lacking in beta diversity. For example, while over 2000 plant species were listed for the deciduous forest realm in North America (Bazzaz and Parrish 1982), fewer than 300 were listed for the Great Plains (Weaver and Fitzpatrick 1934). Conversely, point diversity may be high. A limestone grassland in Switzerland contained 40 species per square meter (Andreas and Leutert 1996), whereas a mixed-hardwood forest in north-central Virginia contained only 13 herbs per square meter (Gilliam et al. 1995). Also, ecotypic variation within formations (e.g., the tallgrass prairie) may be extensive (McMillan 1959).

Grasslands are generally located in the interior of large land masses (Risser et al. 1981) on level to rolling topography (Anderson 1982). Although grassland climates vary widely, they are generally subject to seasonal temperature extremes (e.g., -40 to 43^{0}C in North American tallgrass; Nichols and Entine 1978), alternating between a dry and a wet season, and receive about 25 to 100 cm of annual precipitation (Walter 1973, Risser et al. 1981, Anderson 1990).

According to Transeau (1905), the ratio of annual precipitation (P) to annual potential evapotranspiration (PET) can be used to define a grassland region. Where P is only 20 to 60% of the PET, short-grass or mid-grass prairie occurs. Tall-grass prairie occurs in regions in which the ratio of rainfall to PET is 60 to 80%, oak-forest/oak-savanna where the ratio is 80 to 100%, and deciduous forest, about 100 to 110%.

North American Grasslands

The origin of the grassland environment in North America dates back 25 million years to the Oligocene Epoch, and the climatic changes caused by the uplift of the Rocky Mountain (Risser et al. 1981). In its approximate present location, the first extensive grassland formation occurred five to seven million years ago during the transition between the Miocene and Pliocene Epochs (Axelrod 1985). At that time, oceanic chilling and Antarctic ice growth contributed to a drying trend in central North America, reinforced by rainshadow from continued Rocky Mountain uplift, which restricted forest and facilitated an "explosive" evolution of grasses (Axelrod 1985). During the Pleistocene, 10,000-300,000 years before present (YBP) (Risser et al. 1981), central North America was cooler and moister and predominately wooded, although grassland occurred locally as a forest-grassland mosaic (Risser et al. 1981, Axelrod 1985). A subsequent warming trend, called the Hypsithermal, began approximately 10,000 YBP with a peak between 7,000 and 8,000 YBP (Anderson 1990). The Hypsithermal, evident from lake sediment cores and paleobotanical data, caused the advance of prairie into boreal and eventually mixed deciduous forest (Anderson 1990). About 11,000 YBP, massive extinctions of large grassland mammals such as the horse, mammoth and ground sloth took place, perhaps owing to the hunting practices of Native Americans (Martin 1975). To facilitate hunting of bison and other animals, aborigines traditionally set fire to North American grasslands beginning at least 10,000 YBP, and thus promoted the advance of prairie to the east (Anderson 1990). For example, the eastward migration of the bison (*Bison bison*) is largely attributed to anthropogenic fire (Pyne 1983, Hart 1990). Bison crossed the Mississippi River about 1000 A.D. and reached Massachussets by the seventeenth century (Roe 1970). Likewise, prairie spread from the base of the Rocky Mountains as far east as present-day Long Island, New York (Blizzard 1931). Although climatic cooling has favored westward expansion of deciduous forest, for the last 5,000 years it has been deterred by fire at the prairie-forest border (Anderson 1990).

Prior to Euro-American settlement, grassland was the largest continuous vegetation formation in North America (Risser et al. 1981), covering one-ninth of the North American continent (Chadwick 1993), and totalling 160 million ha (Chadwick 1995). Spanning approximately 1610 km east-west and 3220 km north-south (Nichols and Entine 1978), the grassland stretched from the central plains of Texas north to the aspen-parkland of Alberta and Saskatchewan and from the Rocky Mountains eastward as a wedge to Illinois, Indiana, and Ohio (Wright and Bailey 1982). Sloping eastward as a catena from the base of the Rocky Mountains at 1829 m above sea level (ASL), the short-grass prairie grades into mid- or mixed-grass at 914 to 1524 m ASL; and mixed-grass prairie grades into tall-grass or true prairie between 274 and 610 m ASL (Wright and Bailey 1982). Short-grasses range in height from 15 to 60 cm, mixed-grasses from 60 to 120 cm, and tall-grasses from 120 to 300 cm (Risser et al. 1981). Annual grassland precipitation increases from 25 cm in the west to 100 cm in the east (Risser et al. 1981) with a corresponding increase in annual net production of 2 t/ha, 3 t/ha, and 5 t/ha for short-grass, mixed-grass, and tallgrass prairie, respectively (Walter 1973). West to east differences also include an increase in soil organic matter, soil depth, and available nutrients (Bazzaz and Parrish 1982).

Given the amount of annual precipitation which occurs in the tallgrass prairie (75 to 100 cm; Risser et al. 1981), a climate-based life zone diagram by Holdridge (1967) (cited in Collins and Gibson 1990) indicates that woody vegetation, not prairie, is climatically suited to this region. The tallgrass prairie, therefore, is a dysclimax to which we now turn our attention for the purposes of this study.

The Tallgrass Prairie

The tallgrass prairie, or true prairie, differs from the short- and mixed-grass prairie in that it has two peak periods of rainfall (rather than one) and higher plant species richness (Risser et al. 1981). It is at greater risk of drought than the contiguous northeastern deciduous forest (Risser et al. 1981) since it does not experience deep soil recharge during periods of extreme drought, such as the great drought of 1933-1934 (Britton and Messenger 1969). Also referred to as the prairie peninsula, it is wedge-shaped in geographic outline, with its base at about the 98th meridian from Manitoba south to Texas, then reaching east to Ohio with remnant disjunct islands or forest-openings scattered throughout the the northeastern deciduous forest (Transeau 1935).

Although true prairie once occupied 3% or 575,000 square kilometers of the North American continent, (Knapp and Seastedt 1986), little remains. By 1830, the majority of the true prairie had been settled and cultivated (Risser et al. 1981). In Illinois, Indiana, and Ohio, 99.9% of the original tallgrass prairie has been eliminated (Chadwick 1995). The largest remaining tract of undisturbed black-soil prairie is a 2 ha pocket in agrarian McLean County, Illinois (Schafer 1990). ("Black-soil" refers to the soil order Mollisol, dominant in temperate grasslands; Foth 1990.)

A pristine tallgrass prairie will contain 250 herbaceous species over an area of about 2,600 ha (Risser et al. 1981), but point diversity is low relative to other grasslands (Collins and Gibson 1990). For example, Peet et al. (1983) found an average of 18 species per square meter in a mesic tallgrass prairie, whereas Andreas and Leutert (1996) identified 40 species per square meter in a limestone grassland in Switzerland. Ninety five percent of tallgrass indigens are perennials, living up to 20 or more years (Blake 1935, Risser et al. 1981). Major species of the tallgrass prairie have broad ecological amplitudes and a relatively large geographical range (Risser et al. 1981). True prairie consists of a matrix of a few dominant warm-season (C_4) grasses and many interstitial species (usually C_3) (Collins and Gibson 1990). While grasses account for 70 to 98% of ground cover (Lippert and Hopkins 1950), they comprise 10% of the species, composites 26%, legumes 7%, mints 4%, and the Liliaceae 4% (Curtis 1959). Twelve species come into bloom per week from April to September (Chadwick 1993), and 70 at the height of the growing season in June (Walter 1973). Seasonal aboveground biomass production exceeds decomposition by 20% (Golley and Golley 1972). Two-thirds of the prairie biomass occurs belowground (Nichols and Entine 1978), 75% of which is in the top 25 cm of the soil (Risser et al. 1981). Still, most tallgrass indigens have rooting depths in excess of 1.5 m (Risser et al. 1981).

The true prairie is characterized by an association of three dominant genera, i.e., *Andropogon-Panicum-Sorghastrum*. There are two seral communities which make up 75% of the true prairie, i.e., the *Quercus-Andropogon* of the Cross Timbers area (Kansas, Texas) and the northern Midwest (Minnesota, North Dakota, Wisconsin) and the *Juniperus-Quercus-Sporobolus-Andropogon* of Alabama, Arkansas, Michigan, and Tennessee (Risser et al. 1981). While the prairie-forest interface is "remarkably" abrupt in northern Minnesota and Illinois (Buell and Facey 1960), the transition is a broad macromosaic in southern Minnesota, Iowa, and Illinois (Davis 1977).

Middle West Savanna

The Midwestern savanna is essentially but "not always" a transitional community between the true prairie and the eastern deciduous forest (Nuzzo 1986). Formerly 11,000,000 to 13,000,000 hectares, only 0.02%, or 2, 607 ha remain (Nuzzo 1986, Breining 1993). Today the midwestern savanna (i.e., the barrens subclass) is the most endangered terrestrial community in the Midwest and is listed as globally imperiled (White 1984a,b).

The term "savanna" was first used in the sixteenth century by the Taino Indians of the grassy, treeless plains of the Caribbean islands and later by Spanish explorers (Breining 1993). The term applied only to tropical or subtropical grasslands until the 1950's when ecologists expanded the definition to include temperate plant communities as well (Odum 1953, Oosting 1956, Dyksterhuis 1957). Definitions of Middle West savanna variously describe a grassland sward with "scattered" trees, primarily oak, with nonoverlapping canopies of 10 to 80% (or even s

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90%) cover (Cottam 1949, Haney and Apfelbaum 1990), although 50% represents a suggested upper limit by Nuzzo (1986) and Heikens (1991). The word savanna is sometimes preceeded by the descriptors "oak" and "scrub" to provide additional character information (Nuzzo 1986). Savanna trees occur in cohorts with distinct age classes corresponding to precipitation cycles. Each precipitation event may endure for five to 12 years and return every 25 to 50 years. These wet periods may reduce or eliminate fire, and permit the recruitment of *Quercus* spp. (Haney and Apfelbaum 1990). Tree cohorts usually range between 25 and 250 years in age (Curtis 1959, Haney and Apfelbaum 1990).

In Wisconsin, oak savanna herbs had a similarity index of 0.50 to 0.58 relative to typical prairie flora and 0.53 relative to the dry-oak-forest herbaceous flora (Curtis 1959). Bray (1957) noted that southern Wisconsin prairie harbored both prairie plants and climax forest herbs. In the early 1800s (presettlement), savanna in southern Illinois was an order of magnitude lower than proximate forested areas in tree density, 15.8 trees/ha vs. 159.8 (Anderson and Anderson 1975). Similarly, in Wisconsin, Cottam (1949) estimated that tree density of a former oak opening had increased from 5.7 trees/ha in 1834 to 57 trees/ha in 1946.

Middle West Forest-Openings

Savanna remnants (also called forest-openings) occur as relic grassland outliers surrounded by forest; they vary in size from a few square meters (Hanson 1922) to over 65 km^2 (McInteer 1942). Although Midwest forest-openings were originally "very extensive" (Braun 1950), they are also "time-transgressive" communities (Heikens and Robertson 1995) known to succeed to closed forest in 10 to 40 years (Schwegman and Anderson 1984, Nuzzo 1986). Accounts after 1825 report the loss of these communities (Sauer 1927). Aerial photographs and research since 1938 document increases in forest herbs and woody species cover and frequency with concommitant decreases in prairie taxa over time (Aldrich et al. 1982, Heikens and Robertson

1995) as do forest-opening studies in Wisconsin (Dorney and Dorney 1989), Ontario (Catling and Catling 1993), Nebraska (Hanson 1922), Missouri (Guyette and McGinnes 1982), Illinois (Robertson and Heikens 1994), Indiana (Bacone and Casebere 1983), Ohio (Hardin 1988) and Kentucky (Baskin and Baskin 1978).

The recent literature emphasizes the distinguishing characteristics and classification of forest-openings, their origin and the reasons for their existence. The terms barrens and glades are frequently used to denote certain types of forest-openings. White and Madany (1978) classified barrens and glade forest-openings, also historically known as oak openings, scalds, rock ledges, etc., as savanna subclasses, equivalent to the level of the forest community. Heikens (1991) provides a key for savanna types (and also includes hill prairie and open forest), which separates communities based on vegetation and soil characteristics. For example, barrens have ≥10% cover of characteristic prairie species, soil depth ≥10 to <40 cm, and exposed rock of >1% to ≤5%. Barrens are grasslands co-dominant with trees, typically *Quercus stellata* (post oak) or *Quercus marilandica* (blackjack oak). Furthermore, barrens are identified by substrate type into, chert, shale, and sandstone barrens.

The term barrens is known from settlement of the Midwest when pioneers judged local open areas to be too poor to support timber, and therefore sterile and unproductive (Ellesworth 1838). However, the Public Land Survey records of the 1800's show that barrens occurred on soils that were "good" as well as "poor," dry and "well-watered" (Hutchison 1982). Although extant barrens usually occur on south to southwest facing slopes (Heikens 1991), they were historically found on all types of topography, including valleys and streamsides (Hutchison 1982, Anderson and Schwegman 1991), and on a variety of substrates (Heikens 1991). A common barrens feature includes open grown trees which appear stunted and gnarled. This physiognomy may be due to a combination of moisture deficit, periodic drought, shallow soil and nutrient deficiency (Reich and Hinckley 1980). Barrens communities contain a combination of prairie and woodland herb species, though certain prairie indigens, such as species of *Silphium*, are generally absent (Vestal 1936). Unglaciated barrens contain a large number of endemic plants. For example, the Mid-Appalachian shale barrens, accessible since the late Tertiary, harbor 18 endemic and six disjunct, near-endemic species (Keener 1983). Forest-openings in Tennessee contain 23 endemics (Baskin and Baskin 1989), and Kentucky, one (Baskin and Baskin 1978). Only two rock outcrop communities in the unglaciated eastern United States are known to have no endemics: the Shawnee Hills of southern Illinois, and the southern Appalachians in western North Carolina and northeastern Georgia (Baskin and Baskin 1988).

Barrens are thought to exist for a variety of reasons. Large wintering herds of bison maintained large timber-free areas in Blue Licks, Kentucky and in some cases nearly denuded the land of vegetation (Hutchison et al. 1986). The excrement from thousands of roosting pigeons killed trees for "several square miles" near Huntington, Indiana (Hutchison et al. 1986). Drought, oak wilt, tornados, lightning strikes, fire, and isolated edaphic conditions are also factors responsible for local openings in the forest (Hutchison et al. 1986, Hutchison 1987, Hutchison 1994).

Barrens sometimes intergrade with similar habitats known as glades. According to Heikens (1991), however, glades have a greater percentage of exposed rock and shallower soil than barrens. For example, limestone glades contain >10% cover prairie species, 1 to 5% exposed rock, soil depth <10 cm, and scattered *Juniperus virginiana* and/or *Quercus muhlenbergii*. Other glades, i.e., sandstone and shale, also have >5% cover exposed rock and soil depth <10 cm, though cover of prairie species is <10% (Heikens 1 991). A study by Jefferies (1987) supports these dichotomies. Mean soil depth in an Arkansas sandstone glade was 5.2 cm, cover of soil and bare rock, 39.6%, and *Juniperus virginiana* was the most important woody species .

Early use of the term glade referred to wet areas (Hutchison et al. 1986), although in the Midwest they have also come to denote grass-dominated communities that are substrate-controlled (Heikens and Robertson 1995). Rock ledge communities (usually horizontal or broadly rounded bare-rock shelves or slopes at the top of cliffs, less than a meter and up to 18.3 m wide; Winterringer and Vestal 1956) are sometimes considered to be glades. *Juniperus virginiana* (eastern redcedar) is a common associate of glades, however, dense, even-aged stands have been known to replace some openings since the time of Euro-American settlement (Guyette and McGinnes 1982). Glades often occur on south to southwest facing slopes on shallow, erosive soil with extensive exposed bedrock. Soil water content in summer is frequently below the permanent wilting point (Baskin and Baskin 1988). For example, in a 225 m^2 exposed area (albeit in a barrens), of 35,000 seedlings established in April or May, only nine survived by mid-June (Keener 1983). Direct exposure to sun and insolation causes patches of bare, thin soil to heat up 14 to 17^{0}C over air temperature (Winterringer and Vestal 1956, Diboll 1984), and air above the grassland is two to four times as dry as in the surrounding shrubs and woods (Hanson 1922). These phenomena are critical to the development of glade vegetation which consequently blooms in mid and late spring when moisture is available (Harper 1926).

Five small cedar glades in Kentucky (glade area not available) contained a total of 148 plant species (Baskin and Baskin 1978). Jeffries (1987) in Arkansas found 76 species in two glades ranging from 0.05 to 0.8 km in area. Baskin and Baskin (1978) suggest that glades act as refugia for prairie flora. However, McCarty and Hassien (1984) report that inconspicuous prairie plants remain in closed woodland understories.

Disturbance

It has long been recognized that periodic (natural) disturbance events are necessary for the perpetuation of grasslands (Transeau 1935, Sears 1942, Dyksterhuis 1957, Axelrod 1985).

Disturbance has been referred to as a natural component of intrinsic regulatory importance and its role in these communities has been compared to a cyclic occurrence, such as the annual passage of seasons, in which the post-disturbance community resembles the pre-disturbance community, such that it appears stable through time (Loucks et al. 1985, Collins 1990). This process is known as autosuccession (Loucks et al. 1985) and disturbance is defined as a process which limits "...plant biomass by causing its partial or total destruction (Grime 1979, p. 39)."

There are three classes of disturbance in grassland, namely, climatic, pyric, and biotic, all of which vary in size, frequency, and intensity (Malanson 1987). Disturbances historically included fire, drought, windstorms, grazing, burrowing (Loucks et al. 1985), and local degradative episodes of disease, such as oak wilt (Transeau 1935). Today, these events can be simulated to a limited extent by herbicides, cutting, mowing, conservative grazing and, in some cases, by controlled or prescribed burning.

Fire

Since the early 1960's the use of fire for ecosystem management has been accepted by biologists of all disciplines (Wright and Bailey 1982). Its perception as a damaging agent in forests (Miller 1920) and grasslands by scientists (e.g., Weaver and Albertson 1936, Hopkins et al. 1948) and land stewards (e.g., USDA-Forest Service) has been revised with numerous ecological papers (e.g., the Leopold Report of 1963; Leopold et al. 1963). Researchers also cite numerous accounts of burning by Native Americans to harvest food (e.g., grain, nuts, fruit), improve forage, drive animals, clear land (for travel, defense, and aggression), and reduce pests such as snakes, flies, and mosquitoes (Pyne 1983, Axelrod 1985). Conflagrations were often expansive and frequent. In 1885 one fire traveled 282 km, another burned an area 32 by 97 km in Texas (Wright and Bailey 1982). Open oak-hickory forests in southern Illinois were burned annually (by Native Americans, then settlers), until 1930 when the Shawnee National Forest was created (Miller 1920, Anderson 1972, DeSelm 1989). Fire frequency was also determined by the roughness of the topography and the presence of fire breaks such as streams or escarpments (Anderson 1990). For example, rock outcrops seldom supported a fire because of their sparse vegetation (Harper 1926). Before settlement, level to rolling topography in the Midwest burned every 5 to 10 years, while dissected topography burned every 20 to 30 (Wright and Bailey 1982).

Under natural conditions tallgrass prairie usually burned every two to four years (Aber and Melilo 1991), midgrass every 15 to 30, and shortgrass, not more than every five to 10 years (Wright and Bailey 1982). Peak fire probability is in July and August and secondarily in late spring, although fires can occur at any time of the year (Bragg 1982). Prescribed fires average 102 to 388°C at the soil surface with an extreme range of 83 to 682°C (Wright and Bailey 1982). Sixty degrees Celcius is the standard thermal death point for vegetation (of a given tissue moisture and exposure time, usually about 10 minutes), but grass species (below ground parts) have been known to survive temperatures up to 75°C (Jameson 1961). Dry fuel must reach 346 ± 40°C to combust (Wright and Bailey 1982). Over an 18-year period in a Kansas tallgrass prairie an average of 63 to 89% of aboveground biomass (3,090 to 4,350 kg/ha) was removed by combustion (values based on annual burns conducted at four different times of the year) (Ojima et al. 1990). A typical fire will cause the soil to heat to 66 to 79°C at a depth of 0.64 cm for 2 to 4 minutes after passing. Temperature increases below this depth are negligible, regardless of soil texture (Wright and Bailey 1982, Svejcar 1990).

Fire and Tallgrass Prairie Vegetation. Pyric events may create patches of bare soil which, during the growing season, heat up 2 to 17°C over surrounding air temperatures (10°C average) (Kucera and Ehrenreich 1962, Wright and Bailey 1982). High soil temperatures stimulate microbial activity, decomposition of organic matter, and nitrogen mineralization (Ojima et al. 1990). After fire, the amount of photosynthetically active radiation reaching emerging shoots increases by 60% (Knapp 1984) and regrowth is therefore precocious (Svejcar 1990). Herb canopy closure may be complete two to three weeks after fire (Eisele et al. 1989, Svejcar 1990). In addition, phenological development is earlier (Bazzaz and Parrish 1982), accompanied by as much as a 60% increase in plant height (Curtis and Partch 1950). Soil moisture is also depleted earlier in the season, causing more rapid vegetation senescence and a reduction of live aboveground biomass to levels comparable to unburned prairie by the end of the growing season (Svejcar 1990).

Most prescribed fires are set in spring, between late March and April (Benning and Bragg 1993). "Early spring" burns occur around 20 March and 10 April, "late spring" around 1 May (Benning and Bragg 1993). These burns typically favor "warm-season" C_4 species (blooming between July and October) (Howe 1994) and stimulate large increases in cover (Kucera and Koelling 1964, Towne and Owensby 1984), productivity (Svejcar 1990), and, for grasses, tiller number (Svejcar 1990), flowering stems, and caryopse number (Glenn-Lewin et al. 1990). However, the response of a given species may vary across its geographic range (Svejcar 1990). For example, the flowering increase of *Andropogon gerardii* (big bluestem) ranged from 54 to 3780% at sites in Wisconsin, Illinois, and Iowa (Glenn-Lewin et al. 1990). Furthermore, a species may be an "increaser" at one site and a "decreaser" at another. *Sorghastrum nutans* (Indian grass) varied from a 663% increase to a 79% decrease in flowering-stem number among burned Wisconsin, Illinois, and Iowa sites (Glenn-Lewin et al. 1990). Moisture regime also contributes to species response to fire. After a dry-year burn in spring, the net productivity of *Schizachyrium scoparium* (little bluestem) was 58% lower than in unburned plots (Hopkins et al. 1948); but in wet-year burn plots it was 81% above the control in mixed-grass prairie (Wink and Wright 1973).

Towne and Owensby (1984) in a 56-year study of annually burned tallgrass prairie in Kansas found that a three-week difference in the timing of a spring burn resulted in significant differences in herbage yield and species composition. Consistently, in a re-established tallgrass prairie in Nebraska, Benning and Bragg (1993) concluded that a difference of four days in spring burning determined whether significant increase for both flowering stem number and flowering stem height of *Andropogon gerardii* was observed. Significant plant response occurred only after 12 May (until 20 May): 8 to 10 days after initiation of plant growth.

The ratio of C_3 to C_4 plants decreases following late spring burns (Towne and Knapp 1996). Late spring burning destroys C_3 grass and forb shoots at a period of maximum growth, yet before the initiation of leaf expansion of C_4 species, thereby favoring the competitive superiority of C_4 plants (Howe 1995). The majority of C_4 species in a tallgrass prairie are grasses while most of the C_3 plants are forbs (Dickinson and Dodd 1976). Towne and Owensby (1984) found forb yield to be highest and grass yield lowest on unburned prairie plots versus annually burned treatment plots lit in winter, early, mid, or late spring. After 12 years of protection from fire on tallgrass prairie in Missouri, Zimmerman and Kucera (1977) noted large populations of perennial dicots, especially *Solidago* spp. (goldenrods). Hartnett (1991), studying the tallgrass prairie forb *Ratibida columnifera* (prairie coneflower), discovered that plants from sites not burned for many years were 2.6 times larger and produced 50% more stems than counterparts from recently burned sites. Therefore, Svejcar (1990) suggests timing a prescribed burn with the phenological stage of a key prairie species. However, relatively few studies document forb response to fire, although most results are species-specific (Glenn-Lewin et al. 1990).

Transitory (one to two year) effects of fire usually include a doubling in tiller number and total aboveground biomass, a variable but positive effect on flowering stem and caryopse number, and a positive second year effect on herbaceous seedling establishment (Glenn-Lewin et al. 1990). Still, exceptions to each of the above trends are reported and sources of variability include site history, species composition, moisture regime, geographic location, timing of burn, and plant growth stage (Svejcar 1990).

The majority of studies report an increase in species richness the year after a burn (Collins and Gibson 1990), especially when fire is periodic or absent for ten or more years (Kucera and Koelling 1964). Patterns in richness the year a fire is set are not clear and often correlate with precipitation (Collins and Gibson 1990). However, a second-year effect is often observed since fire stimulates flowering, and establishment results from recently dispersed seed (Rabinowitz and Rapp 1985). Also, where few seedlings are reported in undisturbed prairie (Blake 1935, Goldberg and Werner 1983), fire creates patches of bare soil favorable to colonization (Rabinowitz and Rapp 1985). In mesic grasslands, variations in species richness are primarily a function of the number of forbs (Blankenspoor 1987). However, annual spring burns increase dominance by the matrix grass species such that richness is lower than in unburned prairie, in addition to depleting the soil seed pool (Collins and Gibson 1990). Dormant-season burns have little effect on species richness (and there are few, if any, winter annuals; Collins & Uno 1983) (Collins and Gibson 1990).

According to Anderson and Schwegman (1991) species diversity is often greatest in ecotones, e.g., prairie to forest. For example, in a mesic southern Illinois barrens, Anderson and Schwegman (1991) found preburn species richness to be lowest, increasing the first two years after fire to a peak 15 years later, when shade tolerant forest herbs and woody species were rapidly invading. At Buffalo Beats prairie in southeastern Ohio, herbaceous species richness likewise increased after fire with forest encroachment (Hardin 1988). Although characteristic prairie species such as *Liatris scariosa*, *Desmodium paniculatum*, and *Lespedeza repens* no longer occurred in unmanaged plots after 22 years, 18 species were new to the prairie opening, six of which were formerly found in the transition zone or forest-opening samples alone. The coefficient of similarity between the former transition area and forest interior was nearly identical.

Late spring burns, particularly on an annual basis, also lower species diversity and community heterogeneity (Collins and Gibson 1990). A model by Gibson and Hulbert (1987) shows a gradual increase in species diversity after fire for six to seven years, after which it declines. This inversely correlates with a one to two year peak in the cover and productivity of grasses (and annuals for one year) following fire after which cover and productivity decrease (Risser et al. 1981, Collins and Gibson 1990). For example, following fire in sown swards of *Andropogon gerardii* and *Sorghastrum nutans*, productivity was three to four times higher than unburned plots (Hadley and Kieckhefer 1963). After 22 years of postfire succession in southeastern Ohio, cover of *Andropogon gerardii* decreased from 50 to 16% (Hardin 1988).

Eventually, without periodic fire, woody species dominate prairie sites (Anderson 1983, Anderson and Schwegman 1991, Heikens and Robertson 1994). Haney and Apfelbaum (1990) noted the release of oak from rootstocks of unknown age in former oak savanna (now closed forest) following fire cessation in the upper Midwest. The number of trees in unburned tallgrass prairie increased 60% over five years in northeastern Kansas (Briggs and Gibson 1992). Bragg and Hulbert (1976) reported an increase of 40% in woody plant cover in unburned tallgrass prairie over a 30-year period in Kansas. The most obvious change in an oak opening is recruitment to sapling and tree layers, whereas tree seedling numbers decrease over time (Bragg and Hulbert 1976). In a Minnesota savanna, tree ($\geq$10 cm dbh) recruitment was 5 to 45 stems/ha over a five year period. Over the course of a major drought, the unburned plots had a larger percentage of shrub or sapling stems (plot size=0.375 ha), 58 verus 48%, respectively (Faber-Langendoen and Tester 1993). Between 1834 and 1946 an oak opening in southwestern Wisconsin showed an increase in the frequency of *Quercus alba* (white oak) and *Quercus velutina* (black oak) of 37 to 83% and 20 to 53%, respectively, while the shade-intermediate pioneer species *Quercus macrocarpa* (bur oak), declined from 72 to 8% (Cottam 1949). Concurrently, the understory frequency of prairie grasses also declined from 57 to 0%, *Ceanothus* sp. (redroot) 59 to 14%, and *Silphium terebinthinaceum* (prairie dock) from 5 to 0%.

Fire and Plant Adaptations. Although tallgrass prairie may quickly succeed to woody vegetation, fire kills or retards woody growth (Bragg and Hulbert 1976, Wright and Bailey 1982, Abrams and Hulbert 1987, Briggs and Gibson 1992). Tree mortality often results not from cambial damage but from root injury and canopy scorching from hot gases (Spurr and Barnes 1992). Fire-sensitive species such as *Juniperus virginiana* (eastern redcedar) have shallow roots and thin bark (Arend 1950) and are impeded by a fire frequency less than 20 to 30 years (Wright and Bailey 1982). Trees with bark thickness in excess of one centimeter experience little heat damage (Wright and Bailey 1982). Oak, a dominant savanna tree, experiences <4% mortality when not stressed by drought (Faber-Langendoen and Tester 1993). However, losses from oak wilt in the red-oak group exceeded 20% within five years of a fire in an oak woodland in southern Wisconsin (McCune and Cottam 1985). With windstorm and drought in southeast Texas, oak mortality exceeded 50% (Glitzenstein and Harcombe 1988). But where fire destabilized closed forest in central Illinois, causing 47.6% mortality within three years of a burn, nearby savanna trees experienced no damage (Anderson and Brown 1983). Anderson and Brown (1983) determined that the survival of savanna trees was due to ground layer shading, which restricted herbaceous growth, and to wind action, which removed basal litter, thereby preventing fire from reaching within 30 cm of the base of any savanna tree. Ko and Reich (1993) concur. Although soil moisture, nutrient and organic matter levels were higher beneath savanna oak, total aboveground biomass was 50 to 100% lower than in uncanopied areas.

Fire-prone environments harbor a higher proportion of resprouting woody species than non-fire environments (Parker and Kelly 1989). One hundred percent of woody species in California sage (Malanson and Westman 1985), 65% in the fynbos of South Africa (Kruger 1977, as cited in Trabaud 1987), and 50% of California sclerophyllous scrub (Mooney and Dunn 1972) are capable of resprouting. Trees regenerate by root suckers, stump sprouts, basal burls (basal stem swellings developed around stem wounds) (Lacey and Johnston 1990), and grubs (oak and hickory sprouts killed by annual fires). Oaks are notorious resprouters (e.g., *Quercus macrocarpa*, *Q. stellata*) (Burns and Honkala 1990). In 1913 John Muir noted the presence of grubs about 100 years old in Wisconsin oak savanna (Cottam 1949). Liming and Johnston (1944) discovered sprouts (about 4 years old) from oak "stools" (enlarged callus-like structures at groundline formed from repeated sprout mortality due to periodic fires) in annually burned oak-hickory forest of the Missouri Ozarks. The root systems of these sprouts averaged 23.9 years in age. Likewise, oak seedling sprouts from southeastern Ohio grew from rootstocks up to 37 years old (Merz and Boyce 1956).

Grassland herbs have been refered to as pyrophytes, particularly in Europe, but the term has recently been deemed "ambiguous" and "inappropriate" as propagative strategies allowing plants to succeed in fire-prone environments are difficult to distinguish from traits allowing regeneration in response to other disturbances such as drought or grazing (Trabaud 1987). Still, many grassland herbs have propagative traits advantageous to regeneration after fire, grazing, and drought. For example, many species are rhizomatous. Rhizomes are underground stems that can serve as storage organs and sites of water and nutrient absorption, regeneration (via shoots), and anchorage (Risser et al. 1981). They occur approximately 2.5 cm belowground (for grasses) (Wright and Bailey 1982), safe from the scorching effects of fire, and may be 5 to 10 mm in diameter, and 2 to 4 m long (Risser et al. 1981). Similarly, the depth of subterranean plant organs was found to be species-specific in understory herbs in Acadia forest, New Brunswick (Flinn and Wein 1977). Forbs frequently root deeply, e.g., *Amorpha canescens* and *Liatris punctata* roots may exceed 5 m (Weaver and Darland 1949). In general, after fire, root and rhizome biomass increases 50% or less (Svejcar 1990). Seastedt and Ramundo (1990) found that root length under litter (unburned prairie) was 70% that without litter.

Vesicular-arbuscular- (VA) mycorrhizae, a type of endo-mycorrhizae, generally confer a large advantage to C_4 grasses (Hartnett et al. 1994). These fungi are symbionts, ubiquitous in tallgrass prairie, which aid a plant in disease resistance, nutrient and water uptake, growth, and interplant linkage (Gibson and Hetrick 1988). With an April burn in Kansas, flowering and stem density of *Andropogon gerardii* and *Sorghastrum nutans* was significantly higher with mycorrhizae than without. C_3 grasses and forbs are generally facultative, and show smaller growth responses than C_4 grasses (Hartnett et al. 1994).

Fire and the Soil Seed Bank. The primary mode of reproduction in grasslands is vegetative (Abrams 1988, Keddy et al. 1989). Vegetative propagation is, however, costly in terms of energy expenditure per reproductive unit and consequently, the number of propagules is limited (Fenner 1985). The production of a large number of seeds maximizes the potential for dispersal and likelihood of reaching "safe sites" or uncolonized patches (Parker et al. 1989). This strategy is employed by sparse grasses. Rabinowitz (1978) determined that rare or sparse prairie grasses like *Sphenopholis obtusata* are light-seeded, 0.06-1.76 mg, and common grasses like *Andropogon gerardii* are heavy-seeded, 2.23-2.8 mg. Small seeds are able to germinate more quickly than large seeds and to subsequently preempt patches (Hull 1973, Rabinowitz 1978). Likewise, prodigious seed output allows annuals to heavily stock the seed bank. Seed bank dominion is also based upon seed persistence or the ability to maintain viability over long periods of time (Fenner 1985, Levin 1990). This phenomenon has been described as the persistent stage in the life cycle of an otherwise transient species (Parker et al. 1989).

Correspondence of species between the aboveground flora and soil seed bank may be due to a rapid turnover of the seed bank subsequent to disturbance. Fenner (1985), Hartnett and Richardson (1989) and Roberts and Vankat (1991) assert that the more frequently a habitat is disturbed, the more closely the species composition of the soil seed bank will resemble the extant vegetation. However, reports of highest consonance between aboveground vegetation and the seed bank come from a regularly burned chaparral (fire interval 20 years) (Wright and Bailey 1982) which shows an overlap of 50% (Parker and Kelly 1989), not from the tallgrass prairie (fire interval 2-5 years).

Most studies report that seed bank species composition is not representative of the existing vegetation (Rabinowitz 1981, Johnson and Anderson 1986, Schiffman and Johnson 1992). A seed bank study of a tallgrass prairie (burned every four years) by Rabinowitz and Rapp (1980) confirms this assertion. While the seed bank contained 30 species, a floristic survey named 82 flowering plants. Twenty one species contributed 7.8% of the total seed while the remaining nine contributed 92.2%. The dominants of the site, *Andropogon gerardii*, *Schizachyrium scoparium*, and *Vernonia baldwinii*, were absent from the seed bank.

Fire and Nutrient Cycling. Fire in tallgrass prairie accelerates the oxidative process of organic matter decay (Harvey et al. 1976, cited in Wright and Bailey 1982), volatilizing nitrogen (N) and sulfur, and depositing cations in ash (Wright and Bailey 1982). Ash leachate may stimulate seed germination, as in the chaparral (Keeley 1987). The percolation of cations in soil has been shown to increase root depth and the equitability of root distribution in the soil horizons (Aber and Melilo 1991). Cations percolate through the soil following rain, displacing hydrogen ions, and raising soil pH slightly in the upper 1 to 10 cm, e.g., from 5.87 to 6.07 (Owensby and Wyrill 1973), for a period of one or two years (Raison 1979).

The tallgrass prairie, like most terrestrial ecosystems, is N-limited (Seastedt and Ramundo 1990). In a typical fire (200°C), over 90% of N in aboveground plant material is volatilized (Wright and Bailey 1982), resulting in a loss of about 1-2 g/m^2 (Ojima et al. 1990). However, postfire vegetation immediately experiences a marked increase in production (Knapp 1985, Svejcar and Browning 1988). With annual burning, postfire productivity is also sustained over time. After 10 years of annual burning at a site with 17% composition *Andropogon gerardii*, productivity was

15 to 20% higher than that of unburned prairie (Towne and Owensby 1984). In Kansas, aboveground productivity was still 30% higher than the unburned control after 18 years of annual burning (Towne and Owensby 1984). These effects are associated with immediate microclimatic change, and greater plant efficiency (more biomass per g N) (Ojima et al. 1990). Longterm annual (30 yr) and periodic (4 yr) burns significantly reduced extractable ammonium in the top 5 cm of soil (Vance and Henderson 1984) and soil ammonium concentration was shown to recover only partially 50 years after a single fire in a Finland forest (Viro 1974).

After fire, grasses obtain about 7% of N from bulk precipitation, 7% from mineralization of organic matter, and <17% from atmospheric N-fixation (Sclesinger 1991). The rest is thought to come from retranslocation and root decay (Abbadie et al. 1992). The N budget for an annually burned prairie has been calculated by Seastedt (1985). One to two grams of N $m^{-2}yr^{-1}$ enter via precipitation, 30% of which is absorbed by microbes on standing dead vegetation. Peak live aboveground vegetation uses 4 g N $m^{-2}yr^{-1}$, with a 25% turnover, and 1-2 g N $m^{-2}yr^{-1}$ are volatilized while 0.5-0.7 g N $m^{-2}yr^{-1}$ are deposited on the soil via ash and unburned debris (Ojima et al. unpublished, in Seastedt 1988). Roots use 5-6 g N $m^{-2}yr^{-1}$. Live roots have a 30-40% turnover rate.

Longterm burning may favor N-fixation. Additions of ash following fire provide inorganic phosphorus (P) in amounts comparable to those bound organically in the original standing material. Phosphorus stimulates N-fixation by terrestrial cyanobacteria (i.e., *Nostoc muscorum*) and litter removal increases soil temperature favorable for algal growth until canopy closure (about three weeks) (Eisele et al. 1989).

N-fixing legumes may also increase in number following fire. For example, after 15 years of annual late spring fires, legume density was significantly higher (8 ± 1 stems/m^2) than in unburned plots (3.0 ± 0.3 stems/m^2), although total biomass was not significantly different (Towne and Knapp 1996). Unlike most forbs, Towne and Knapp (1996) discovered that legume biomass increased from about 11% to about 25% after 10 years of annual burning. Anderson and VanValkenburg (1977) found net density of legumes increased from 17,554 to 63,320 stems/ha following fire in a successional southern Illinois forest-opening and legume production was at least seven times greater on burned than on unburned plots.

Large increases in the exotic legumes, *Lespedeza striata* and *L. stipulacea* (from 0 to 2,366 and 486 to 4,364 stems/ha, respectively) were found subsequent to a forest-opening burn in southern Illinois (Van Valkenburg 1977). Thompson and Heineke (1977) also found significant increases in frequency of the exotic legumes, *L. stipulacea* and *L. striata*, as well as *Coronilla varia*, *Glycine max*, *Lespedeza cuneata*, *Medicago lupulina* and *M. sativa* along periodically burned railroad right-of-ways in southern Illinois while Diboll (1984) noted an increase in the European legume *Trifolium repens* following an experimental prairie burn in east-central Wisconsin. Martin et al. (1975) found native *Cassia*, *Desmodium*, and exotic *Lespedeza* spp. to increase in burned-over forest cuts in the Piedmont (Virginia to Georgia).

Fire, the Litter Layer and Water Relations. Longterm unburned prairie is said to be energy-limited as standing dead plant material and litter reduce usable solar inputs significantly relative to burned prairie (Seastedt and Ramundo 1990). Seastedt (1988) suggests a 1-2 year lag time between foliage production and litter deposition on a burned site. Consequently, large increases in production are followed by litter accumulation about three years postfire (Wright and Bailey 1982). An unburned prairie planting in Wisconsin (planted and left untreated for six years) bore thatch with 40.0 $\pm$ 9.4% cover, 10-40 cm deep, while a site burned in April bore 29.0 $\pm$ 6.0% cover thatch, 2 to 10 cm deep, the following June. Although litter does not release allelochemics (Rice and Parenti 1978), decreases in production with time are widely attributed to a layer of thatch. For example, Curtis and Partch (1950) found that the most important factor affecting flowering of *Andropogon gerardii* was the presence of litter. Burned plots which were recovered with litter were not significantly different from controls in the number of flowering stems, basal area per clump, or average height of flowering stems whereas those which were not recovered following a fire had significantly taller (60%) flowering stems and greater production (six times greater) of flowers than the control.

With litter removal and the release from light limitation, increased plant growth decreases soil moisture for one to two months after fire (Ojima et al. 1990). Soil moisture losses in summer can be greater in tallgrass prairie than under woodland canopy (Kucera 1952). For example, in spring, Minnesota savanna soil moisture was intermediate between a mesic oak woods and xeric prairie (Ovington et al. 1963). Beneath savanna trees in Wisconsin, soil moisture was significantly higher at the 5-30 cm depth than surrounding open savanna during dry periods. It was, however, similar after a period of rain, despite a 33% reduction of rain under tree canopies (Ko and Reich 1993).

Climatic

Drought. Drought, like fire, is an important environmental control of woody species. Transeau (1935) recounted the great drought of 1913-1914 in which thousands of trees along the prairie-forest border died. Albertson and Weaver (1945) documented 30 to 93% mortality of native deciduous trees (*Ulmus* spp., *Fraxinus* spp., *Celtis occidentalis*), 35 to 80% for *Juniperus virginiana* from Oklahoma to Nebraska in hedgerows, timberbelts, and the like under the drought conditions of the 1930s. Hanson (1922) attributed the presence of dead *Quercus macrocarpa* saplings and shrubs (0.3-1.5 m high) in prairie inclusions in Nebraska to a past xerophytic period. Walter (1973) noted that the effects of the 1934-1941 drought were still evident in 1953, in so far as recurrent drought every century was partially responsible for the treeless prairie. Furthermore, woodlands had lower tree mortality rates than open savanna during drought with 21.4 and 6.1% for

Quercus ellipsoidalis and *Quercus macrocarpa*, respectively (Faber-Langendoen and Tester 1993).

Lightning. From the tropical forest to the tundra, lightning is an important source of fire ignition (Wright and Bailey 1982, Trabaud 1987, Hart 1990). Ten thousand wild fires occur in the United States each year, 80% of them in the Rocky Mountain and Pacific coast states (Spurr and Barnes 1992). Lightning without precipitation is less common in the eastern reaches of the tallgrass prairie (Howe 1994). A study in the northern Great Plains mixed-grass prairie (Montana, North Dakota, and South Dakota) determined that 293 lightning-caused fires between 1940 and 1981 averaged 10.8 ha in area, even though most were suppressed (Higgins 1984). Higgins (1984) deduced a fire frequency of 6.0 yr^{-1} 10,000 km^{-2}, with 73% of fire events occurring in July and August. Eighty-eight percent of lightning fires burned 3.64 ha or less and strikes were most common on top of buttes.

Howe (1994) attributed dormant season and spring burns to anthropogenic sources. He further demonstrated that midseason burns were important in increasing the C_3:C_4 ratio, species diversity and community heterogeneity in prairie. When lumping species into flowering guilds, the late-flowering dominants (flowering between July and October) had 47% cover after a mid-July burn in a tallgrass prairie planting in Wisconsin, 92% after a March burn, and 80% on the control while perennials flowering before mid-July showed 46%, 6%, and 17% cover, respectively.

Biotic

Bison. Historically, the bison-grassland relationship was significant. Risser et al. (1981) estimated a pre-Euroamerican settlement population of 50 to 125 million bison (*Bison bison*). Like mid-season burns, these large native ungulates reduce dominance of matrix (graminoid) species. By preferentially grazing graminoids instead of forbs, they enhance species diversity (Collins and

Gibson 1990). Bison were observed three times more frequently on watersheds dominated by C_4 grasses that were burned in spring than in unburned areas (Vinton et al. 1993). Light grazing removed about 15% of aboveground material (Collins and Barber 1985), moderate, 45%, and heavy, 77% (Shariff et al. 1994). Laboratory-simulated herbivory showed that the grass genus *Zea* can compensate for up to 50% of tissue loss (Dyer et al. 1982). And Vickery (1972) (cited in Dyer et al. 1982) found that pasture net primary production under light sheep stocking was 40% higher than without. Bison also created wallows (concave depressions 3-5 m in diameter) which disrupted matrix species (Collins and Barber 1985).

Non-native Plants. Non-native plants such as *Melilotus* spp. (sweetclover), *Alliaria petiolata* (garlic mustard), *Rhamnus* spp. (buckthorn), and *Lonicera* spp. (shrubby honeysuckle) are known to overtake Midwestern forest-opening remnants, leading to the demise of many prairie indigens (Haney and Apfelbaum 1990). Drew (1947) called the presence of the exotic legume *Melilotus* spp. in north-central Missouri prairie "devastating." Likewise, *Melilotus* has threatened to overtake portions of Simpson barrens in southern Illinois, despite periodic fires (A. Biagi, pers. observation). Heitlinger (1975) reported the invasion and takeover of degraded prairies by *Melilotus alba* in the absence of fire disturbance. Anderson and Schwegman (1971) reported a decrease in the exotic vine, *Lonicera japonica* (Japanese honeysuckle), after a spring burn which proceeded after *L. japonica* leaf emergence in a mesic southern Illinois barrens. The prolific Eurasian plant, *Alliaria petiolata* has recently found its way to southern Illinois along railroad right-of-ways (A. Biagi, pers. observation). It is known to form dense thickets in Midwestern savannas, and to green-up early in the season and remain so well into the fall (Packard 1990).

Project Goal

Given the loss of savanna remnants throughout the Midwest, their imperiled nature and novelty to ecological research until very recent times, critical questions concerning the requirements for their persistence, particularly the role of fire, stand to be addressed. Management (cutting and burning) of forest-openings in southern Illinois since a 1988 pre-management reconnaissance has presented the opportunity to compare pre- and post-management and control site vegetation over time. Mapping of site boundaries and transect plotting was done to provide further indication of the effect of fire in the comparison of managed and unmanaged site opening, transition and forest interior vegetation subhabitats.

METHODS

Overall Plan

In 1993, nine of 22 forest-openings examined by Heikens (1991) in 1988 were chosen for study (Figure 1 and Table 1). The study was limited to nine sites because of time and logistical constraints; site selection was based on the factors described below. In the five years following the 1988 vegetation sampling of Heikens (1991), four of the nine sites were managed via prescribed burning and the mechanical removal of woody vegetation. In the present study the sites were resampled in order to determine the effects of management, as well as the nature of changes occurring due to purely natural processes.

Random-plot sampling in 1993 was facilitated by the permanent plot stakes installed by A. Heikens in 1989 at four of the nine study sites. A comparison was made between managed and unmanaged sites in 1993, especially between sites which were of the same substrate and classification type (e.g., barrens, glades), and were close in proximity. Site variables for all nine sites were also compared to their former (1988) condition.

Sampling in 1994 was conducted using north-south transects which spanned the opening area and extended into the forest-interior. Forest-interior vegetation was compared with opening vegetation and north-south gradients were examined for vegetation patterns. In 1994 the dimensions of the nine forest-openings were mapped using canopy cover and dbh limits to distinguish the opening from the forest.

Research permission, as well as records documenting site management history (Table 2), were obtained from respective land owners, viz., the Shawnee National Forest-Forest Service, The Nature Conservancy, and the Illinois Department of Natural Resources (formerly the Illinois

Table 1. Locations of the nine studied forest-openings in southern Illinois.

Site	County	Quadrangle	Township	Range	Section
Managed:					
Brown	Union	Jonesboro	12S	2W	23 (N1/2 NW1/4 NE1/4)
Cave	Johnson	Karnak	13S	3E	28 (SE1/4 NW1/4)
Gibbons	Pope	Herod	11S	7E	4 (S1/2 NW1/4 SW1/4)
Wildcat	Johnson	Karnak	13S	2E	24 (S1/2 NW1/4)
Unmanaged:					
Berryville	Union	Jonesboro	12S	2W	26 (W1/2 NE1/4 NE1/4)
Cedar	Johnson	Lick Creek	11S	2E	31 (N1/2 SW1/4 NE1/4)
Gyp	Pope	Herod	11S	7E	17 (NW1/4 NE1/4)
Pounds	Gallatin	Karbers Ridge	10S	8E	36 (N1/2 SW1/4)
Round	Johnson	Goreville	11S	2E	27 (S1/2 NE1/4 SW1/4)

Berryville=Berryville Shale Glade, Brown=Brown Shale Barrens, Cave=Cave Creek Limestone Glade, Cedar=Cedar Bluff Sandstone Glade, Gibbons=Gibbons Creek Sandstone Barrens, Gyp=Gyp Williams Sandstone Barrens, Pounds=Pounds Hollow Sandstone Glade, Round=Round Bluff Sandstone Glade, Wildcat=Wildcat Bluff Limestone Glade.

Department of Conservation).

Site Descriptions

The study sites are located in southern Illinois on rolling topography known as the Shawnee Hills (Mohlenbrock 1982). The average growing season is 200 days in length, with a continental (cool winter, warm summer) climate (Mohlenbrock 1982). All nine forest-opening study sites are on slopes of 20 to 50% inclination (Heikens 1991) at elevations of 122 to 229 m. In fact, four are delimited by sheer bluffs and two others by ledges or steep slopes. All openings are irregular in outline and have an aspect of south or west.

As described by Heikens (1991), the glade type forest-opening has >5% cover of exposed rock, soil depth <10 cm, and canopy cover <80%. Conversely, barrens have <5% rock cover and soil is 10 to 40 cm in depth (Heikens 1991). In general, forest-opening canopy cover does not exceed 80%, and Heikens (1991) suggests that a canopy cover of 50% is probably the best

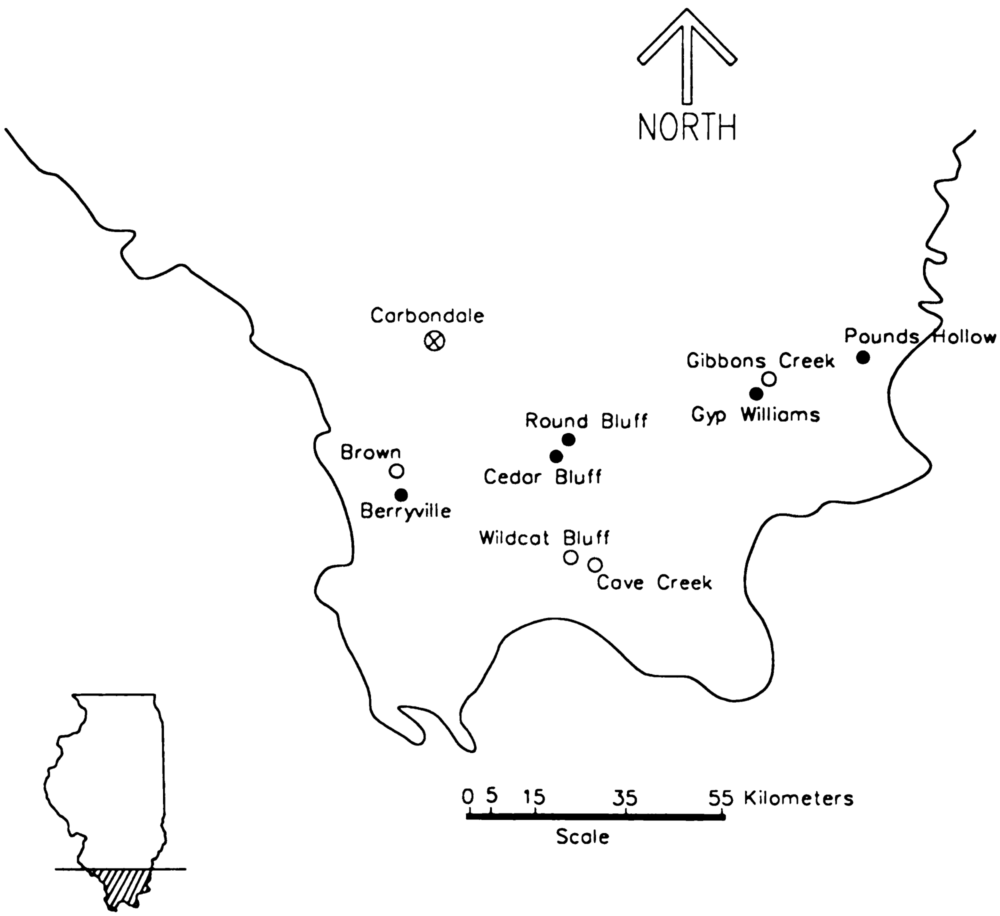


Figure 1. Nine study sites and Carbondale, in southern Illinois.

○ –Managed sites, ● –Unmanaged sites.

Table 2. Site ownership and management history. This information was obtained from the following sources: the Illinois Department of Natural Resources Prescribed Burning Report (K.A. West, unpublished data) and the Nature Conservancy (M.D. Hutchison, unpublished data).

Site	Ownership	Burn Date	% Area Burned	Fire Intensity	Air Temp.	% Rel. Humidity	Wind Dir.,Speed	Flame Length	Rate of Spread	Other Management (Date)
Managed sites:										
BRN	IDNR	3/2/90	85%	cool	10°C	52%	NE, 3 m/s	NA	NA	Tree cutting at edge (9/17/93)
CAV	IDNR	2/19/86	40%	cool	6°C	70%	N-NW, 4 m/s	1 m	0.5 m/s	Tree cutting at edge (12/3/86)
		3/14/89	85%	moderate	18°C	70%	S, 5 m/s	1-2 m	2 m/min.	
GIB	TNC	11/21/89	NA	NA	NA	NA	NA	NA	NA	
		3/16/94	NA	NA	NA	NA	NA	NA	NA	
WLC	IDNR	3/18/82	90%	mod.-hot	29°C	48%	S, 1 m/s	1-8+ m	2 m/min.	
		3/7/88	100%	hot	11°C	65%	S-SW, 4 m/s	1-4 m	2 m/min.	
		10/30/90	80%	moderate	24°C	45%	S-SW, 12 m/s	2 m	12 m/min.	
Unmanaged sites:										
BVL	IDNR									
CDR	USFS									
GYP	USFS									
PDS	USFS									
RND	IDNR									

IDNR=Illinois Department of Natural Resources, TNC=The Nature Conservancy, USFS=United States Forest Service
NA=Not available
BVL=Berryville Shale Glade, BRN=Brown Shale Barrens, CAV=Cave Creek Limestone Glade, CDR=Cedar Bluff Sandstone Glade, GIB=Gibbons Creek Sandstone Barrens, GYP=Gyp Williams Sandstone Barrens, PDS=Pounds Hollow Sandstone Glade, RND=Round Bluff Sandstone Glade, WLC=Wildcat Bluff Limestone Glade

threshold for defining savannas and barrens. Glades and barrens are further classified by substrate and associated vegetation.

Six sites were glades and three were barrens occurring on shale, limestone, and sandstone substrates. Two glades (Cave Creek Limestone Glade and Wildcat Bluff Limestone Glade) and two barrens (Brown Shale Barrens and Gibbons Creek Sandstone Barrens) had been managed. Berryville Shale Glade (unmanaged) and Brown Shale Barrens (managed) were selected for study due to the extreme rarity of the occurrence of forest-openings on shale substrate. Gibbons Sandstone Barrens (managed) and Gyp Williams Sandstone Barrens (unmanaged) occur within several kilometers of each other and were selected in order to compare the effects of management in 1993 on proximate forest-openings of the same classification and substrate. Cave Creek Limestone Glade (managed) and Wildcat Bluff Limestone Glade (managed) were selected for their high plant-species richness and pristine quality and for the comparison of two nearby managed limestone glades. Similarly, Cedar Bluff Sandstone Glade (unmanaged) and Round Bluff Sandstone Glade (unmanaged) allowed the comparison of two nearby unmanaged sites of the same substrate and classification. Pounds Hollow Sandstone Glade (unmanaged) was chosen because of its distinctiveness in having expansive rock shelves.

The managed sites were open and dominated by the herbaceous vegetation layer. At the unmanaged glades, Round Bluff Sandstone Glade and Cedar Bluff Sandstone Glade, young woods or "doghair" stands of saplings, dense and close growth with heavy litter and sparse understory, persisted at the periphery of the open rock pavement. However, Pounds Hollow Sandstone Glade and Berryville Shale Glade, also unmanaged glades, had gradual transitions from openings to ericaceous shrubs to forest. Another unmanaged site, Gyp Williams Sandstone Barrens, was primarily open-forest with scattered patches of *Schizachyrium scoparium* and *Sorghastrum nutans*.

Management techniques that have been applied at the treated sites include prescribed burning, cutting and manual removal of woody seedlings, shrubs, and saplings, and cutting and girdling of trees. The majority of tree removal occurred within 15 to 20 m of the opening and residual stump height was usually <30 cm. An herbicide, such as Roundup, was applied to stumps of deciduous trees. The woody species targeted for removal, such as *Acer saccharum*, *Fraxinus americana*, *Quercus alba*, and *Ulmus* spp. typified mesophytic habitats. Characteristic forest-opening species such as *Quercus stellata*, *Quercus prinoides* var. *acuminata*, and *Vaccinium arboreum* were usually not removed from the sites. No site had received more than three management treatments, future plans of the respective land stewards for the forest-openings will continue to include cutting and burning. The management interval will primarily involve constraints due to human resources (personnel, time, finances) and the successional status of the sites.

Prescribed burns required about ten to twelve trained individuals who used a rake or leaf blower to clear a fire break around the desired area. A backfire (a fire started to put out an oncoming fire) was then ignited, shortly after which the forest-opening was ignited. The burn superintendent notes the following information pertaining to the burn process: ignition time, "mop up" time, acreage burned, percent of area burned, description of fire intensity (cool, moderate, hot), average rate of spread of fire, flame length, containment difficulty, air temperature, relative humidity, wind direction, wind velocity, days since last rain, fine fuel moisture, burning index, burn objective, deviations from burn plan, and date of succeeding evaluation.

Managed Sites

The managed sites, their names and important prescribed burn information are described in Table 2.

Brown Shale Barrens. Brown Shale Barrens-managed (hereafter referred to as Brown-MGD) is situated on the south side of a 152-m hill and is truncated on the south by a near-vertical drop-off to a stream (Figure 2). The opening is in the midst of oak-hickory woodland and the most important barrens species are *Helianthus divaricatus*, *Dichanthelium laxiflorum*, and *Schizachyrium scoparium* with an occasional oak, *Quercus stellata* or *Q. marilandica* , and *Vaccinium arboreum*. This site also harbors uncommon species, e.g., *Muhlenbergia capillaris* and *Polygala verticillata*.

In March, 1990 the site was burned by the Illinois Department of Natural Resources (IDNR) and in September, 1993 the IDNR and members of the Southern Illinois Native Plant Society selectively cut woody seedlings, saplings, and trees at the northern and southern transitional regions of the site. Targeted genera included *Ulmus* spp., *Acer* spp., and *Fraxinus* sp. less than 25 years old (Heikens et al. 1994).

Brown-MGD is a relatively pristine barrens. Heikens (1991) noted that, "Brown barrens is perhaps the best example of a barrens in Illinois." As early as 1977, the Illinois Natural Areas Inventory noted, "Little past use is evident" and "There are no signs of stumps or grazing." Also, the dimensions of the site given at that time, 30 by 150 m, are nearly identical to those reported after methodical measurement in 1994.

Cave Creek Limestone Glade. Cave Creek Limestone Glade-managed (hereafter referred to as Cave-MGD) is a species-rich forest-opening which has had selective tree removal in the opening and transitional areas as well as stump herbicide treatments and prescribed burns to control woody and exotic vegetation (Figure 3). In February, 1986, 40% of the glade area was burned and again in March 1989, 85% of the area burned. In December, 1986, cutting took place, primarily in the transition zone, and stumps of deciduous species were treated with Roundup herbicide.

Brickellia eupatorioides, *Schizachyrium scoparium*, and *Silphium terebinthinaceum* are the three most important herbs in the opening with sporadic gnarled *Quercus shumardii*, *Q. prinoides* var. *acuminata* and *Q. stellata*. Other common species include *Sorghastrum nutans*, *Echinacea pallida*, *Bouteloua curtipendula*, and *Aster oblongifolius*. *Salvia azurea* var.

grandiflora, *Camassia scillioides*, *Carex meadii*, *Clematis pitcheri*, and *Onosmodium hispidissimum* are some of the notable uncommon species which occur there.

Cave-MGD is delimited in the south by a primary road just north of which is a telephone line corridor. These right-of-ways have exposed the area to a suite of exotic herbs and vines. Among those which now occur in the glade proper are *Campsis radicans*, *Festuca arundinacea*, and *Melilotus alba*.

Gibbons Creek Sandstone Barrens. Gibbons Creek Sandstone Barrens-managed (hereafter referred to as Gibbons-MGD) was burned in November, 1989 and March, 1994. It is located in the midst of oak-hickory forest and the opening is co-dominated by the herbs *Schizachyrium scoparium*, *Helianthus divaricatus*, *Dichanthelium laxiflorum* and the woody species, *Quercus* spp., *Carya* spp., and *Ulmus alata*. *Lactuca hirsuta* and *Cirsium carolinianum*, uncommon forbs of dry woods, also occur there.

Wildcat Bluff Limestone Glade. Wildcat Bluff Limestone Glade-managed (hereafter referred to as Wildcat-MGD) is a high-quality site, harboring numerous prairie indigens. It received prescribed burns in March, 1982, March, 1988, and October, 1990. The 1990 burn was reported to have accomplished the desired objective: "Fire resulted in presumed mortality of sugar maple saplings, elm, other mesophytic species which were threatening to dominate the understory...and overshadow barrens vegetation openings (K.A. West 1990, unpublished data)."

The most important species of the opening are *Silphium terebinthinaceum*, *Helianthus divaricatus*, *Verbesina virginica*, *Quercus prinoides* var. *acuminata*, *Quercus shumardii* and *Quercus stellata*. There is, however, a notable paucity of trees and saplings in the open area. There is also a distinct moisture gradient at Wildcat-MGD. The eastern edge of the opening is rocky and dry while the western is low and mesic.

Unmanaged Sites

Berryville Shale Glade. Berryville Shale Glade-unmanaged (hereafter referred to as Berryville-UMG) is a remote undisturbed forest-opening with a highly unstable, gravel-like substrate. The glade area is open with an occasional gnarled *Quercus stellata* or *Q. marilandica* and a carpet-like growth of mosses and lichens. The most important species of the opening are *Danthonia spicata*, bryophytes, lichens, *Quercus stellata*, *Q. marilandica* and *Vaccinium arboreum*.

Cedar Bluff Sandstone Glade. The most successionally advanced forest-opening site, Cedar Bluff Sandstone Glade-unmanaged (hereafter referred to as Cedar-UMG), has a dense overstory layer in which *Juniperus virginiana*, *Ulmus alata*, *Quercus stellata*, and *Fraxinus americana* are the most important tree species (Figure 5). The glade is also heavily impacted by hikers, campers, and horses. During the growing season, vegetation is stamped down into footpaths and, on the eastern end of the glade, bare patches are created by tent use. A horse-riding trail leading to the site has resulted in a gully over four feet deep. The most important herbs at this site are *Toxicodendron radicans*, *Danthonia spicata*, and *Parthenocissus quinquefolia*. Although 19 exotic species occur here, most occur as isolated individuals or in small clumps.

Gyp Williams Sandstone Barrens. A remote forest-opening located atop a steep 183-m hill, Gyp Williams Sandstone Barrens-unmanaged (hereafter referred to as Gyp-UMG) is highly integrated with the surrounding dry oak-hickory forest (Figure 6). Remnant patches of exposed rock slabs and prairie plants like *Lithospermum canescens*, *Sorghastrum nutans*, or *Manfreda virginica* are few, isolated, and small. At the northern and southern ends of the barrens "wolf trees," or large trees with a gnarled, open-grown appearance, occur amidst a younger, even-aged woodland.

Pounds Hollow Sandstone Glade. A highly trafficked site, Pounds Hollow Sandstone Glade-unmanaged (hereafter referred to as Pounds-UMG), is an attractive look-out area as it is flat and unobstructed. The most important species of the opening are xerophytic *Carex* spp., *Smilax bona-nox*, *Dichanthelium laxiflorum*, and *Juniperus virginiana*. However, due to the mottled appearance of the rocks, it appears that extensive lichen cover may have been destroyed. Also, the glade has a locally exotic tree, *Pinus echinata*, which has successfully established in crevices in the glade proper and a dense growth of the exotic vine *Lonicera japonica* at the eastern site edge.

Round Bluff Sandstone Glade. Round Bluff Sandstone Glade-unmanaged (hereafter referred to as Round-UMG) is a xeric, east-west escarpment where plant growth is confined to cracks and shallow pans of soil (Figure 7). Annuals, succulents, and other xerophytic species are common. The most important species in the opening are *Schizachyrium scoparium*, *Diodia teres*, and *Carex* spp. Important trees of the opening include *Juniperus virginiana*, *Ulmus alata*, and *Quercus stellata*. Other locally abundant, but relatively uncommon herbs are *Opuntia humifusa*, *Talinum parviflorum*, and *Trichostema dichotoma*.

Sampling Methods

Vegetation Composition

In order to reevaluate and compare sites originally surveyed by Heikens (1991), effort was made to sample in a manner consistent with hers. Therefore, as in Heikens (1991), 15-30 plots were selected randomly from the "opening" area of each site via a grid arranged with 8.5 m between plot centers (Table 3). Permanent plots were preferentially used where available (Table 3). Plots were circular, and 50 m^2 (radius=3.99 m) for woody plants (tree seedlings, shrubs and saplings and trees) and rock exposed at the soil surface. Unlike Heikens (1991), four nested 1-m^2 plots placed at each cardinal direction were used for sampling herbaceous species. Smaller herbaceous plots were used to facilitate the observation of small and sparse herbs as well as to improve the accuracy of herb cover estimation. Also, canopy cover was estimated for trees rooted in the plots, not plot aerial canopy cover, as in Heikens (1991) (A. Heikens, pers. communication). Coverage estimates included tree seedlings, shrubs/saplings, and trees.

Cover classes were according to Menges et al. (1987): 0-1, 2-7, 8-25, 26-50, 51-75, 76-93, and 94-100%. In addition, an eighth class, "trace," was used as recommended by Heikens (pers. communication). Percent-cover estimation followed Daubenmire (1959) in which the sum of

Figure 2. Brown Shale Barrens-Managed in May, 1993. This site is located in the midst of oak-hickory woodland and may be the best example of a barrens in Illinois (Heikens 1991).

Figure 3. Cave Creek Limestone Glade-Managed in August, 1993.

Figure 4. Berryville Shale Glade-Unmanaged in August, 1993.

Figure 5. Cedar Bluff Sandstone Glade-Unmanaged in June, 1993. The successional advancement at this site is evident with the dense overstory, primarily *Juniperus virginiana*.

Figure 6. Gyp Williams Sandstone Barrens-Unmanaged in July, 1993. This barrens is highly integrated with the surrounding oak-hickory forest with remnant patches of prairie species, usually about 5 m^2, dominated by *Schizachyrium scoparium* and *Sorghastrum nutans*.

Figure 7. Round Bluff Sandstone Glade-Unmanaged in July, 1993. At this escarpment plant growth is confined to cracks and shallow pans of soil.


2
5
3
6
4
7

Table 3. Number of 50-m^2 plots used in 1988 and 1993 vegetation sampling. The number of permanent plots relocated in 1994 is also listed.

Site	**No. of plots:** **1988**	**1993**	**No. permanent plots used, 1993**	**No. permanent plots relocated, 1994**
Berryville	23	28	11	19
Brown	30	30	27	30
Cave	27	27	9	14
Cedar	30	30	*	*
Gibbons	15	15	*	*
Gyp	30	30	*	*
Pounds	30	30	*	*
Round	23	23	*	*
Wildcat	18	18	1	1

*Indicates that no permanent plots were installed. Berryville=Berryville Shale Glade, Brown=Brown Shale Barrens, Cave=Cave Creek Limestone Glade, Cedar=Cedar Bluff Sandstone Glade, Gibbons=Gibbons Creek Sandstone Barrens, Gyp=Gyp Williams Sandstone Barrens, Pounds=Pounds Hollow Sandstone Glade, Round=Round Bluff Sandstone Glade, Wildcat=Wildcat Bluff Limestone Glade.

the values for cover in a plot may exceed 100% when aboveground parts of neighboring plants overlap.

Species lists were assembled for each site over the course of the 1993 and 1994 field seasons including an early spring reconnaissance in March 1994. Visitation dates are provided in Table 4. Floristic surveys documented vascular plants found in the "opening" area (<75% canopy cover and <6.6 cm dbh) and surrounding transitional areas to within 8.5 m of the opening as permanent plots at Berryville-UMG, Brown-MGD and Cave-MGD occurred in this area. Therefore, since "opening" parameters were not specifically defined prior to 1994, permanent plots were used as a partial guide to the area included in the floristic survey. However, Heikens's surveys (1991) included vascular (and nonvascular) plants in the openings, but not in the transitional areas, roadsides, etc. (A. Heikens, pers. communication). A complete species list for each site is given in Appendix A; nomenclature follows Mohlenbrock (1986) for vegetation, and Heikens (1991) for forest-opening classification. Perennial plants which deposit yearly lignified

Table 4. Site visitation dates, 1993 and 1994.

BVL	BRN	CAV	CDR	GIB	GYP	PDS	RND	WLC
6-5-93	6-12-93	8-1-93	6-23-93	5-30-93	7-16-93	7-24-93	7-5-93	7-10-93
6-11-93	6-19-93	8-19-93	6-26-93	5-31-93	7-17-93	7-25-93	7-11-93	7-11-93
6-12-93	6-20-93	8-20-93	6-27-93	6-3-93	7-18-93	4-9-94	7-15-93	8-22-93
6-19-93	8-22-93	8-21-93	4-9-94	6-4-93	7-22-93	5-27-94	4-9-94	4-9-94
8-22-93	4-9-94	4-9-94	7-30-94	8-20-93	7-29-93	5-28-94	7-23-94	7-14-94
4-9-94	8-6-94	5-20-94	7-31-94	4-9-94	4-9-94	8-7-94	7-24-94	7-16-94
6-10-94	8-8-94	6-17-94		5-20-94	8-10-94			7-17-94
6-11-94	8-11-94	6-18-94		6-12-94	8-12-94			7-22-94
6-12-94		6-19-94		6-17-94				
6-17-94		6-26-94		8-14-94				
		6-30-94		8-15-94				
				8-16-94				
				8-17-94				

BVL=Berryville Shale Glade, BRN=Brown Shale Barrens, CAV=Cave Creek Limestone Glade, CDR=Cedar Bluff Sandstone Glade, GIB=Gibbons Creek Sandstone Barrens, GYP=Gyp Williams Sandstone Barrens, PDS=Pounds Hollow Sandstone Glade, RND=Round Bluff Sandstone Glade, WLC=Wildcat Bluff Limestone Glade.

growth layers (i.e., woody taxa) are listed first, although a small portion of these which were characteristically decumbent, trailing, or low in stature were sampled and analyzed with the herbaceous taxa as indicated. When encountered during plot sampling, the number of plots of occurrence, dominance and species relative importance are given. An abbreviation denoting Illinois-threatened and Illinois-endangered taxa is given. No federally listed taxa were located.

A dual collection of voucher specimens was made for two sites located on USDA-Forest Service land, Cedar-UMG and Gyp-UMG. Plant collection on Nature Preserves (Illinois Department of Natural Resources) and Nature Conservancy land, as well as a US Forest Service designated Natural Area (i.e., Pounds-UMG), was prohibited. Sets of voucher specimens for Cedar-UMG and Gyp-UMG were donated to the Shawnee National Forest-Forest Service and the Beal-Darlington Herbarium at Michigan State University. Specimens for Cedar-UMG include personal collection numbers 1906-2030, 2693-2697, 2839-2903, and for Gyp-UMG, 2128-2246, 2692, 2698, 2699 and 2904-2954.

Vegetation Spatial Patterns

In 1994 up to five belt transects, oriented north-south, were systematically placed in each forest-opening at least 8.5 m apart (Table 5). The 5-m-wide transects were continuous and their length extended 15 m beyond the point at which at least 75% canopy cover was reached and a tree size-class of $\geq$6.6 cm diameter at breast height (dbh) attained, unless the transect was otherwise precluded by a road, stream, or bluff edge. No transect was placed within 15 m of an east-west edge with the aforementioned tree size and canopy cover boundaries. Therefore, the length of the east-west axis as well as impassable topography (e.g., a bluff edge) of each site constrained the number of transects. At Gyp-UMG, however, no boundaries of the above definition could be designated at any of the cardinal directions due to a homogeneous canopy cover of at least 80%. Therefore, a threshold boundary of 80% alone with no dbh class was used in transect layout at this site.

Table 5. Summary of 1994 plot-sampling layout. The subsample transect numbers correspond to those depicted in Appendix B, Figures 8a-8i.

Site	**No. of Transects**	**Subsample Transect**	**Total No. of Plots: FI-N**	**TS-N**	**OP**	**TS-S**	**FI-S**
Berryville	2	2	4	4	13	4	4
Brown	5	3	10	8	13	5	4
Cave	4	3	8	8	55	6	6
Cedar	5	3	16	6	0	0	0
Gibbons	4	3	6	6	20	6	6
Gyp	1	1	NA	NA	NA	NA	NA
Pounds*	4	NA	5	7	9	6	4
Round	5	4	10	9	4	0	0
Wildcat	3	2	6	6	58	6	6

*Woody species sampling based on two adjacent 5 x 5-m plots.
NA=Not applicable
FI-N=Forest Interior-North, TS-N=Transition Zone-North, OP=Opening, TS-S=Transition Zone-South, FI-S=Forest Interior-South
Berryville=Berryville Shale Glade, Brown=Brown Shale Barrens, Cave=Cave Creek Limestone Glade, Cedar=Cedar Bluff Sandstone Glade, Gibbons=Gibbons Creek Sandstone Barrens, Gyp=Gyp Williams Sandstone Barrens, Pounds=Pounds Hollow Sandstone Glade, Round=Round Bluff Sandstone Glade, Wildcat=Wildcat Bluff Limestone Glade.

The transect was divided into 5 x 5-m increments in which trees, shrubs/saplings, and woody seedlings were identified to species, counted, and assigned to size classes as follows: trees ($\geq$6.6 cm dbh), shrubs/saplings ($\geq$2.54 to <6.6 cm dbh), and seedlings (<2.54-cm dbh). Clumps of woody seedlings were counted as part of a single individual when aboveground connections were obvious (e.g., coppicing). Conversely, individual shoots of clonal species (e.g., *Rhus aromatica*) and species with multiple sprouts found growing in clumps, while potentially connected belowground, were not explored as such and were therefore tallied singly.

Tree dbh was recorded in all transects, and in one transect per site, tree crown diameter (the average of perpendicular cardinal measurements), and height class were also obtained. Height classes were assigned as follows: 1.5-4.9 m, 5-9.9 m, 10-24.9 m, >25 m. Transects in which this additional data on trees and soil were taken are listed under "subsample transect" in Table 5; the transect numbers correspond to those depicted in Appendix B, Figures 8a-8i. At Brown-MGD, density and diameter of stumps at ground level were also recorded in the subsample transect.

Herbaceous vegetation, bryophytes and lichens were sampled in noncontiguous 1-m^2 nested plots placed interior to the middle of the 5 m^2 western transect edge. Dominance was recorded using the cover classes according to Menges et al. (1987). Exposed rock was measured in the same way as herbaceous vegetation at seven of nine forest-openings.

In 1994 all nine study sites were mapped using the previously described "opening" boundaries (Appendix B, Figures 8a-8i). Site maps are arranged on grids with 5 m between vertices. Scale and orientation is provided in the legend. Heikens's (1991) permanent plots, marker trees, and other significant features are provided for orientation. The points marking the perimeter of the opening (estimated as the point at which a canopy cover of $\geq$75% and a tree size of $\geq$6.6 cm dbh are reached) are represented with "XXX." Where no estimation symbols or "established" bounds are given, the connections were interpolated. Significant features including bluff edges, rock shelves, thickets, footpaths, fences, roads and streams were originally located relative to 1-7 arbitrary east-west baselines with a compass accurate to one degree. The maps are depicted in plan view (from above looking down) and were generated using AutoCAD, Version 13.

Soil Measurements

In 1993, following Heikens (1991), soil probes from five randomly chosen locations at each site were combined, dried, mixed, and then sent to A & L Laboratory, Memphis, Tennessee where the following analyses were performed: pH, buffer pH, estimated nitrogen release, percent organic matter, cation exchange capacity, texture (percent sand, silt, and clay), and parts per million of phosphorus, potassium, calcium, magnesium, manganese, and zinc. The probes extended to the maximum depth penetrable (≤32 cm in 1993). Soil depth was measured for each probe.

In 1994, samples were drawn from the mid-opening, forest-edge boundary and forest-interior (15 m beyond forest-edge boundary) of the subsample transect for eight of the nine forest-openings. Samples were immediately sealed in air-tight containers and subsequently weighed, dried, then reweighed to determine percent soil moisture. Soil depth was again measured for the first five probes.

Climatic Information

The following climatic information was obtained from the Midwestern Climate Center, Champaign, Illinois for Carbondale, Illinois (≤90 km from the study sites), for the years 1910 through 1994: monthly precipitation (with water equivalent for snow included), monthly snowfall and monthly average temperature.

Analytical Methods

Vegetation composition in 1993 was assessed in a variety of ways. As in Heikens (1991), the midpoints of the species cover classes were used for calculations. The "trace" cover class received a value of 0.1. Dominance consisted of the total of areal coverage values divided by the area sampled (Cox 1990). Relative Importance (RI) was computed by dividing the sum of relative dominance or relative density and relative frequency by two then multiplying by 100 (dividing by 2 provided an average value for, e.g., relative dominance and relative frequency). RI was calculated separately for woody and herbaceous taxa. RI was then used as a weight in a physiognomic classification scheme by Raunkaier (1934) (cited in Smith 1966) in which species were placed into one of five nominal groups according to the position of the perennating bud. A definition of each life form catagory is given in Table 6. Bud position was determined by referring to floristic manuals, i.e., Gray's Manual of Botany (Fernald 1950), Manual of the Vascular Plants of the Northeastern United States and Canada (Gleason and Cronquist 1991), and Flora of the Great Plains (Barkley et al. 1986), or, in a few instances, by inspection of numerous herbarium specimens.

Table 6. Raunkaier's life form categories.

Life Form	**Description***
Therophyte	Annuals, completing their life cycle in one season.
Geophyte	Buds buried belowground, on a bulb or rhizome.
Hemicryptophyte	Perennial shoots or buds near ground level, often covered with litter.
Chamaephyte	Perennial shoots or buds above ground level up to 25 cm.
Phanerophyte	Perennial buds over 25 cm above ground level.

*Descriptions according to Raunkaier (1934), cited in Smith (1966).

The cumulative species list of herbs for each site was evaluated with Raunkaier's life form categories, as was the sampling data of 1988 and 1993, in which species were assigned to a life form category and then summed by RI. For data of 1988, 1993 and 1994, herb families were also summed by RI. Ferns (members of Pteridophyta) were grouped for comparison with other vascular plant families.

All herbaceous taxa for a site were classified by life history (annual, biennial, perennial). Similarly, each herbaceous species was classified by life form: grass, forb (an herbaceous dicot), legume and exotic. Note that the first two categories are mutually exclusive whereas the legume and exotic categories are not. A single species may belong to as many as three of four categories. For example, *Kummerowia striata* is an exotic legume which is also a forb. This classification scheme also excludes certain groups such as ferns and sedges.

Herbs were also placed in up to four of nine habitat types. Table 7 provides a summary of the habitats derived from Mohlenbrock (1986). Again, each species was given an equal "vote," receiving a maximum value of one. A low-fidelity species occurring in three habitats, for example, would contribute the value one-third to each habitat type. Species values for each habitat type were then summed. Habitat and life history summaries are based upon the cumulative species list for each site.

Woody taxa in 1988 and 1993 were grouped according to their shade tolerance, viz., tolerant, intermediate, and intolerant, and then group RI values were tallied. Shade tolerance for each species was preferentially assigned using Silvics of North America, Volumes I and II (Burns and Honkala 1990) when possible, then Michigan Trees (Barnes and Wagner 1981), and finally using habitat descriptions in Guide to the Vascular Flora of Illinois (Mohlenbrock 1986).

Comparison of site similarity between 1988 and 1993, and between sites in 1993, was calculated using Jaccard's index. Comparisons of management responses were made with the four managed sites, Brown-MGD, Cave-MGD, Gibbons-MGD, and Wildcat-MGD throughout.

Site sampling data for 1988 and 1993 were not normally distributed, nor could they be transformed to approximate the normal distribution. Therefore, analyses of a site between years were made using the Mann-Whitney U test via the Statistical Package for the Social Sciences (SPSS), Version 6.1. Within-year statistical comparisons were also made between proximate sites

Table 7. Habitat categories and descriptions used to characterize herbaceous vegetation.

Habitat	Descriptions*
Bluff	Includes exposed slopes, cliffs, outcroppings, and ridges.
Disturbed	Includes disturbed soil, disturbed places, and roadsides.
Edge	Includes edges of woods and edges of fields.
Open	Includes open areas, openings, clearings, fields, pastures, and meadows.
Open Woods	Includes woodlands with continuous canopies, usually not >85% cover.
Prairie	Includes relatively undisturbed native grasslands which are not typically flooded.
Lowland	Includes streambanks, wet areas, wetlands, swamps, low ground, and floodplains.
Thicket	Includes any area characterized by dense woody growth, usually <3 m high.
Woods	Includes woods which are moist, rich, dry, rocky, flat, and upland.

*Descriptions according to Mohlenbrock (1986).

with the same substrate and forest-opening classification with 1993 data. Poaceae, Asteraceae, and exposed rock cover were analyzed in this way. A correlation analysis for total herb number and site opening size was performed using Excel, Version 5.0.

Floristic spatial patterns in the 1994 data, if present, were assessed by dividing the transects into five sections or subhabitats, forest interior-north, transition zone-north, opening, transition zone-south and forest interior-south. Plots for the transition zones were selected relative to the forest boundary, one plot interior and one exterior, for all sites. Forest interior plots were the remaining two plots, distal to the forest-opening.

Appendix C gives RI by subhabitat for woody and herbaceous species located in the 1994 plot sampling. RI was also used to weight herb species classed by Raunkaier's life forms and to weight shade tolerance categories for woody seedlings, shrub/saplings, and trees. No subhabitats were assigned for Gyp-UMG in which no continuous open area was present.

Shannon and Simpson diversity indices were calculated for herbs within each subhabitat. Species-area curves were used to ensure that comparisons were conducted using an adequate proportion of herb species inhabiting each subhabitat.

Data for 1994 were not normally distributed, despite transformation, and therefore, analysis was pursued using the Kruskal-Wallis test via SPSS. Seedling density and percent cover for Poaceae, Asteraceae, and exposed rock were compared statistically. Subhabitats with less than five plots were omitted from analysis.

RESULTS

Vegetation Composition

Herb Species Composition

Belonging to 88 families, 472 plant species were identified in this study. The largest families, the Asteraceae, Poaceae, Fabaceae, Rosaceae, and Cyperaceae comprised 68, 60, 28, 24, and 22 species, respectively, out of the 375 herb taxa encountered across all sites. The average number of species per site increased from 68 in 1988 to 192 in 1993-94, representing an increase of 182% (Table 8); however, given that 1988 surveys occurred in the opening while the 1993-94 surveys occurred in the opening and transitional area, one might expect an increase in total species number. Unmanaged sites averaged an increase of 154.5% in total species number between sampling years while managed sites increased 223.2%. The difference in the total number of herb species between years ranged from 63 (at Pounds-UMG) to 140 (at Cave-MGD). The average difference for woody species was 32. Cave-MGD had the highest species richness in 1994 with 261 species, while Pounds-UMG had the lowest, with 149.

In an effort to facilitate assessment of herb cover and the observation of inconspicuous herb species, four nested 1-m^2 plots were used in 1994. When mean species richness in the 1988, 50-m^2 plots were compared to that of the mean found in four nested 1-m^2 plots, herb number increased 38.1% (4.5 species) (Table 9). Species richness increase between sampling periods was greater for unmanaged sites (58.4%) than for managed sites (23.5%). More species were found at managed sites in both years. However, the difference between managed and unmanaged sites was greater in 1988 (6.4 species), before treatment, than afterwards (4.8 species).

The Poaceae and Asteraceae held the top two positions of relative importance (RI) for six sites in 1988 and 1993 (Table 10). The managed sites averaged a 0.7% increase in Asteraceae RI

Table 8. The total number of species in the overall site and the total number of herb species within plots in 1988 and 1993-94. Overall site surveys in 1988 included the opening area only. In 1993-94 overall surveys included the opening and surrounding 15 m. Values for 1988 are derived from Heikens (1991).

	Site	Herbs 1988	Herbs 1993-94	Woody 1988	Woody 1993-94	Total 1988	Total 1993-94	Total # Herbs in Plots 1993	Total # Herbs in Plots 1988
Managed									
	Brown Shale Barrens	51	159	19	56	70	215	33	66
	Cave Creek Limestone Glade	50	190	26	71	76	261	33	93
	Gibbons Creek Sandstone Barrens	41	178	18	55	59	233	27	75
	Wildcat Bluff Limestone Glade	50	128	21	54	71	182	37	63
	Mean ± 1 SE (managed sites)	48 ± 2.3	164 ± 13.5	21 ± 1.8	59 ± 4.0	69 ± 3.6	223 ± 16.6	33 ± 4.1	74 ± 6.8
Unman.									
	Berryville Shale Glade	48	121	29	52	77	173	39	52
	Cedar Bluff Sandstone Glade	36	129	19	58	56	187	20	74
	Gyp Williams Sandstone Barrens	56	125	23	50	79	175	38	64
	Pounds Hollow Sandstone Glade	49	112	18	37	67	149	30	48
	Round Bluff Sandstone Glade	32	110	21	47	53	157	12	60
	Mean ± 1 SE (unmanaged sites)	44 ± 4.3	119 ± 3.7	22 ± 4.4	49 ± 3.5	66 ± 5.3	168 ± 6.8	28 ± 5.2	60 ± 4.6
All Sites	Mean ± 1 SE	46 ± 2.5	139 ± 9.7	22 ± 1.3	53 ± 3.0	68 ± 3.2	192 ± 12.3	30 ± 2.9	66 ± 4.5

Table 9. Mean (± 1 SE) number of herb species per m^2 in 1993, per 50 m^2 in 1988 and the average of four nested 1-m^2 plots in 1993. Values for 1988 are derived from Heikens (1991).

	Site	N	1988 (per 50 m^2)	N	1993 (per m^2)	N	1993 (nested 4 m^2)
Managed							
	Brown Shale Barrens	30	13.0 ± 0.5	120	9.9 ± 0.3	30	17.7 ± 0.8
	Cave Creek Limestone Glade	27	14.9 ± 0.6	108	11.1 ± 0.3	27	22.3 ± 1.0
	Gibbons Creek Sandstone Barrens	15	11.3 ± 0.4	60	8.7 ± 0.5	15	15.9 ± 1.6
	Wildcat Bluff Limestone Glade	18	22.1 ± 0.7	72	10.8 ± 0.3	18	19.7 ± 1.0
	Mean (managed sites)		15.3 ± 2.4		10.1 ± 0.5		18.9 ± 1.4
Unman.							
	Berryville Shale Glade	23	9.0 ± 1.1	112	5.4 ± 0.3	28	9.9 ± 0.8
	Cedar Bluff Sandstone Glade	30	6.7 ± 0.6	120	9.2 ± 0.3	30	19.3 ± 0.9
	Gyp Williams Sandstone Barrens	30	14.4 ± 0.4	120	9.1 ± 0.3	30	19.6 ± 0.9
	Pounds Hollow Sandstone Glade	30	9.5 ± 0.8	120	2.7 ± 0.3	30	7.4 ± 1.1
	Round Bluff Sandstone Glade	23	5.3 ± 0.4	92	6.2 ± 0.3	23	14.5 ± 0.9
	Mean (unmanaged sites)		8.9 ± 1.6		6.5 ± 1.2		14.1 ± 2.4
All Sites	Mean		11.8 ± 1.7		8.1 ± 0.9		16.3 ± 1.6

Table 10. Relative importance (%) of the three most important herb families in 1988 and 1993. Values for 1988 are derived from Heikens (1991).

Site	1988		1993	
Berryville Shale Glade-unmanaged	Asteraceae	23.9	Poaceae	31.3
	Poaceae	21.3	Asteraceae	17.0
	Fabaceae	16.3	Lamiaceae	15.2
Brown Shale Barrens-managed	Poaceae	50.9	Poaceae	37.9
	Asteraceae	23.7	Asteraceae	22.7
	Fabaceae	6.3	Fabaceae	7.9
Cave Creek Limestone Glade-managed	Asteraceae	49.7	Asteraceae	39.0
	Poaceae	20.1	Poaceae	13.7
	Smilacaceae	5.9	Lamiaceae	5.9
Cedar Bluff Sandstone Glade-unmanaged	Poaceae	47.4	Poaceae	33.9
	Euphorbiaceae	9.2	Vitaceae	9.7
	Smilacaceae	9.1	Anacardiaceae	7.3
Gibbons Creek Sandstone Barrens-managed	Poaceae	49.4	Poaceae	33.2
	Asteraceae	12.0	Asteraceae	18.9
	Euphorbiaceae	7.9	Fabaceae	9.6
Gyp Williams Sandstone Barrens-unmanaged	Poaceae	39.3	Asteraceae	28.9
	Asteraceae	14.8	Poaceae	20.3
	Euphorbiaceae	14.4	Vitaceae	11.7
Pounds Hollow Sandstone Glade-unmanaged	Poaceae	35.9	Poaceae	40.9
	Euphorbiaceae	10.5	Euphorbiaceae	9.2
	Ferns	8.5	Ferns	6.5
Round Bluff Sandstone Glade-unmanaged	Poaceae	49.1	Poaceae	35.3
	Euphorbiaceae	15.9	Euphorbiaceae	9.1
	Hypericaceae	8.9	Rubiaceae	7.7
Wildcat Bluff Limestone Glade-managed	Asteraceae	37.2	Asteraceae	44.9
	Poaceae	22.0	Poaceae	10.6
	Lamiaceae	6.2	Fabaceae	9.9

between 1988 and 1993, and an 11.8% decrease for Poaceae. Unmanaged sites increased 3.6% for Asteraceae and decreased 6.3% for Poaceae RI over time. The Fabaceae and Euphorbiaceae also appeared among the top three most important families at four sites on at least one sampling date.

The grasses, *Schizachyrium scoparium* and *Danthonia spicata*, were the most important forest-opening species at five of nine sites in both 1988 and 1993 (Table 11). At unmanaged sites, *Danthonia spicata* was 4.5% (1988: pretreatment) to 6.8% (1993: post-treatment) more important than at managed sites. Although it did decrease in RI over time, this decrease was less for unmanaged sites (-23.6%) than for managed sites (-64.0%). *Schizachyrium scoparium* was slightly more important (2.0 to 2.6%) at managed sites than at unmanaged sites for both years despite a 53.1% decrease at the managed sites over time. At the two managed limestone glades, Cave-MGD and Wildcat-MGD, *Silphium terebinthinaceum* of the Asteraceae family was among the most important species for both sampling dates. However, it too decreased over time (-36.9% at Cave-MGD and -42.9% at Wildcat-MGD). *Helianthus divaricatus* was present among the top three most important herb species at five sites for at least one sampling year. At the managed sites it increased 33.3% from 1988 (RI=6.2%) to 1993 (RI=9.3%), whereas at the unmanaged sites a slight decrease (RI=-3.7%) was observed. It is notable that at Gyp-UMG, *Parthenocissus quinquefolia*, a characteristic woodland species, replaced *Schizachyrium scoparium*, a dominant prairie species, in the first RI position in 1993.

Mean herb cover (%) increased 61.9% from 1988 to 1993 (Table 12). Although herb cover increased over time at the unmanaged sites, it did not increase at the managed sites. Still, managed sites exceeded unmanaged sites in both years, averaging 21.4% (1993) to 24.0% (1988) more herb cover. The limestone glades, Cave-MGD and Wildcat-MGD, had the highest cover for both years.

Table 11. Relative importance (%) of the three most important herb species in 1988 and 1993. Values for 1988 are derived from Heikens (1991).

Site	1988		1993	
Berryville Shale Glade-unmanaged	*Danthonia spicata*	10.5	*Danthonia spicata*	15.7
	Helanthus divaricatus	10.3	*Cunila origanoides*	15.1
	Cunila origanoides	9.6	*Schizachyrium scoparium*	8.8
Brown Shale Barrens-managed	*Schizachyrium scoparium*	28.7	*Schizachyrium scoparium*	16.2
	Helianthus divaricatus	11.3	*Dichanthelium laxiflorum*	11.3
	Danthonia spicata	10.2	*Helianthus divaricatus*	9.8
Cave Creek Limestone Glade-managed	*Schizachyrium scoparium*	18.8	*Silphium terebinthinaceum*	8.2
	Silphium terebinthinaceum	13.0	*Schizachyrium scoparium*	7.9
	Aster oblongifolius	9.6	*Verbesina virginica*	5.8
Cedar Bluff Sandstone Glade-unmanaged	*Danthonia spicata*	23.9	*Danthonia spicata*	9.9
	Schizachyrium scoparium	14.3	*Parthenocissus quinquefolia*	9.5
	Dichanthelium acuminatum	9.2	*Toxicodendron radicans*	7.3
Gibbons Creek Sandstone Barrens-managed	*Danthonia spicata*	21.9	*Helianthus divaricatus*	15.6
	Schizachyrium scoparium	15.4	*Dichanthelium acuminatum*	12.7
	Dichanthelium laxiflorum	7.0	*Schizachyrium scoparium*	9.0
Gyp Williams Sandstone Barrens-unmanaged	*Schizachyrium scoparium*	22.9	*Parthenocissus quinquefolia*	11.3
	Helianthus divaricatus	5.8	*Antennaria plantaginifolia*	9.9
	Lespedeza virginica	5.2	*Helianthus divaricatus*	7.9
Pounds Hollow Sandstone Glade-unmanaged	*Schizachyrium scoparium*	18.9	*Schizachyrium scoparium*	10.9
	Danthonia spicata	8.7	*Danthonia spicata*	8.4
	Cheilanthes lanosa	7.9	*Crotonopsis elliptica*	8.2
Round Bluff Sandstone Glade-unmanaged	*Schizachyrium scoparium*	25.4	*Schizachyrium scoparium*	10.8
	Danthonia spicata	17.1	*Danthonia spicata*	10.5
	Crotonopsis elliptica	15.9	*Diodia teres*	6.5
Wildcat Bluff Limestone Glade-managed	*Silphium terebinthinaceum*	17.5	*Silphium terebinthinaceum*	10.0
	Schizachyrium scoparium	15.4	*Helianthus divaricatus*	8.1
	Smilax bona-nox	4.4	*Solidago* sp.	5.3

Table 12. Mean (± 1 SE) herb cover in 1988 and 1993. Values for 1988 are derived from Heikens (1991).

	Site	N	1988	N	1993	Difference
Managed						
	Brown Shale Barrens	30	28.7 ± 1.9	120	38.2 ± 1.6	9.4
	Cave Creek Limestone Glade	27	50.9 ± 2.5	108	42.6 ± 1.8	-8.3
	Gibbons Creek Sandstone Barrens	15	13.9 ± 1.2	60	32.0 ± 3.4	18.0
	Wildcat Bluff Limestone Glade	18	30.0 ± 2.1	72	48.5 ± 2.3	18.5
	Mean (managed sites)		30.9 ± 7.6		40.3 ± 3.5	9.4
Unmanaged						
	Berryville Shale Glade	23	5.1 ± 0.7	112	18.4 ± 1.5	13.4
	Cedar Bluff Sandstone Glade	30	5.6 ± 1.1	120	23.4 ± 1.3	17.8
	Gyp Williams Sandstone Barrens	30	10.9 ± 0.8	120	31.3 ± 1.5	20.4
	Pounds Hollow Sandstone Glade	30	7.1 ± 0.9	120	9.5 ± 1.4	2.4
	Round Bluff Sandstone Glade	23	5.9 ± 1.1	92	12.2 ± 1.1	6.3
	Mean (unmanaged sites)		6.9 ± 1.0		18.9 ± 3.9	12.1
All Sites	Mean		17.6 ± 5.3		28.5 ± 4.5	11.9

Categorization of Herb Species

Grasses, Forbs, Legumes and Exotics. In the forest-openings studied, forbs comprised the largest percentage of species (66.1% ± 1.6%), followed by grasses (17.3% ± 1.2%), legumes (included in the forb category) (9.2% ± 0.9%) and exotics (6.6% ± 1.6%) (Table 13). Unmanaged sites had a slightly higher percentage of grasses and exotics than managed sites (Δx=4.3% and 1.5%, respectively). However, managed and unmanaged sites were similar in the percentage of legumes and exotics. Sites proximate to human activity, Cave-MGD, Cedar-UMG, Pounds-UMG and Round-UMG, had the highest percentage of exotic species, together averaging 4.5% higher than the overall average.

Life History. Perennials were the dominant life history type (as a proportion of all species) among forest-opening herbs (75.8% ± 2.5%), followed by annuals (20.6% ± 2.7%) then biennials (3.6% ± 0.4%) (Table 14). Managed- and unmanaged-site herb floras were also dominated by perennials and did not differ in the percentages of life history types.

Raunkaier's Life Forms. When classified by life form, it was determined that most forest-opening herb species were geophytes (40.4% ± 3.8%), hemicryptophytes (38.0% ± 5.6%) or therophytes (20.6% ± 8.1%) (Table 15). Managed and unmanaged sites did not differ in the proportion of any life form except the geophytes, which were higher for managed (42.6% ± 0.9%) than for unmanaged sites (38.8% ± 2.1%). Also, managed sites had more geophytes (42.6% ± 0.9%) than hemicryptophytes (39.4% ± 1.9%).

Categorization by Habitat. The herbaceous flora of the forest-openings was most highly associated with the woodland habitat (47.7% ± 2.2%), followed by disturbed, open, bluff, prairie and open woods habitats (Table 16). All other habitat association percentages were ≤1.8%. Managed sites had a higher percentage of characteristic prairie species (9.8% ± 1.8%) than unmanaged sites (6.9% ± 0.6%) while unmanaged sites were higher for species normally found in a

Table 13. The percentage of grasses, forbs, legumes and exotic herbs in the study sites in 1993-94. Category percentages are the proportion of species out of the cumulative (1993-94) herb species lists. Each species was placed into up to three of the categories. The grass and forb (an herbaceous dicot) and the grass and legume categories are mutually exclusive.

	Site	% Grass	% Forb	% Legume	% Exotic
Managed					
	Brown Shale Barrens	15.1	68.6	10.1	4.4
	Cave Creek Limestone Glade	15.3	72.6	9.5	14.7
	Gibbons Creek Sandstone Barrens	15.2	67.9	10.7	2.2
	Wildcat Bluff Limestone Glade	14.1	69.5	10.2	1.6
	Mean ± 1 SE (managed sites)	14.9 ± 0.3	69.7 ± 1.0	10.1 ± 0.2	5.7 ± 3.1
Unmanaged					
	Berryville Shale Glade	14.9	65.3	8.3	4.1
	Cedar Bluff Sandstone Glade	20.9	60.5	6.2	11.6
	Gyp Williams Sandstone Barrens	16.0	69.6	13.6	2.4
	Pounds Hollow Sandstone Glade	24.1	60.7	9.8	7.1
	Round Bluff Sandstone Glade	20.0	60.0	4.5	10.9
	Mean ± 1 SE (unmanaged sites)	19.2 ± 1.7	63.2 ± 1.9	8.5 ± 1.6	7.2 ± 1.8
All Sites	Mean ± 1 SE	17.3 ± 1.2	66.1 ± 1.6	9.2 ± 0.9	6.6 ± 1.6

Table 14. Herb life history (%) by site in 1993-94. Category percentages are the proportion of species out of the cumulative (1993-94) herb species lists.

	Site	% Annual	% Biennial	% Perennial
Managed				
	Brown Shale Barrens	23.9	3.1	72.9
	Cave Creek Limestone Glade	20.5	4.7	74.7
	Gibbons Creek Sandstone Barrens	17.4	3.9	78.7
	Wildcat Bluff Limestone Glade	6.3	3.9	89.8
	Mean ± 1 SE (managed sites)	17.0 ± 3.8	3.9 ± 0.3	79.0 ± 3.8
Unmanaged				
	Berryville Shale Glade	23.9	2.5	73.6
	Cedar Bluff Sandstone Glade	25.6	3.9	70.5
	Gyp Williams Sandstone Barrens	10.4	5.6	84.0
	Pounds Hollow Sandstone Glade	25.0	0.9	74.1
	Round Bluff Sandstone Glade	32.7	3.6	63.6
	Mean ± 1 SE (unmanaged sites)	23.5 ± 3.6	3.3 ± 0.8	73.2 ± 3.3
All Sites	Mean ± 1 SE	20.6 ± 2.7	3.6 ± 0.4	75.8 ± 2.5

Table 15. Raunkaier's life forms (%) for herb species in 1993-94. Life form categories are summed by relative importance. Life form categories are according to Raunkaier (1934).

	Site	%CHA	%GEO	%HEM	%THE
Managed					
	Brown Shale Barrens	0.6	41.5	33.9	23.9
	Cave Creek Limestone	1.1	37.9	40.5	20.5
	Gibbons Creek Sandstone Barrens	0.6	41.6	40.4	17.4
	Wildcat Bluff Limestone Glade	1.6	49.2	42.9	6.3
	Mean ± 1 SE (managed sites)	0.9 ± 0.2	42.6 ± 0.9	39.4 ± 1.9	17.0 ± 3.8
Unmanaged					
	Berryville Shale Glade	0.8	37.2	38.0	23.9
	Cedar Bluff Sandstone Glade	0.8	41.1	32.6	25.6
	Gyp Williams Sandstone Barrens	0.8	40.8	48.0	10.4
	Pounds Hollow Sandstone Glade	0.9	38.4	35.7	25.0
	Round Bluff Sandstone Glade	0.9	36.4	30.0	32.7
	Mean ± 1 SE (unmanaged sites)	0.8 ± 0.0	38.8 ± 2.1	36.9 ± 3.1	23.5 ± 3.6
All Sites	Mean ± 1 SE	0.9 ± 0.3	40.4 ± 3.8	38.0 ± 5.6	20.6 ± 8.1

CHA=Chamaephyte, GEO=Geophyte, HEM=Hemicryptophyte, THE=Therophyte.

Table 16. Categorization of 1993-94 site herb species into nine habitat types. Percentages are the proportion of herb species occurring in that habitat type out of the cumulative species list at each site. Herbs may occur in more than one habitat type. Species lists are based upon a floristic survey of the opening and contiguous 15 m. Habitat types are derived from Mohlenbrock (1986).

	Site	BLF	DTB	EDG	OPN	OPW	PRA	LLD	TCT	WDS
Managed										
	Brown	7.8	12.1	0.2	12.0	8.7	5.9	2.4	1.3	49.7
	Cave	3.9	21.1	0.6	8.9	7.2	12.6	2.2	1.6	41.8
	Gibbons	6.2	9.4	0.5	10.3	9.7	7.4	1.3	1.7	53.5
	Wildcat	3.9	6.4	0.0	6.5	10.4	13.3	1.4	2.0	55.9
	Mean ± 1 SE	5.5 ± 0.9	12.3 ± 3.2	0.3 ± 0.1	9.4 ± 1.2	9.0 ± 0.7	9.8 ± 1.8	1.8 ± 0.3	1.7 ±0.1	50.2 ± 3.1
Unmanaged										
	Berryville	8.9	11.6	0.7	10.5	9.2	7.9	1.5	1.1	48.5
	Cedar	12.0	17.4	0.3	10.9	5.4	6.1	1.4	0.4	46.1
	Gyp	7.0	8.5	0.3	8.3	10.3	8.6	1.3	0.8	54.9
	Pounds	16.1	15.1	0.4	13.4	6.9	7.1	1.3	0.9	37.1
	Round	12.4	16.7	0.8	16.0	3.3	5.2	3.0	0.5	41.7
	Mean ± 1 SE	11.3 ± 1.6	13.9 ± 1.7	0.5 ± 0.1	11.8 ± 1.3	7.0 ± 1.3	6.9 ± 0.6	1.7 ± 0.3	0.7 ± 0.1	45.7 ± 3.0
Glades	Mean ± 1 SE	9.6 ± 2.0	14.7 ± 2.1	0.5 ± 0.1	11.0 ± 1.4	7.1 ± 1.0	8.7 ± 1.4	1.8 ± 0.3	1.1 ± 0.3	45.2 ± 2.7
Barrens	Mean ± 1 SE	6.9 ± 0.5	9.9 ± 1.1	0.3 ± 0.1	10.2 ± 1.1	9.6 ± 0.5	7.3 ± 0.8	1.7 ± 0.4	1.3 ± 0.3	52.7 ± 1.6
All Sites	Mean ± 1 SE	8.7 ± 1.4	13.1 ± 1.6	0.4 ± 0.1	10.8 ± 0.9	7.9 ± 0.8	8.2 ± 0.9	1.8 ± 0.2	1.1 ± 0.2	47.7 ± 2.2

BLF=Bluff, DTB=Disturbed, EDG=Edge, OPN=Open, OPW=Open Woods, PRA=Prairie, LLD=Lowland, TCT=Thicket, WDS=Woods
Berryville=Berryville Shale Glade, Brown=Brown Shale Barrens, Cave=Cave Creek Limestone Glade, Cedar= Cedar Bluff Sandstone Glade, Gibbons=Gibbons Creek Sandstone Barrens, Gyp=Gyp Williams Sandstone Barrens, Pounds=Pounds Hollow Sandstone Glade, Round=Round Bluff Sandstone Glade, Wildcat=Wildcat Bluff Limestone Glade.

bluff type habitat. Glades differed from barrens in having a greater proportion of bluff and disturbed herb associates, while barrens had a greater proportion of woods and open woods herbs than glades.

The forest-opening habitat category means (above) were compared with those of three other communities, i.e., an undisturbed hill prairie in southern Illinois (Voigt and Mohlenbrock 1964), an invaded railroad right-of-way remnant prairie in west-central Kentucky (Bryant 1977), and a pristine, lowland mixed-hardwood forest in east-central Illinois (Aikman and Ebinger 1991) (Figure 9). The categories permitting the greatest discrimination among the aforementioned studies were the woodland and disturbed habitats. For the woodland habitat, forest-openings placed below the hardwood forest and above the hillprairie and railroad right-of-way sites. Forest-opening herbs were second only to the railroad right-of-way community for percent association to the disturbed habitat.

Site Similarity

Forest-opening similarity of the herbaceous flora between 1988 and 1994 was 19.3% ± 1.1% (Table 17). Although managed and unmanaged sites both averaged ≈19% similarity, managed sites had more herb species in common (37.0 ± 2.0) than unmanaged sites (30.8 ± 2.7) over time.

The mean Jaccard index (%) for all possible site pairs was 5.5% higher and there were 35.6 more common herb species than the same-site, 1988-1994 comparison in Table 17 (Table 18). Managed site pairs and sites with the same classification (i.e., the same substrate and forest-opening type) had more herb species in common than unmanaged sites and site combinations with dissimilar management histories. Sites with the same classification also had the highest Jaccard similarity (30.8% ± 1.4%).

Figure 9. Percent association of the herbaceous flora of the study sites, a railroad right-of-way, a hill prairie, and a hardwood forest to nine habitat types. Habitat associations follow Mohlenbrock (1986). Sources: Railroad right-of-way (n=96 species) Bryant 1977, Hill prairie (n=39 species) Voigt and Mohlenbrock 1964, Hardwood forest (n=21 species) Aikman and Ebinger 1991.

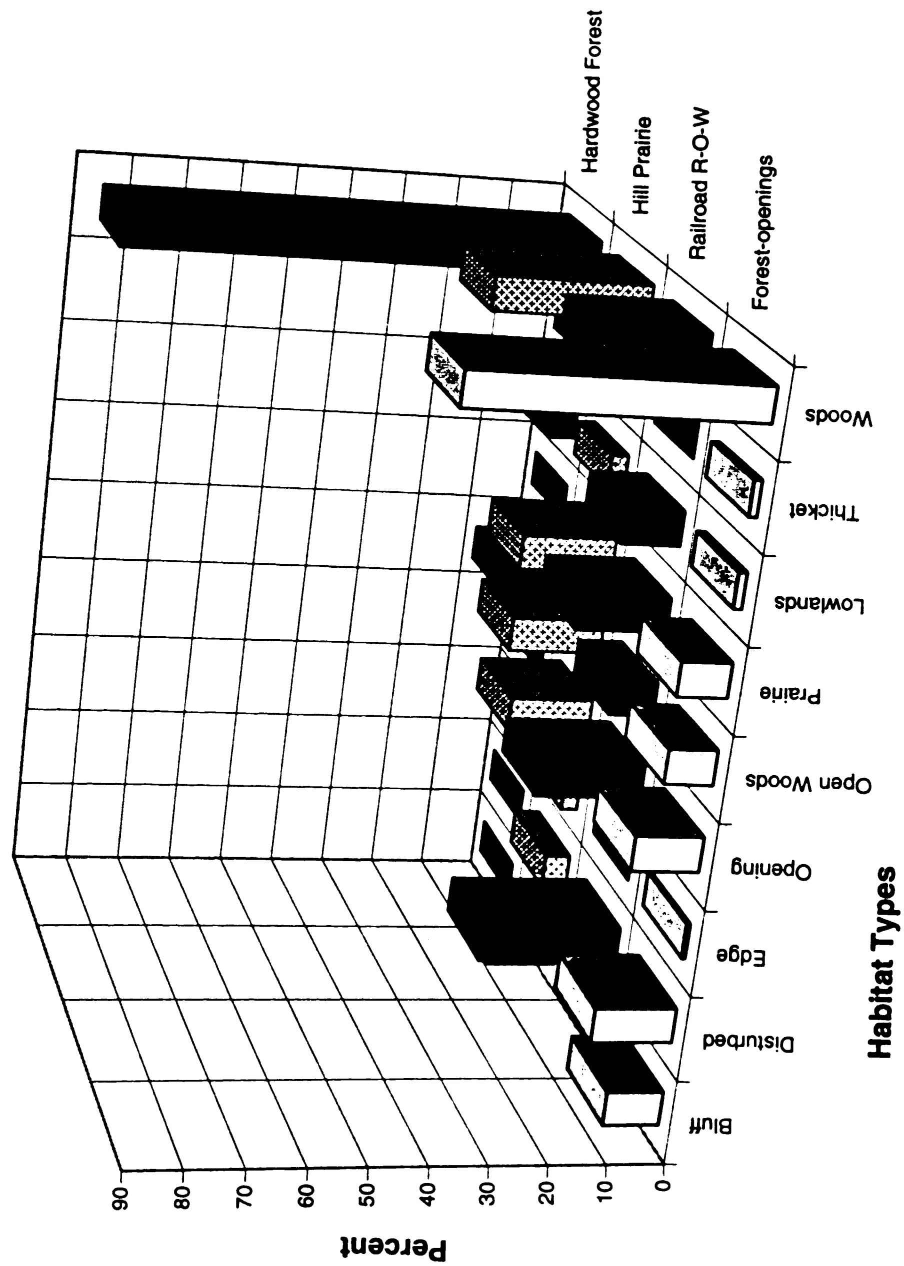

Percent
0
10
20
30
40
50
60
70
80
90
Habitat Types
Bluff
Disturbed
Edge
Opening
Open Woods
Prairie
Lowlands
Thicket
Woods
Hardwood Forest
Hill Prairie
Railroad R-O-W
Forest-openings

Table 17. Jaccard site similarity for herbs and the number of common herb species for the study sites in 1988 and 1993-94. Data for 1988 are derived from Heikens (1991). The Jaccard index is described in Mueller-Dombois and Ellenberg (1974). The mean ± 1 SE is reported.

	Site	% Similarity	No. Common Herbs
Managed			
	Brown Shale Barrens	19.5	39
	Cave Creek Limestone Glade	17.4	39
	Gibbons Creek Sandstone Barrens	14.9	31
	Wildcat Bluff Limestone Glade	22.3	39
	Mean ± 1 SE (managed sites)	18.5 ± 1.6	37.0 ± 2.0
Unmanaged			
	Berryville Shale Glade	23.0	35
	Cedar Bluff Sandstone Glade	15.4	24
	Gyp Williams Sandstone Barrens	19.5	33
	Pounds Hollow Sandstone Glade	23.6	37
	Round Bluff Sandstone Glade	18.4	25
	Mean ± 1 SE (unmanaged sites)	19.9 ± 1.5	30.8 ± 2.7
All Sites	Mean ± 1 SE	19.3 ± 1.1	33.6 ± 1.9

Table 18. Similarity of herb composition (Jaccard index) among pairs of sites in 1994. Site combinations are ranked from most to least similar. The Jaccard index described in Mueller-Dombois and Ellenberg (1974) was used. The mean ± 1 SE is reported.

Sites	% Similarity	No. Common Herbs
GIB^{m} & GYP^{u}	33.9	103
PDS^{u} & CDR^{u}	31.9	77
RND^{u} & CDR^{u}	31.8	76
CAV^{m} & WLC^{m}	30.8	98
GIB^{m} & BRN^{m}	30.6	103
GYP^{u} & BRN^{m}	30.3	86
BRN^{m} & BVL^{u}	30.0	84
GIB^{m} & BVL^{u}	29.1	87
BVL^{u} & CDR^{u}	28.4	71
GIB^{m} & WLC^{m}	28.1	86
BRN^{m} & CDR^{u}	27.4	79
GYP^{u} & WLC^{m}	27.3	69
CAV^{m} & GIB^{m}	27.2	100
GYP^{u} & BVL^{u}	26.0	64
GYP^{u} & CDR^{u}	25.9	66
PDS^{u} & BRN^{m}	25.8	70
PDS^{u} & RND^{u}	25.7	57
RND & BRN^{m}	25.3	68
RND^{u} & BVL^{u}	24.7	57
PDS^{u} & BVL^{u}	24.5	57
PDS^{u} & GYP^{u}	24.1	57
GIB^{m} & CDR^{u}	23.8	73
PDS^{u} & GIB^{m}	23.4	68
WLC^{m} & BRN^{m}	23.3	67
GIB^{m} & RND^{u}	22.6	65
GYP^{u} & RND^{u}	22.6	53
CAV^{m} & GYP^{u}	22.2	70
CAV^{m} & BVL^{u}	22.2	69
WLC^{m} & BVL^{u}	21.7	54
CAV^{m} & BRN^{m}	20.6	72
CAV & CDR^{u}	19.3	62
WLC^{m} & CDR^{u}	18.7	48
CAV^{m} & RND^{u}	17.3	52
PDS^{u} & WLC^{m}	16.3	39
PDS^{u} & CAV^{m}	15.9	48
RND^{u} & WLC^{m}	15.1	36
Mean (both sites managed)	26.8 ± 1.6 (n=6)	87.7 ± 6.2 (n=6)
Mean (both sites unmanaged)	26.6 ± 1.0 (n=10)	63.5 ± 2.7 (n=10)
Mean (dissimilar mgt. histories)	23.4 ± 1.2 (n=20)	66.5 ± 3.8 (n=20)

Table 18 (cont'd).

Mean (same substrate and for.-opening classification)	30.8 ± 1.4 (n=5)	82.2 ± 8.3 (n=5)
Mean (all combinations)	24.8 ± 0.8	69.2 ± 2.8

[m]Managed site.
[u]Unmanaged site.
BVL=Berryville Shale Glade, BRN=Brown Shale Barrens, CAV=Cave Creek Limestone Glade, CDR=Cedar Bluff Sandstone Glade, GIB=Gibbons Creek Sandstone Barrens, GYP=Gyp Williams Sandstone Barrens, PDS=Pounds Hollow Sandstone Glade, RND=Round Bluff Sandstone Glade, WLC=Wildcat Bluff Limestone Glade.

Eleven herbs and 16 woody species were common to all nine study sites (Table 19). All 11 herbs are native, seven are forbs, and eight are perennials. All 16 woody species are also native. However, exotic species were also shared by all sites (Table 20). Exotics found in the forest-openings included 40 herbs and eight woody species. Fifteen of these were found at Cave-MGD alone. Seven exotic plant species were found at Berryville-UMG, 11 at Brown-MGD, 31 at Cave-MGD, 19 at Cedar-UMG, 5 at Gibbons-MGD, 3 at Gyp-UMG, 11 at Pounds-UMG, 14 at Round-UMG, and 4 at Wildcat-MGD.

Woody Species Composition

Despite the different methods used to estimate canopy cover in 1988 (Heikens 1991) and 1993, the top two most important species were the same over time at five of the sites (i.e., Berryville-UMG, Cave-MGD, Cedar-UMG, Gyp-UMG, and Pounds-UMG) (Table 21). At Cave-MGD, *Quercus rubra* (red oak) and *Quercus shumardii* (Shumard's oak) are believed to be the same species, although diagnosed differently, as they are difficult to distinguish. *Juniperus virginiana* (eastern redcedar) was conspicuous as the most important overstory member at all of the sandstone glades for both years. All other forest-openings, viz., the shale glade and barrens sites, were characterized by *Quercus stellata*, often accompanied by *Vaccinium arboreum*, *Ulmus alata*, and *Quercus marilandica*.

Table 19. Species common to all study sites in 1993 and 1994.

Species	Common Name
Woody:	
Amelanchier arborea	Shadbush
Carya ovata	Shagbark Hickory
Carya texana	Black Hickory
Celtis tenuifolia	Dwarf Hickory
Cornus florida	Flowering Dogwood
Diospyros virginiana	Common Persimmon
Fraxinus americana	White Ash
Juglans nigra	Black Walnut
Parthenocissus quinquefolia	Virginia Creeper
Prunus serotina	Wild Black Cherry
Quercus rubra	Red Oak
Quercus stellata	Post Oak
Quercus velutina	Black Oak
Toxicodendron radicans	Poison Ivy
Ulmus alata	Winged Elm
Vitis aestivalis	Summer Grape
Herbaceous:	
Acalypha gracilens	Three-seeded Mercury
Ambrosia artemisiifolia	Common Ragweed
Carex umbellata	Sedge
Cunila origanoides	Dittany
Danthonia spicata	Curly Oat Grass
Dichanthelium laxiflorum	Panic Grass
Helianthus divaricatus	Woodland Sunflower
Lespedeza repens	Creeping Bush Clover
Ruellia humilis	Wild Petunia
Schizachyrium scoparium	Little Bluestem
Solidago ulmifolia	Elm-leaved Goldenrod

Table 20. Exotic species encountered at the study sites in 1993 and 1994.

Species	Common Name	Sites of Occurrence*
Woody:		
Campsis radicans	Trumpet Creeper	BN, CV, RD
Elaeagnus umbellata	Autumn Olive	WC
Ligustrum vulgare	Common Privet	BN, CD
Lonicera japonica	Japanese Honeysuckle	BV, BN, CV, CD, PD, RD
Lonicera sp. (shrub)		BN, CD, WC
Morus alba	White Mulberry	BV, GB
Pinus echinata	Shortleaf Pine	PD
Rosa multiflora	Multiflora Rose	BV, CV, CD, PD
Herbaceous:		
Abutilon theophrastii	Velvet-leaf	CV
Achillea millefolium	Common Yarrow	BN, CD, GP
Allium vineale	Field Garlic	BV, CV, CD, PD, RD
Anagallis arvensis	Scarlet Pimpernel	CV
Asparagus officinalis	Asparagus	BN
Bromus commutatus	Hairy Chess	CV, CD, RD, WC
Bromus racemosus	Chess	CV, CD, PD
Capsella bursa-pastoris	Shepherd's-purse	CV
Cardamine hirsuta	Spring Cress	CD
Cardamine sp.		BV, BN, CV, GB, GP, RD
Coronilla varia	Crown Vetch	BN
Cosmos bipinnatus	Cosmos	CV
Daucus carota	Wild Carrot	RD
Dianthus armeria	Deptford Pink	CV, CD
Digitaria sanguinalis	Crab Grass	PD
Digitaria sp.		CD
Festuca arundinacea	Large Fescue	CV, CD, PD, RD
Kummerowia stipulacea	Korean Bush Clover	CV, RD
Kummerowia striata	Japanese Bush Clover	CD, GB, PD, RD, WC
Lactuca serriola	Prickly Lettuce	BV, BN, CV, CD, GB, RD
Lespedeza cuneata	Sericea Lespedeza	CV, CD, GP, PD
Leucanthemum vulgare	Ox-eye Daisy	CV
Matricaria matricarioides	Pineapple-weed	CV
Medicago lupulina	Black Medic	CV
Melilotus alba	White Sweet Clover	CV
Phleum pratense	Timothy	CV
Plantago lanceolata	Buckhorn	BN, CV
Poa compressa	Canadian Bluegrass	CV, CD, PD, RD
Poa pratensis	Kentucky Bluegrass	CD
Polygonum convolvulus	Black Bindweed	BV
Rumex acetosella	Sour Dock	CD
Setaria faberi	Giant Foxtail	CV
Sida spinosa	Prickly Sida	CV

Table 20 (cont'd).

Taraxacum officinale	Common Dandelion	CV
Torilis japonica	Hedge Parsley	CV
Trifolium campestre	Low Hop Clover	CV
Trifolium pratense	Red Clover	CV
Verbascum thapsus	Woolly Mullein	CV, CD, RD
Veronica arvensis	Corn Speedwell	RD
Viola raphanesquii	Johnny-jump-up	BV, BN, CV, GB, PD, RD

*BV=Berryville Shale Glade-Unmanaged, BN=Brown Shale Barrens-Managed, CV=Cave Creek Limestone Glade-Managed, CD=Cedar Bluff Sandstone Glade-Unmanaged, GB=Gibbons Creek Sandstone Barrens-Managed, GP=Gyp Williams Sandstone Barrens-Unmanaged, PD=Pounds Hollow Sandstone Glade-Unmanaged, RD=Round Bluff Sandstone Glade-Unmanaged, WC=Wildcat Bluff Limestone Glade-Managed.

Table 21. Relative importance (%) of the three most important woody species in 1988 and 1993. Canopy cover in 1993 was estimated according to Daubenmire (1959). In 1988 the sum of all overhead canopy was used to estimate cover. Values for 1988 are derived from Heikens (1991).

Site	1988 Species	% RI	1993 Species	% RI
Berryville Shale Glade-unmanaged	*Quercus stellata*	22.6	*Quercus stellata*	26.8
	Quercus marilandica	17.5	*Quercus marilandica*	14.9
	Vaccinium arboreum	14.7	*Vaccinium arboreum*	8.8
Brown Shale Barrens-managed	*Quercus stellata*	40.9	*Quercus stellata*	36.5
	Ulmus alata	22.1	*Ligustrum vulgare*	14.8
	Vaccinium arboreum	12.4	*Vaccinium arboreum*	10.5
Cave Creek Limestone Glade-managed	*Quercus prinoides* var.*	40.9	*Quercus prinoides* var.*	17.6
	Quercus rubra	12.7	*Quercus shumardii*	14.7
	Diospyros virginiana	8.9	*Acer saccharum*	9.9
Cedar Bluff Sandstone Glade-unmanaged	*Juniperus virginiana*	25.3	*Juniperus virginiana*	23.1
	Quercus stellata	20.9	*Quercus stellata*	19.5
	Quercus marilandica	18.7	*Ulmus alata*	8.8
Gibbons Creek Sandstone Glade-managed	*Quercua stellata*	29.7	*Quercus stellata*	24.7
	Ulmus alata	24.1	*Fraxinus americana*	12.8
	Carya texana	17.1	*Ulmus alata*	10.3
Gyp Williams Sandstone Barrens-unmanaged	*Quercus stellata*	28.1	*Quercus stellata*	19.9
	Ulmus alata	20.5	*Ulmus alata*	17.0
	Quercus marilandica	17.2	*Carya texana*	15.9
Pounds Hollow Sandstone Glade-unmanaged	*Juniperus virginiana*	30.9	*Juniperus virginiana*	32.6
	Ulmus alata	17.9	*Ulmus alata*	13.7
	Vaccinium arboreum	16.7	*Vaccinium arboreum*	13.3
Round Bluff Sandstone Glade-unmanaged	*Juniperus virginiana*	34.9	*Juniperus virginiana*	43.3
	Quercus marilandica	15.7	*Ulmus alata*	15.2
	Vaccinium arboreum	13.1	*Quercus stellata*	12.2
Wildcat Bluff Limestone Glade-managed	*Quercus prinoides* var.*	28.7	*Quercus prinoides* var.*	14.9
	Juniperus virginiana	14.5	*Quercus stellata*	10.2
	Querecus rubra	10.3	*Diospyros virginiana*	9.1

RI=Relative Importance.
**Quepri=Quercus prinoides* var. *acuminata*

showed comparable values for sites with expansive openings (i.e., Cave-MGD, Pounds-UMG, and Wildcat-MGD) or with very little opening remaining at all (i.e., Cedar-UMG and Gyp-UMG) (Table 22). The canopy cover values in 1993 were lower than in 1988 at sites in which the opening was not expansive (i.e., Berryville-UMG, Brown-MGD, and Round-UMG). For both years (pre- and post-management), canopy cover was greater at the unmanaged than at the managed sites. However, mean forest-opening canopy cover for all sites in 1988 (38.9% ± 7.5%) and 1993 (29.0% ± 5.2%) did not differ.

The mean number of tree species (per 50 m^2) was lower in 1988 (4.7 ± 0.3) than in 1993 (7.2 ± 0.6) (Table 23). In 1993 there were nearly the same number of trees encountered at managed sites (7.1 ± 0.4) as at unmanaged sites (7.3 ± 0.6). However, managed and unmanaged site tree species number increased 77.5% and 40.4%, respectively, over time.

Rock Cover

Forest-opening rock cover (expressed as a percentage of total ground surface) for all sites did not differ between 1988 (20.3% ± 7.1%) and 1993 (14.4% ± 6.7%) (Table 24). However, exposed rock cover was greater at unmanaged sites than at managed sites for both sampling years.

Statistical Comparisons: 1988 and 1993

Within-site statistical comparison of each forest-opening (1988 and 1993) showed that all sites were significantly different (α=0.05) for Poaceae and Asteraceae cover except Berryville-UMG (Table 25). Percent cover of exposed rock was significant for about half of the forest-openings, i.e., Cave-MGD, Cedar-UMG, Gibbons-MGD, and Gyp-UMG.

Between-site management comparisons for 1993 show that the unmanaged sandstone glade combination was significantly different in percent cover of exposed rock (α=0.05) (Table 26). Conversely, the managed-unmanaged site comparison was significant for Poaceae and Asteraceae cover. Neither management combination showed significance for canopy cover.

Table 22. Mean (± 1 SE) canopy cover (%) in 1988 and 1993 via two different methods. Canopy cover in 1993 was estimated according to Daubenmire (1959). In 1988 the sum of all overhead canopy was used to estimate cover. Values for 1988 are derived from Heikens (1991).

	Site	N	1988	N	1993
Managed					
	Brown Shale Barrens	30	29.5 ± 0.2	30	9.4 ± 2.4
	Cave Creek Limestone Glade	27	18.0 ± 3.9	27	15.0 ± 3.5
	Gibbons Creek Sandstone Barrens	15	26.8 ± 5.8	15	45.8 ± 11.4
	Wildcat Bluff Limestone Glade	18	16.6 ± 3.3	18	12.2 ± 2.8
	Mean (managed sites)		22.7 ± 3.2		20.6 ± 8.5
Unmanaged					
	Berryville Shale Glade	23	79.6 ± 7.4	28	37.7 ± 4.5
	Cedar Bluff Sandstone Glade	30	49.1 ± 4.9	30	42.9 ± 3.5
	Gyp Williams Sandstone Barrens	30	67.8 ± 6.0	30	50.0 ± 3.5
	Pounds Hollow Sandstone Glade	30	21.8 ± 3.2	30	18.1 ± 3.2
	Round Bluff Sandstone Glade	23	41.4 ± 4.1	23	30.1 ± 5.1
	Mean (unmanaged sites)		51.9 ± 10.1		35.8 ± 5.5
All Sites	Mean		38.9 ± 7.5		29.0 ± 5.2

Table 23. Mean (± 1 SE) number of tree species (per 50 m^2) in 1988 and 1993. Values for 1988 are derived from Heikens (1991).

	Site	N	1988	N	1993	Difference
Managed						
	Brown Shale Barrens	30	3.7 ± 0.2	30	6.0 ± 0.5	2.3
	Cave Creek Limestone Glade	27	3.3 ± 0.3	27	6.7 ± 0.8	3.4
	Gibbons Creek Sandstone Barrens	15	4.1 ± 0.3	15	7.9 ± 0.4	3.7
	Wildcat Bluff Limestone Glade	18	4.9 ± 0.4	18	7.6 ± 1.0	2.6
	Mean (managed sites)		4.0 ± 0.3		7.1 ± 0.4	3.1
Unmanaged						
	Berryville Shale Glade	23	5.5 ± 0.4	28	8.8 ± 0.6	3.3
	Cedar Bluff Sandstone Glade	30	5.7 ± 0.3	30	9.1 ± 0.6	3.4
	Gyp Williams Sandstone Barrens	30	5.9 ± 0.3	30	9.3 ± 0.5	3.4
	Pounds Hollow Sandstone Glade	30	4.0 ± 0.3	30	4.0 ± 0.5	0.0
	Round Bluff Sandstone Glade	23	4.8 ± 0.4	23	5.2 ± 0.6	0.4
	Mean (unmanaged sites)		5.2 ± 0.3		7.3 ± 1.1	2.1
All Sites	Mean		4.7 ± 0.3		7.2 ± 0.6	2.5

Table 24. Mean (± 1 SE) cover of exposed rock (as a percentage of total ground surface) in 1988 and 1993. Values for 1988 are derived from Heikens (1991).

	Site	N	1988	N	1993	Difference
Managed						
	Brown Shale Barrens	30	1.1 ± 0.2	30	0.1 ± 0.2	-1.0
	Cave Creek Limestone Glade	27	23.6 ± 2.7	27	14.0 ± 1.6	-9.6
	Gibbons Creek Sandstone Barrens	15	4.7 ± 1.3	15	1.3 ± 0.5	-3.4
	Wildcat Bluff Limestone Glade	18	5.8 ± 1.1	18	5.6 ± 1.2	-0.2
	Mean (managed sites)		8.8 ± 5.0		5.3 ± 3.1	-3.6
Unmanaged						
	Berryville Shale Glade	23	23.4 ± 6.2	28	10.9 ± 3.1	-12.4
	Cedar Bluff Sandstone Glade	30	11.0 ± 2.7	30	3.3 ± 0.8	-7.7
	Gyp Williams Sandstone Barrens	30	4.4 ± 1.4	30	0.9 ± 0.2	-3.6
	Pounds Hollow Sandstone Glade	30	62.0 ± 6.9	30	60.0 ± 4.6	-1.9
	Round Bluff Sandstone Glade	23	46.5 ± 4.3	23	33.8 ± 5.0	-12.7
	Mean (unmanaged sites)		29.5 ± 10.9		21.8 ± 11.2	-7.7
All Sites	Mean		20.3 ± 7.1		14.4 ± 6.7	-5.8

Table 25. Probability values for the comparison (1988 and 1993) of Poaceae, Asteraceae, and rock cover in the opening of the study sites. The Mann-Whitney U test was used and an asterisk indicates a significant difference between sites (α=0.05). Data for 1988 were obtained from Heikens (1991, unpublished data).

	Site	p-Value Poaceae	Asteraceae	Rock
Managed	Brown Shale Barrens	0.0000*	0.0000*	0.3103
	Cave Creek Limestone Glade	0.0000*	0.0000*	0.0000*
	Gibbons Creek Sandstone Barrens	0.0000*	0.0000*	0.0032*
	Wildcat Bluff Limestone Glade	0.0000*	0.0000*	0.7540
Unmanaged	Berryville Shale Glade	0.7753	0.0786	0.2070
	Cedar Bluff Sandstone Glade	0.0087*	NA	0.0137*
	Gyp Williams Sandstone Barrens	0.0000*	0.0021*	0.0001*
	Pounds Hollow Sandstone Glade	0.0000*	0.0000*	0.4681
	Round Bluff Sandstone Glade	0.0000*	NA	0.0621

NA=Not available. No Asteraceae were located in the 1988 sampling at Cedar Bluff Sandstone Glade-Unmanaged or Round Bluff Sandstone Glade-Unmanaged.

Table 26. Probability values for site management comparisons of Poaceae, Asteraceae, canopy and rock cover in the site openings in 1993. The Mann-Whitney U test was used and an asterisk indicates a significant difference between sites (α=0.05).

	Site Combination	p-Value Poaceae	Asteraceae	Canopy	Rock
Unmanaged-Unmanaged	Cedar-Round (Glades)	0.7377	0.7420	0.6804	0.0000*
Managed-Unmanaged	Gibbons-Gyp (Barrens)	0.0000*	0.0002*	0.1253	0.3514

Cedar=Cedar Bluff Sandstone Glade, Gibbons=Gibbons Creek Sandstone Barrens, Gyp=Gyp Williams Sandstone Barrens, Round=Round Bluff Sandstone Glade.

Correlation analysis between total herb number and site opening area yielded $0.0005<p<0.005$. Therefore, a positive correlation between species richness and opening area was improbable for these sites.

Vegetation Subhabitats

Herb Species Composition

At six of seven sites, a member of the Poaceae or Asteraceae was the most important herb in the opening subhabitat (Table 27). In fact, 71% of the top three opening positions (15 of the 21 positions) were occupied by members of Poaceae and Asteraceae versus 46% in the forest interior-north, 63% in the transition zone-north, 39% in the transition zone-south, and 50% in the forest interior-south. Species like *Parthenocissus quinquefolia*, *Toxicodendron radicans*, and *Galium* sp., while absent among the top three positions in the opening, were present in the transition and forest interior subhabitats at many sites (e.g., Cedar-UMG, Gibbons-MGD, and Wildcat-MGD). An interesting pattern existed in the first position at four of the forest-opening sites (i.e., Berryville-UMG, Brown-MGD, Gibbons-MGD, and Pounds-UMG). For example, at Berryville-UMG, *Danthonia spicata* was the most important species in the forest interior-north, transition zone-north, and opening while *Cunila origanoides* was the most important herb in the transition zone-south and forest interior-south. Wildcat-MGD displayed a nearly symmetric pattern about the opening subhabitat with *Parthenocissus quinquefolia* in the first position in the forest interior-north, transition zone-north, transition zone-south, and in second position in the forest interior-south.

Poaceae RI was more important in the opening (and forest interior-north) of unmanaged sites than of managed sites (Table 28). Conversely, managed sites exceeded unmanaged sites for Asteraceae RI in the opening (and transition zone-north) (Table 29). No differences were observed among subhabitats for mean forest-opening Asteraceae RI ($\approx$21).

Relative

Table 27. Relative importance (%) of the three most important herb species in five subhabitats of the study sites in 1994.

Site	FI-N		TS-N		OP		TS-S		FI-S	
BVL	*Dan spi*	37.2	*Dan spi*	38.4	*Dan spi*	39.9	*Cun ori*	12.8	*Cun ori*	15.3
	Cun ori	21.4	*Cun ori*	15.9	*Cun ori*	22.5	*Hel div*	12.8	*Hel div*	15.3
	Ant pla	10.7	*Tep vir*	15.9	*Tep vir*	9.2	*Sol nem*	12.8	*Les rep*	10.5
BRN*	*Hel div*	10.8	*Hel div*	17.9	*Hel div*	17.4	*Ast* sp.	15.7	*Sch sco*	16.9
	Sol ulm	9.7	*Pyc ten*	11.0	*Dic lax*	11.9	*Car umb*	11.3	*Hel div*	15.1
	Par qui	8.7	*Dic lax*	6.9	*Sch sco*	9.8	*Ast pat*	10.6	*Dic lax*	9.8
CAV*	*Hel div*	11.3	*Smi bon*	11.9	*Bri eup*	33.1	*Par qui*	6.9	*Ver vir*	10.4
	Sol ulm	10.6	*Sol ulm*	9.3	*Sch sco*	7.9	*Eup cor*	6.9	*Tox rad*	7.5
	Par qui	10.2	*Hel div*	8.4	*Sil ter*	7.5	*Rat pin*	5.4	*Smi bon*	7.2
CDR	*Tox rad*	18.9	*Dan spi*	36.4						
	Dan spi	11.9	*Man vir*	6.4						
	Par qui	10.4	*Ely vir*	5.4						
GIB*	*Dic lax*	9.5	*Dic lax*	14.9	*Dic lax*	9.6	*Hel div*	12.8	*Hel div*	16.4
	Hel div	9.0	*Hel div*	11.2	*Sch sco*	8.9	*Par fas*	9.3	*Par qui*	10.9
	Par qui	7.2	*Dan spi*	9.2	*Hel div*	8.6	*Par qui*	8.4	*Gal pil*	7.4
PDS	*Tox rad*	16.6	*Hel div*	17.8	*Car* sp.	22.9	*Car* sp.	30.0	*Car* sp.	19.9
	Dan spi	10.5	*Dod mea*	12.8	*Smi bon*	18.5	*Luz mul*	30.0	*Dic lax*	15.9
	Les rep	8.9	*Tox rad*	10.7	*Dic lax*	8.6	*Cro ell*	10.0	*Kri dan*	12.2
RND	*Dan spi*	12.0	*Sch sco*	17.9	*Sch sco*	23.3				
	Par qui	9.9	*Dan spi*	8.8	*Dio ter*	16.7				
	San can	8.9	*Cro ell*	8.7	*Car* sp.	13.9				

Table 27 (cont'd).

WLC*	*Par qui*	17.5	*Par qui*	12.6	*Sil ter*	11.4	*Par qui*	7.6	*Ver vir*	11.3
	Gal cir	13.5	*Sol ulm*	7.5	*Hel div*	7.3	*Hel div*	7.2	*Par qui*	9.9
	Amp bra	6.6	*Sol pet*	5.0	*Ver vir*	6.1	*Big cap*	6.1	*Big cap*	8.9

*Managed site.

FI-N=Forest Interior-North, TS-N=Transition Zone-North, OP=Opening, TS-S=Transition Zone-South, FI-S=Forest Interior-South.

BVL=Berryville Shale Glade, BRN=Brown Shale Barrens, CAV=Cave Creek Limestone Glade, CDR=Cedar Bluff Sandstone Glade, GIB=Gibbons Creek Sandstone Barrens, PDS=Pounds Hollow Sandstone Glade, RND=Round Bluff Sandstone Glade, WLC=Wildcat Bluff Limestone Glade.

Amp bra=Amphacarpa bracteata, Ant pla=Antennaria plantaginifolia, Ast sp. =*Aster* sp., *Ast pat=Aster patens, Big cap=Bignonia capriolata, Bri eup=Brickellia eupatorioides, Car* sp. =*Carex* sp., *Car umb=Carex umbellata, Cro ell=Crotonopsis elliptica, Cun ori=Cunila origanoides, Dan spi=Danthonia spicata, Dic lax=Dichanthelium laxiflorum, Dio ter=Diodia teres, Dod mea=Dodecatheon meadia, Ely vir=Elymus virginicus, Eup cor=Euphorbia*

Table 28. Relative importance (%) of the Poaceae family in five subhabitats of the study sites in 1994.

	Site	FI-N	TS-N	OP	TS-S	FI-S
Managed						
	Brown Shale Barrens	23.3	25.5	38.5	46.2	41.9
	Cave Creek Limestone Glade	2.9	5.4	14.4	9.8	4.9
	Gibbons Creek Sandstone Barrens	21.3	38.5	39.2	22.9	12.4
	Wildcat Bluff Limestone Glade	16.0	14.6	7.6	11.3	4.4
	Mean ± 1 SE (managed sites)	15.9 ± 4.6	21.0 ± 7.1	24.9 ± 8.2	22.6 ± 8.4	15.9 ± 8.9
Unmanaged						
	Berryville Shale Glade	47.9	38.4	48.4	11.1	6.3
	Cedar Bluff Sandstone Glade	38.6	60.9	---	---	---
	Pounds Hollow Sandstone Glade	30.1	10.4	32.3	21.1	23.9
	Round Bluff Sandstone Glade	13.3	42.4	38.2	---	---
	Mean ± 1 SE (unmanaged sites)	32.5 ± 7.4	38.0 ± 10.4	39.6 ± 4.7	16.1 ± 5.0	15.1 ± 8.8
All Sites	Mean ± 1 SE	24.2 ± 5.1	29.5 ± 6.7	31.2 ± 5.6	20.4 ± 5.6	15.6 ± 6.0

FI-N=Forest Interior-North, TS-N=Transition Zone-North, OP=Opening, TS-S=Transition Zone-South, FI-S=Forest Interior-South.

Table 20.

Table 29. Relative importance (%) of the Asteraceae family in five subhabitats of the study sites in 1994.

	Site	FI-N	TS-N	OP	TS-S	FI-S
Managed						
	Brown Shale Barrens	27.3	26.6	28.9	27.4	30.2
	Cave Creek Limestone Glade	21.4	40.2	37.3	34.4	26.7
	Gibbons Creek Sandstone Barrens	21.9	17.4	17.0	20.3	25.2
	Wildcat Bluff Limestone Glade	12.1	30.9	29.0	29.0	12.2
	Mean ± 1 SE (managed sites)	20.7 ± 3.2	28.8 ± 4.7	28.1 ± 4.2	27.8 ± 2.9	22.7 ± 4.8
Unmanaged						
	Berryville Shale Glade	20.7	11.6	9.2	30.9	33.7
	Cedar Bluff Sandstone Glade	3.9	1.4	---	---	---
	Pounds Hollow Sandstone Glade	21.7	26.6	5.0	0.0	12.2
	Round Bluff Sandstone Glade	3.4	8.6	---	---	---
	Mean ± 1 SE (unmanaged sites)	12.4 ± 5.1	12.1 ± 5.3	7.1 ± 2.1	15.5 ± 15.5	22.9 ± 10.8
All Sites	Mean ± 1 SE	16.6 ± 3.2	20.1 ± 4.6	23.7 ± 5.2	23.7 ± 5.1	22.8 ± 4.1

FI-N=Forest Interior-North, TS-N=Transition Zone-North, OP=Opening, TS-S=Transition Zone-South, FI-S=Forest Interior-South.

Cyperaceae were more important in the opening of unmanaged sites than of managed sites (Table 30). For all sites, mean Cyperaceae RI in the opening exceeded that in the transition zone-north and forest interior-north.

Managed sites exceeded unmanaged sites in mean number of herb species (per m^2) in all subhabitats except the transition zone-north (Table 31). In the opening (and transition zone-south) of unmanaged sites, there were fewer herb species than in the other subhabitats. There was, however, no difference in the mean number of herb species among subhabitats for the managed sites or for all sites.

Mean herb cover (%) for all of the forest-openings did not differ among subhabitats (Table 32). However, cover at managed sites exceeded that of unmanaged sites for all subhabitats. Herb cover at managed sites also peaked in the opening subhabitat (48.3% ± 8.4%).

Rock, Bryophyte and Lichen Cover

Mean cover of exposed rock (expressed as a percentage of total ground surface), was highest in the opening (17.2% ± 3.6%) and transition zone-south (10.7 ± 3.8) subhabitats of all of the forest-openings (Table 33). At unmanaged sites the opening had the highest cover value (16.6% ± 0.0%), however, the transition zone-south and forest interior-south values were not available (due to truncation of unmanaged sites by bluffs). Managed sites had a higher percent cover of exposed rock in the opening than all of the other subhabitats except the transition zone-south.

Mean bryophyte cover for all sites (5.6% to 9.0%) did not differ among subhabitats (Table 34). However, unmanaged site bryophyte cover exceeded that for managed sites in the opening subhabitat. Unmanaged sites also exceeded managed sites in opening subhabitat for lichen cover (Table 35). At managed sites, the opening and northern subhabitats exceeded that in the southern subhabitats. On average, forest-opening lichen cover ranged from 0.3% to 3.4%.

Table 30. Relative importance (%) of the Cyperaceae family in five subhabitats of the study sites in 1994.

	Site	FI-N	TS-N	OP	TS-S	FI-S
Managed						
	Brown Shale Barrens	11.5	10.3	5.6	5.4	4.9
	Cave Creek Limestone Glade	1.7	2.4	2.1	1.6	0.0
	Gibbons Creek Sandstone Barrens	7.0	7.3	14.3	20.8	15.9
	Wildcat Bluff Limestone Glade	1.4	6.2	0.7	1.5	3.3
	Mean ± 1 SE (managed sites)	5.4 ± 2.4	6.6 ± 1.6	5.7 ± 3.1	7.3 ± 4.6	6.0 ± 3.4
Unmanaged						
	Berryville Shale Glade	0.0	0.0	6.7	2.3	6.3
	Cedar Bluff Sandstone Glade	6.2	5.2	---	---	---
	Pounds Hollow Sandstone Glade	7.2	5.2	22.9	10.6	19.9
	Round Bluff Sandstone Glade	6.7	4.8	19.1	---	---
	Mean ± 1 SE (unmanaged sites)	5.0 ± 1.7	3.8 ± 1.3	16.2 ± 5.7	6.5 ± 4.1	13.1 ± 6.8
All Sites	Mean ± 1 SE	5.2 ± 1.4	5.2 ± 1.1	10.2 ± 3.3	7.0 ± 3.1	8.4 ± 3.2

FI-N=Forest Interior-North, TS-N=Transition Zone-North, OP=Opening, TS-S=Transition Zone-South, FI-S=Forest Interior-South.

Table 31. Mean (± 1 SE) number of herb species (per m^2) in five subhabitats of the study sites in 1994.

	Site	N	FI-N	N	TS-N	N	OP	N	TS-S	N	FI-S
Managed											
	Brown Shale Barrens	10	10.2 ± 0.9	8	1.0 ± 0.8	13	8.0 ± 0.9	5	9.0 ± 1.3	4	10.8 ± 0.8
	Cave Creek Limestone Glade	8	8.9 ± 1.3	8	12.1 ± 1.1	55	11.8 ± 0.5	6	11.7 ± 0.8	6	12.3 ± 1.0
	Gibbons Creek Sandstone Barrens	6	12.3 ± 1.2	6	10.0 ± 1.2	20	9.0 ± 0.6	6	8.5 ± 1.4	6	7.5 ± 0.7
	Wildcat Bluff Limestone Glade	6	6.8 ± 1.9	6	8.5 ± 2.1	58	12.3 ± 0.6	6	12.5 ± 1.1	6	9.7 ± 1.1
	Mean (managed sites)		9.6 ± 1.2		7.9 ± 2.4		10.3 ± 1.0		10.4 ± 0.9		10.1 ± 1.0
Unmanaged											
	Berryville Shale Glade	4	3.0 ± 1.1	4	10.0 ± 1.6	13	2.3 ± 0.4	4	2.5 ± 1.9	4	6.8 ± 1.1
	Cedar Bluff Sandstone Glade	16	6.9 ± 0.5	6	7.0 ± 0.8		---		---		---
	Pounds Hollow Sandstone Glade	5	7.6 ± 1.6	7	6.6 ± 1.5	9	3.1 ± 0.6	6	1.7 ± 0.8	4	4.3 ± 1.3
	Round Bluff Sandstone Glade	10	8.9 ± 0.8	9	6.1 ± 0.9	4	5.0 ± 0.7		---		---
	Mean (unmanaged sites)		6.6 ± 1.3		7.4 ± 0.9		3.5 ± 0.8		2.1 ± 0.4		5.6 ± 1.3
All Sites	Mean		8.1 ± 0.9		7.7 ± 1.2		7.4 ± 1.5		7.7 ± 1.9		8.6 ± 1.2

FI-N=Forest Interior-North, TS-N=Transition Zone-North, OP=Opening, TS-S=Transition Zone-South, FI-S=Forest Interior-South.

Table 32. Mean (± 1 SE) cover (%) of herb species in five subhabitats of the study sites in 1994.

	Site	N	FI-N	N	TS-N	N	OP	N	TS-S	N	FI-S
Managed											
	Brown Shale Barrens	10	26.5 ± 3.1	8	34.1 ± 10.5	13	42.5 ± 4.5	5	6.9 ± 8.7	4	38.9 ± 7.3
	Cave Creek Limestone Glade	8	23.6 ± 5.8	8	34.4 ± 7.7	55	52.5 ± 2.9	6	41.8 ± 12.4	6	69.0 ± 17.8
	Gibbons Creek Sandstone Barrens	6	29.6 ± 4.7	6	33.9 ± 6.9	20	29.1 ± 3.3	6	22.6 ± 4.0	6	25.4 ± 5.6
	Wildcat Bluff Limestone Glade	6	24.1 ± 7.4	6	21.8 ± 4.7	58	68.9 ± 4.7	6	38.8 ± 2.5	6	36.2 ± 6.3
	Mean (managed sites)		25.9 ± 1.4		31.1 ± 3.1		48.3 ± 8.4		27.5 ± 8.1		42.4 ± 9.3
Unmanaged											
	Berryville Shale Glade	4	7.6 ± 2.7	4	19.5 ± 3.1	13	5.4 ± 1.4	4	4.6 ± 4.7	4	14.7 ± 2.5
	Cedar Bluff Sandstone Glade	16	27.6 ± 4.5	6	25.6 ± 6.3		---		---		---
	Pounds Hollow Sandstone Glade	5	10.5 ± 5.5	7	15.4 ± 9.6	9	5.4 ± 2.2	6	0.8 ± 0.4	4	5.6 ± 3.0
	Round Bluff Sandstone Glade	10	24.7 ± 3.4	9	22.5 ± 6.6	4	23.0 ± 6.0		---		---
	Mean (unmanaged sites)		17.6 ± 5.0		20.8 ± 2.2		11.3 ± 5.9		2.7 ± 1.9		10.2 ± 4.6
All Sites	Mean		21.8 ± 2.9		25.9 ± 2.6		32.4 ± 8.9		19.3 ± 7.3		31.6 ± 9.1

FI-N=Forest Interior-North, TS-N=Transition Zone-North, OP=Opening, TS-S=Transition Zone-South, FI-S=Forest Interior-South.

Table 33. Mean (± 1 SE) cover of exposed rock (a percentage of total ground surface) in five subhabitats of the study sites in 1994.

	Site	N	FI-N	N	TS-N	N	OP	N	TS-S	N	FI-S
Managed											
	Brown Shale Barrens	10	0.1 ± 0.1	8	2.1 ± 1.9	13	4.0 ± 1.6	5	1.7 ± 0.9	4	0.1 ± 0.1
	Cave Creek Limestone Glade	8	22.6 ± 4.6	8	12.5 ± 5.7	55	17.3 ± 2.9	6	20.0 ± 10.3	6	4.8 ± 2.9
	Gibbons Creek Sandstone Barrens	6	0.8 ± 0.7	6	3.4 ± 2.6	20	24.5 ± 4.1	6	12.0 ± 2.5	6	13.6 ± 5.4
	Wildcat Bluff Limestone Glade	6	24.8 ± 5.9	6	14.9 ± 5.3	58	23.4 ± 2.7	6	9.0 ± 6.3	6	5.4 ± 2.2
	Mean (managed sites)		12.1 ± 6.7		8.2 ± 3.2		17.3 ± 4.7		10.7 ± 3.8		5.9 ± 2.8
Unmanaged											
	Cedar Bluff Sandstone Glade	16	1.0 ± 0.9	6	6.5 ± 6.2		---		---		---
	Round Bluff Sandstone Glade	10	1.6 ± 1.6	9	13.3 ± 7.4	4	16.6 ± 15.3		---		---
	Mean (unmanaged sites)		1.3 ± 0.3		9.9 ± 3.4		16.6 ± 0.0		---		---
All Sites	Mean		8.5 ± 4.8		8.8 ± 2.2		17.2 ± 3.6		10.7 ± 3.8		5.9 ± 2.8

FI-=Forest Interior-North, TS-N=Transition Zone-North, OP=Opening, TS-S=Transition Zone-South, FI-S=Forest Interior-South.

Table 34. Mean (± 1 SE) bryophyte cover (%) in five subhabtats of the study sites in 1994.

	Site	N	FI-N	N	TS-N	N	OP	N	TS-S	N	FI-S
Managed											
	Brown Shale Barrens	10	1.7 ± 0.6	8	5.2 ± 4.6	13	7.7 ± 3.9	5	2.4 ± 0.9	4	2.0 ± 1.2
	Cave Creek Limestone Glade	8	0.6 ± 0.5	8	8.4 ± 7.7	55	0.3 ± 0.1	6	0.0 ± 0.0	6	0.0 ± 0.0
	Gibbons Creek Sandstone Barrens	6	4.1 ± 2.5	6	3.3 ± 2.6	20	4.3 ± 1.6	6	0.2 ± 0.1	6	0.0 ± 0.0
	Wildcat Bluff Limestone Glade	6	5.4 ± 3.3	6	0.3 ± 0.1	58	2.1 ± 1.1	6	2.8 ± 2.6	6	0.1 ± 0.1
	Mean (managed sites)		2.9 ± 1.1		4.3 ± 1.7		3.6 ± 1.6		1.4 ± 0.7		0.5 ± 0.5
Unmanaged											
	Berryville Shale Glade	4	18.6 ± 14.6	4	14.4 ± 8.4	13	29.2 ± 9.8	4	0.2 ± 0.2	4	0.2 ± 0.2
	Cedar Bluff Sandstone Glade	16	0.1 ± 0.0	6	10.4 ± 5.9		---		---		---
	Pounds Hollow Sandstone Glade	5	13.3 ± 12.3	7	1.2 ± 0.7	9	13.6 ± 6.5	6	45.9 ± 18.4	4	37.6 ± 21.0
	Round Bluff Sandstone Glade	10	0.9 ± 0.5	9	1.8 ± 0.7	4	6.0 ± 3.5		---		---
	Mean (unmanaged sites)		8.2 ± 4.6		6.9 ± 3.3		16.3 ± 6.8		23.1 ± 22.9		18.9 ± 18.7
All Sites	Mean		5.6 ± 2.4		5.6 ± 1.8		9.0 ± 3.7		8.6 ± 1.5		6.7 ± 6.2

FI-N=Forest Interior-North, TS-N=Transition Zone-North, OP=Opening, TS-S=Transition Zone-South, FI-S=Forest Interior-South.

Table 35. Mean (± 1 SE) lichen cover (%) in five subhabtats of the study sites in 1994.

	Site	N	FI-N	N	TS-N	N	OP	N	TS-S	N	FI-S
Managed											
	Brown Shale Barrens	10	0.4 ± 0.1	8	1.3 ± 0.6	13	0.8 ± 0.4	5	0.2 ± 0.1	4	0.1 ± 0.1
	Cave Creek Limestone Glade	8	1.6 ± 0.7	8	2.6 ± 1.9	55	0.1 ± 0.0	6	0.0 ± 0.0	6	0.0 ± 0.0
	Gibbons Creek Sandstone Barrens	6	0.1 ± 0.1	6	0.8 ± 0.6	20	2.7 ± 1.1	6	0.2 ± 0.1	6	0.3 ± 0.1
	Wildcat Bluff Limestone Glade	6	2.2 ± 0.8	6	0.8 ± 0.6	58	0.9 ± 0.3	6	0.2 ± 0.1	6	0.2 ± 0.1
	Mean (managed sites)		1.1 ± 0.5		1.4 ± 0.4		1.1 ± 0.6		0.2 ± 0.1		0.2 ± 0.1
Unmanaged											
	Berryville Shale Glade	4	2.0 ± 1.2	4	10.5 ± 9.0	13	2.9 ± 0.5	4	0.2 ± 0.2	4	1.3 ± 1.3
	Cedar Bluff Sandstone Glade	16	0.1 ± 0.1	6	4.1 ± 2.5		---		---		---
	Pounds Hollow Sandstone Glade	5	0.8 ± 0.8	7	5.2 ± 2.8	9	8.7 ± 3.9	6	0.7 ± 0.7	4	13.4 ± 8.9
	Round Bluff Sandstone Glade	10	0.5 ± 0.4	9	1.5 ± 0.6	4	6.0 ± 3.5		---		---
	Mean (unmanaged sites)		0.9 ± 0.4		5.3 ± 1.9		5.9 ± 1.7		0.5 ± 0.2		7.4 ± 6.1
All Sites	Mean		0.9 ± 0.3		3.4 ± 1.2		3.2 ± 1.2		0.3 ± 0.1		2.6 ± 2.4

FI-N=Forest Interior-North, TS-N=Transition Zone-North, OP=Opening, TS-S=Transition Zone-South, FI-S=Forest Interior-South.

Categorization of Herb Species

Raunkaier's Life Forms. Hemicryptophytes and geophytes were the most important forest-opening life forms (29.9% to 47.2%), followed by phanerophytes and therophytes (5.6% to 18.7%), then chamaephytes (≈3.4%) (Table 36). Most forest-opening subhabitat values for hemicryptophytes and geophytes did not differ. The same was true for managed and unmanaged life form RI, in which standard error showed overlap in values for at least four of five subhabitats.

Herb Species Diversity

Simpson diversity (Ds) for all of the forest-openings did not differ among subhabitats (Table 37). However, managed sites had greater Ds diversity than unmanaged sites in the opening, and southern subhabitats. Similarly, Shannon diversity (H') was greater for managed sites than for unmanaged sites in all subhabitats except the forest interior-north. Mean Shannon diversity did not differ among subhabitats for all of the forest-openings.

Tree Seedling Composition

Six forest-opening sites (i.e., Cave-MGD, Cedar-UMG, Gibbons-MGD, Pounds-UMG, Round-UMG and Wildcat-MGD) showed interesting trends in seedling importance (Table 38). For example, at Wildcat-MGD, *Rhus aromatica* occurred in the first position in the opening, *Ulmus rubra* was most important in both of the southern subhabitats and *Ostrya virginiana* in both of the northern subhabitats. Seedlings of mesophytic species (i.e., *Ulmus* sp.) did not occur in the first position in the opening of any site but were first in importance in the transition and forest interior subhabitats.

Seedlings of the genus *Quercus* occurred in 22 of the 35 (62.9%) of the first RI positions and often accounted for ≥30% of tree seedling importance (Table 39). Cumulative seedling RI of *Quercus* spp., however, did not show consistent peaks or troughs in the opening. Throughout the limestone glades, Cave-MGD and Wildcat-MGD, *Ulmus* was an important genus of tree seedling.

Table 36. Raunkaier's life form (%) for herbs in five subhabitats of the study sites in 1994. Life form categories are summed by relative importance. Categories are according to Raunkaier (1934). The mean ± 1 SE is reported.

Site	FI-N	TS-N	OP	TS-S	FI-S
Chamaephyte:					
Berryville	21.4	15.9	22.5	12.8	15.3
Brown*	0.6	0.0	0.0	8.8	0.0
Cave*	0.8	0.6	0.1	0.0	0.0
Cedar	0.9	2.5	---	---	---
Gibbons*	0.0	0.0	0.0	0.0	3.6
Pounds	1.8	1.7	0.0	0.0	4.1
Round	0.0	0.0	0.0	---	---
Wildcat*	2.6	2.5	0.7	0.0	0.0
Geophyte:					
Berryville	20.7	11.6	17.9	35.4	40.6
Brown*	40.6	42.1	52.2	61.8	61.9
Cave*	44.1	40.8	44.8	41.1	17.2
Cedar	25.9	22.4	---	---	---
Gibbons*	37.8	43.3	49.1	41.6	43.6
Pounds	20.2	35.1	30.5	60.0	39.9
Round	27.9	38.3	41.9	---	---
Wildcat*	21.6	45.4	36.6	43.3	43.3
Hemicryptophyte:					
Berryville	52.9	72.4	57.8	33.7	38.4
Brown*	38.2	49.7	35.5	26.6	31.5
Cave*	36.1	35.5	40.0	39.6	37.9
Cedar	36.6	62.2	---	---	---
Gibbons*	41.7	45.5	31.9	29.9	19.8
Pounds	47.4	31.4	33.4	20.0	39.9
Round	38.5	25.3	16.8	---	---
Wildcat*	45.1	33.3	45.3	36.0	36.0
Phanerophyte:					
Berryville	4.9	0.0	0.0	18.1	0.0
Brown*	13.6	4.8	8.9	1.4	0.0
Cave*	18.1	21.8	11.9	19.3	44.9
Cedar	33.6	2.5	---	---	---
Gibbons*	11.6	3.7	1.6	8.4	24.4
Pounds	21.7	19.6	20.9	10.0	0.0
Round	25.6	6.9	0.0	---	---
Wildcat*	20.1	18.8	15.1	18.3	21.6
Therophyte:					
Berryville	0.0	0.0	1.8	0.0	5.8
Brown*	7.0	3.4	3.4	1.4	6.6
Cave*	0.8	1.2	3.2	0.0	0.0
Cedar	2.9	10.4	---	---	---
Gibbons*	8.8	7.5	17.5	20.1	8.7
Pounds	8.9	12.2	15.1	10.0	16.2

Table 36 (cont'd).

Round	7.9	29.5	41.3	---	---
Wildcat*	10.6	0.0	2.4	2.3	2.8
Mean (managed sites):					
Chamaephyte	1.0 ± 0.6	0.8 ± 0.6	0.2 ± 0.2	2.2 ± 2.2	0.9 ± 0.9
Geophyte	36.0 ± 4.9	42.9 ± 0.9	45.7 ± 3.4	46.9 ± 4.9	41.5 ± 9.2
Hemicryptophyte	40.3 ± 1.9	41.0 ± 3.9	38.2 ± 2.9	33.0 ± 2.9	31.3 ± 4.1
Phanerophyte	15.9 ± 1.9	12.3 ± 4.7	9.4 ± 2.9	11.9 ± 4.3	22.7 ± 9.2
Therophyte	6.8 ± 2.1	3.0 ± 1.6	6.6 ± 3.6	5.9 ± 4.7	4.5 ± 1.9
Mean (unmanaged sites):					
Chamaephyte	6.0 ± 5.1	5.0 ± 3.7	7.5 ± 7.5	6.4 ± 6.4	9.7 ± 5.6
Geophyte	23.7 ± 1.9	26.9 ± 6.1	30.1 ± 6.9	47.7 ± 12.3	40.3 ± 0.4
Hemicryptophyte	43.9 ± 3.8	47.8 ± 11.5	36.0 ± 11.9	26.9 ± 6.9	39.2 ± 0.7
Phanerophyte	21.5 ± 6.0	7.3 ± 4.4	6.9 ± 6.9	14.1 ± 4.1	0.0 ± 0.0
Therophyte	4.9 ± 2.1	13.0 ± 6.1	19.4 ± 11.6	5.0 ± 5.0	11.0 ± 5.2
Mean (all sites):					
Chamaephyte	3.5 ± 0.3	2.9 ± 0.4	3.3 ± 3.2	3.6 ± 2.3	3.8 ± 2.4
Geophyte	29.9 ± 3.4	34.9 ± 4.2	39.0 ± 4.5	47.2 ± 4.5	41.1 ± 5.8
Hemicryptophyte	42.1 ± 2.1	44.4 ± 5.8	37.2 ± 4.8	30.9 ± 2.9	33.9 ± 3.1
Phanerophyte	18.7 ± 3.1	9.8 ± 3.1	8.3 ± 3.1	12.6 ± 2.9	15.2 ± 7.5
Therophyte	5.9 ± 1.4	8.0 ± 3.5	12.1 ± 5.4	5.6 ± 3.3	6.7 ± 2.3

FI-N=Forest Interior-North, TS-N=Transition Zone-North, OP=Opening, TS-S=Transition Zone-South, FI-S=Forest Interior-South.
*Managed site.

Table 37. Simpson and Shannon diversity for herb species in five subhabitats of the study sites in 1994.

		Site	FI-N	TS-N	OP	TS-S	FI-S
Simpson (Ds):							
	Managed	Brown Shale Barrens	9.8	8.4	5.8	5.9	6.3
		Cave Creek Limestone Glade	9.9	10.7	12.2	19.7	13.3
		Gibbons Creek Sandstone Barrens	15.6	9.9	11.8	12.0	9.9
		Wildcat Bluff Limestone Glade	8.7	16.4	9.6	21.9	12.4
		Mean ± 1 SE (managed sites)	11.0 ± 1.6	11.4 ± 1.7	9.9 ± 1.5	14.9 ± 3.7	10.5 ± 1.6
	Unmanaged	Berryville Shale Glade	3.7	19.7	3.4	9.3	8.0
		Pounds Hollow Sandstone Glade	7.1	4.8	3.1	1.9	6.2
		Round Bluff Sandstone Glade	13.8	5.7	5.9	---	---
		Mean ± 1 SE (unmanaged sites)	8.2 ± 2.9	10.1 ± 4.8	4.1 ± 0.9	5.6 ± 3.7	7.1 ± 0.9
All Sites		Mean ± 1 SE	9.8 ± 1.5	10.8 ± 2.1	7.4 ± 1.4	11.8 ± 3.2	9.4 ± 1.2
Shannon (H'):							
	Managed	Brown Shale Barrens	2.6	2.4	2.1	2.2	2.2
		Cave Creek Limestone Glade	2.6	2.8	2.9	3.2	2.9
		Gibbons Creek Sandstone Barrens	3.1	2.7	2.8	2.7	2.7
		Wildcat Bluff Limestone Glade	2.6	3.1	2.8	3.3	2.9
		Mean ± 1 SE (managed sites)	2.7 ± 0.1	2.8 ± 0.1	2.7 ± 0.2	2.9 ± 0.3	2.7 ± 0.2
	Unmanaged	Berryville Shale Glade	1.5	0.9	1.3	2.4	2.4
		Pounds Hollow Sandstone Glade	2.2	1.9	1.5	0.7	2.0
		Round Bluff Sandstone Glade	2.8	1.9	1.9	---	---

Table 37 (cont'd)

Table 37 (cont'd).

	Mean ± 1 SE (unmanaged sites)	2.2 ± 0.4	1.6 ± 0.3	1.6 ± 0.2	1.6 ± 0.9	2.2 ± 0.2
All Sites	Mean ± 1 SE	2.5 ± 0.2	2.2 ± 0.3	2.2 ± 0.2	2.4 ± 0.4	2.5 ± 0.2

FI-N=Forest Interior-North, TS-N=Transition Zone-North, OP=Opening, TS-S=Transition Zone-South, FI-S=Forest Interior-South.

Table 38. Relative importance (%) of the three most important species of tree seedlings in five subhabitats of the study sites in 1994.

Site	FI-N		TS-N		OP		TS-S		FI-S	
BVL	*Ame arb*	24.5	*Que ste*	21.9	*Que ste*	17.9	*Que ste*	26.0	*Que vel*	13.8
	Vac pal	22.1	*Que mar*	18.8	*Que mar*	14.4	*Que vel*	12.3	*Car tex*	12.6
	Que vel	8.3	*Vac arb*	10.9	*Rhu cop*	12.6	*Rhu aro*	11.4	*Sas alb*	12.2
BRN*	*Ost vir*	17.5	*Que ste*	14.9	*Que ste*	22.2	*Vac arb*	26.0	*Ulm ala*	23.7
	Que ste	15.2	*Ost vir*	13.7	*Vac arb*	13.2	*Ulm ala*	16.6	*Vac arb*	20.4
	Que vel	7.8	*Car gla*	8.3	*Ulm ala*	12.0	*Que ste*	15.8	*Que ste*	10.3
CAV*	*Ulm rub*	14.6	*Rhu aro*	19.8	*Que pri*	12.8	*Ulm rub*	14.0	*Ulm rub*	22.4
	Cel ten	9.4	*Ulm rub*	11.1	*Rhu aro*	12.3	*Cel ten*	11.3	*Cel ten*	15.1
	Rhu aro	9.3	*Cel ten*	6.8	*Ulm rub*	9.9	*Rhu aro*	10.8	*Ace sac*	9.0
CDR	*Que ste*	11.8	*Que ste*	25.1						
	Car ovt	11.3	*Ulm ala*	18.6						
	Rhu aro	9.9	*Jun vir*	9.8						
GIB*	*Sym orb*	23.1	*Ulm ala*	25.6	*Que ste*	16.3	*Que ste*	16.3	*Que ste*	16.1
	Car tex	12.3	*Sym orb*	21.2	*Car tex*	14.1	*Que mar*	10.8	*Car tex*	10.6
	Ulm ala	10.3	*Car tex*	12.9	*Vac pal*	9.5	*Vac arb*	9.5	*Que vel*	9.9
PDS	*Que ste*	21.6	*Que ste*	19.9	*Ame arb*	19.2	*Que alb*	21.5	*Que alb*	23.4
	Vac arb	14.0	*Ame arb*	13.9	*Que ste*	16.2	*Ame arb*	13.8	*Ame arb*	13.0
	Que mar	8.4	*Vac arb*	12.6	*Vac arb*	15.7	*Que ste*	7.7	*Que rub*	9.9
RND	*Ulm ala*	13.9	*Ulm ala*	16.6	*Vac arb*					
	Jun vir	11.0	*Rhu aro*	16.1	*Ulm ala*					
	Car ovt	9.3	*Car ovt*	10.7	*Que ste*					
WLC*	*Ost vir*	19.3	*Ost vir*	19.9	*Rhu aro*	17.0	*Ulm rub*	24.9	*Ulm rub*	16.8
	Ulm rub	17.6	*Ulm rub*	11.1	*Ulm rub*	12.9	*Rhu aro*	8.8	*Ost vir*	11.2
	Ace sac	8.9	*Ace sac*	7.2	*Ost vir*	11.6	*Ulm ala*	8.6	*Cer can*	9.3

*Managed site.

FI-N=Forest Interior-North, TS-N=Transition Zone-North, OP=Opening, TS-S=Transition Zone-South, FI-S=Forest Interior-South.

BVL=Berryville Shale Glade, BRN=Brown Shale Barrens, CAV=Cave Creek Limestone Glade, CDR=Cedar Bluff Sandstone Glade, GIB=Gibbons Creek Sandstone Barrens, PDS=Pounds Hollow Sandstone Glade, RND=Round Bluff Sandstone Glade, WLC=Wildcat Bluff Limestone Glade.

Ace sac=Acer saccharum, Ame arb=Amelanchier arborea, Car gla=Carya glabra, Car ovt=Carya ovata, Car tex=Carya texana, Cel ten=Celtis tenuifolia, Cer can=Cercis canadensis, Jun vir=Juniperus virginiana, Ost vir=Ostrya virginiana, Que mar=Quercus marilandica, Que pri=Quercus prinoides var. *acuminata, Que rub=Quercus rubra, Que ste=Quercus stellata, Que*

Table 38 (cont'd).

vel=Quercus velutina, Rhu aro=Rhus aromatica, Rhu cop=Rhus copallina, Sas alb=Sassafras albidum, Sym orb=Symphoricarpos orbiculatus, Ulm ala=Ulmus alata, Ulm rub=Ulmus rubra, Vac arb=Vaccinium arboreum, Vac pal=Vaccinium pallidum.

Table 39. Relative importance (%) of the three most important tree seedling genera in five subhabitats of the study sites in 1994. Seedlings are listed to species when possible.

Site	FI-N		TS-N		OP		TS-S		FI-S	
BVL	*Que* sp.	29.2	*Que* sp.	62.6	*Que* sp.	47.4	*Que* sp.	52.2	*Que* sp.	37.8
	Vac sp.	25.8	*Vac arb*	10.9	*Rhu* sp.	16.9	*Rhu* sp.	14.5	*Car* sp.	15.7
	Ame arb	24.5	*Ame arb*	10.7	*Ame arb*	9.9	*Car tex*	10.5	*Sas alb*	12.2
BRN*	*Que* sp.	32.9	*Que* sp.	31.2	*Que* sp.	33.5	*Que* sp.	26.8	*Que* sp.	26.2
	Ost vir	17.5	*Car* sp.	17.7	*Car* sp.	24.1	*Vac arb*	26.0	*Ulm ala*	23.7
	Car sp.	17.2	*Ost vir*	13.7	*Vac arb*	13.2	*Ulm ala*	16.6	*Vac arb*	20.4
CAV*	*Ulm* sp.	20.1	*Rhu aro*	19.9	*Que* sp.	19.2	*Ulm rub*	14.1	*Ulm* sp.	23.2
	Que sp.	15.4	*Ulm* sp.	15.9	*Rhu* sp.	12.6	*Que* sp.	12.0	*Cel ten*	15.1
	Rhu sp.	9.9	*Que* sp.	7.7	*Ulm* sp.	11.6	*Cel ten*	11.4	*Ace* sp.	12.4
CDR	*Que* sp.	22.1	*Que* sp.	35.9						
	Car sp.	21.6	*Ulm ala*	18.6						
	Rhu sp.	12.2	*Car* sp.	13.5						
GIB*	*Que* sp.	24.9	*Ulm ala*	25.6	*Que* sp.	41.2	*Que* sp.	44.7	*Que* sp.	45.1
	Sym orb	23.1	*Que* sp.	22.8	*Car* sp.	17.1	*Car* sp.	12.8	*Car* sp.	17.8
	Car sp.	20.8	*Sym orb*	21.2	*Vac* sp.	10.0	*Vac* sp.	12.4	*Ame arb*	9.2
PDS	*Que* sp.	43.1	*Que* sp.	38.9	*Que* sp.	33.4	*Que* sp.	46.6	*Que* sp.	53.7
	Vac arb	14.0	*Ame arb*	13.9	*Ame arb*	19.2	*Ame arb*	13.8	*Ame arb*	13.0
	Car sp.	8.9	*Vac arb*	12.6	*Vac arb*	15.7	*Car* sp.	8.9	*Vac arb*	8.0
RND	*Car* sp.	13.9	*Ulm ala*	16.6	*Vac arb*	50.2				
	Ulm ala	13.9	*Rhu aro*	16.1	*Sas alb*	12.8				
	Que sp.	13.5	*Car* sp.	15.6	*Ulm ala*	12.8				

Table 39 (cont'd).

WLC*	*Ulm* sp.	20.0	*Ost vir*	19.9	*Ulm* sp.	17.8	*Ulm* sp.	33.5	*Ulm* sp.	24.3
	Ost vir	19.3	*Que* sp.	12.0	*Rhu* sp.	17.1	*Rhu aro*	8.8	*Ost vir*	11.2
	Ace sp.	10.8	*Ulm rub*	11.1	*Ost vir*	11.6	*Cer can*	8.3	*Cer can*	9.3

*Managed site.

FI-N=Forest Interior-North, TS-N=Transition Zone-North, OP=Opening, TS-S=Transition Zone-South, FI-S=Forest Interior-South.

BVL=Berryville Shale Glade, BRN=Brown Shale Barrens, CAV=Cave Creek Limestone Glade, CDR=Cedar Bluff Sandstone Glade, GIB=Gibbons Creek Sandstone Barrens, PDS=Pounds Hollow Sandstone Glade, RND=Round Bluff Sandstone Glade, WLC=Wildcat Bluff Limestone Glade.

Ace sp.=*Acer* sp., *Amearb=Amelanchier arborea*, *Car* sp.=*Carya* sp., *Cartex=Carya texana*, *Celten=Celtis tenuifolia*, *Cercan=Cercis canadensis*, *Ostvir=Ostrya virginiana*, *Que* sp.=*Quercus* sp., *Rhuaro=Rhus aromatica*, *Rhu* sp.=*Rhus* sp., *Sasalb=Sassafras albidum*, *Symorb=Symphoricarpos orbiculatus*, *Ulmala=Ulmus alata*, *Ulmrub=Ulmus rubra*, *Ulm* sp.=*Ulmus* sp., *Vacarb=Vaccinium arboreum*, *Vac* sp.=*Vaccinium* sp.

The mean number of tree seedling species (per 25 m^2) for all of the study sites was greatest in the forest interior-north (10.2 ± 0.9) and least in the opening subhabitat (5.9 ± 0.9) (Table 40). Managed sites had more seedling species in the forest interior-north and transition zone-north than unmanaged sites.

Forest-opening tree seedling density (per 25 m^2) ranged from 33.9 ± 9.5 to 62.1 ± 12.2 (Table 41). Managed sites had more seedlings than unmanaged sites in both the northern and southern transition zones. While there was no difference in the number of seedlings among subhabitats for managed sites, there were fewer seedlings in the opening of unmanaged sites than in any other subhabitat except the transition zone-north.

Shade-intolerant was the most important forest-opening shade tolerance category for tree seedlings in the opening subhabitat (51.8% ± 7.6%) (Table 42). For all subhabitats, shade-intolerant and/or shade-tolerant seedlings were more important than shade-intermediate tree seedlings. Unmanaged sites exceeded managed sites in shade intolerance in the opening and transition zone-north while managed sites exceeded unmanaged in the opening for RI in the shade-intermediate category. The opening of unmanaged sites had the lowest shade-intermediate value. There was no difference among subhabitats or between managed and unmanaged sites for shade tolerance.

Shrub and Sapling Composition

High RI values are a result of the paucity of individuals in the shrub and sapling canopy layer (Table 43). Several of the sites showed a continuity of shrub and sapling species in the opening and conterminous zones. For example, at Cedar-UMG, Pounds-UMG, and Round-UMG, *Juniperus virginiana* was the most important sapling in the opening and transition zone subhabitats. At Gibbons-MGD, *Ulmus alata* was most important in the opening and northern subhabitats while at Wildcat-MGD, *Ostrya virginiana* was the most important sapling in all

Table 40. Mean (± 1 SE) number of tree seedling species (per 25 m^2) in five subhabitats of the study sites in 1994.

	Site	N	FI-N	N	TS-N	N	OP	N	TS-S	N	FI-S
Managed											
	Brown Shale Barrens	10	13.8 ± 0.7	8	11.0 ± 1.1	13	4.4 ± 0.8	5	6.4 ± 1.7	4	7.0 ± 1.9
	Cave Creek Limestone Glade	6	10.6 ± 1.7	6	10.5 ± 1.6	18	6.2 ± 0.7	4	8.2 ± 3.1	6	9.8 ± 1.5
	Gibbons Creek Sandstone Barrens	6	10.7 ± 1.1	6	7.8 ± 0.9	20	7.6 ± 0.5	6	9.3 ± 0.6	6	9.0 ± 1.2
	Wildcat Bluff Limestone Glade	6	10.5 ± 0.4	6	11.7 ± 1.0	59	9.7 ± 0.5	6	11.0 ± 1.1	6	12.0 ± 1.1
	Mean (managed sites)		11.4 ± 0.8		10.3 ± 0.9		6.9 ± 1.1		8.7 ± 0.9		9.5 ± 1.0
Unmanaged											
	Berryville Shale Glade	4	8.5 ± 0.5	4	5.8 ± 1.5	13	7.3 ± 0.8	4	7.8 ± 1.3	4	12.0 ± 0.8
	Cedar Bluff Sandstone Glade	16	8.7 ± 0.7	1	7.8 ± 0.0		---		---		---
	Pounds Hollow Sandstone Glade	5	5.9 ± 1.0	7	4.0 ± 0.7	9	3.3 ± 1.1	6	5.1 ± 1.6	4	5.5 ± 1.8
	Round Bluff Sandstone Glade	10	12.6 ± 1.0	9	7.0 ± 1.5	4	3.0 ± 0.4		---		---
	Mean (unmanaged sites)		8.9 ± 1.4		6.2 ± 0.8		4.5 ± 1.4		6.5 ± 1.3		8.8 ± 3.2
All Sites	Mean		10.2 ± 0.9		8.2 ± 0.9		5.9 ± 0.9		7.9 ± 0.9		9.2 ± 1.1

FI-N=Forest Interior-North, TS-N=Transition Zone-North, OP=Opening, TS-S=Transition Zone-South, FI-S=Forest Interior-South.

Table 41. Density (per 25 m^2) of tree seedlings in five subhabitats of the study sites in 1994. Data are reported as mean ± 1 SE.

	Site	N	FI-N	N	TS-N	N	OP	N	TS-S	N	FI-S
Managed											
	Brown Shale Barrens	10	107.8 ± 11.6	8	54.9 ± 9.3	13	19.5 ± 4.3	5	73.6 ± 12.8	4	30.3 ± 12.7
	Cave Creek Limestone Glade	8	16.0 ± 9.3	8	24.5 ± 17.8	55	8.9 ± 4.2	6	36.3 ± 20.2	6	21.8 ± 17.3
	Gibbons Creek Sandstone Barrens	6	92.3 ± 5.6	6	97.2 ± 29.7	20	68.0 ± 11.7	6	58.8 ± 7.8	6	47.2 ± 12.8
	Wildcat Bluff Limestone Glade	6	48.8 ± 9.8	6	68.5 ± 13.9	58	68.3 ± 4.9	6	81.0 ± 8.9	6	55.5 ± 7.8
	Mean (managed sites)		66.2 ± 20.9		61.3 ± 15.1		41.2 ± 15.7		62.4 ± 9.9		38.7 ± 7.7
Unman.											
	Berryville Shale Glade	4	66.5 ± 11.4	4	25.5 ± 9.4	13	39.8 ± 6.7	4	42.8 ± 8.6	4	38.8 ± 3.6
	Cedar Bluff Sandstone Glade	16	39.5 ± 3.8	6	41.5 ± 7.3		---		---		---
	Pounds Hollow Sandstone Glade	5	27.6 ± 5.0	7	17.2 ± 7.2	9	16.6 ± 5.9	6	35.9 ± 11.7	4	36.1 ± 13.0
	Round Bluff Sandstone Glade	10	98.3 ± 6.8	9	48.2 ± 14.1	4	16.8 ± 6.6		---		---
	Mean (unmanaged sites)		57.9 ± 15.7		33.1 ± 7.1		24.4 ± 7.7		39.4 ± 3.5		37.5 ± 1.3
All Sites	Mean		62.1 ± 12.2		47.2 ± 9.4		33.9 ± 9.5		54.7 ± 7.9		38.3 ± 4.9

FI-N=Forest Interior-North, TS-N=Transition Zone-North, OP=Opening, TS-S=Transition Zone-South, FI-S=Forest Interior-South.

Table 42. Tree seedling shade tolerance in five subhabitats of the study sites in 1994. Shade tolerance classes are summed by relative importance (%). Tree seedling shade tolerance designations are according to Burns and Honkala (1990), Barnes and Wagner (1981), and Mohlenbrock (1986).

	Site	FI-N	TS-N	OP	TS-S	FI-S
Intolerant:						
Managed	Brown Shale Barrens	39.8	39.0	57.2	62.6	43.9
	Cave Creek Limestone Glade	27.0	26.3	33.8	31.1	25.5
	Gibbons Creek Sandstone Barrens	52.8	45.7	56.6	61.4	42.1
	Wildcat Bluff Limestone Glade	15.4	22.9	19.4	25.2	26.4
	Mean ± 1 SE (managed sites)	33.8 ± 8.1	33.5 ± 5.3	41.8 ± 9.2	45.1 ± 9.8	34.5 ± 4.9
Unmanaged	Berryville Shale Glade	43.1	57.9	59.8	47.1	30.5
	Cedar Bluff Sandstone Glade	43.9	55.5	---	---	---
	Pounds Hollow Sandstone Glade	71.8	59.6	53.3	57.1	31.0
	Round Bluff Sandstone Glade	38.6	34.8	82.3	---	---
	Mean ± 1 SE (unmanaged sites)	49.4 ± 7.6	51.9 ± 5.8	65.1 ± 8.8	52.1 ± 5.0	30.8 ± 0.2
Intermediate:						
Managed	Brown Shale Barrens	22.4	21.5	24.1	14.5	20.6
	Cave Creek Limestone Glade	44.0	43.2	38.6	41.4	40.5
	Gibbons Creek Sandstone Barrens	28.8	23.6	24.7	19.1	32.8
	Wildcat Bluff Limestone Glade	9.7	13.5	11.1	7.6	8.7
	Mean ± 1 SE (managed sites)	26.2 ± 7.1	25.5 ± 6.3	24.6 ± 5.6	20.7 ± 7.3	25.7 ± 6.9
Unmanaged	Berryville Shale Glade	16.9	20.9	18.7	26.9	37.9
	Cedar Bluff Sandstone Glade	25.6	15.1	---	---	---
	Pounds Hollow Sandstone Glade	16.6	16.9	14.0	17.5	43.1
	Round Bluff Sandstone Glade	23.6	21.2	0.0	---	---

Table 42 (cont'd).

	Mean ± 1 SE (unmanaged sites)	20.7 ± 2.3	18.5 ± 1.5	10.9 ± 5.6	22.2 ± 2.4	40.5 ± 4.7
Tolerant:						
Managed	Brown Shale Barrens	37.7	39.5	18.7	22.9	35.5
	Cave Creek Limestone Glade	28.9	30.5	27.6	27.5	34.0
	Gibbons Creek Sandstone Barrens	18.4	30.7	18.7	19.5	25.1
	Wildcat Bluff Limestone Glade	74.9	63.5	69.5	67.3	64.9
	Mean ± 1 SE (managed sites)	39.9 ± 12.3	41.1 ± 7.8	33.6 ± 12.1	34.3 ± 11.1	39.9 ± 8.7
Unmanaged	Berryville Shale Glade	39.9	21.2	21.5	25.9	31.6
	Cedar Bluff Sandstone Glade	30.5	29.4	---	---	---
	Pounds Hollow Sandstone Glade	11.6	23.5	32.7	25.4	25.9
	Round Bluff Sandstone Glade	37.9	43.9	17.7	---	---
	Mean ± 1 SE (unmanaged sites)	29.9 ± 6.4	29.5 ± 5.1	23.9 ± 4.5	25.7 ± 0.2	28.8 ± 2.9
Mean ± 1 SE (all sites):						
	Intolerant	41.6 ± 5.9	42.7 ± 5.0	51.8 ± 7.6	47.4 ± 6.5	33.2 ± 3.2
	Intermediate	23.5 ± 3.6	21.9 ± 3.3	18.7 ± 4.6	21.2 ± 4.8	30.6 ± 5.5
	Tolerant	34.9 ± 6.7	35.3 ± 4.8	29.5 ± 6.9	31.4 ± 7.3	36.2 ± 5.9

FI-N=Forest Interior-North, TS-N=Transition Zone-North, OP=Opening, TS-S=Transition Zone-South, FI-S=Forest Interior-South.

Table 43. Relative importance (%) for the three most important shrub and sapling species in five subhabitats of the study sites in 1994.

Site	FI-N		TS-N		OP		TS-S		FI-S	
BVL	*Vac arb*	45.5	*Que mar*	47.2	*Que mar*	59.0	*Fra ame*	25.0	*Car tex*	50.0
	Vac pal	23.7	*Vac arb*	34.7	*Vac arb*	29.2	*Que ste*	25.0	*Ulm ala*	50.0
	Que mar	20.5	*Que ste*	18.1	*Que ste*	11.8	*Sas alb*	25.0		
							Ulm ala	25.0		
BRN*	none		none		*Que ste*	50.0	*Vac arb*	58.3	*Vac arb*	76.2
					Vac arb	50.0	*Ulm ala*	41.7	*Ulm ala*	23.8
CAV*	*Ost vir*	28.8	*Cor dru*	39.4	*Fra ame*	23.9	*Cer can*	70.8	none	
	Fra ame	22.5	*Ace sac*	21.9	*Cer can*	19.9	*Jun vir*	29.2		
	Car tex	16.3	*Fra ame*	12.9	*Que pri*	15.7				
			Que shu	12.9						
			Ulm rub	12.9						
CDR	*Jun vir*	33.5	*Jun vir*	100						
	Ulm ala	31.6								
	Fra ame	9.7								
GIB*	*Ulm ala*	50.0	*Ulm ala*	69.0	*Ulm ala*	48.1	*Vac arb*	55.0	*Car ovt*	50.0
	Car tex	25.0	*Car tex*	15.5	*Ame arb*	14.8	*Ulm ala*	45.0	*Ulm ala*	50.0
	Fra ame	25.0	*Jun vir*	15.5	*Car tex*	14.8				
PDS	*Vac arb*	39.7	*Jun vir*	41.7	*Jun vir*	31.7	*Jun vir*	32.5	*Dio vir*	33.3
	Que mar	22.6	*Ame arb*	26.3	*Ulm ala*	23	*Vac arb*	17.5	*Ame arb*	16.7
	Ulm ala	18.8	*Vac arb*	22.5	*Vac arb*	21.7	*Que alb*	15.0	*Que alb*	16.7
									Vac arb	16.7
RND	*Car gla*	50.0	*Jun vir*	70.8	*Jun vir*	73.3				
	Ulm ala	22.5	*Ulm ala*	29.2	*Ulm ala*	26.7				
	Jun vir	16.3								
WLC*	*Ost vir*	46.0	*Ost vir*	75.0	*Ost vir*	55.6	*Ost vir*	50.0	*Ulm rub*	40.2
	Ace sac	21.6	*Ace sac*	25.0	*Ulm rub*	19.0	*Cel ten*	25.0	*Cra* sp.	29.4
	Ame arb	10.8			*Ace sac*	6.3	*Ulm rub*	25.0	*Ost vir*	25.3

*Managed site.

FI-N=Forest Interior-North, TS-N=Transition Zone-North, OP=Opening, TS-S=Transition Zone-South, FI-S=Forest Interior-South.

BVL=Berryville Shale Glade, BRN=Brown Shale Barrens, CAV=Cave Creek Limestone Glade, CDR=Cedar Bluff Sandstone Glade, GIB=Gibbons Creek Sandstone Barrens, PDS=Pounds Hollow Sandstone Glade, RND=Round Bluff Sandstone Glade, WLC=Wildcat Bluff Limestone Glade.

Ace sac=Acer saccharum, Ame arb=Amelanchier arborea, Car gla=Carya glabra, Car

Table 43 (cont'd).

ovt=Carya ovata, Car tex=Carya texana, Cel ten=Celtis tenuifolia, Cer can=Cercis canadensis, Cor dru=Cornus drummondii, Cra sp.=*Crataegus* sp., *Fra ame=Fraxinus americana, Jun vir=Juniperus virginiana, Ost vir=Ostrya virginiana, Que alb=Quercus alba, Que mar=Quercus marilandica, Que pri=Quercus prinoides* var. *acuminata, Que shu=Quercus shumardii, Que ste=Quercus stellata, Que vel=Quercus velutina, Sas alb=Sassafras albidum, Ulm ala=Ulmus alata, Ulm rub=Ulmus rubra, Vac arb=Vaccinium arboreum, Vac pal=Vaccinium pallidum.*

subhabitats except the forest interior-south.

The mean number of shrub and sapling species (per 25 m^2) for all sites ranged from 0.6 ± 0.1 to 0.9 ± 0.2 (Table 44). There was no difference among forest-openings for mean shrub and sapling species richness. Likewise, managed and unmanaged sites did not differ in the number of shrub and sapling species among subhabitats.

Shrub and sapling density (per 25 m^2) for all sites was lower in the opening than in the northern subhabitats (Table 45). Except for the forest interior-north, managed and unmanaged site subhabitats did not differ in density.

Shade-tolerant and shade-intolerant shrubs and saplings were more important than the shade-intermediate category in all subhabitats except the forest interior-south (Table 46). Unmanaged sites exceeded managed sites for shade intolerance in the opening and northern subhabitats. However, managed sites exceeded unmanaged sites in the opening in the shade-intermediate category and in both of the transition zones for shade tolerance.

Tree Composition

Fire-tolerant *Quercus* species were the most important trees in the opening of all of the managed sites (Table 47). Although the opening at one unmanaged site (Berryville-UMG) was dominated by *Quercus marilandica*, the openings of the two other unmanaged sites were dominated by *Juniperus virginiana*, a fire-intolerant species. At all managed sites, mesophytic species such as *Fraxinus americana*, *Ulmus alata*, and *Acer saccharum* increased in RI in the transition and forest interior subhabitats.

Species of *Quercus* occurred in 22 of the 35 (62.9%) first positions of RI and often accounted for ≥35% of forest-opening RI (Table 48). Relative importance for this genus also peaked in the opening, accounting for 56.7% of opening RI for trees. *Juniperus virginiana* RI also peaked in the opening, at ≈24%.

Table 44. Mean (± 1 SE) number of shrub and sapling species (per 25 m^2) in five subhabitats of the study sites in 1994.

	Site	N	FI-N	N	TS-N	N	OP	N	TS-S	N	FI-S
Managed											
	Brown Shale Barrens	10	0.0 ± 0.0	8	0.0 ± 0.0	13	0.2 ± 0.1	5	0.6 ± 0.4	4	0.8 ± 0.5
	Cave Creek Limestone Glade	8	0.6 ± 0.3	8	0.8 ± 0.5	55	0.7 ± 0.1	6	0.5 ± 0.2	6	0.0 ± 0.0
	Gibbons Creek Sandstone Barrens	6	0.7 ± 0.3	6	1.0 ± 0.4	20	0.7 ± 0.2	6	0.7 ± 0.3	6	0.3 ± 0.2
	Wildcat Bluff Limestone Glade	6	1.3 ± 0.4	6	0.5 ± 0.3	58	0.2 ± 0.1	6	0.7 ± 0.3	6	2.0 ± 0.3
	Mean (managed sites)		0.7 ± 0.3		0.6 ± 0.2		0.5 ± 0.1		0.6 ± 0.0		0.8 ± 0.4
Unmanaged											
	Berryville Shale Glade	4	1.8 ± 0.3	4	1.0 ± 0.4	13	0.6 ± 0.2	4	1.0 ± 0.4	4	0.5 ± 0.5
	Cedar Bluff Sandstone Glade	16	1.7 ± 0.2	6	0.3 ± 0.2		---		---		---
	Pounds Hollow Sandstone Glade	5	0.9 ±0.4	7	0.6 ± 0.3	9	0.7 ± 0.3	6	1.3 ± 0.6	4	0.8 ± 0.5
	Round Bluff Sandstone Glade	10	0.8 ± 0.2	9	0.7 ± 0.2	4	0.8 ± 0.3		---		---
	Mean (unmanaged sites)		1.3 ± 0.3		0.7 ± 0.1		0.7 ± 0.1		1.2 ± 0.2		0.7 ± 0.2
All Sites	Mean		0.9 ± 0.2		0.6 ± 0.1		0.6 ± 0.1		0.8 ± 0.1		0.7 ± 0.3

FI-N=Forest Interior-North, TS-N=Transition Zone-North, OP=Opening, TS-S=Transition Zone-South, FI-S=Forest Interior-South.

Table 45. Density (per 25 m^2) of shrubs and saplings in five subhabitats of the study sites in 1994. Data are reported as mean ± 1 SE.

	Site	N	FI-N	N	TS-N	N	OP	N	TS-S	N	FI-S
Managed											
	Brown Shale Barrens	10	0.0 ± 0.0	8	0.0 ± 0.0	13	0.2 ± 0.1	5	0.8 ± 0.6	4	1.8 ± 1.2
	Cave Creek Limestone Glade	8	1.0 ± 0.5	8	1.4 ± 0.9	55	1.1 ± 0.2	6	0.7 ± 0.3	6	0.0 ± 0.0
	Gibbons Creek Sandstone Barrens	6	0.7 ± 0.3	6	1.2 ± 0.5	20	0.6 ± 0.2	6	0.8 ± 0.5	6	0.3 ± 0.2
	Wildcat Bluff Limestone Glade	6	1.8 ± 0.5	6	1.0 ± 0.7	58	0.3 ± 0.1	6	0.7 ± 0.3	6	3.7 ± 0.6
	Mean (managed sites)		0.9 ± 0.4		0.9 ± 0.3		0.6 ± 0.2		0.8 ± 0.0		1.5 ± 0.8
Unmanaged											
	Berryville Shale Glade	4	4.0 ± 1.4	4	2.3 ± 1.0	13	0.7 ± 0.2	4	1.0 ± 0.4	4	0.5 ± 0.5
	Cedar Bluff Sandstone Glade	16	2.1 ± 0.4	6	0.3 ± 0.2		---		---		---
	Pounds Hollow Sandstone Glade	5	1.3 ± 0.6	7	1.1 ± 0.8	9	0.9 ± 0.5	6	2.5 ± 0.6	4	0.8 ± 0.5
	Round Bluff Sandstone Glade	10	1.0 ± 0.3	9	1.1 ± 0.4	4	1.0 ± 0.4		---		---
	Mean (unmanaged sites)		2.1 ± 0.7		1.2 ± 0.4		0.9 ± 0.1		1.8 ± 0.7		0.7 ± 0.2
All Sites	Mean		1.5 ± 0.4		1.1 ± 0.2		0.7 ± 0.1		1.1 ± 0.3		1.2 ± 0.6

FI-N=Forest Interior-North, TS-N=Transition Zone-North, OP=Opening, TS-S=Transition Zone-South, FI-S=Forest Interior-South.

Table 46. Shrub and sapling shade tolerance in five subhabitats of the study sites in 1994. Species were located in plot sampling. Shade tolerance classes are weighted by relative importance. The shade tolerance designations are according to Burns and Honkala (1990), Barnes and Wagner (1981), and Mohlenbrock (1986). The mean ± 1 SE is reported.

		Site	FI-N	TS-N	OP	TS-S	FI-S
Intolerant:							
	Managed	Brown Shale Barrens	0.0	0.0	100	58.3	76.2
		Cave Creek Limestone Glade	38.8	65.2	52.2	29.2	0.0
		Gibbons Creek Sandstone Barrens	25.0	15.5	14.8	54.9	0.0
		Wildcat Bluff Limestone Glade	0.0	0.0	19.0	25.0	0.0
		Mean (managed sites)	15.9 ± 9.6	20.2 ± 15.4	46.5 ± 19.7	41.9 ± 8.6	19.1 ± 19.1
	Unmanaged	Berryville Shale Glade	100	100	100	75.0	0.0
		Cedar Bluff Sandstone Glade	43.2	100	---	---	---
		Pounds Hollow Sandstone Glade	81.2	64.2	65.0	45.0	16.7
		Round Bluff Sandstone Glade	66.3	73.3	70.8	---	---
		Mean (unmanaged sites)	72.7 ± 12.0	84.4 ± 9.2	78.6 ± 10.8	60.0 ± 14.9	8.4 ± 8.3
Intermediate:							
	Managed	Brown Shale Barrens	0.0	0.0	0.0	0.0	0.0
		Cave Creek Limestone Glade	16.3	0.0	2.2	0.0	0.0
		Gibbons Creek Sandstone Glade	25.0	15.5	14.8	0.0	50.0
		Wildcat Bluff Limestone Glade	21.6	0.0	0.0	0.0	0.0
		Mean (intermed.-managed sites)	15.7 ± 5.5	3.9 ± 3.9	4.3 ± 3.6	0.0 ± 0.0	12.5 ± 12.5
	Unmanaged	Berryville Shale Glade	0.0	0.0	0.0	0.0	50.0
		Cedar Bluff Sandstone Glade	10.2	0.0	---	---	---
		Pounds Hollow Sandstone Glade	0.0	0.0	0.0	22.5	33.3

Table 46 (cont'd).

	Round Bluff Sandstone Glade	11.3	0.0	0.0	---	---
	Mean (intermed.-unmanaged sites)	5.4 ± 3.1	0.0 ± 0.0	0.0 ± 0.0	11.3 ± 11.3	41.7 ± 12.5
Tolerant:						
Managed	Brown Shale Barrens	0.0	0.0	0.0	41.7	23.8
	Cave Creek Limestone Glade	45.0	34.8	45.6	70.8	0.0
	Gibbons Creek Sandstone Glade	49.9	69.0	70.3	45.0	50.0
	Wildcat Bluff Limestone Glade	78.4	100	80.9	75.0	100
	Mean (tolerant-managed sites)	43.3 ± 16.2	50.9 ± 21.6	49.2 ± 17.3	58.1 ± 8.6	43.5 ± 21.4
Unmanaged	Berryville Shale Glade	0.0	0.0	0.0	25.0	50.0
	Cedar Bluff Sandstone Glade	46.6	0.0	---	---	---
	Pounds Hollow Sandstone Glade	18.8	35.8	35.0	32.5	50.0
	Round Bluff Sandstone Glade	22.5	26.7	29.2	---	---
	Mean (tolerant-unmanaged sites)	21.9 ± 9.6	15.6 ± 9.2	21.4 ± 10.8	28.8 ± 3.8	50.0 ± 0.0
Mean (all sites):						
	Intolerant	44.3 ± 12.9	52.3 ± 14.7	60.3 ± 13.0	47.9 ± 7.7	15.5 ± 12.4
	Intermediate	10.6 ± 3.5	1.9 ± 1.9	2.4 ± 2.1	3.8 ± 3.8	22.2 ± 10.2
	Tolerant	32.7 ± 9.6	33.3 ± 12.7	37.3 ± 11.9	48.3 ± 8.3	45.6 ± 13.6

FI-N=Forest Interior-North, TS-N=Transition Zone-North, OP=Opening, TS-S=Transition Zone-South, FI-S=Forest Interior-South.

Table 47. Relative importance (%) for the three most important tree species in five subhabitats of the study sites in 1994.

Site	FI-N		TS-N		OP		TS-S		FI-S	
BVL	*Que mar*	62.5	*Que mar*	50.0	*Que mar*	66.8	*Car tex*	50.0	*Que vel*	42.9
	Que ste	37.5	*Que ste*	50.0	*Que ste*	33.2	*Que ste*	50.0	*Car gla*	14.3
									Car tex	14.3
BRN*	*Que ste*	50.0	*Que ste*	63.3	*Que ste*	100	*Que ste*	100	*Ulm ala*	100
	Car gla	25.0	*Car gla*	15.6						
	Ulm ala	25.0	*Ulm ala*	10.6						
CAV*	*Fra ame*	35.4	*Que ste*	27.2	*Que pri*	33.3	*Que pri*	36.7	*Ace sac*	20.8
	Que pri	35.4	*Fra ame*	17.2	*Que shu*	25.0	*Cor flo*	26.7	*Que pri*	20.8
	Que ste	17.4	*Que shu*	14.2	*Fra ame*	16.7	*Fra ame*	18.3	*Fra ame*	14.6
CDR	*Jun vir*	40.2	*Jun vir*	45.3						
	Ulm ala	32.1	*Ulm ala*	32.8						
	Fra ame	10.6	*Que ste*	21.9						
GIB*	*Que ste*	28.6	*Que ste*	33.2	*Que ste*	44.9	*Que ste*	43.7	*Que ste*	73.3
	Car tex	19.1	*Ulm ala*	28.6	*Car tex*	17.8	*Ulm ala*	25.4	*Car tex*	17.8
	Fra ame	14.1	*Car tex*	19.1	*Que mar*	16.9	*Car tex*	18.3	*Car gla*	8.9
PDS	*Que ste*	32.6	*Jun vir*	66.7	*Jun vir*	68.3	*Jun vir*	56.3	*Jun vir*	37.5
	Jun vir	21.8	*Que ste*	16.7	*Que mar*	18.3	*Que ste*	21.8	*Dio vir*	12.5
	Que mar	21.8	*Que mar*	8.3	*Ulm ala*	13.3	*Car gla*	12.7	*Que alb*	12.5
RND	*Jun vir*	47.2	*Ulm ala*	48.9	*Jun vir*	100				
	Ulm ala	28.2	*Jun vir*	31.3						
	Fra ame	15.5	*Car gla*	19.8						
WLC*	*Ost vir*	27.5	*Ace sac*	86.8	*Que pri*	20.9	*Ulm rub*	26.7	*Car ovt*	24.7
	Car ovt	16.3	*Que alb*	19.6	*Que shu*	16.9	*Car ovt*	18.3	*Cra* sp.	24.7
	Fra ame	11.3	*Car gla*	13.4	*Que ste*	15.5	*Ost vir*	18.3	*Fra ame*	16.7

*Managed site.

FI-N=Forest Interior-North, TS-N=Transition Zone-North, OP=Opening, TS-S=Transition Zone-South, FI-S=Forest Interior-South.

BVL=Berryville Shale Glade, BRN=Brown Shale Barrens, CAV=Cave Creek Limestone Glade, CDR=Cedar Bluff Sandstone Glade, GIB=Gibbons Creek Sandstone Barrens, PDS=Pounds Hollow Sandstone Glade, RND=Round Bluff Sandstone Glade, WLC=Wildcat Bluff Limestone Glade.

Ace sac=Acer saccharum, Car gla=Carya glabra, Car ovl=Carya ovalis, Car ovt=Carya ovata, Car tex=Carya texana, Cra sp.=*Crataegus* sp., *Dio vir=Diospyros virginiana, Fra ame=Fraxinus americana, Jug nig=Juglans nigra, Jun vir=Juniperus virginiana, Ost vir=Ostrya virginiana, Que alb=Quercus alba, Que coc=Quercus coccinea, Quemar=Quercus*

Table 47 (cont'd).

marilandica, Que pri=Quercus prinoides var. *acuminata, Que shu=Quercus shumardii, Que ste=Quercus stellata, Que vel=Quercus velutina, Ulm ala=Ulmus alata, Ulm rub=Ulmus rubra*

Table 48. Relative importance (%) for the three most important tree genera in five subhabitats of the study sites in 1994. Trees are listed to species when possible.

Site	FI-N		TS-N		OP		TS-S		FI-S	
BVL	*Que* spp.	100	*Que* spp.	100	*Que* spp.	100	*Car tex*	50.0	*Que vel*	71.5
							Que ste	50.0	*Car* spp.	28.6
BRN*	*Que ste*	50.0	*Que ste*	63.3	*Que ste*	100	*Que ste*	100	*Ulm ala*	100
	Car gla	25.0	*Car gla*	26.2						
	Ulm ala	25.0	*Ulm ala*	10.6						
CAV*	*Que* spp.	64.6	*Que* spp.	48.5	*Que* spp.	58.3	*Que* spp.	55.0	*Que* spp.	35.4
	Fra ame	35.4	*Fra ame*	17.2	*Fra ame*	16.7	*Cor flo*	26.7	*Ace sac*	20.8
			Dio vir	10.0	*Cer can*	8.3	*Fra ame*	18.3	*Fra ame*	14.6
			Ost vir	10.0	*Cor dru*	8.3			*Jug nig*	14.6
					Ost vir	8.3			*Ulm rub*	14.6
CDR	*Jun vir*	40.2	*Jun vir*	45.3						
	Ulm ala	32.1	*Ulm ala*	32.8						
	Fra ame	10.6	*Que ste*	21.9						
GIB*	*Car* spp.	38.1	*Que* spp.	47.2	*Que* spp.	61.8	*Que ste*	43.7	*Que ste*	73.3
	Car tex	28.6	*Ulm ala*	28.6	*Car tex*	17.8	*Car* spp.	31.0	*Car* spp.	26.7
	Fra ame	14.1	*Car tex*	19.1	*Ulm ala*	10.2	*Ulm ala*	25.4		
PDS	*Que* spp.	54.4	*Jun vir*	66.7	*Jun vir*	68.3	*Jun vir*	56.3	*Jun vir*	37.5
	Jun vir	21.8	*Que* spp.	25.0	*Que mar*	18.3	*Que* spp.	30.9	*Que* spp.	37.5
	Jug nig	15.9	*Ulm ala*	8.3	*Ulm ala*	13.3	*Car gla*	12.7	*Dio vir*	12.5
									Ulm ala	12.5
RND	*Jun vir*	47.2	*Ulm ala*	48.9	*Jun vir*	100				
	Ulm ala	28.2	*Jun vir*	31.3						
	Fra ame	15.5	*Car gla*	19.8						
WLC*	*Que* spp.	45.2	*Que* spp.	33.0	*Que* spp.	58.5	*Que* spp.	36.6	*Car ovt*	24.7
	Ost vir	27.5	*Ace sac*	26.8	*Car tex*	11.7	*Ulm rub*	26.7	*Cra* spp.	24.7
	Car ovt	16.3	*Car* spp.	26.8	*Ace sac*	10.4	*Car ovt*	18.3	*Que* spp.	20.2
							Ost vir	18.3		

*Managed site.

FI-N=Forest Interior-North, TS-N=Transition Zone-North, OP=Opening, TS-S=Transition Zone-South, FI-S=Forest Interior-South.

BVL=Berryville Shale Glade, BRN=Brown Shale Barrens, CAV=Cave Creek Limestone Glade, CDR=Cedar Bluff Sandstone Glade, GIB=Gibbons Creek Sandstone Barrens, PDS=Pounds Hollow Sandstone Glade, RND=Round Bluff Sandstone Glade, WLC=Wildcat Bluff Limestone Glade.

Table 48 (cont'd).

Ace sac=Acer saccharum, Car gla=Carya glabra, Car ovt=Carya ovata, Car spp.=*Carya* spp., *Car tex=Carya texana, Cor dru=Cornus drummondii, Cor flo=Cornus florida, Cra* spp.=*Crataegus* spp., *Dio vir=Diospyros virginiana, Fra ame=Fraxinus americana, Jug nig=Juglans nigra, Jun vir=Juniperus virginiana, Ost vir=Ostrya virginiana, Que alb=Quercus alba, Que coc=Quercus coccinea, Que mar=Quercus marilandica, Que* spp.=*Quercus* spp., *Que ste=Quercus stellata, Ulm ala=Ulmus alata, Ulm rub=Ulmus rubra*.

The mean number of tree species (per 25 m^2) for all sites and for unmanaged sites was lower in opening than in any other subhabitat except the transition zone-south (Table 49). Managed and unmanaged sites did not differ in tree species number in any subhabitat.

Density of forest-opening trees (per 25 m^2) ranged from 0.9 ± 0.2 to 2.0 ± 0.3 and was greater in the northern subhabitats than in the opening (Table 50). Managed and unmanaged site tree density was similar among subhabitats except in the forest interior-north (which was greater for unmanaged sites).

The majority of forest-opening trees were shade-intolerant in all subhabitats except the forest interior-south (Table 51). Shade intolerance was greater in the opening (83.4% ± 6.7%) than any other subhabitat except the forest interior-north (69.8% ± 8.7%). Over 95% (95.6% ± 4.4%) of trees in the opening of unmanaged sites were shade-intolerant, versus 74.3% ± 9.0% in managed sites. Managed sites exceeded unmanaged sites for shade-intermediate tree values in the opening and both of the northern subhabitats.

Forest-opening subhabitats were similar in mean tree diameter at breast height (dbh) (cm) (except the forest interior-south which was lower than the transition zone-north) (Table 52). Managed and unmanaged sites showed overlap of dbh values for all subhabitats as well as little variation among subhabitats.

Mean forest-opening tree height (m) (≈13.8 m) did not differ among subhabitats (Table 53). Surprisingly, trees which occurred in the opening at managed sites were ≈10.2 m taller than those in the opening at unmanaged sites. However, unmanaged sites were represented by trees from a single site. Managed sites also exceeded unmanaged sites in tree height in the northern and southern forest interior zones.

Mean crown diameter (m) for all sites did not differ among subhabitats (Table 54). At managed sites, crown diameter tended to be greater in one or both of the northern subhabitats than

Table 49. Mean (± 1 SE) number of tree species (per 25 m^2) in five subhabitats of the study sites in 1994.

	Site	N	FI-N	N	TS-N	N	OP	N	TS-S	N	FI-S
Managed											
	Brown Shale Barrens	10	0.5 ± 0.2	8	1.1 ± 0.2	13	0.5 ± 0.1	5	0.2 ± 0.2	4	0.3 ± 0.3
	Cave Creek Limestone Glade	8	1.0 ± 0.4	8	1.5 ± 0.2	55	0.2 ± 0.1	6	0.8 ± 0.4	6	0.9 ± 0.1
	Gibbons Creek Sandstone Barrens	6	1.7 ± 0.6	6	1.7 ± 0.5	20	1.1 ± 0.2	6	1.4 ± 0.2	6	1.5 ± 0.3
	Wildcat Bluff Limestone Glade	6	1.3 ± 0.2	6	2.3 ± 0.9	58	1.3 ± 0.1	6	1.7 ± 0.3	6	1.5 ± 0.2
	Mean (managed sites)		1.1 ± 0.3		1.7 ± 0.3		0.8 ± 0.3		1.0 ± 0.3		1.1 ± 0.3
Unmanaged											
	Berryville Shale Glade	4	1.0 ± 0.0	4	1.0 ± 0.4	13	0.8 ± 0.2	4	0.5 ± 0.3	4	1.8 ± 0.1
	Cedar Bluff Sandstone Glade	16	2.1 ± 0.2	6	1.8 ± 0.2		---		---		---
	Pounds Hollow Sandstone Glade	5	1.0 ± 0.4	7	0.6 ± 0.3	9	0.3 ± 0.2	6	0.8 ± 0.3	4	1.0 ± 0.3
	Round Bluff Sandstone Glade	10	1.9 ± 0.3	9	0.9 ± 0.3	4	0.3 ± 0.3				
	Mean (unmanaged sites)		1.5 ± 0.3		1.1 ± 0.3		0.5 ± 0.2		0.7 ± 0.2		1.4 ± 0.4
All Sites	Mean		1.3 ± 0.2		1.4 ± 0.2		0.6 ± 0.2		0.9 ± 0.2		1.2 ± 0.2

FI-N=Forest Interior-North, TS-N=Transition Zone-North, OP=Opening, TS-S=Transition Zone-South, FI-S=Forest Interior-South.

Table 50. Density (per 25 m^2) of trees in five subhabitats of the study sites in 1994. Data are reported as mean ± 1 SE.

	Site	N	FI-N	N	TS-N	N	OP	N	TS-S	N	FI-S
Managed											
	Brown Shale Barrens	10	1.0 ± 0.5	8	1.3 ± 0.3	13	0.8 ± 0.3	5	0.2 ± 0.2	4	0.3 ± 0.3
	Cave Creek Limestone Glade	8	1.1 ± 0.4	8	2.1 ± 0.4	55	0.2 ± 0.1	6	1.0 ± 0.5	6	1.1 ± 0.3
	Gibbons Creek Sandstone Barrens	6	1.8 ± 0.5	6	1.8 ± 0.6	20	1.5 ± 0.3	6	1.6 ± 0.4	6	2.4 ± 0.4
	Wildcat Bluff Limestone Glade	6	1.7 ± 0.4	6	2.7 ± 1.2	58	1.5 ± 0.1	6	2.0 ± 0.6	6	1.8 ± 0.3
	Mean (managed sites)		1.4 ± 0.2		1.9 ± 0.3		1.0 ± 0.3		1.2 ± 0.4		1.4 ± 0.5
Unmanaged											
	Berryville Shale Glade	4	2.0 ± 0.7	4	1.0 ± 0.4	13	1.5 ± 0.4	4	0.5 ± 0.3	4	1.8 ± 0.1
	Cedar Bluff Sandstone Glade	16	3.6 ± 0.5	6	4.0 ± 1.5		---		---		---
	Pounds Hollow Sandstone Glade	5	1.7 ± 0.4	7	1.3 ± 0.7	9	0.6 ± 0.3	6	1.2 ± 0.5	4	1.0 ± 0.3
	Round Bluff Sandstone Glade	10	2.8 ± 0.4	9	1.9 ± 0.7	4	0.3 ± 0.3		---		---
	Mean (unmanaged sites)		2.5 ± 0.4		2.1 ± 0.7		0.8 ± 0.4		0.9 ± 0.4		1.4 ± 0.4
All Sites	Mean		1.9 ± 0.3		2.0 ± 0.3		0.9 ± 0.2		1.1 ± 0.3		1.4 ± 0.3

FI-N=Forest Interior-North, TS-N=Transition Zone-North, OP=Opening, TS-S=Transition Zone-South, FI-S=Forest Interior-South.

Table 51. Tree shade tolerance in five subhabitats of the study sites in 1994. Shade tolerance classes are summed by relative importance (%). The shade tolerance designations are according to Burns and Honkala (1990), Barnes and Wagner (1981), and Mohlenbrock (1986). The mean ± 1 SE is reported.

	Site	FI-N	TS-N	OP	TS-S	FI-S
Intolerant:						
Managed	Brown Shale Barrens	75.0	98.4	100	100	0.0
	Cave Creek Limestone Glade	64.6	48.5	66.7	55.0	50.0
	Gibbons Creek Sandstone Barrens	61.8	52.3	71.9	43.7	82.2
	Wildcat Bluff Limestone Glade	22.5	13.4	58.4	18.3	20.2
	Mean (managed sites)	55.9 ± 11.5	53.2 ± 17.4	74.3 ± 9.0	54.3 ± 17.1	38.1 ± 17.9
Unmanaged	Berryville Shale Glade	100	100	100	50.0	14.3
	Cedar Bluff Sandstone Glade	63.0	67.2	---	---	---
	Pounds Hollow Sandstone Glade	100	91.7	86.7	100	62.5
	Round Bluff Sandstone Glade	71.8	51.1	100	---	---
	Mean (unmanaged sites)	83.7 ± 9.6	77.5 ± 11.2	95.6 ± 4.4	75.0 ± 25.0	38.4 ± 24.1
Intermediate:						
Managed	Brown Shale Barrens	0.0	0.0	0.0	0.0	0.0
	Cave Creek Limestone Glade	35.4	24.3	16.7	18.3	29.2
	Gibbons Creek Sandstone Glade	28.6	19.1	17.8	30.9	17.8
	Wildcat Bluff Limestone Glade	50.0	46.4	18.1	63.3	43.8
	Mean (intermed.-managed sites)	28.5 ± 10.5	22.5 ± 9.5	13.2 ± 4.4	28.1 ± 13.3	20.5 ± 7.7
Unmanaged	Berryville Shale Glade	0.0	0.0	0.0	50.0	85.7
	Cedar Bluff Sandstone Glade	2.4	0.0	---	---	---
	Pounds Hollow Sandstone Glade	0.0	0.0	0.0	0.0	12.5
	Round Bluff Sandstone Glade	0.0	0.0	---	---	---

Table 51 (cont'd).

	Mean (intermed.-unmanaged sites)	0.8 ± 0.6	0.0 ± 0.0	0.0 ± 0.0	25.0 ± 25.0	49.1 ± 36.6
Tolerant:						
Managed	Brown Shale Barrens	25.0	10.6	0.0	0.0	100
	Cave Creek Limestone Glade	0.0	27.2	16.7	26.7	20.8
	Gibbons Creek Sandstone Glade	9.5	28.6	10.2	25.4	0.0
	Wildcat Bluff Limestone Glade	27.5	40.2	23.5	18.3	44.9
	Mean (tolerant-managed sites)	15.5 ± 6.5	26.7 ± 6.1	12.6 ± 5.0	17.6 ± 6.2	41.4 ± 21.6
Unmanaged	Berryville Shale Glade	0.0	0.0	0.0	0.0	0.0
	Cedar Bluff Sandstone Glade	34.5	32.8	---	---	---
	Pounds Hollow Sandstone Glade	0.0	8.3	13.3	0.0	25.0
	Round Bluff Sandstone Glade	28.2	48.9	0.0	---	---
	Mean (tolerant-unmanaged sites)	15.7 ± 9.1	22.5 ± 11.2	4.4 ± 4.4	0.0 ± 0.0	12.5 ± 12.5
Mean (all sites):						
	Intolerant	69.8 ± 8.7	65.3 ± 10.6	83.4 ± 6.7	61.2 ± 13.3	38.2 ± 12.9
	Intermediate	14.6 ± 7.2	11.2 ± 6.1	7.5 ± 3.9	27.1 ± 10.6	30.0 ± 12.2
	Tolerant	15.6 ± 5.2	24.6 ± 5.9	9.1 ± 3.3	11.7 ± 5.4	31.8 ± 15.3

FI-N=Forest Interior-North, TS-N=Transition Zone-North, OP=Opening, TS-S=Transition Zone-South, FI-S=Forest Interior-South.

Table 6

Table 52. Mean (± 1 SE) tree diameter at breast height (cm) in five subhabitats of the study sites in 1994. Tree diameter was measured in the subsample transect plots at each site.

	Site	N	FI-N	N	TS-N	N	OP	N	TS-S	N	FI-S
Managed											
	Brown Shale Barrens	10	21.9 ± 4.1	10	23.4 ± 3.9	10	20.7 ± 3.0	1	50.0 ± 0.0	1	7.8 ± 0.0
	Cave Creek Limestone Glade	9	20.9 ± 3.9	17	17.6 ± 2.2	12	14.9 ± 2.9	6	11.4 ± 1.5	8	15.3 ± 1.9
	Gibbons Creek Sandstone Barrens	11	14.2 ± 2.9	11	16.7 ± 3.2	29	17.0 ± 1.8	9	15.2 ± 3.9	15	15.2 ± 1.7
	Wildcat Bluff Limestone Glade	10	17.1 ± 4.4	8	17.9 ± 3.6	40	24.8 ± 2.1	6	17.3 ± 5.4	11	17.1 ± 4.8
	Mean (unmanaged sites)		18.5 ± 1.8		18.9 ± 1.5		19.4 ± 2.2		23.5 ± 8.9		13.9 ± 2.1
Unmanaged											
	Berryville Shale Glade	8	15.5 ± 3.4	4	19.8 ± 6.3	19	16.9 ± 1.5	2	25.4 ± 2.6	7	14.6 ± 2.6
	Cedar Bluff Sandstone Glade	57	13.6 ± 0.9	24	14.8 ± 1.9		---		---		---
	Pounds Hollow Sandstone Glade	17	20.5 ± 3.2	18	16.7 ± 1.9	10	13.2 ± 2.0	14	15.6 ± 2.0	8	17.6 ± 3.4
	Round Bluff Sandstone Glade	28	14.2 ± 1.1	19	12.7 ± 1.1	1	21.9 ± 0.0		---		---
	Mean (unmanaged sites)		15.9 ± 1.6		16.0 ± 1.5		17.3 ± 2.5		20.5 ± 4.9		16.2 ± 1.5
All Sites	Mean		17.2 ± 1.2		17.2 ± 1.3		17.7 ± 1.4		22.5 ± 5.8		14.6 ± 1.4

FI-N=Forest Interior-North, TS-N=Transition Zone-North, OP=Opening, TS-S=Transition Zone-South, FI-S=Forest Interior-South.

Table 53. Mean (± 1 SE) tree height (m) in five subhabitats of the study sites in 1994. Tree height was measured in the subsample transect plots at each site.

	Site	N	FI-N	N	TS-N	N	OP	N	TS-S	N	FI-S
Managed											
	Brown Shale Barrens		NA	1	17.5 ± 0.0	4	11.4 ± 3.6	1	17.5 ± 0.0		NA
	Cave Creek Limestone Glade	2	17.5 ± 0.0	3	14.2 ± 3.3	1	7.5 ± 0.0		NA		NA
	Gibbons Creek Sandstone Barrens	3	17.5 ± 0.0	3	22.3 ± 2.7	8	15.0 ± 1.6	4	12.5 ± 2.9	5	18.5 ± 3.2
	Wildcat Bluff Limestone Glade	2	16.3 ± 8.8	5	18.6 ± 1.8	14	21.9 ± 1.7	3	14.2 ± 3.3	5	9.5 ± 2.0
	Mean (managed sites)		17.1 ± 0.4		18.5 ± 1.7		13.9 ± 3.1		14.7 ± 1.5		14.0 ± 4.5
Unmanaged											
	Berryville Shale Glade		NA		NA	16	3.5 ± 0.3	1	17.5 ± 0.0	4	7.8 ± 3.4
	Cedar Bluff Sandstone Glade	12	10.8 ± 1.4	3	17.5 ± 0.0		---		---		---
	Round Bluff Sandstone Glade	7	7.5 ± 0.1	3	4.7 ± 1.4		NA		---		---
	Mean (unmanaged sites)		9.2 ± 1.6		11.1 ± 6.4		3.5 ± 0.0		17.5 ± 0.0		7.8 ± 0.0
All Sites	Mean		13.9 ± 2.0		16.0 ± 2.5		11.9 ± 3.2		15.4 ± 1.2		11.9 ± 3.3

NA=Not available. The subsample transect did not extend into these subhabitats due to a physical barrier such as a bluff edge.
FI-N=Forest Interior-North, TS-N=Transition Zone-North, OP=Opening, TS-S=Transition Zone-South, FI-S=Forest Interior-South.

Table 54. Mean (± 1 SE) tree crown diameter (m) in five subhabitats of the study sites in 1994. Crown diameter is the average of two perpendicular crown measurements, i.e., the north-south and east-west lengths. It was measured in the subsample transect plots at each site.

	Site	N	FI-N	N	TS-N	N	OP	N	TS-S	N	FI-S
Managed											
	Brown Shale Barrens		NA	1	9.9 ± 0.0	4	5.3 ± 0.7	1	4.7 ± 0.0		NA
	Cave Creek Limestone Glade	2	6.5 ± 3.2	3	5.8 ± 1.5	3	3.6 ± 0.8	1	4.5 ± 0.0	1	4.4 ± 0.0
	Gibbons Creek Sandstone Barrens	3	3.8 ± 0.2	3	6.1 ± 0.8	8	4.1 ± 0.5	4	3.4 ± 0.9	5	4.2 ± 0.8
	Wildcat Bluff Limestone Glade	2	6.8 ± 2.0	5	4.8 ± 0.4	14	6.4 ± 0.8	3	4.8 ± 0.7	5	4.9 ± 1.3
	Mean (managed sites)		5.7 ± 0.9		6.7 ± 1.1		4.9 ± 0.6		4.4 ± 0.3		4.5 ± 0.2
Unmanaged											
	Berryville Shale Glade		NA		NA	16	3.5 ± 0.3	1	7.7 ± 0.0	4	3.1 ± 0.5
	Cedar Bluff Sandstone Glade	12	2.4 ± 0.3	3	7.0 ± 1.6		---		---		---
	Round Bluff Sandstone Glade	7	3.1 ± 0.1	3	3.0 ± 0.7		NA		---		---
	Mean (unmanaged sites)		2.8 ± 0.4		5.0 ± 1.9		3.5 ± 0.0		7.7 ± 0.0		3.1 ± 0.0
All Sites	Mean		4.5 ± 0.9		5.3 ± 0.7		4.8 ± 0.6		5.0 ± 0.7		4.2 ± 0.4

NA=Not available. The subsample transect did not extend into these subhabitats due to a physical barrier such as a bluff edge.
FI-N=Forest Interior-North, TS-N=Transition Zone-North, OP=Opening, TS-S=Transition Zone-South, FI-S=Forest Interior-South.

in the opening and southern subhabitats. Managed site crown diameter exceeded that for unmanaged sites in the opening and both of the forest interior subhabitats.

Cutting of seedlings, shrubs and saplings, and trees at Brown-MGD (in a north-south 5 m x 40 m transect) consisted of the removal of a total of 13 seedlings, 10 shrubs and/or saplings, and 9 trees (Figure 10). The majority of woody species removal occurred in the transition and forest interior subhabitats, not in the opening. Mean diameter at ground level (dgl) (cm) was lowest in the opening for shrubs and saplings (due to an absence of stumps therein) (Table 55). Mean tree dgl was similar in all subhabitats.

Statistical Comparisons among Subhabitats: 1994

All of the managed sites were significantly different (α=0.05) among subhabitats for Poaceae cover while only one of the three unmanaged sites was significantly different for Poaceae cover (i.e., Pounds-UMG) (Table 56). None of the unmanaged sites were significant for Asteraceae cover. While most of the forest-openings were not significant for seedling density, most were significant for cover of exposed rock at the soil surface.

Site Open-Area Estimates

Total open area per site ranged from 450 to 7825 m^2, with a mean of 3956 ± 839.1 m^2 (Table 57). The managed sites had the four largest open areas. Openings at some of the sites occurred as discontinuous fragments, i.e., Cedar-UMG, Gibbons-MGD, Gyp-UMG, and Round-UMG. Therefore, length (m) estimates are also provided for the longest continuous east-west and north-south site dimensions. The east-west axis of five of eight sites was longer than the north-south axis.

Soil Measurements: 1993 and 1994

All soils of forest-opening sites analyzed were a silty loam or loam textural class (Table 58). Together the sites averaged more silt than sand or clay. Unmanaged sites had a greater

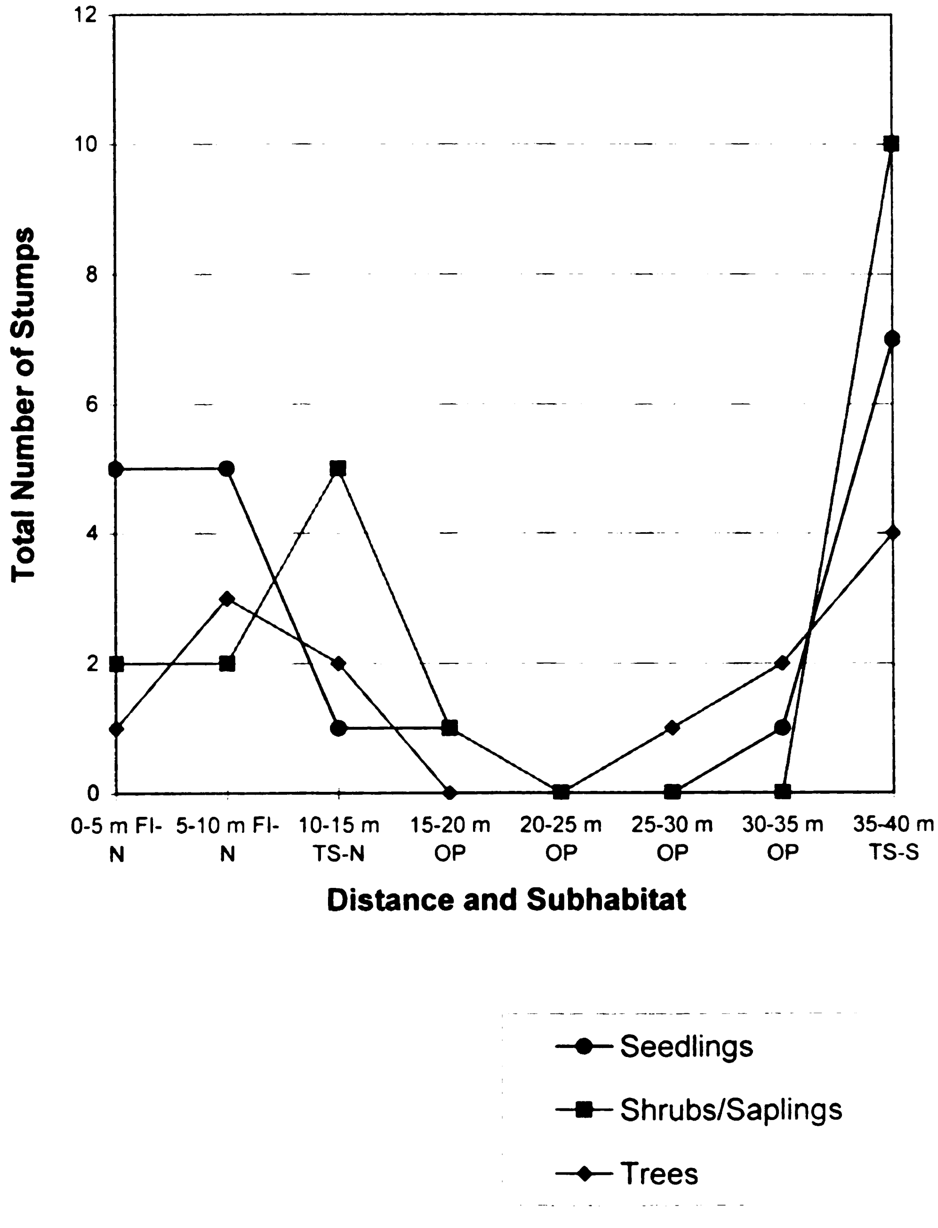


Figure 10. Total number of seedling, shrub and sapling and tree stumps versus distance (from north to south) along a transect with four subhabitats at Brown Shale Barrens-Managed in 1994. The subsample transect terminated in a bluff in the transition zone.

Table 55. Mean (± 1 SE) diameter at ground level (cm) of stumps in four subhabitats at Brown Shale Barrens-Managed in 1994. Cut stumps were measured in the subsample transect which terminated in a bluff edge in the transition zone-south subhabitat.

	FI-N	TS-N	OP	TS-S
No. of 25 m^2 plots:	2	1	4	1
Mean stump diameter at ground:				
Shrubs/Saplings	5.6	4.8	0.0	4.4
Trees	10.6	14.5	10.3	10.0

FI-N=Forest Interior-North, TS-N=Transition Zone-North, OP=Opening, TS-S=Transition Zone-South.

Table 56. Probability values for within-site comparison of Poaceae, Asteraceae, and rock cover and seedling density in 1994. Subhabitat zones with less than five plots were omitted from analysis. The Mann-Whitney U test was used and an asterisk indicates a significant difference between sites (α=0.05).

Site	Zones Used:	p-Value Poaceae	Asteraceae	Seedling Density	Exposed Rock
Managed					
Brown Shale Barrens	1-4	0.0002*	0.1112	0.0000*	0.0391*
Cave Creek Limestone Glade	1-5	0.0008*	0.0000*	0.0507	0.4133
Gibbons Creek Sandstone Barrens	1-5	0.0353*	0.0000*	0.0869	0.0002*
Wildcat Bluff Limestone Glade	1-5	0.0000*	0.1348	0.3023	0.0255*
Unmanaged					
Cedar Bluff Sandstone Glade	1-2	0.0784	0.6001	0.5797	0.0161*
Pounds Hollow Sandstone Glade	1-4	0.0012*	0.4826	0.1268	NA
Round Bluff Sandstone Glade	1-2	0.7375	0.9362	0.0271*	0.0917

Subhabitat Zone 1=Forest Interior-North, 2=Transition Zone-North, 3=Opening, 4=Transition Zone-South, 5=Forest Interior-South.
NA=Not available.

Table 57. Area (m^2) and greatest continuous cardinal dimension (m) of the site opening in 1994.

	Site	Area	Length North-South	East-West
Managed				
	Brown Shale Barrens	4350	40	170
	Cave Creek Limestone Glade	6650	145	110
	Gibbons Creek Sandstone Barrens	5675	65	150
	Wildcat Bluff Limestone Glade	7825	125	100
	Mean ± 1 SE (managed sites)	6125 ± 737.0	94 ± 24.7	133 ± 33.0
Unmanaged				
	Berryville Shale Glade	2700	95	45
	Cedar Bluff Sandstone Glade	450	8	40
	Gyp Williams Sandstone Barrens	725	20	20
	Pounds Hollow Sandstone Glade	4250	40	180
	Round Bluff Sandstone Glade	2975	60	95
	Mean ± 1 SE (unmanaged sites)	2220 ± 717.3	45 ± 15.4	76 ± 28.8
All Sites	Mean ± 1 SE	3956 ± 839.1	66 ± 15.6	101 ± 19.3

Table 58. Soil texture summary for the study sites in 1993. Five soil probes (8.3 ± 1.2 cm deep on average) were combined. Samples taken from the opening at Pounds Hollow Sandstone Glade, Round Bluff Sandstone Glade and Wildcat Bluff Limestone Glade were too small for textural analysis.

	Site	% Sand	% Silt	% Clay	Texture Class
Managed					
	Brown Shale Barrens	13	62	25	Silty Loam
	Cave Creek Limestone Glade	35	42	23	Loam
	Gibbons Creek Sandstone Barrens	31	50	19	Silty Loam
	Mean ± 1 SE (managed sites)	26.3 ± 6.8	51.3 ± 5.8	22.3 ± 1.8	
Unmanaged					
	Berryville Shale Glade	22	60	18	Silty Loam
	Cedar Bluff Sandstone Glade	23	60	17	Silty Loam
	Gyp Williams Sandstone Barrens	20	61	19	Silty Loam
	Mean ± 1 SE (unmanaged sites)	21.7 ± 0.9	60.3 ± 0.3	18.0 ± 0.6	
All Sites	Mean ± 1 SE	24 ± 3.2	56 ± 3.3	20 ± 1.3	

proportion of sand than clay due to the higher proportion of unmanaged than managed sites with a sandstone substrate and exposed rock.

The limestone glades, Cave-MGD and Wildcat-MGD, had the highest pH values of any forest-opening site, at 7.4 and 6.9, respectively (Table 59). The average pH for the remaining sites was 4.9 ± 0.2. Cation exchange capacity (CEC) was also highest at the two limestone glades.

Mean soil depth for all forest-openings (managed and unmanaged) did not differ between 1988 and 1993 (Table 60).

Forest-opening subhabitats did not differ in mean soil depth (cm) (Table 61). Unmanaged sites exceeded managed sites for depth in the opening; however, the unmanaged comparison value was based on a single site. The opening of unmanaged sites also had the greatest soil depth among unmanaged site subhabitats.

Mean soil moisture (≈14.5%) for all of the study sites, did not differ among subhabitats. All managed and unmanaged site subhabitats were similar in percent soil moisture (Table 62).

Climatic Data: 1993 and 1994

Mean monthly temperature (°C) during the spring and growing season of 1988 and 1993 was consistent with the 1910-1993 average (Figure 11). Monthly precipitation values (cm) (1988 and 1993), however, diverged greatly from the 1910-1993 mean during the growing season (Figure 12). From April through August, 1988 rainfall was below the 1910-1993 average. In 1988, only during March 1988 did precipitation surpass the 1910-1993 average. Conversely, in June and July of 1993, precipitation exceeded average rainfall. The difference between June 1988 and 1993 rainfall was 16.9 cm (6.6 inches).

Table 59. Summary of soil characteristics for the study sites in 1993. Nutrient units are in parts per million. Samples taken from the opening at Pounds Hollow Sandstone Glade were too small for analysis.

Character	BVH	BRN*	CAV*	CDR	GIB*	GYP	RND	WLC*
pH	5.4	5.2	7.4	4.8	4.4	4.5	5.2	6.9
Buffer pH	6.70	6.53	NA	6.48	6.49	6.56	6.82	NA
Phosphorus	8	5	5	5	11	5	9	6
Potassium	100	104	280	78	64	72	70	346
Calcium	1060	1130	6000	740	280	290	400	4860
Magnesium	65	142	94	92	52	72	74	145
Manganese	70	89	42	118	72	74	208	157
Zinc	3.0	3.1	0.4	3.7	1.6	2.3	3.3	5.5
%Org. Matter	7.4	4.0	5.6	3.9	3.0	2.6	7.9	6.7
ENR	192	124	156	122	104	96	202	178
CEC	8.5	10.8	31.5	8.8	6.1	5.8	4.3	26.8

*Managed site.

BVH=Berryville Shale Glade, BRN=Brown Shale Barrens, CAV=Cave Creek Limestone Glade, CDR=Cedar Bluff Sandstone Glade, GIB=Gibbons Creek Sandstone Barrens, GYP=Gyp Williams Sandstone Barrens, RND=Round Bluff Sandstone Glade, WLC=Wildcat Bluff Limestone Glade. ENR=Estimated nitrogen release, CEC=Cation exchange capacity (meq/100g).

NA=Not available.

Table 60. Mean (± 1 SE) soil depth (cm) for the study sites in 1988 and 1993. Five soil depth measurements were taken at all of the sites. Values for 1988 are from Heikens (1991). Standard error values for 1988 data were not available.

	Site	1988	1993	Difference
Managed				
	Brown Shale Barrens	7.9	12.4 ± 4.9	4.5
	Cave Creek Limestone Glade	6.8	13.1 ± 2.9	6.3
	Gibbons Creek Sandstone Barrens	9.5	9.1 ± 2.8	-0.4
	Wildcat Bluff Limestone Glade	8.6	2.6 ± 1.2	-6.0
	Mean (managed sites)	8.2 ± 0.6	9.3 ± 2.4	1.1
Unmanaged				
	Berryville Shale Glade	8.5	4.2 ± 0.7	-4.3
	Cedar Bluff Sandstone Glade	5.7	18.4 ± 2.9	12.7
	Gyp Williams Sandstone Barrens	10.8	11.1 ± 4.5	0.3
	Pounds Hollow Sandstone Glade	4.0	1.0 ± 0.7	-3.0
	Round Bluff Sandstone Glade	4.3	2.7 ± 0.3	-1.6
	Mean (unmanaged sites)	6.7 ± 1.3	7.5 ± 3.2	0.8
All Sites	Mean	7.3 ± 0.8	8.3 ± 1.9	1.0

Table 61. Mean (± 1 SE) soil depth (cm) in five subhabitats of the study sites in 1994. Five soil depth measurements were taken at each location of all of the sites. Soil depth at Pounds Hollow Sandstone Glade-Unmanaged was not available.

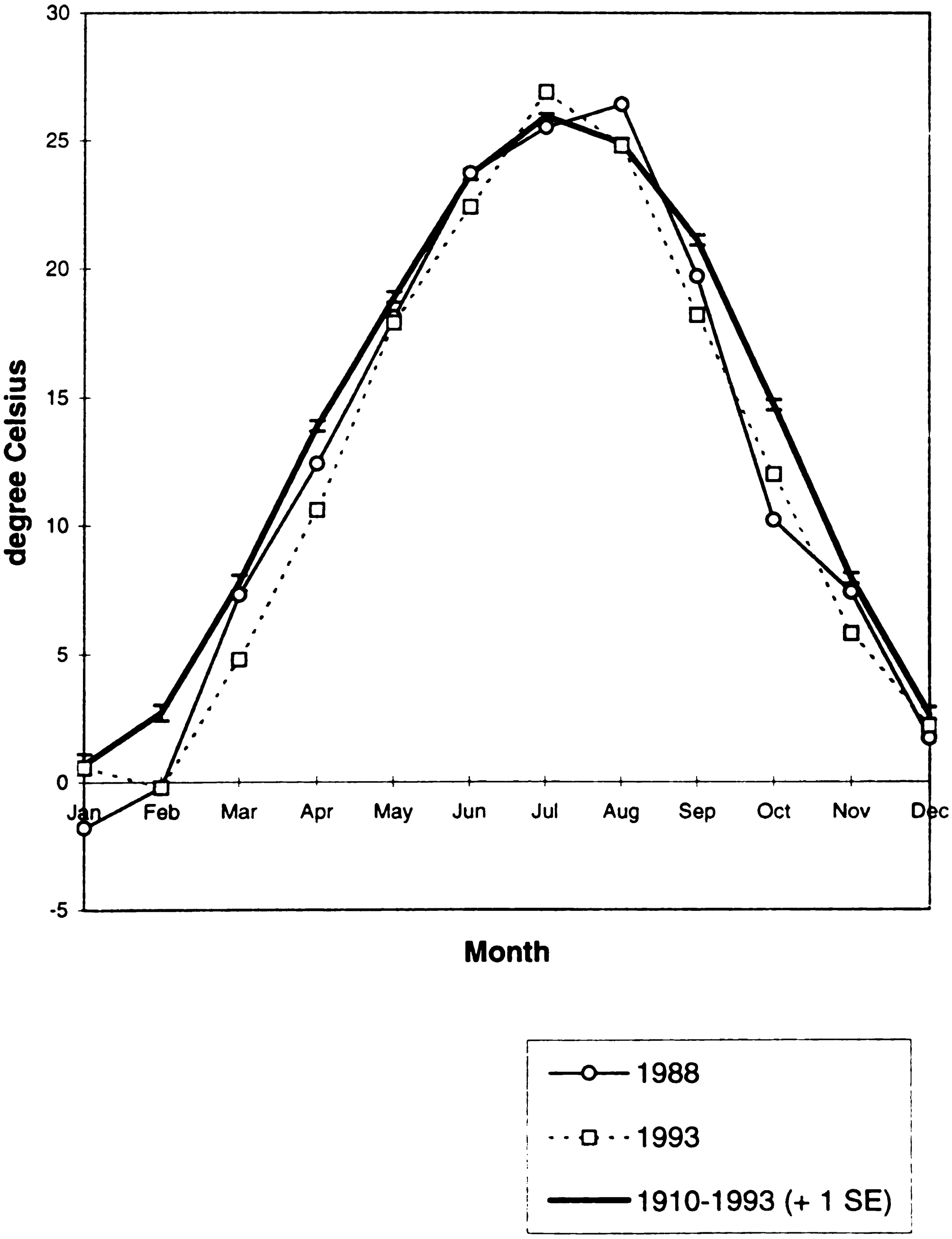
	Site	FI-N	TS-N	OP	TS-S	FI-S
Managed						
	Brown Shale Barrens	13.2 ± 1.7	15.5 ± 0.9	4.6 ± 0.9	---	---
	Cave Creek Limestone Glade	7.6 ± 1.3	6.0 ± 0.7	5.2 ± 1.3	15.4 ± 3.6	16.4 ± 0.9
	Gibbons Creek Sandstone Barrens	4.0 ± 1.1	6.7 ± 1.7	5.2 ± 0.6	3.5 ± 0.7	2.9 ± 0.5
	Wildcat Bluff Limestone Glade	6.0 ± 1.3	5.0 ± 0.7	6.4 ± 0.7	5.6 ± 0.9	5.0 ± 1.0
	Mean (managed sites)	7.7 ± 1.9	8.3 ± 0.5	5.4 ± 0.4	8.2 ± 3.7	8.1 ± 3.1
Unmanaged						
	Berryville Shale Glade	7.6 ± 0.8	8.8 ± 1.6	18.8 ± 1.5	5.8 ± 0.4	9.2 ± 1.1
	Cedar Bluff Sandstone Glade	9.4 ± 1.2	---	---	---	---
	Round Bluff Sandstone Glade	11.2 ± 1.2	3.0 ± 0.4	---	---	---
	Mean (unmanaged sites)	9.4 ± 1.0	5.9 ± 2.9	18.8 ± 0.0	5.8 ± 0.0	9.2 ± 0.0
All Sites	Mean	8.4 ± 1.2	7.5 ± 1.8	8.0 ± 2.7	7.6 ± 2.7	8.4 ± 2.4

Table 62. Soil moisture (%) in five subhabitats of the study sites in 1994. Five soil extractions were combined on the given extraction date. Mean extraction depth was 8.7 ± 0.9, n=33, and all measurements <25 cm.

	Site	Extraction Date	FI-N	TS-N	OP	TS-S	FI-S
Managed							
	Brown Shale Barrens	8/8/94	9.9	---	16.2	---	---
	Cave Creek Limestone Glade	6/19 and 6/26/94	14.8	23.7	14.1	23.5	26.2
	Gibbons Creek Sandstone Barrens	8/16/94	4.5	5.2	4.1	5.3	4.1
	Wildcat Bluff Limestone Glade	7/16/94	18.0	14.9	17.4	24.2	17.0
	Mean ± 1 SE (managed sites)		11.8 ± 2.9	14.6 ± 5.3	12.9 ± 3.0	17.7 ± 6.2	15.8 ± 6.4
Unmanaged							
	Berryville Shale Glade	6/12/94	18.5	20.5	18.6	17.4	15.6
	Cedar Bluff Sandstone Glade	7/31/94	12.8	---	10.0	---	6.6
	Round Bluff Sandstone Glade	7/24/94	10.4	10.5	---	---	---
	Mean ± 1 SE (unmanaged sites)		13.9 ± 2.4	15.5 ± 5.0	14.3 ± 4.3	17.4 ± 0.0	11.1 ± 4.5
All Sites	Mean ± 1 SE		12.7 ± 1.9	14.9 ± 3.3	13.4 ± 2.2	17.6 ± 4.4	13.9 ± 3.9

FI-N=Forest Interior-North, TS-N=Transition Zone-North, OP=Opening, TS-S=Transition Zone-South, FI-S=Forest Interior-South.

Figure 11. Mean daily temperature (deg. C) versus month in southern Illinois for three different periods of time. Source: Midwestern Climate Center for Carbondale, Illinois.


30
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1910-1993 (+ 1 SE)

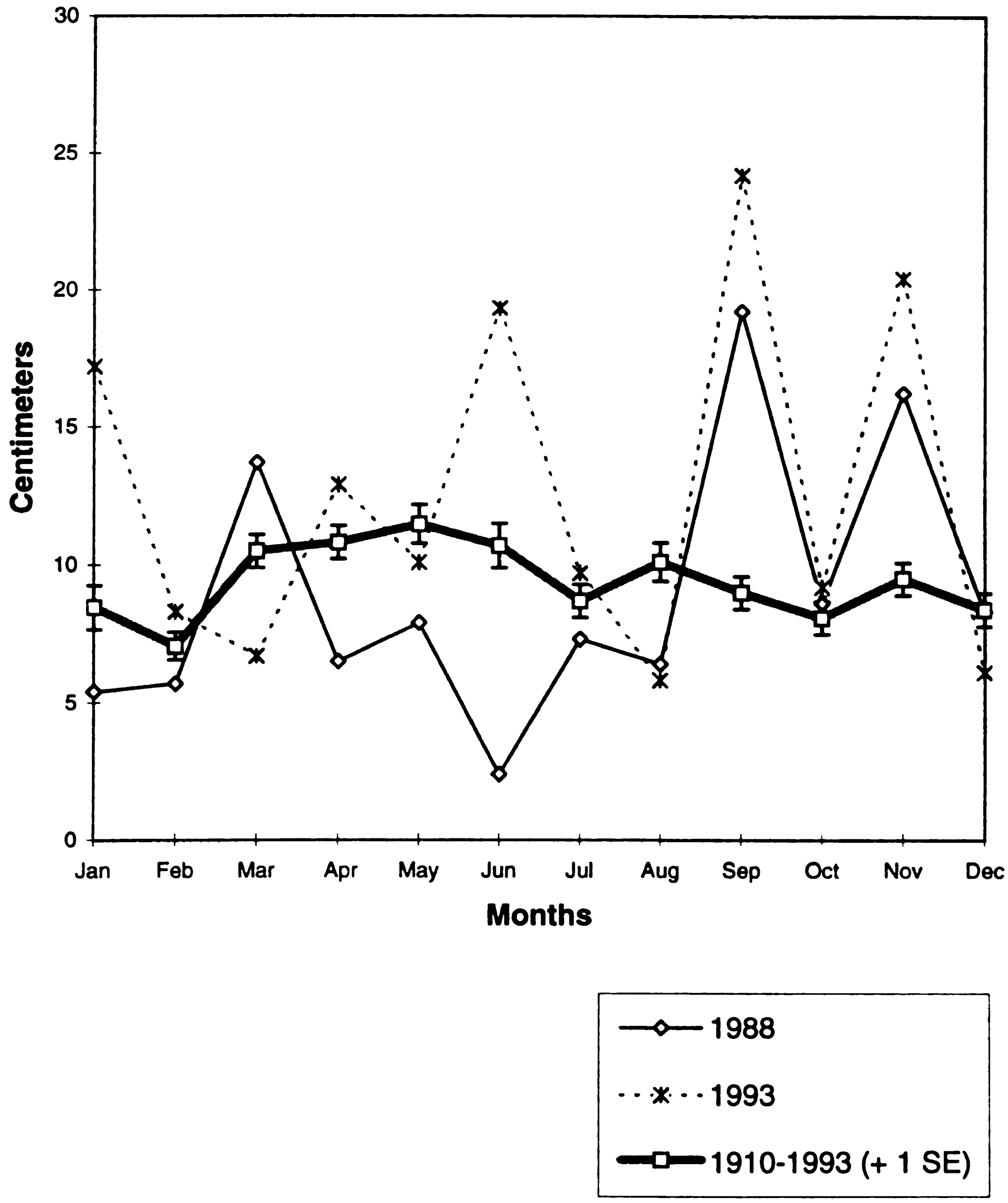

Figure 12. Total precipitation (cm) versus month in southern Illinois for three different periods of time. Source: Midwestern Climate Center for Carbondale, Illinois.

DISCUSSION

Vegetation Composition

Herb Species Composition

The reasons for the changes in herb species composition between 1988 (Heikens 1991) and 1993-94 were difficult to elucidate as they were confounded by various factors, including the effects of the drought of 1988, management treatment, successional changes, and differences in project sampling emphasis. Heikens's (1991) sampling and floristic surveys were confined to the open area of each studied site (A. Heikens, pers. communication). As the 1993-94 floristic surveys included the openings and an 8.5 m border area, these floristic survey findings are not directly comparable. However, plot sampling for both years was confined to the opening. Therefore, a better between-year comparison is made using the total number of herb species found within plots (Table 8) and the average number of herb species per plot (up to 30 50-m^2 plots were used for herbs in 1988 versus four nested 1-m^2 plots located within each of the same number of 50-m^2 plots in 1993) (Table 11).

Plot sampling data showed an overall increase of 36 herb species in all plots collectively between years, despite the greater total area sampled in 1988 (Table 8). The total number of herb species increased both over time and after management. The mean number of herb species per plot also increased from 11.8 ± 1.7 to 16.3 ± 1.6 over time (Table 11). The smaller plots used in 1993 may have facilitated the observation of small and sparse herbs at the expense of missing a greater variety of microhabitats (and therefore different species) potentially encountered in the larger plots used in the earlier study. Using fewer but larger plots might decrease the amount of time spent in sampling herb species; however, difficulty of accurately assessing herb cover, especially of small or sparse individuals, is an inevitable consequence for a 50 m^2 plot size for herbs.

Herb species number was greater at managed sites than at unmanaged sites in both 1988 (before management) and 1993 (after management) (Table 8). Percent increase of herb number between sampling periods for unmanaged sites, 58.4% exceeded that for managed sites, 23.5%, when 50 m^2 plots (1988) were compared with four nested 1-m^2 plots (1993). As the increase in species number was not simply a response to management treatment, temporal differences in herb composition may possibly be attributed to climate factors. The 1988 growing-season was characterized by a severe drought, "...one of the worst in the century," (Anonymous 1988) during which precipitation was 41.1% (April-August) lower than average (1910-1993) in southern Illinois (Figure 4). In contrast, 1993 growing-season precipitation was 11.6% above average, and rainfall for June was 16.9 cm higher than in 1988. Piper (1995), studying four tallgrass prairie sites in Kansas found that, in general, species number was lowest in the drought year (1989) and higher before and afterward (1986 to 1992). Tilman and El Haddi (1992) reported that the number of species in native prairie and European-grass fields in Minnesota declined 37% in response to the 1988 drought. Furthermore, a major portion of this loss was found to be annual species (up to 7.3 per 20 x 60 m field) and species loss was independent of pre-drought abundance. The loss of perennial species was inversely correlated with pre-drought abundance. To determine whether the proportion of annuals was lower in 1988 than in 1993, the percent life history composition of two sites, Cave-MGD and Pounds-UMG, was calculated for 1988. In 1988 the proportion of annuals was 2.4% for Cave-MGD (20.5% in 1993) and 19.4% for Pounds-UMG (25.0% in 1993) (Table 14). Therefore, both sites did have a lower (5.6% to 18.1%) proportion of annual species during conditions of severe moisture-stress than afterward. However, without data on pre-drought herb composition, the effect of drought on herb composition, if any, is impossible to ascertain.

An increase in herbaceous cover at the unmanaged sites (173.9%) and not at the managed sites (the means were within one standard error of each other) may indicate succession in the herb layer (Table 12). According to Barbour et al. (1980), vegetative cover generally increases with increasing succession. Likewise, forest-opening sites which appeared to be incorporating woodland herb species into the top three positions of relative importance (RI) (Table 10), were also those which exhibited the greatest increase in herb cover between sample periods; for example, the longterm unmanaged sites (i.e., no anthropogenic fire since c. 1930 in southern Illinois, Anderson and Schwegman 1991), Cedar and Gyp, both showed an increase in herb cover in the opening, together averaging a 260.9% increase in cover (versus the mean for all unmanaged sites, 173.9%), as well as an increase in RI position of broadleaf woodland herbs such as *Parthenocissus quinquefolia*, *Toxicodendron radicans*, or of successional, open-woods species like *Helianthus divaricatus* and *Solidago* sp. Anderson and Schwegman (1991) noted an increase in the frequency of woodland herbs with succession in a mesic southern Illinois barrens (sampled 15 years postfire) and a decrease in frequency of prairie species (e.g., *Schizachyrium scoparium* and *Sorghastrum nutans*). Hardin (1988) similarly reported an increase in cover and frequency of forest interior herb species after 22 years of succession in a prairie inclusion in southeastern Ohio. Still, the 1993 cover values of herbs (28.5% ± 4.5%) were much lower than values reported for similar habitats in the literature. For example, Jeffries (1987) found an average herb cover of 52.6% for three sandstone glades in Arkansas. Adjacent to the glade proper at Cedar-UMG, Pounds-UMG and Round-UMG there was a dense, even-aged stand (a "dog-hair" stand) of woody species in the sapling to small tree size class. The presence of a few sporadic prairie species within this area (e.g., *Liatris* sp. at Pounds-UMG) suggests that succession had progressed to the point that the opening was relegated to the rock outcrop alone.

Poaceae RI declined more between sample periods at managed sites (-11.8%) than at unmanaged sites (-6.3%) (Table 9). *Schizachyrium scoparium*, a characteristic prairie grass, appeared to be particularly sensitive to management and was on average 10.4% lower in RI for managed sites in 1993 (Table 10, Appendix A). Asteraceae in the managed sites also decreased in RI (-2.0%), while increasing in RI in the unmanaged sites (2.6%) (Table 9, Appendix A). The increase in Asteraceae RI at unmanaged sites from 1988 to 1993 and decrease in characteristic prairie Poaceae species at the managed sites with time (averaging 4.8 years postfire for the 1993 sampling) was consistent with studies by Zimmerman and Kucera (1977), Towne and Owensby (1984), Abrams et al. (1986), and Hartnett (1991) report that nongraminoid species increase (e.g., biomass, number of stems) with time after disturbance. Piper (1995) stated that there was an inverse relationship between productivity and species diversity (diversity primarily being a function of the number of forb species) in grasslands. As total biomass of the dominant species decreases, competition between grasses and forbs presumably decreases and species richness and evenness increase. According to Dhillion and Anderson (1994), grass productivity was higher on burned than on unburned sites during the growing season following the fire in both drought and nondrought years. Svejcar (1990) found aboveground biomass to achieve levels comparable to unburned prairie by the fall after a spring burn. Risser et al. (1981) and Collins and Gibson (1990) also state that cover and productivity return to preburn levels in one to two years following fire in tallgrass prairie. A model by Gibson and Hulbert (1987) predicts a peak in diversity six to seven years following fire after which diversity declines. Therefore, a thorough assessment of forest-opening productivity and species diversity in response to management may shed light on the hypothesis regarding dominance/productivity and competition cycles in forest-openings. Even so, the Asteraceae or Poaceae remained in the first RI position for all sites in both years and for seven of nine sites, the same family remained in the first position both years.

Three of four managed sites (excepting Cave-MGD) exhibited an increase in RI (30.5%) of the Fabaceae, whereas four of five unmanaged sites (excepting Round-UMG) showed a decrease in RI (-46.6%) for this family between 1988 and 1993 (Appendix A). This complements the findings of Martin et al. (1975), Anderson and VanValkenburg (1977), and Towne and Knapp (1996), who found increases in legumes (e.g., density, biomass) after fire management.

Statistical Comparisons: 1988 and 1993. Mann-Whitney U tests showed significant differences between years for Poaceae and Asteraceae cover (Table 25), in all sites except Berryville, a xeric unmanaged glade which did not show signs of undergoing successional change as seen in rank of percent similarity values (Table 17), woody species RI (Table 21) or herb species RI (Table 10). Between-year differences in herb cover (Table 12), presumably due to succession, may be responsible for the nearly uniform significance results for Poaceae and Asteraceae.

To test for differences in Poaceae and Asteraceae cover between managed and unmanaged sites, the Gibbons-MGD and Gyp-UMG data sets were compared (Table 26). Gibbons-MGD and Gyp-UMG are both sandstone barrens which occur within five miles of each other and differ primarily in management history. These sites showed significant differences in Poaceae and Asteraceae cover but not in rock cover in 1993. In 1993, Gibbons, which was fire-managed in 1989, was visually more open with a nearly continuous graminoid layer. In 1993, Gyp-UMG resembled an open forest with isolated patches of *Schizachyrium scoparium* and *Sorghastrum nutans* under canopy openings roughly 5 x 10 m. Poaceae RI was 12.9% higher at Gibbons-MGD than at Gyp-UMG in 1993, but Asteraceae RI was 10% lower (Table 9). This further supports the contention that increases in Asteraceae and decreases in Poaceae occur with successional progression. Two unmanaged sites, Cedar and Round, were also compared to each other for Poaceae and Asteraceae cover and no significant differences were found (Table 26). Both sites are unmanaged sandstone glades which occur within ten miles of each other. At both glades, Poaceae and Asteraceae cover was sparse, and consisted largely of isolated clumps of *Danthonia spicata* or *Schizachyrium scoparium* with few specimens of Asteraceae.

Site Similarity. Although 34 of the 1988 opening herb species (74% of the total for 1988) were relocated in the opening and/or transition in 1993-94 (Table 17), all of the possible combinations of forest-opening site pairs were more alike in 1994 (24.8% ± 0.8%) (Table 18) than the same site compared over time (1988 and 1993-94) (19.3% ± 1.1%) (Table 17). Presumably then, drought and successional change were more important in determining herb species similarity than differences in management, substrate or forest-opening type (Table 18). Also, since the transition zone was included in the 1993-94 surveys and not in 1988, sampling methods may have distinguished the sampling years. Managed sites and managed site pairs had a greater number of common herbs than unmanaged sites. However, sites of a common classification (i.e., the same substrate and forest-opening type) were more similar (30.8% ± 1.4%) than sites with the same management history. These sites were close in proximity, i.e., Gibbons-MGD and Gyp-MGD, Cedar-UMG and Round-UMG, Cave-MGD and Wildcat-MGD (Figure 1), but did not necessarily have similar (or any) management histories.

Compared to herb species (11), more woody species (16) were shared among all forest-opening sites (Table 19). All of these woody and herbaceous taxa are typical of the oak-hickory forests of this region. Exotic plants were also found at all of the study sites (11.7 on average) despite the fact that a few sites, i.e., Gyp-UMG and Wildcat-MGD, were surrounded by forest and were not easily or frequently accessed by humans (Table 20). The number of exotics appeared to correlate strongly with proximity and/or frequency of human visitation rather than with site management history (if any), forest-opening type or substrate. In most instances, forest-opening exotics were found in small isolated patches or as solitary individuals. However, a few exceptions existed at Cave-MGD which had more exotics (31) than any other study site. *Festuca arundinacea* was common along the road at Cave-MGD, and appeared to be extending north into the glade. Robust individuals of *Campsis radicans* also appeared to be successfully established at the site. In addition, *Medicago lupulina* and *Kummerowia stipulacea* occurred at the southern perimeter of the opening but have been known to increase with fire-disturbance (Van Valkenburg 1977, Thompson and Heineke 1977). Although infrequent, individuals of *Verbascum thapsus* grew to >1.2 m and bore large seed heads. Only a single individual of *Melilotus alba* (Fabaceae) was found in the glade proper at Cave-MGD.

The unmanaged sites bore a suite of small, solitary exotics most likely introduced by hikers and campers (and horse riders at Cedar-UMG). Only two exotic species were found at Cedar-UMG in 1988 versus 19 in 1994. For example, at Cedar-MGD heavy visitor use in 1993 exposed sizable (>5 m^2) patches of bare soil. Exotics increased from two to 11 at Pounds-UMG, from one to 14 at Round-UMG and from zero to eight at Berryville-UMG.

The managed sites, Brown, Gibbons, and Wildcat, also contained relatively few exotic species with eleven, five and four species, respectively. The exotics at these sites were uncommon except for *Viola raphanesquii*, a tiny spring ephemeral, found throughout the opening at Gibbons-MGD and an extensive ground cover of *Coronilla varia* at Brown-MGD found along the northeastern slope overlooking the roadway.

Categorization of Herb Species

Grasses, Forbs, Legumes and Exotics. The variability in the proportion of grasses, forbs, legumes and exotics was unexpectedly low among forest-opening sites in 1993 (Table 13). For example, the percentage of legume species varied little among sites (9.2% ± 0.9%), despite their disparate management histories. Other studies of Midwestern forest-openings have found dramatic increases in native and exotic legumes after management (e.g., Martin et al. 1975, Anderson and VanValkenburg 1977). However, these effects were immediate and not studied beyond the first year postfire. The site with the greatest percentage of legumes, Gyp, was a long-term unmanaged site. The sampled forest-openings contained 9.2% ± 0.9% legumes and 17.3% ± 1.2% grasses. In comparison, tallgrass prairies contain a similar percentage of legumes (9.2%), but a lower proportion of grass species (10%) (Curtis 1959).

Life History. The percentages of annuals, biennials and perennials (for managed and unmanaged sites and on a site by site basis) were unexpectedly similar, with the exception of Wildcat-MGD (Table 14). Wildcat-MGD had the highest percentage of perennials (89.8%) and had also received more burn management treatments (3) than any other site. However, Gyp-UMG also had a high percentage of perennials (84.0%) but had received no management. The sampled forest-openings differed in the estimate for perennials of Risser et al. (1981) (95%) for the tallgrass prairie by about 20%, averaging 75.8% ± 2.5%. Due to their xeric nature, the southern Illinois forest-openings examined in this study had a substantial component of annuals, averaging 20.6% ± 2.7% of all species.

Raunkaier's Life Forms. According to Walter (1973), "most" prairie and steppe species in temperate climates are hemicryptophytes. However, in the sampled forest-openings, hemicryptophytes and geophytes were found in comparable proportions, at 38.0% ± 5.6% and 40.4% ± 3.8%, respectively (Table 15). In fact, managed sites had a greater proportion of geophytes than hemicryptophytes and a higher percentage of geophytes than unmanaged sites. In light of Walter (1973), the high percentage of geophytes may be a consequence of the high proportion of woodland species found in these forest-openings. Bray (1957) attributed the occurrence of 21 non-aggressive climax forest herbs (e.g., *Claytonia virginica*, *Erythronium albidum*, *Trillium recurvatum*) located in Middle West prairies to their geophytic physiognomy which allowed them to escape late spring fires through regeneration from underground parts. When the forest-opening herbs were categorized by habitat, 47.7 ± 6.6% of the species had a woodland habitat affinity (Table 16). In addition, 10.8% of herbs were characteristic of an open woods habitat, giving these forest-openings a composite 58.5% woodland/open woods type herb flora. However, when geophytes from the most species-rich site, Cave-MGD, were analyzed by habitat, 42.6% were associated with woodlands and 11.3% with open woods, about the same proportions as would be expected from a random sample of all forest-opening herbs. The high percentage of geophytes, therefore, was not attributable to the high proportion of woodland herbs in the forest-openings. In addition, many authors (e.g., Anderson 1982, Anderson 1990, and Seastedt and Ramundo 1990) underscore the importance of rhizomatous (geophytic) herb species in regularly burned tallgrass prairie.

Categorization by Habitat Although managed sites exc.eeded unmanaged sites in the proportion of herb species typically occurring in a prairie habitat, the difference was small (2.9%) (Table 16). Overall, the proportion of species occurring in each habitat type was unexpectedly similar for managed and unmanaged sites. The barrens flora has been described as a mixture of forest and prairie species (White and Madany 1978, Packard 1990, Hutchison 1994). For example, in Wisconsin, oak savanna had a similarity index of 50% to 58% with prairie, and 53% with dry oak forest (Curtis 1959). However, the forest-opening herb flora was primarily typical of woodlands (47.7% ± 2.2%) with disturbed, bluff, open, and prairie habitat association percentages between five and 15%. Heikens's (1991) dichotomous key separates barrens, limestone glades, and loess hill prairie from sandstone glades, shale glades, and open forests as sites with ≥10% prairie species, such as *Aster* sp., *Brickellia eupatorioides*, *Euphorbia corollata*, *Helianthus* sp., *Lespedeza* sp., *Schizachyrium scoparium*, *Silphium terebinthinaceum* and *Solidago* sp. Categorization of the sampled forest-openings into habitat types supports Heikens's (1991) key for limestone glades with 12.9% characteristic prairie species, and sandstone and shale glades with 6.6%, but not barrens which averaged 7.3%.

The forest-openings were intermediate between the hill prairie and hardwood forest for species affinity to a woodland habitat and had a larger proportion of prairie associate species than the hardwood forest (Figure 9). This also supports the assertion that forest-openings harbor a flora that is transitional between forest and prairie.

Woody Species Composition

Many of the same overstory species were found at the study sites in the same RI position in 1988 and 1993 despite the different methodologies used to estimate canopy cover (Table 21). As indicated in the key by Heikens (1991), different forest-opening types were characterized by particular woody species. Both limestone glades were dominated by *Quercus prinoides* var. *acuminata* (yellow chestnut oak), all sandstone glades by *Juniperus virginiana* (eastern redcedar) and the barrens and shale glade by *Quercus stellata* (post oak) for both years. Results for the sandstone glades concur with Jeffries (1987) who also determined *Juniperus virginiana* to be the most important tree species in three Arkansas sandstone glades. Consecutive burns at Wildcat (spring 1982, spring 1988, fall 1990) undoubtedly eliminated *Juniperus virginiana*, a fire-sensitive species, as no individuals were found in 1993 although Heikens (1991) noted it in 9 of 18 plots (RI=14.5%) in 1988. Anderson and Schwegman (1991) found that redcedar was eliminated from a mesic southern Illinois barrens after one fire.

A greater number of woody species (per 50 m^2) were present in 1993 than in 1988 at both managed and unmanaged sites (Table 23). No difference in woody species number was found between managed and unmanaged sites in 1993, whereas unmanaged sites had more woody species than managed sites in 1988. A greater number of species of tree seedlings were encountered in the forest interior subhabitats (and transition zone-north) than in the opening of managed sites in 1994 (Table 40). Areas with permanent plot stakes from the 1988 sampling in some instances overlapped area defined as transition in 1994 (see Appendix B: Figures 8f-h). These finds suggest that succession was occurring at both managed and unmanaged sites for woody species (versus herb succession which occurred at unmanaged sites only). The length of time since management (averaging 4.8 years at the 1993 sampling) may have been long enough to allow woody species establishment. Data from a mesic barrens in southern Illinois suggests that management encourages resprouting and woody growth. Anderson and Schwegman (1991) found an increase ($\approx$16,000 stems/ha to 30,000 stems/ha) in seedling stems (between 1.4 m and $\leq$1.2 cm dbh) one year after fire cessation. Shearin et al. (1972) reported enhanced germination of *Liriodendron tulipifera* in hardwood and pine plantations in South Carolina for three growing seasons following a prescribed burn. The between-year increase in woody species may also involve the survival rate of tree seedlings through the severe drought of 1988. Keener (1983) noted the desiccation and mortality of nearly 35,000 seedlings (albeit herbacous) in a 225 m^2-barrens between April/May and mid-June (nine seedlings survived). Mesophytic tree seedlings, observed in 1990 (two years post-drought) by Heikens et al. (1994) at Brown-MGD (i.e., *Acer saccharum*), were not observed in 1988 (Heikens 1991).

Between-site canopy cover comparisons were not significantly different for managed-unmanaged and unmanaged-unmanaged site combinations in 1993 (Table 26). It was unexpected that the Gibbons-MGD and Gyp-UMG canopy comparison was not significant as Gyp-UMG had few canopy openings whereas Gibbons-MGD was a visibly open mosaic of openings (>5 m^2) and canopy. However, Gibbons-MGD had only recently received a single burn (fall 1989) and the shrub and sapling layer appeared vigorous in 1993.

Rock Cover

The mean percentage of exposed rock for all forest-openings decreased 5.8% between 1988 and 1993 (Table 24). Since average herb cover was 11.9% higher in 1993 than in 1988 (Table 12), a concomitant decrease in exposed rock presumably resulted from colonization by plants, especially those successional species which spread by runners, covering the rock surface and trapping litter (e.g., *Parthenocissus quinquefolia*, *Toxicodendron radicans*, and *Antennaria plantaginifolia*). The sites with the greatest estimated percent increase in herb cover (i.e., Berryville-UMG, Cedar-UMG, Gibbons-MGD, Gyp-UMG, and Round-UMG), were also among sites with the greatest decline in rock cover since 1988. This generalization however, was not true for Cave (burned in 1986) which had a decrease in herb cover and did not have a build up of litter in the opening in 1993-94.

Barrens had less exposed rock than glades in 1993 (at 0.8% and 21.3%, respectively) (Table 24). This result concurs with the key by Heikens (1991), in which barrens have ≤5% exposed rock cover, (averaging 3.1% for 4 barrens sites in Heikens 1991) and glades have at least five percent cover of exposed rock (averaging 22.3% for 12 sites in Heikens 1991). Therefore, the ratio of barrens to glades, 2:2 for managed sites and 1:4 for unmanaged sites, undoubtedly contributed to the greater mean percentage of exposed rock for unmanaged sites in both years.

Between-year statistical comparisons of percent cover of exposed rock were significantly different for two of the managed sites (Cave and Gibbons) and two unmanaged sites (Cedar and Gyp) (Table 25). Cave-MGD and Gibbons-MGD were burned one year prior to sampling while the other managed sites, burned three years earlier, were sampled after a longer postfire period. Fire management at Cave and Gibbons may have caused significant change in the herb layer (e.g., increased dominance by grasses) and decreased litter, thereby altering exposure of the surface rock. The absence of fire may have contributed to a combination of herb growth and litter buildup responsible for the significant change in rock cover at Cedar-UMG and Gyp-UMG. Significantly different percentages of rock cover between 1988 and 1993 at Cave-MGD (burned in 1989) may be attributable to the decrease in herb cover (Table 12). The decrease in herb cover since 1988, however, is difficult to explain as Gibbons-MGD was burned in 1989 as well and showed an increase in herbaceous cover. However, Gibbons-MGD is a more mesic site with greater (30.8%) canopy cover (Table 22) whereas Cave-MGD is a xeric, more exposed site.

Significant differences in percent cover of rock cover between two unmanaged sites in 1993 may be attributed to the fact that at Cedar, no extensive rock shelves existed, whereas at Round a 5- to 15-m shelf extended along about 80 m of the glade (Table 26).

Despite the fall 1989 burn at Gibbons, rock cover values between sites (Gibbons-MGD and Gyp-UMG) were not significantly different in 1993 (Table 26). Both sites showed significant decreases in rock cover since 1988 (average loss of 3.5%) (Table 25). Although Gyp-UMG appeared to be undergoing herb and overstory succession, exposed stones and bedrock were still evident at the soil surface. This may be due to its hilltop location and to weathering. Fire management did appear to remove litter on and around surface rock at Gibbons-MGD. Therefore, it is not entirely clear why these sites were not significantly different.

Vegetation Subhabitats

Herb Species Composition

Herbaceous species distribution patterns appeared to correspond with spatial gradients in the forest-openings (Table 27). These changes were especially pronounced at the managed sites which had large continuous tracts of open area. For example, Cave-MGD had an exemplary continuum of species. An open area approximately 145 x 110 m (north-south x east-west) (Table 57) graded from dry woods at the northern hilltop through the opening to mesic woodland in the south. Species of dry woods, such as *Helianthus divaricatus*, *Solidago ulmifolia, and Parthenocissus quinquefolia*, important in the forest interior-north, were replaced by *Smilax bona-nox* (catbrier) in the transition zone-north. The opening was dominated by prairie forbs such as *Brickellia eupatoriodes* (false boneset) and *Silphium terebinthinaceum* (prairie-dock) interspersed with *Schizachyrium scoparium*, *Bouteloua curtipendula*, and *Carex* sp. The transition zone-south contained a mixture of woodland (e.g., *Parthenocissus quinquefolia*) and prairie species (e.g., *Ratibida pinnata*). Finally, the forest interior-south was dominated by woodland species such as *Verbesina virginica* (tickweed) and *Toxicodendron radicans*.

Just as managed sites exceeded unmanaged sites in the mean number of herb species (per plot) in both 1988 and 1993 (Table 11), managed sites exceeded unmanaged sites in herb species richness (the number of species per m^2) in all subhabitats in 1994 (except the transition zone-north) (Table 31). While there was no difference in the number of herb species among subhabitats for managed sites, the opening subhabitat (and transition zone-south) was lowest in species richness for unmanaged sites. This may suggest that management was effective in maintaining (or enhancing) species richness in the opening of managed sites. It may also indicate that herb species richness in the opening subhabitat of the unmanaged sites (Berryville, Pounds, and Round) was typically lower than other subhabitats because the openings of these glades were characterized by high insolation, exposed rock "pavement" and a few herb species adapted to tolerate moisture-stress such as spring ephemerals and succulents (e.g., *Opuntia* sp., *Sedum pulchellum* and *Talinum parviflorum*).

In accord with the findings for herb cover in 1988 and 1993 (Table 12), in 1994, managed site herb cover exceeded unmanaged site cover, and did so in all subhabitats (Table 32). Managed site herb cover was highest in the opening. Conversely, herb cover did not peak in the opening of unmanaged sites, suggesting that management was effective in maintaining (if not enhancing) relatively dense herb cover in the opening. Because the opening of the unmanaged glade sites (all four unmanaged sites were glades) was strongly influenced by the substrate, herb cover might be expected to trough therein. However, herb cover was lower in the transition zone-south than all other subhabitats. This may reflect the importance of the southern exposure (insolation and moisture stress) adjoining the characteristic glade "pavement".

Although the RI of forest-opening Poaceae was greater in the opening (and forest interior-north) of unmanaged sites than of managed sites, inspection of RI on a site by site basis showed peaks in abundance of Poaceae in all subhabitats except the forest interior-south (Table 28). Based on field observations, Poaceae RI seemed to track topographic moisture gradients more than any other factor, increasing in dry areas. For example, high exposure, raised topography, and xerophytic vegetation in the opening and northern subhabitats were visible features at Berryville-UMG and Poaceae RI averaged 36.2% higher in these subhabitats than in the transition zone-south and forest interior-south. Similarly, the opening and southern subhabitats at Brown-MGD appeared to be more xeric than transition zone-north and forest interior-north, and were also zones of highest Poaceae RI, differing by an average of 17.8%. Preliminary soil moisture results, however, did not support this hypothesis (Table 62). Most sites showed moisture trends which did not correspond with Poaceae RI in a positive or negative way. However, far more extensive testing of soil moisture, especially of seasonal variation across the subhabitats, would be necessary to establish its effect on herb species distribution.

Although all forest-opening subhabitats were within one standard error of each other (≈16 to 24%) for Asteraceae RI (Table 31), mean Asteraceae RI was higher in the opening (and transition zone-north) of managed sites than of unmanaged sites. According to a model by Gibson and Hulbert (1987) for the tallgrass prairie, diversity (primarily determined by the number of forb species) could be expected to increase for six or seven years after fire, after which diversity declines. Since management occurred an average of 3.8 years prior to the 1994 sampling, fire may have maintained species richness in the opening (Table 31) as well as herb species diversity (Table 37) as, in part, reflected in Asteraceae RI values relative to the unmanaged sites.

Relative importance for Cyperaceae, as for Poaceae, was greater in the opening subhabitat of unmanaged sites than of managed sites (Table 30). However, unlike the grasses, sedges tended to dominate in subhabitats which were relatively mesic. For example, at Berryville-UMG sedges increased in the transition zone-south and forest interior-south which were lower topographically and more mesic than in the north. At Brown-MGD the transition zone-north and forest interior-north which were canopied, had higher sedge RI values (averaging 10.9%) than the exposed and drier southern site perimeter (5.2%).

In general, broadleaf species characteristic of the forest interior (e.g., *Parthenocissus quinquefolia*, *Toxicodendron radicans*, and *Galium* sp.) were absent among the top three RI positions in the opening, appearing in the transition and forest interior subhabitats (Table 27). At Cave-MGD and Wildcat-MGD (sites which had been burned more than once prior to 1994) the herb species in the first RI position in the opening was not ubiquitous in the oak-hickory forests of southern Illinois and was not prevalent in adjacent subhabitats. At Cave-MGD *Brickellia eupatorioides* was 25.2% more important in the opening than the species in the second RI position and therefore may serve as an opening indicator species. Furthermore, this species was not found in sample plots outside the opening subhabitat. At Wildcat-MGD *Silphium terebinthinaceum* did occur in the transition zone-south (1.5%) (Appendix C); however, RI was 9.9% higher in the opening (11.4%). Therefore, *Silphium terebinthinaceum* may also serve as an indicator of the opening subhabitat at Wildcat-MGD.

Danthonia spicata of dry woods and bluffs, *Dichanthelium laxiflorum* of woodlands and xeric *Carex* sp. (probably *C. artitecta* of dry woods and *C. umbellata* of dry woods and sandstone rocks) accounted for 21.4% of the total opening RI for herbaceous species, while *Schizachyrium scoparium*, a characteristic prairie species, accounted for 8.0% of the total opening RI (Table 27, Appendix C). Therefore, unusual grass and sedge species appeared to be important forest-opening matrix species which occur within the *Andropogon-Panicum-Sorghastrum* association of the Midwestern tallgrass prairie (Risser et al. 1981).

Categorization of Herb Species

Raunkaier's Life Forms. The majority of the life form category values for managed and unmanaged sites (and across subhabitats) did not differ statistically in 1994 (Table 36). The most important life forms were the geophytes (averaging 38.4% of total life form RI for herbs across subhabitats) and hemicryptophytes (averaging 37.7% across subhabitats). The ratio of forest-opening geophytes to hemicryptophytes was compared to that of a hill prairie in southern Illinois (38 herb species, Voigt and Mohlenbrock 1964) and a mesic mixed hardwood forest in east-central Illinois (21 herb species, Aikman and Ebinger 1991) to better ascertain typical values for each of these habitats in this region. The forest-opening ratio (geophytes:hemicryptophytes) was 1.02, the prairie, 1.15, and the forest, 3.76. Therefore, the forest-opening herb life form ratio was proportionately more similar to a prairie habitat than to a mesic forest. In this study, the proportion of geophytes in the opening of managed sites was 34.1% greater than that of unmanaged sites with a ratio of 1.20, comparable to the estimate for the hill prairie.

Herb Species Diversity

Although mean forest-opening herb diversity using the Simpson (Ds) and Shannon (H') indexes did not differ among subhabitats for all sites, consistent differences were observed between managed and unmanaged sites (Table 37). Managed site Ds and H' diversity exceeded that of unmanaged sites in the opening and southern subhabitats (and in the transition zone-north for H'). Species richness was also greater in the opening and southern subhabitats (and forest interior-north) for managed sites than for unmanaged sites (Table 31). As H' is influenced more by species richness than Ds, it followed expectation that managed sites exceeded unmanaged sites in diversity in the opening and southern subhabitats. Ds is more sensitive to relative abundance of species (dominance and evenness) and was also greater in the opening and southern subhabitats of managed sites, providing further information about the diversity in these subhabitats.

A study of diversity in mixed-grass prairie by Collins and Barber (1985) concurs with Denslow's (1980) model, more specific than the intermediate-disturbance hypothesis, in which diversity is maximized under a natural disturbance regime and minimized under undisturbed or severely disturbed conditions. The managed sites in this study did have higher diversity in the opening than unmanaged sites. However, a study by Collins and Adams (1983) reported no trends in diversity, evenness, or species richness in the course of succession of mature tallgrass prairie in Oklahoma to shrub-grassland.

Woody Species Composition

Shade Tolerance. In all three woody strata (seedling, shrub/sapling and tree) the proportion of shade-intolerant species in the opening of unmanaged sites exceeded that of managed sites (Tables 42, 46 and 51). The ratio of glades to barrens was greater for unmanaged (4:0) than for managed sites (2:2). This may indicate that the opening substrate of unmanaged sites was more important in determining woody species composition (shade tolerance) than management. Counter to expectation, however, on average, the shade-intolerant RI values for the opening of all of the glades were comparable to barrens (shrubs and saplings) or lower (seedlings and trees). However, the sandstone and shale glades which comprised the unmanaged site comparison had more exposed rock (22.9%) (Table 33) and a more shallow soil depth (19.7%) (Table 60) in the opening than the managed limestone glades and averaged 91.8% higher in the proportion of shade-intolerant woody species (seedlings, shrubs/saplings and trees) in the opening. Therefore, the xeric nature of the opening of the unmanaged glades may account for the high proportion of shade-intolerant species relative to the managed sites. Alternatively, Anderson and Schwegman (1991) suggested the preclusion of mesophytic woody vegetation (shade-tolerant) in early successional habitats by prairie indigens. Regarding a prairie inclusion in northeastern Nebraska, Hanson (1922) noted that the highest growing-season (May-September) evaporation occurred in the prairie (air near the surface was two to four times drier than that in the surrounding wooded area) and maintained that this, not fire, precluded woody invasion. Percent cover of rock was not given. Hanson (1922) further described grassland succession through three stages as *Quercus-Quercus* (shade-intolerants) to *Quercus-Carya* to *Tilia-Ostrya* (shade-tolerants). Hardin (1988) described the seedling stratum in a prairie inclusion in southeastern Ohio as originally consisting of *Carya* sp. and *Quercus alba* (shade-intolerants) which succeeded after 22 years by *Ostrya virginiana*, *Crataegus* sp., *Prunus serotina* and *Sassafras albidum* (both shade-tolerant and shade-intolerant). Therefore, managed sites may also have incorporated shade-tolerant species due to succession in all of the woody layers since the previous burn (averaging 3.8 years at the 1994 sampling). Also, vigorous resprouting of mesophytic shade-tolerant species such as *Ostrya virginiana*, *Ulmus rubra*, *Amelanchier arborea* and *Acer saccharum* as well as extensive thickets of *Rhus aromatica* (shade tolerant) were observed at all of the managed sites. This may account for the decrease in the proportion of shade-intolerant species in the opening.

The proportion of shade-intolerant woody species in the opening (of managed and unmanaged sites) increased from the understory to the overstory. In forests, shade-tolerant understory layers generally subtend predominately shade-intolerant overstory (Oliver and Larson 1990). Relative importance of sapling *Quercus* spp. in the opening (26.5%) was comparable to that of seedlings (28.4%) (Tables 43 and 38, respectively). However, *Quercus* spp. were more important in the tree stratum (54.6%) of the opening, especially at managed sites (69.7%) (versus 39.4% at unmanaged sites). Selection of fire- and drought-resistant and/or shade-intolerant species would be expected in the opening at both managed and unmanaged sites.

Density. The length of time since management (averaging 3.8 years for the 1994 sampling) may have obscured differences in the opening for woody seedling density (per 25 m^2) between managed and unmanaged sites, allowing time for seedling establishment at the managed sites (Table 41). Although there was no difference in seedling density between managed and unmanaged site openings, managed sites had more seedlings in the transition zone subhabitats. Seedling density is known to increase in response to management (Anderson and Schwegman 1991). Anderson and Schwegman (1991) found a doubling in seedling density (seedlings were defined by height and therefore may have included resprouts) one year after fire in a mesic southern Illinois barrens site. Seedling density subsequently declined, reaching pre-burn levels about ten years postfire. Conversely, shrub and sapling density decreased one year after the fire then rapidly increased. Hardin (1988) in a prairie inclusion in southeastern Ohio reported that seedling density was originally higher in the transition zones than in the opening, though this situation was reversed after 22 years of subsequent succession.

The forest openings had a sparse shrub and sapling layer, giving them the characteristic open, park-like aspect of midwestern savanna (Table 45). Tree density values and to a lesser extent, shrub and sapling density values, particularly in the forest interior subhabitats, did not reflect what was visually a marked contrast beween the opening and forest interior subhabitats.

Species Richness. Mean tree and tree seedling species richness (although sometimes within one standard error) were lower in the opening than in any other subhabitat for managed and un[illegible] sites (Tables 40 and 49). Managed and unmanaged sites did not differ among sub[illegible] species richness in any of the woody strata (with the exception of the nor[illegible] seedlings). Mean forest-opening density values for all three canop[illegible] within one standard error of other subhabitats) were also lowest in the opening (Tables 41, 45 and 50). Therefore, peaks in the opening percent rock cover (17.2 ± 3.6, excepting the transition zone-south), shallow soil depth and exposure (insolation and moisture stress) may account for the trough in woody species richness in the opening. Alternatively, Garman (1925), Transeau (1935) and Walter (1973) attributed the lack of woody seedlings in the prairie to competitive exclusion by grasses.

Approximately four more woody seedling species (per 25 m^2) were found in the forest interior subhabitats (9.7) than in the opening (5.9) of the forest-openings (Table 40). The forest interior-north would provide a favorable environment for mesophytic seedlings with less moisture stress and exposure than the opening and southern subhabitats. Species richness of woody seedlings was also more numerous in the northern subhabitats of the managed sites than of the unmanaged sites. This may also be attributed to the more mesic nature of the barrens than the glades which comprised the unmanaged site controls. In combination with the more moderate environment in the northern subhabitats, management may have had a positive influence on seedling species richness by clearing away litter and providing a more favorable substrate for resprouting and/or germination. Shearin et al. (1972) found that prescribed burning increased *Liriodendron tulipifera* seedling number and height growth significantly three growing-seasons after a burn in pine and hardwood plantation stands in South Carolina. They attributed the change to improved (earlier) germination of seedlings. In the present study, a greater number of tree seedling species, including mesophytic species (e.g., *Liriodendron tulipifera*, *Fagus grandifolia* and *Liquidambar styraciflua*), were counted in 1993 than in 1988.

Canopy Measurements. Mean tree crown diameter, height and dbh for all forest-openings did not differ among subhabitats (Tables 54, 53 and 52, respectively). However, mean tree height and crown diameter of managed sites exceeded that of unmanaged sites in the opening and forest interior subhabitats. This most likely reflects the more mesic nature of the barrens and limestone glades which comprised the managed sites versus the xeric unmanaged sandstone and shale glades. The xeric growing conditions and shallow soil of the unmanaged glade sites are also known to produce a stunted, gnarled growth of trees (Reich and Hinckley 1980). However, height differences were difficult to discern given the lack of habitat qualifying as opening in the subsample transect at the unmanaged sites. Although it is generally assumed that open-grown trees (especially in upper Midwest savanna) are larger (taller, greater dbh) than forest-grown trees, Anderson and Anderson (1975) found that dbh values for savanna trees in Illinois did not differ from those based upon governmental land office records of 52.8 ± 4.7 cm versus 44.7 ± 3.3 cm in surrounding forest.

Soil Measurements: 1993 and 1994

The classification key by Heikens (1991) separates glades from barrens based upon soil depth. According to her key, glades have a soil depth ≤10 cm whereas barrens have a depth of 10 to nearly 40 cm. However, in 1988 three barrens averaged 9.4 cm depth (the six glades averaged 6.3 cm) and two of three barrens (Brown-MGD and Gibbons-MGD) had soil depth values less than 10 cm (Heikens 1991). In 1993 glades averaged 7.0 ± 2.9 cm soil depth (Table 60). Still, the Cave-MGD and Cedar-UMG glades had values of 13.1 ± 2.9 cm and 18.4 ± 2.9 cm, respectively. In 1993, barrens averaged 10.9 ± 0.9 cm, with Gibbons (9.1 cm) below the 10-cm criterion of Heikens. Findings by Jeffries (1987) concur with the key by Heikens (1991). The three sandstone glades studied by Jeffries (1987) had a mean soil depth of 5.2 cm. Although boundaries for soil depth can be used to distinguish glades and barrens, these results suggest that individual sites may not be representative of their respective forest-opening type.

SUMMARY AND CONCLUSIONS

The effect of management on Poaceae and Asteraceae RI followed trends described by others in the literature. Averaging 4.8 years since fire management at the 1993 sampling, Poaceae RI declined at both managed (-11.8%) and unmanaged sites (-6.3%) while Asteraceae RI declined at managed sites (-2.0%) but increased at unmanaged sites (2.6%). Gibson and Hulbert (1987) and Piper (1995) reported that as dominance of graminoid species declines, the number of forbs (primarily composed of Asteraceae species) and diversity increase for approximately six to seven years, after which diversity declines. The Fabaceae also showed an increase in RI with management (30.5% for three of four managed sites), even after an extended postfire period whereas RI decreased for four of five unmanaged sites (-46.6%). This complements the findings of Martin et al. (1975), Anderson and VanValkenburg (1977) and Towne and Knapp (1996) who found increases in legumes (e.g., density, biomass) after fire management.

The findings for the 1994 transect data involved the comparison of relatively mesic barrens and limestone glades (the managed sites) with more xeric, exposed sandstone and shale glades (the unmanaged sites) (Gyp, an unmanaged, comparatively mesic barrens, had a closed canopy and therefore zonation into subhabitats was not possible). The ratio of glades to barrens was greater for unmanaged (4:0) than for managed sites (2:2). These site-specific differences confounded the effects of management. The managed sites were more species-rich (herbs) (excepting the transition zone-south) and had greater herb cover than the unmanaged sites in all subhabitats. In the opening managed sites showed a peak in herb cover while unmanaged sites troughed in herb species richness. These differences are believed to reflect differences imposed by exposure, moisture regime and exposed rock cover (e.g., barrens averaged 0.8% while glades averaged 21.3%). unmanaged sites. Sites managed (prescribed burn) more than once contained characteristic prairie species which were in the first RI position and were unique to the opening (excepting the transition zone-south at Wildcat-MGD). Management was also believed to maintain zonable subhabitats and However, it is also believed that management was responsible for maintaining, if not enhancing, herb species richness and cover in the managed forest-openings, especially in the opening. Asteraceae RI and herb species diversity were also higher in the opening of managed than of distinct distributions of herbs at the more mesic barrens and limestone glade sites (versus Gyp-UMG which had succeeded to a closed-canopy).

Herb species composition showed some striking similarities among the sampled forest-openings, regardless of previous management history (if any), substrate or forest-opening type. There was little variability among sites in the proportion of grasses, forbs, legumes and exotics, and in categories of life history (annual, biennial, perennial), life form (chamaephyte, geophyte, hemicryptophyte, therophyte) and percent association with a particular habitat type (e.g., bluff, open woods). However, when subdivided into subhabitats and compared the sampled forest-opening values did differ from values for similar habitats in other studies. The forest-openings had a lower proportion of perennials (by ≈20%) and a higher proportion of annuals (by ≈20%) than the tallgrass prairie (Risser et al. 1981). This is attributable to their xeric characteristics, i.e., shallow soil, southern to western exposure, elevated topographic position and relatively high percentage of exposed rock. These features were also largely responsible for their longevity as openings (especially the unmanaged glades), causing them to be unattractive for cultivation and slower to succeed to closed forest.

The findings of this study supported others (White and Madany 1978, Nuzzo 1986, Packard 1990, Hutchison 1994) who contend that the forest-opening herb flora is transitional between a prairie and a forest, with values intermediate between east-central Illinois mixed hardwood forest and southern Illinois hill prairie habitats in the percentage of typical woodland and prairie species inhabitants. Still, the forest-openings had a composite 58.5% woodland/open woods type herb flora and only an 8.2% association with a prairie habitat. However, the opening subhabitat of managed sites more closely approximated a southern Illinois hill prairie in the ratio of geophytes to hemicryptophytes than an east-central mixed hardwood forest. Also, the high percentage of geophytes (often rhizomatous species) found in the opening of managed sites (34.1% higher in the opening of managed sites than unmanaged sites) is underscored by many authors as an important feature of grasslands (Anderson 1982, Anderson 1990, Seastedt and Ramundo 1990).

Forest-opening data were influenced by drought and succession and results attributable to both of these factors supported others in the literature. Both managed and unmanaged sites increased in herbaceous species richness since the 1988 drought-year sampling (by an average of 4.5 species per plot; the average of up to 30, four 1-m^2 plots in 1993 was compared to that of 50 m^2 plots in 1988). The percent increase for unmanaged sites, 58.4%, exceeded that for managed sites, 23.5%. Although no pre-drought data were available, species richness (especially the number of annual species; Tilman and El Haddi 1992) has been reported to be lower during the severe drought and higher before and afterward (Piper 1995). Likewise, the proportion of annuals was 5.6% to 18.1% higher in 1993 for two of the sampled forest-openings.

Succession was responsible for the increase in herb cover which occurred at several of the unmanaged sites as evinced by the concommitant increase in relative importance of broadleaf woodland herbs (e.g., *Parthenocissus quinquefolia*, *Toxicodendron radicans*) and successional, open woods species (e.g., *Helianthus divaricatus*, *Solidago* sp.) and the presence of solitary prairie species under dense, even-aged forest (sapling to small tree in size) bordering the glade rock outcrops. Barbour et al. (1980) state that in general, vegetative cover increases during succession. Woody succession appeared to be taking place at both managed and unmanaged sites. Woody species richness increased at both unmanaged sites (40.4%) and managed sites (75.0%) (averaging 4.8 years since fire management at the 1993 sampling). Similar results are reported by Hardin (1988) and Anderson and Schwegman (1991). Also, in several instances, permanent plots installed in 1988 occurred in area defined as transition in 1994. Although the number of exotic species also increased (11.7) for all sites since 1988, this appeared to correlate with proximity and/or frequency of human visitation, rather than with forest-opening type or management history (if any).

Transect data yielded unexpected descriptive information regarding herb species distribution. For example, the openings were composed of unusual matrix species. Although Midwestern savanna are typically dominated by prairie grasses such as *Schizachyrium scoparium*, *Andropogon gerardii*, *Sorghastrum nutans* and *Panicum virgatum*, 21.4% of the opening subhabitat RI was comprised of *Danthonia spicata*, xeric *Carex* sp. (probably *C. artitecta* and *C. umbellata*), *Dichanthelium laxiflorum* (woodland species) and 8.0% *Schizachyrium scoparium*. The Poaceae appeared to track topographic moisture gradients, increasing in RI in dry subhabitats while the Cyperaceae favored more mesic areas.

The opening subhabitat of managed and unmanaged sites was similar in that woody species richness and density for all canopy strata were lower than in the transition or forest interior subhabitats (although sometimes within one standard error). As noted by Heikens (1991) and Jeffries (1987) the openings of different forest-opening types are characterized by particular woody species. For example, *Juniperus virginiana* was most important in the opening at the sandstone glades. At both managed and unmanaged sites, however, shrub and sapling and tree density values did not reflect what was visually a marked decrease between the opening and forest interior.

Differences in forest-opening woody species composition, like herb composition, appeared to be confounded by differences in managed and unmanaged site substrate and moisture regime. For example, in the seedling, shrub and sapling and tree strata of the opening subhabitat, shade-intolerant species were more important at the unmanaged than at the managed sites. Additionally, vigorous resprouting of mesophytic, shade-tolerant species (e.g., *Ostrya virginiana*, *Amelanchier arborea*) and extensive thickets of *Rhus aromatica* (shade-tolerant) often occurred at the managed sites. Tree height and crown diameter in the opening and forest interior of managed sites exceeded that of unmanaged sites. The xeric growing conditions and shallow soil of glade sites are known to produce a stunted, gnarled growth of trees (Reich and Hinckley 1980). The forest-openings, like forests, increased in RI of shade-intolerant species from the understory to the overstory of the opening regardless of management history (if any) (Oliver and Larson 1990). This was primarily due to an increase in *Quercus* sp. Selective forces for *Quercus* include periodic and seasonal drought, fire and exposure in the opening subhabitat.

The sampled forest-openings had an aspect of south or west. The perimeter of the opening subhabitats were undulating, and the east-west axis was longer than the north-south axis for five of eight sites. The openings ranged from 450 to 7825 m^2. Although the openings of managed sites were larger in area (175.9%) and more species-rich (34.0% for opening plots; plot size was larger in 1988 sampling) than unmanaged sites, there was no correlation between site opening area and total herb number ($0.0005<p<0.005$). Management was effective in maintaining a rich herb flora and open, parklike aspect and if continued, can preserve open areas uniquely representative of Midwestern savanna.

RECOMMENDATIONS

The continuation of management (fire and cutting) at the barrens and limestone glades is recommended as it appears to have been successful in maintaining the opening with characteristic prairie species and in reducing woody growth. Frequency and extent of management at these sites should be carefully evaluated along with the future goals of the respective land stewards. Selective tree cutting or girdling, although not recommended within the open rock outcrop "pavement" area at Berryville-UMG, Cedar-UMG, Pounds-UMG and Round-UMG is suggested at the perimeter (currently an abrupt canopy at the glade edge) to encourage growth of prairie species. Fire management is also recommended at this perimeter for Cedar-UMG and Round-UMG to remove the thick accumulation of litter.

Factors that signal management by prescribed burning is needed include a decline of forest-opening Fabaceae and Poaceae species (especially *Schizachyrium scoparium*) and a concommitant increase in Asteraceae and characteristic woodland herb species such as *Parthenocissus quinquefolia*, *Toxicodendron radicans*, *Galium* sp., *Helianthus divaricatus* and *Solidago* sp. Indications that management by burning and woody plant removal are needed include an increase in the shrub and sapling layer in the opening, especially by resprouting species such as *Ostrya virginiana*, *Amelanchier arborea*, *Rhus aromatica* and *Ulmus rubra* and the establishment of mesophytic tree seedlings such as *Acer saccharum*, *Liriodendron tulipifera*, *Fagus grandifolia* and *Liquidambar styraciflua*. The appearance of *Juniperus virginiana* within the glade openings and especially of "dog-hair" stands (even-aged stands of small trees) adjacent to the glade opening as well as the accumulation of a well-developed litter layer signal a need for management. Indications of site overuse include the appearance and/or increase of exotic species, footpaths, campfires and erosive gulleys.

As suggested by Heikens (1991), resampling of the forest-openings on a periodic basis (e.g., every five years) is recommended to document short- and long-term change and to aid in determining management plans. It is recommended that sampling take place one growing-season before and after management if possible, to facilitate pre- and post-management vegetation comparisons which might otherwise be obscured over a longer sampling interval. For example, did herb cover increase as a response to management or to subsequent succession? Sampling on approximately the same date would aid in consistency of data, especially when comparing the seasonal development of herbs (e.g., herb cover). Site visitation should proceed with caution as the openings vegetation is particularly susceptible to vegetation trampling, moss and lichen destruction and substrate degradation. For example, Berryville shale glade bore large pads of moss and lichen and an extremely unstable, gravel-like shale substrate on a relatively steep slope.

At follow-up surveys, site boundaries can be reevaluated for changes by referring to the site maps, and thereby provide a basis for determining change in area and site perimeter and aid in management decisions (e.g., cutting and girdling of woody species). The installation of permanent plots (at Cedar-UMG, Gyp-UMG, Gibbons-MGD, and Wildcat-MGD) would facilitate accurate longterm sampling and aid in boundary estimation for mapping. Permanent plots would be impractical at the Pounds-UMG and Round-UMG glades given the sheer rock substrate, however. In future sampling it is recommended that species lists be developed separately for the opening, transition and forest interior subhabitats. Also, extending belt transects 15 m further into the forest interior (e.g., for the subsample transect) would help determine gradients in herb composition such as species distribution, diversity, life form, life history beyond the arbitrary forest interior subhabitat which are otherwise only implied by data from the five subhabitat categorization discussed here.

Given that Cedar-UMG and Gyp-UMG appeared to be undergoing herbaceous-layer succession to resemble the surrounding forest (and had well developed litter layers), it is recommended that each be considered for management, i.e., selective tree removal and prescribed burning, and that treatment take place immediately as the characteristic prairie species that remain appear to be declining rapidly. For example at Gyp-UMG, *Lithospermum canescens* and *Polytaenia nuttallii* were each represented by only one specimen. "Wolf trees," (primarily *Quercus stellata*) are trees originally open-grown (with low horizontal branches) but subsequently surrounded by a dense, even-aged stand also occurred at Gyp-UMG. At Round-UMG leaf litter and a "dog-hair" stand of even-aged saplings/small trees occur adjacent to the glade proper. It would be beneficial to the opening vegetation to remove some of the woody growth.

Manual removal of exotic plants would be feasible for most species in the forest-openings given the sporadic and sparse occurrence of these invasives. At Cave-MGD, it is recommended that native shrubs such as *Corylus americana* or *Cornus drummondii* be planted between the opening and the roadcut vegetation (primarily *Festuca arundinacea*) to help secure a boundary between the native vegetation and exotic plants.

At the Cedar-UMG and Pounds-UMG glades, visitor usage appeared to have exceeded the site's capacity to sustain it (e.g., bare patches in excess of 5 m^2 existed at Cedar-UMG and extensive denudation of lichen was evident at Pounds-UMG). It is therefore recommended that access to these sites be limited. For example, several obvious user-created paths and overlook areas provided easy-access to the glade at Pounds-UMG. Shrub and tree planting along the corridors and the addition of guard rails at the overlook areas might impede glade visitation. At Cedar-UMG, fencing and the prohibition of camping and horse riding might also moderate visitor impact.

APPENDICES

APPENDIX A

Species lists for woody and herbaceous taxa from floristic survey of the studied forest-openings in 1993 and 1994 for each site and summary of information relating to species importance for sampling in 1993. Site surveys include the openings and adjacent 8.5-m area. Dominance is the total of areal coverage values divided by the area sampled (Cox 1990). Relative importance is the sum of relative dominance and relative frequency divided by two and multiplied by 100 (yielding a percentage between one and 100). The abbreviations for Illinois-threatened (IL-T) and Illinois-endangered (IL-E) taxa according to Herkert (1991) are given following the Latin binomial.

BERRYVILLE SHALE GLADE

Number of circular 50 m^2 plots for woody taxa: 28
Number of nested 1 m^2 plots for herbaceous taxa: 112
*indicates plant was sampled with the herbaceous taxa and, although bearing a woody stem, was located within the herb layer, i.e., within approximately 1 m of ground level.
***indicates value less than one-one hundredth of a percent.

Woody taxa	No. of plots of occurrence	Dominance	Relative Importance
Acer rubrum	2	0.58	1.2
Acer saccharum	0	0	0
Amelanchier arborea	22	1.02	5.8
Carya glabra	0	0	0
Carya ovalis	3	0.73	1.6
Carya ovata	2	0.04	0.5
Carya texana	10	0.30	2.4
Celtis occidentalis	0	0	0
Celtis tenuifolia	10	0.25	2.4
Cercis canadensis	5	0.08	1.1
Cornus florida	1	0.02	0.2
Crataegus punctata	0	0	0
Crataegus sp.	1	0.02	0.2
Diospyros virginiana	10	0.15	2.2
Fagus grandifolia	0	0	0
Fraxinus americana	16	0.41	3.8
Gleditsia triacanthos	0	0	0
*Hypericum stragulum**	3	0.04	0.4
Juglans nigra	1	0.02	0.2
Juniperus virginiana	2	0.04	0.5
Liriodendron tulipifera	1	***	0.2
Lonicera japonica	0	0	0
*Menispermum canadense**	3	0.21	0.8

Morus alba	0	0	0
Morus rubra	0	0	0
Ostrya virginiana	4	0.07	0.9
*Parthenocissus quinquefolia**	6	0.15	0.9
Prunus serotina	6	0.11	1.4
Quercus alba	14	0.14	3.0
Quercus coccinea	1	0.02	0.2
Quercus imbricaria	9	0.13	1.9
Quercus marilandica	23	7.71	14.9
Quercus prinoides acuminata	0	0	0
Quercus rubra	11	0.13	2.4
Quercus stellata	27	16.11	26.8
Quercus velutina	14	4.04	8.2
Rhus aromatica	5	0.21	1.3
Rhus copallina	2	0.02	0.4
Robinia pseudoacacia	0	0	0
*Rosa carolina**	6	0.45	1.7
Rosa multiflora	0	0	0
Rosa setigera	0	0	0
Sassafras albidum	2	0.04	0.5
Smilax glauca	0	0	0
*Toxicodendron radicans**	11	0.04	1.0
Ulmus alata	16	1.41	5.1
Vaccinium arboreum	20	3.57	8.8
Vaccinium pallidum	6	0.36	1.7
Viburnum prunifolium	1	0.02	0.2
*Vitis aestivalis**	2	0.01	0.2
Vitis sp.*	5	0.01	0.4
Vitis vulpina	0	0	0

Herbaceous taxa	No. of plots of occurrence	Dominance	Relative Importance
Acalypha gracilens	3	0.02	0.3
Agrimonia rostellata	0	0	0
Allium canadense	1	***	0.1
Allium vineale	0	0	0
Ambrosia artemisiifolia	0	0	0
Antennaria plantaginifolia	18	0.79	3.7
Apocynum cannabinum	0	0	0
Arabis canadensis	0	0	0
Arisaema triphyllum	0	0	0
Aristida dichotoma	0	0	0
Aristolochia serpentaria	0	0	0
Asclepias tuberosa	2	0.29	0.9
Asplenium platyneuron	0	0	0
Aster patens	8	0.13	1.0
Aster sp.	30	0.74	4.5
Bidens bipinnata	0	0	0
Brickellia eupatorioides	0	0	0

Bromus pubescens	1	0.04	0.2
Cardamine sp.	0	0	0
Carex artitecta	0	0	0
Carex bushii	0	0	0
Carex cephalophora	0	0	0
Carex communis	0	0	0
Carex flaccosperma	0	0	0
Carex hirsutella	0	0	0
Carex muhlenbergii	0	0	0
Carex retroflexa	0	0	0
Carex sp.	5	0.05	0.6
Carex sp. (Montanae)	20	0.51	3.1
Carex umbellata	0	0	0
Cassia fasciculata	1	***	0.1
Chamaesyce maculata	7	0.03	0.7
Chasmanthium latifolium	0	0	0
Cheilanthes lanosa	10	0.45	2.0
Cirsium discolor	0	0	0
Croton monanthogynus	2	0.01	0.2
Crotonopsis elliptica	5	0.02	0.5
Cunila origanoides	70	3.39	15.1
Danthonia spicata	96	2.84	15.7
Desmodium rotundifolium	0	0	0
Desmodium sp.	3	0.04	0.4
Dichanthelium acuminatum	1	***	0.1
Dichanthelium boscii	0	0	0
Dichanthelium dichotomum	4	0.02	0.4
Dichanthelium laxiflorum	14	0.67	2.9
Dichanthelium linearifolium	20	0.38	2.7
Dichanthelium malacophyllum	0	0	0
Dichanthelium microcarpon	3	0.01	0.3
Dioscorea quaternata	0	0	0
Dioscorea villosa	0	0	0
Dodecatheon meadia	3	0.18	0.8
Eragrostis capillaris	0	0	0
Erigeron annuus	0	0	0
Erigeron strigosus	0	0	0
Eupatorium altissimum	0	0	0
Euphorbia corollata	25	0.34	3.0
Festuca obtusa	0	0	0
Galactia regularis	0	0	0
Galium aparine	0	0	0
Galium circaezans	1	0.04	0.2
Geranium carolinianum	0	0	0
Hedeoma pulegioides	0	0	0
Hedyotis longifolia	4	0.05	0.5
Hedyotis pusilla	0	0	0
Hedyotis sp.	5	0.05	0.6
Helianthus divaricatus	34	1.29	6.4

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Heuchera americana	0	0	0
Hieracium gronovii	7	0.13	0.9
Hybanthus concolor	0	0	0
Hypericum punctatum	0	0	0
Juncus sp.	0	0	0
Krigia dandelion	0	0	0
Krigia sp.	5	0.02	0.5
Lactuca floridana	0	0	0
Lactuca serriola	0	0	0
Lechea tenuifolia	4	0.02	0.4
Lepidium virginicum	0	0	0
Lespedeza hirta	5	0.15	0.8
Lespedeza procumbens	2	0.07	0.4
Lespedeza repens	40	0.64	5.1
Liatris sp.	1	***	0.1
Luzula multiflora	0	0	0
Monarda bradburiana	0	0	0
Muhlenbergia sobolifera	0	0	0
Nothoscordum bivalve	0	0	0
Oxalis stricta	2	0.01	0.2
Oxalis violacea	10	0.03	0.9
Parietaria pensylvanica	0	0	0
Paronychia fastigiata	0	0	0
Passiflora lutea	1	***	0.1
Penstemon hirsutus	0	0	0
Penstemon sp.	3	0.01	0.3
Phlox pilosa	0	0	0
Physalis virginiana	4	0.11	0.6
Poinsettia dentata	3	0.01	0.3
Polygonum convolvulus	0	0	0
Polygonum cristatum	1	***	0.1
Polygonum tenue	2	0.01	0.2
Psoralea psoralioides	14	0.66	2.9
Pycnanthemum tenuifolium	2	***	0.2
Ranunculus sp.	5	0.02	0.5
Ruellia caroliniensis	0	0	0
Ruellia humilis	0	0	0
Ruellia pedunculata	0	0	0
Sanicula canadensis	0	0	0
Schizachyrium scoparium	31	2.29	8.8
Scutellaria sp.	0	0	0
Setaria glauca	0	0	0
Sisyrinchium sp.	0	0	0
Smilacina racemosa	2	0.07	0.4
Solidago nemoralis	0	0	0
Solidago ulmifolia	0	0	0
Sphenopholis obtusata	1	0.04	0.2
Stylosanthes biflora	10	0.07	1.0
Tephrosia virginiana	10	0.66	2.6

Triodanis perfoliata	0	0	0
Verbena urticifolia	0	0	0
Vernonia gigantea	0	0	0
Viola raphanesquii	0	0	0
Vulpia octoflora	0	0	0
Woodsia obtusa	3	0.08	0.5

BROWN SHALE BARRENS

Number of circular 50 m^2 plots for woody taxa: 30
Number of nested 1 m^2 plots for herbaceous taxa: 120
*indicates plant was sampled with the herbaceous taxa and, although bearing a woody stem, was located within the herb layer, i.e., within approximately 1 m of ground level.
*.*indicates value less than one tenth of a percent.
***indicates value less than one-one hundredth of a percent.

Woody taxa	No. of plots of occurrence	Dominance	Relative Importance
Acer rubrum	4	0.01	1.2
Acer saccharum	2	0.03	0.7
Amelanchier arborea	0	0	0
Aralia spinosa	0	0	0
Campsis radicans	0	0	0
Carya cordiformis	0	0	0
Carya glabra	1	0.02	0.4
Carya ovalis	2	0.02	0.7
Carya ovata	17	0.27	6.2
Carya texana	0	0	0
Carya tomentosa	0	0	0
Celtis tenuifolia	1	0.02	0.4
Cercis canadensis	1	***	0.3
Cornus florida	0	0	0
Corylus americana	2	0.03	0.7
Crataegus engelmannii	0	0	0
Crataegus monogyna	1	0.02	0.4
Crataegus sp.	1	0.02	0.4
Diospyros virginiana	3	0.05	1.1
Euonymus atropurpurea	1	0.02	0.4
Fagus grandifolia	0	0	0
Fraxinus americana	9	0.78	6.7
Gleditsia triacanthos	0	0	0
Hypericum stragulum	0	0	0
Juglans nigra	1	0.13	0.9
Juniperus virginiana	0	0	0
Ligustrum vulgare	1	0.02	14.8
Liriodendron tulipifera	3	0.01	0.9
*Lonicera japonica**	9	0.21	0.7
Lonicera sp. (shrub)	1	0.02	0.4

Morus rubra	0	0	0
Ostrya virginiana	2	0.03	0.7
*Parthenocissus quinquefolia**	3	0.07	0.2
Prunus serotina	0	0	0
Quercus alba	1	***	0.3
Quercus coccinea	0	0	0
Quercus imbricaria	7	0.12	2.6
Quercus prinoides acuminata	1	0.02	0.4
Quercus rubra	2	0.02	0.7
Quercus stellata	24	5.63	36.5
Quercus velutina	4	0.07	1.5
Rhus copallina	0	0	0
Rosa carolina	0	0	0
Rubus allegheniensis	0	0	0
Rubus flagellaris	0	0	0
Sassafras albidum	1	***	0.3
Smilax bona-nox	0	0	0
Smilax glauca	0	0	0
Symphoricarpos orbiculatus	0	0	0
*Toxicodendron radicans**	5	0.02	0.2
Ulmus alata	15	0.88	8.9
Ulmus americana	0	0	0
Ulmus rubra	2	0.03	0.7
Vaccinium arboreum	16	1.13	10.5
Viburnum prunifolium	2	0.02	0.7
*Vitis aestivalis**	2	0.01	0.1
*Vitis vulpina**	2	***	0.1

Herbaceous taxa	No. of plots of occurrence	Dominance	Relative Importance
Acalypha gracilens	93	0.58	4.7
Acalypha virginica	0	0	0
Achillea millefolium	0	0	0
Agalinis tenuifolia	0	0	0
Agrimonia rostellata	0	0	0
Agrostis perennans	0	0	0
Ambrosia artemiisifolia	22	0.33	1.4
Amphicarpa bracteata	0	0	0
Anemone virginiana	0	0	0
Antennaria plantaginifolia	5	0.88	1.4
Apocynum cannabinum	0	0	0
Arabis laevigata	0	0	0
Arisaema dracontium	1	0.03	0.1
Aristida sp.	1	0.13	0.2
Aristolochia serpentaria	0	0	0
Asclepias tuberosa	1	0.13	0.2
Asclepias variegata	0	0	0
Asparagus officinalis	0	0	0
Asplenium platyneuron	10	0.13	0.6

Aster patens	24	0.58	1.8
Aster sp.	68	3.03	6.8
Bidens bipinnata	0	0	0
Bromus pubescens	0	0	0
Cacalia atriplicifolia	0	0	0
Cardamine sp.	0	0	0
Carex artitecta	0	0	0
Carex bushii	2	0.07	0.2
Carex cephalophora	8	0.09	0.5
Carex digitalis	0	0	0
Carex glaucodea	13	0.29	0.9
Carex hirsutella	4	0.08	0.3
Carex muhlenbergii	2	0.01	0.1
Carex retroflexa	0	0	0
Carex rosea	2	0.04	0.1
Carex sp.	46	1.45	3.8
Carex umbellata	0	0	0
Cassia fasciculata	1	***	*.*
Cassia nictitans	9	0.21	0.7
Chasmanthium latifolium	0	0	0
Cirsium discolor	0	0	0
Claytonia virginica	0	0	0
Conyza canadensis	0	0	0
Coronilla varia	0	0	0
Croton monanthogynus	25	0.19	1.3
Cunila origanoides	1	***	*.*
Cynoglossum virginianum	0	0	0
Cyperus ovularis	4	0.02	0.2
Cystopteris protrusa	0	0	0
Danthonia spicata	56	2.34	5.4
Desmodium canescens	0	0	0
Desmodium nudiflorum	0	0	0
Desmodium paniculatum	0	0	0
Desmodium rotundifolium	0	0	0
Desmodium sp.	7	0.15	0.5
Dichanthelium acuminatum	66	1.15	4.3
Dichanthelium boscii	0	0	0
Dichanthelium depauperatum	2	0.01	0.1
Dichanthelium dichotomum	0	0	0
Dichanthelium laxiflorum	107	5.19	11.3
Dichanthelium linearifolium	0	0	0
Dichanthelium malacophyllum	1	0.03	0.1
Dichanthelium polyanthes	0	0	0
Dichanthelium sphaerocarpon	0	0	0
Dichanthelium villosissimum	0	0	0
Diodia teres	3	0.07	0.2
Dioscorea quaternata	0	0	0
Dodecatheon meadia	0	0	0
Elymus sp.	1	***	*.*

Elymus villosus	0	0	0
Elymus virginicus	0	0	0
Eragrostis spectabilis	0	0	0
Erechtites hieracifolium	0	0	0
Erigeron annuus	0	0	0
Erigeron strigosus	24	0.16	1.2
Eupatorium rugosum	1	***	*.*
Eupatorium serotinum	0	0	0
Euphorbia corollata	8	0.06	0.4
Galactia regularis	0	0	0
Galium aparine	0	0	0
Galium circaezans	1	***	*.*
Galium pilosum	0	0	0
Galium triflorum	1	***	*.*
Geranium carolinianum	15	0.06	0.7
Geranium maculatum	0	0	0
Geum canadense	0	0	0
Gnaphalium purpureum	3	0.01	0.1
Hackelia virginiana	0	0	0
Hedeoma pulegioides	0	0	0
Hedyotis purpurea	0	0	0
Hedyotis pusilla	0	0	0
Helianthus divaricatus	63	5.42	9.8
Heuchera americana	0	0	0
Hieracium gronovii	0	0	0
Hypericum drummondii	0	0	0
Hypericum punctatum	0	0	0
Juncus secundus	0	0	0
Juncus sp.	11	0.05	0.5
Juncus tenuis	2	0.01	0.1
Krigia dandelion	0	0	0
Lactuca serriola	0	0	0
Lechea tenuifolia	16	0.15	0.9
Lespedeza procumbens	19	0.49	1.4
Lespedeza repens	0	0	0
Lespedeza violacea	0	0	0
Lespedeza virginica	3	0.04	0.2
Liparis lilifolia	0	0	0
Lobelia inflata	0	0	0
Luzula multiflora	1	***	*.*
Manfreda virginica	8	0.24	0.6
Monarda bradburiana	0	0	0
Muhlenbergia capillaris	0	0	0
Muhlenbergia sobolifera	0	0	0
Myosotis verna	3	0.01	0.1
Nothoscordum bivalve	0	0	0
Oxalis stricta	30	0.21	1.5
Oxalis violacea	3	0.01	0.1
Parietaria pensylvanica	0	0	0

Paronychia pensylvanica	0	0	0
Passiflora lutea	1	***	*.*
Penstemon pallidus	5	0.17	*.*
Penstemon sp.	16	0.49	1.3
Physalis pruinosa	0	0	0
Physalis virginiana	4	0.13	0.3
Phytolacca americana	0	0	0
Plantago lanceolata	0	0	0
Plantago virginica	16	0.09	0.8
Poinsettia dentata	0	0	0
Polygala verticillata	25	0.16	1.3
Polygonum tenue	1	***	*.*
Polystichum acrostichoides	0	0	0
Potentilla simplex	0	0	0
Prenanthes altissima	0	0	0
Psoralea psoralioides	0	0	0
Pycnanthemum tenuifolium	28	0.40	1.7
Ranunculus hispidus	4	0.01	0.2
Rudbeckia hirta	0	0	0
Ruellia caroliniensis	0	0	0
Ruellia humilis	8	0.46	0.9
Sabatia angularis	0	0	0
Sanicula canadensis	0	0	0
Schizachyrium scoparium	103	9.04	16.2
Senecio glabellus	0	0	0
Solidago caesia	0	0	0
Solidago juncea	0	0	0
Solidago missouriensis	0	0	0
Solidago nemoralis	1	0.13	0.2
Solidago ulmifolia	0	0	0
Sphenopholis obtusata	3	0.01	0.1
Stylosanthes biflora	55	2.08	5.0
Tradescantia virginiana	0	0	0
Triodanis perfoliata	84	0.38	4.0
Vallerianella radiata	4	0.01	0.2
Veronicastrum virginicum	0	0	0
Viola raphanesquii	3	0.01	0.1
Viola sororia	0	0	0
Viola triloba	0	0	0
Vulpia octoflora	3	0.01	0.1
Woodsia obtusa	5	0.11	0.4

CAVE CREEK LIMESTONE GLADE

Number of circular 50 m^2 plots for woody taxa: 27
Number of nested 1 m^2 plots for herbaceous taxa: 108
*indicates plant was sampled with the herbaceous taxa and, although bearing a woody stem, was located within the herb layer, i.e., within approximately 1 m of ground level.

**indicates plant was sampled with the woody taxa.
*.*indicates value less than one tenth of a percent.
***indicates value less than one-one hundredth of a percent.

Woody taxa	No. of plots of occurrence	Dominance	Relative Importance
Acer negundo	5	0.06	1.6
Acer rubrum	6	0.02	1.7
Acer saccharum	7	2.43	9.9
Aesculus glabra	0	0	0
Amelachier arborea	0	0	0
Aralia spinosa	0	0	0
Betula nigra	0	0	0
*Bignonia capreolata**	27	1.13	2.4
*Campsis radicans**	17	0.85	1.7
Carya cordiformis	0	0	0
Carya ovalis	0	0	0
Carya ovata	3	0.06	1.0
Carya texana	0	0	0
Ceanothus americanus	3	0.06	1.0
*Celastrus scandens**	4	0.23	0.4
Celtis occidentalis	2	0.04	0.7
Celtis tenuifolia	12	0.21	3.9
Cercis canadensis	17	0.96	7.9
Cornus drummondii	1	0.02	0.3
Cornus florida	5	1.50	6.3
Corylus americana	0	0	0
Crataegus engelmannii	1	0.02	0.3
Crataegus mollis	4	0.07	1.3
Crataegus sp.	1	0.02	0.3
Crataegus viridis	0	0	0
Diospyros virginiana	10	0.31	3.8
Euonymus atropurpurea	4	0.06	1.3
Fraxinus americana	15	0.93	7.2
Gleditsia triacanthos	1	0.02	0.3
Hypericum prolificum	0	0	0
Ilex decidua	4	0.33	2.2
Juglans nigra	4	0.07	1.9
Juniperus virginiana	8	0.12	2.6
Lindera benzoin	0	0	0
Liquidambar styraciflua	0	0	0
Liriodendron tulipifera	0	0	0
Lonicera japonica	0	0	0
Malus ioensis	1	0.02	0.3
Menispermum canadense	0	0	0
Morus rubra	0	0	0
Ostrya virginiana	1	0.02	0.3
*Parthenocissus quinquefolia**	9	0.24	0.7
Prunus americana	3	0.06	1.0

Prunus serotina	1	0.02	0.3
Quercus marilandica	0	0	0
Quercus prinoides acuminata	21	3.59	17.6
Quercus rubra	1	***	0.3
Quercus shumardii	14	3.29	14.7
Quercus stellata	0	0	0
Quercus velutina	0	0	0
Rhus aromatica	3	0.06	1.0
Rhus copallina	1	0.02	0.3
Rhus glabra	2	0.17	1.1
Rosa carolina*	18	0.41	1.2
Rosa multiflora	0	0	0
Rubus allegheniensis*	7	0.73	1.1
Rubus enslenii (IL-E)	0	0	0
Rubus flagellaris	0	0	0
Rubus occidentalis	0	0	0
Sassafras albidum	0	0	0
Smilax bona-nox*	32	2.00	3.6
Smilax hispida	0	0	0
Smilax rotundifolia	0	0	0
Symphoricarpos orbiculatus	0	0	0
Toxicodendron radicans*	9	0.24	0.7
Ulmus alata	2	0.04	0.7
Ulmus rubra	14	0.39	5.1
Viburnum prunifolium	1	0.02	0.3
Viburnum rufidulum	0	0	0
Vitis aestivalis*	3	0.11	0.3
Vitis vulpina	0	0	0

Herbaceous taxa	No. of plots of occurrence	Dominance	Relative Importance
Abutilon theophrastii	0	0	0
Acalypha gracilens	23	0.11	1.1
Agrimonia rostellata	0	0	0
Agrostis alba	0	0	0
Allium vineale	1	***	*.*
Ambrosia artemisiifolia	7	0.06	0.4
Anagallis arvensis	0	0	0
Andropogon gerardii	0	0	0
Anemone virginiana	0	0	0
Apocynum cannabinum	0	0	0
Arabis canadensis	1	***	*.*
Aristida sp.	3	0.01	0.1
Aristolochia serpentaria	3	0.05	0.2
Arundinaria gigantea	0	0	0
Asarum canadense	0	0	0
Asclepias syriaca	0	0	0
Asclepias tuberosa	0	0	0
Asclepias verticillata	1	***	*.*

Asclepias viridiflora	2	0.04	0.1
Aster oblongifolius	63	1.88	4.8
Aster patens	19	0.57	1.5
Aster pilosus	0	0	0
Aster sp.	2	0.07	0.2
Aster turbinellus	0	0	0
Aureolaria flava	0	0	0
Boehmeria cylindrica	0	0	0
Botrychium virginianum	0	0	0
Bouteloua curtipendula	17	0.31	1.1
Brickellia eupatorioides	7	0.24	0.6
Bromus commutatus	0	0	0
Bromus pubescens	11	0.12	0.6
Bromus racemosus	0	0	0
Cacalia atriplicifolia	0	0	0
Camassia scilliodes	0	0	0
Campanula americana	6	0.16	0.4
Capsella bursa-pastoris	0	0	0
Cardamine sp.	0	0	0
Carex artitecta	0	0	0
Carex blanda	0	0	0
Carex cephalophora	0	0	0
Carex meadii	0	0	0
Carex muhlenbergii	0	0	0
Carex retroflexa	0	0	0
Carex sp.	12	0.15	0.7
Carex umbellata	0	0	0
Cassia fasciculata	16	0.49	1.2
*Cassia marilandica***	3	0.06	1.0
Cassia nictitans	1	***	**
Cerastium arvense	0	0	0
Chamaesyce maculata	17	0.14	0.9
Cheilanthes feei	1	0.04	0.1
Cirsium altissimum	2	0.07	0.2
Cirsium discolor	0	0	0
Clematis pitcheri	0	0	0
Conyza canadensis	0	0	0
Coreopsis tripteris	3	0.11	0.3
Cosmos bipinnata	0	0	0
Croton monanthogynus	19	0.19	1.0
Crotonopsis elliptica	0	0	0
Cunila origanoides	0	0	0
Cuscuta sp.	0	0	0
Cynanchum laeve	3	0.05	0.2
Danthonia spicata	1	0.04	0.1
Dentaria laciniata	0	0	0
Desmodium canescens	0	0	0
Desmodium paniculata	0	0	0
Desmodium rotundifoium	2	0.01	0.1

Desmodium sessilifolium	0	0	0
Desmodium sp.	3	0.08	0.2
Dianthus armeria	0	0	0
Dichanthelium boscii	6	0.13	0.4
Dichanthelium laxiflorum	0	0	0
Dichanthelium malacophyllum	0	0	0
Dichanthelium sp.	1	***	*.*
Dichanthelium villosissimum	1	0.15	0.2
Dioscorea quaternata	0	0	0
Dioscorea villosa	8	0.41	0.8
Dodecatheon meadia	0	0	0
Echinacea pallida	32	1.31	2.9
Elymus hystrix	1	***	*.*
Elymus virginicus	11	0.05	0.5
Eragrostis capillaris	1	0.04	0.1
Erechtites hieracifolia	1	0.04	0.1
Erigeron annuus	0	0	0
Eupatorium altissimum	53	1.38	3.8
Eupatorium rugosum	0	0	0
Euphorbia corollata	38	0.40	2.1
Festuca arundinacea	1	0.04	0.1
Fragaria virginiana	5	0.15	0.4
Frasera caroliniensis	0	0	0
Galactia regularis	53	1.27	3.7
Galium circaezans	15	0.10	0.7
Galium concinnum	0	0	0
Galium pilosum	7	0.06	0.4
Gaura longiflora	0	0	0
Geranium carolinianum	2	0.01	0.1
Geranium maculatum	0	0	0
Hedeoma pulegioides	1	***	*.*
Hedyotis purpurea	2	0.01	0.1
Helianthus divaricatus	49	1.36	3.6
Helianthus microcephalus	11	0.94	1.6
Heliopsis helianthoides	0	0	0
Hordeum pusillum	0	0	0
Hybanthus concolor	3	0.08	0.2
Hydrastis canadensis	0	0	0
Hypericum denticulatum	6	0.06	0.3
Ipomoea pandurata	6	0.22	0.5
Iva annua	0	0	0
Kummerowia stipulacea	1	***	*.*
Lactuca canadensis	0	0	0
Lactuca floridana	1	0.04	0.1
Lactuca serriola	0	0	0
Lepidium virginicum	0	0	0
Lespedeza cuneata	0	0	0
Lespedeza procumbens	1	0.04	0.1
Lespedeza repens	1	0.04	0.1

Lespedeza sp.	3	0.01	0.1
Leucanthemum vulgare	0	0	0
Liatris scabra	0	0	0
Lithospermum canescens	11	0.38	0.9
Lysimachia lanceolata	1	0.04	0.1
Manfreda virginica	22	0.55	1.5
Matricaria matricarioides	0	0	0
Medicago lupulina	0	0	0
Melica mutica	0	0	0
Melilotus alba	0	0	0
Monarda bradburiana	21	0.76	1.8
Monarda fistulosa	1	0.15	0.2
Muhlenbergia sobolifera	2	0.01	0.1
Nothoscordum bivalve	0	0	0
Onosmodium hispidissimum	1	0.04	0.1
Oxalis dillenii	0	0	0
Oxalis stricta	5	0.06	0.3
Panicum anceps	0	0	0
Passiflora lutea	1	***	*.*
Pellaea atropurpurea	0	0	0
Penstemon sp.	5	0.02	0.2
Phleum pratense	0	0	0
Phlox pilosa	30	0.30	1.6
Phryma leptostachya	0	0	0
Physalis virginiana	21	0.13	1.0
Physostegia virginiana	46	1.19	3.3
Plantago lanceolata	0	0	0
Plantago rugellii	0	0	0
Poa compressa	0	0	0
Poinsettia dentata	8	0.07	0.4
Polygonum cristatum	2	0.01	0.1
Ranunculus sp.	1	0.04	0.1
Ratibida pinnata	14	0.63	1.3
Rudbeckia hirta	0	0	0
Ruellia caroliniensis	0	0	0
Ruellia humilis	40	0.99	2.8
Ruellia strepens	17	0.50	1.3
Salvia azurea grandiflora (IL-T)	7	0.09	0.4
Salvia lyrata	2	0.04	0.1
Sanguinaria canadensis	0	0	0
Sanicula canadensis	13	0.16	0.7
Schizachyrium scoparium	57	4.70	7.9
Scutellaria leonardii	2	0.07	0.2
Setaria faberi	0	0	0
Setaria glauca	3	0.05	0.2
Sida spinosa	0	0	0
Silene stellata	1	***	*.*
Silphium integrifolium	8	0.41	0.8
Silphium terebinthinaceum	37	5.71	8.2

Sisyrinchium albidum	6	0.05	0.3
Solidago sp.	35	1.16	2.7
Solidago ulmifolia	3	0.11	0.3
Sorghastrum nutans	28	0.95	2.2
Spigelia marilandica	0	0	0
Taenidia integerrima	0	0	0
Taraxacum officinale	0	0	0
Teucrium canadense	0	0	0
Torilis japonica	0	0	0
Tradescantia subaspera	2	0.01	0.1
Tridens flavus	0	0	0
Trifolium campestre	0	0	0
Trifolium pratense	0	0	0
Triosteum angustifolium	0	0	0
Uvularia grandifolia	0	0	0
Verbascum thapsus	0	0	0
Verbena urticifolia	0	0	0
Verbesina helianthoides	0	0	0
Verbesina virginica	44	4.46	5.8
Vernonia gigantea	0	0	0
Viola raphanesquii	0	0	0
Viola sororia	0	0	0
Viola sp.	16	0.23	0.1
Viola triloba	0	0	0
Zizia aurea	5	0.26	0.5

CEDAR BLUFF SANDSTONE GLADE

Number of circular 50 m^2 plots for woody taxa: 30
Number of nested 1 m^2 plots for herbaceous taxa: 120
*indicates plant was sampled with the herbaceous taxa and, although bearing a woody stem, was located within the herb layer, i.e., within approximately 1 m of ground level.
*.*indicates value less than one tenth of a percent.
***indicates value less than one-one hundredth of a percent.

Woody taxa	No. of plots of occurrence	Dominance	Relative Importance
Acer rubrum	0	0	0
Acer saccharum	4	0.04	0.8
Amelanchier arborea	12	0.30	2.5
Carya cordiformis	0	0	0
Carya glabra	20	1.8	5.7
Carya ovalis	12	0.95	3.3
Carya ovata	0	0	0
Carya texana	14	0.70	3.4
Carya tomentosa	1	0.02	0.2
Celastrus scandens	0	0	0
Celtis laevigata	1	0.02	0.2

Celtis occidentalis	8	0.11	1.6
Celtis tenuifolia	4	0.05	0.8
Cercis canadensis	2	0.02	0.4
Cornus florida	2	0.03	0.4
Crataegus englemannii	0	0	0
Diospyros virginiana	10	0.36	2.2
Fagus grandifolia	0	0	0
Fraxinus americana	14	2.49	5.4
Gleditsia triacanthos	0	0	0
*Hypericum stragulum**	1	***	0.1
Juglans nigra	0	0	0
Juniperus virginiana	30	15.15	23.1
Ligustrum vulgare	0	0	0
*Lonicera japonica**	7	0.70	1.8
Lonicera sp. (shrub)	0	0	0
Malus ioensis	0	0	0
Morus rubra	1	0.02	0.2
Ostrya virginiana	10	2.58	4.8
*Parthenocissus quinquefolia**	54	3.30	9.5
Prunus americana	0	0	0
Prunus serotina	2	0.02	0.4
Quercus alba	5	0.08	1.0
Quercus X*bushii*	0	0	0
Quercus coccinea	0	0	0
Quercus imbricaria	1	0.02	0.2
Quercus marilandica	6	0.73	1.9
Quercus prinoides acuminata	1	0.02	0.2
Quercus rubra	7	0.23	1.5
Quercus stellata	27	12.48	19.5
Quercus velutina	10	0.52	2.4
Rhus aromatica	17	0.52	3.7
Rhus copallina	1	0.02	0.2
Rhus glabra	1	0.02	0.2
Rosa multiflora	4	0.07	0.8
Rubus allegheniensis	0	0	0
Rubus enslenii (IL-E)	0	0	0
*Rubus flagellaris**	19	0.79	2.5
*Smilax bona-nox**	4	0.20	0.6
Smilax glauca	0	0	0
Symphoricarpos orbiculatus	9	0.15	1.8
*Toxicodendron radicans**	35	2.67	0.07
Ulmus alata	29	2.98	8.8
Ulmus rubra	2	0.02	0.4
Vaccinium arboreum	6	0.45	1.6
Vaccinium pallidum	1	0.02	0.2
*Vitis aestivalis**	1	0.03	0.1
*Vitis vulpina**	1	***	*.*

Herbaceous taxa	No. of plots of occurrence	Dominance	Relative Importance
Acalypha gracilens	71	0.29	3.8
Achillea millefolium	0	0	0
Agrimonia rostellata	0	0	0
Agrostis elliotiana	2	0.01	0.1
Agrostis perennans	0	0	0
Allium canadense	0	0	0
Allium vineale	0	0	0
Ambrosia artemisiifolia	6	0.03	0.3
Apocynum cannabinum	0	0	0
Arabis laevigata	4	0.01	0.2
Arisaema triphyllum	1	***	0.1
Aristida sp.	0	0	0
Aristolochia serpentaria	0	0	0
Asplenium pinnatifidum	0	0	0
Asplenium platyneuron	8	0.12	0.6
Aster pilosus	0	0	0
Aster sp.	26	0.52	2.3
Bidens bipinnata	3	0.07	0.3
Bromus commutatus	3	0.04	0.2
Bromus pubescens	1	***	0.1
Bromus racemosus	5	0.02	0.3
Cardamine hirsuta	0	0	0
Carex artitecta	0	0	0
Carex blanda	0	0	0
Carex cephalophora	9	0.04	0.5
Carex glaucodea	6	0.05	0.4
Carex hirsutella	19	0.19	1.3
Carex retroflexa	3	0.01	0.2
Carex sp.	35	0.89	3.5
Carex umbellata	0	0	0
Cerastium arvense	1	***	0.1
Chasmanthium latifolium	39	0.99	3.9
Cheilanthes lanosa	14	0.49	1.7
Corydalis flavula	0	0	0
Crotonopsis elliptica	4	0.17	0.5
Cunila origanoides	15	0.37	1.5
Cystopteris protrusa	0	0	0
Danthonia spicata	95	2.61	9.9
Desmodium paniculatum	0	0	0
Desmodium rotundifolium	1	***	0.1
Dianthus armeria	0	0	0
Dichanthelium acuminatum	10	0.16	0.8
Dichanthelium boscii	65	1.06	5.2
Dichanthelium dichotomum	0	0	0
Dichanthelium laxiflorum	27	0.88	3.1
Dichanthelium linearifolium	0	0	0
Dichanthelium malacophyllum	0	0	0

Dichanthelium villosissimum	12	0.23	1.0
Digitaria sp.	4	0.23	0.7
Diodia teres	1	***	*.*
Dodecatheon meadia	1	***	*.*
Dryopteris marginalis	0	0	0
Elymus virginicus	62	1.33	5.7
Erigeron annuus	0	0	0
Erigeron strigosus	11	0.08	0.7
Eupatorium rugosum	3	0.07	0.3
Eupatorium serotinum	0	0	0
Euphorbia corollata	20	0.22	1.4
Festuca arundinacea	1	***	0.1
Galactia regularis	0	0	0
Galium pilosum	6	0.02	0.3
Gnaphalium purpureum	2	0.01	0.1
Hedyotis nutalliana	13	0.05	0.7
Hedyotis pusilla	0	0	0
Helianthus divaricatus	4	0.10	0.4
Heuchera americana	1	0.03	0.1
Hieracium sp.	1	0.03	0.1
Hordeum pusillum	0	0	0
Hypericum gentianoides	0	0	0
Hypericum punctatum	1	***	0.1
Juncus secundus	0	0	0
Juncus tenuis	12	0.35	1.3
Krigia virginica	0	0	0
Kummerowia striata	0	0	0
Lactuca canadensis	0	0	0
Lactuca serriola	0	0	0
Lechea tenuifolia	0	0	0
Leersia virginica	0	0	0
Lepidium virginicum	20	0.06	1.0
Lespedeza cuneata	0	0	0
Lespedeza repens	2	***	0.1
Liatris sp.	0	0	0
Manfreda virginica	1	0.03	0.1
Muhlenbergia sobolifera	2	0.07	0.2
Myosotis verna	4	0.01	0.2
Nothoscordum bivalve	1	***	*.*
Oenothera linifolia	2	0.01	0.1
Opuntia humifusa	1	***	0.1
Oxalis dillenii	7	0.03	0.4
Oxalis stricta	34	0.20	1.9
Oxalis violacea	4	0.02	0.2
Parietaria pensylvanica	19	0.08	1.0
Paronychia fastigiata	1	***	0.1
Paspalum ciliatifolium	0	0	0
Passiflora lutea	0	0	0
Penstemon pallidus	1	0.03	0.1

Penstemon sp.	5	0.14	0.5
Phlox pilosa	39	1.12	4.2
Plantago aristata	0	0	0
Plantago virginica	6	0.02	0.3
Poa compressa	0	0	0
Poa pratensis	7	0.09	0.5
Polygonatum biflorum	0	0	0
Polygonatum commutatum	0	0	0
Polygonum cristatum	19	0.08	1.0
Polygonum tenue	1	***	0.1
Pycnanthemum tenuifolium	3	0.04	0.2
Pyrrhopappus carolinianus	0	0	0
Ranunculus sp.	2	0.04	0.2
Ruellia humilis	0	0	0
Ruellia pedunculata	0	0	0
Rumex acetosella	0	0	0
Sanicula canadensis	30	0.16	1.7
Schizachyrium scoparium	13	0.23	1.1
Scutellaria leonardii	0	0	0
Sedum pulchellum	18	0.08	0.9
Smilacina racemosa	0	0	0
Solidago caesia	19	0.46	1.8
Solidago nemoralis	0	0	0
Solidago sp.	5	0.08	0.4
Solidago ulmifolia	0	0	0
Sphenopholis obtusata	4	0.04	0.3
Stylosanthes biflora	0	0	0
Tephrosia virginiana	0	0	0
Triodanis perfoliata	39	0.16	2.1
Verbascum thapsus	0	0	0
Vulpia octoflora	15	0.06	0.8
Woodsia obtusa	25	0.54	2.3

GIBBONS CREEK SANDSTONE BARRENS

Number of circular 50 m^2 plots for woody taxa: 15
Number of nested 1 m^2 plots for herbaceous taxa: 60
*indicates plant was sampled with the herbaceous taxa and, although bearing a woody stem, was located within the herb layer, i.e., within approximately 1 m of ground level.
*.*indicates value less than one tenth of a percent.
***indicates value less than one-one hundredth of a percent.

Woody taxa	No. of plots of occurrence	Dominance	Relative Importance
Acer saccharum	0	0	0
Amelanchier arborea	5	1.20	3.4
Carya cordiformis	1	0.27	0.7
Carya glabra	2	0.30	1.2

Carya ovalis	0	0	0
Carya ovata	0	0	0
Carya texana	12	3.63	9.1
Ceanothus americanus	0	0	0
Celastrus scandens	0	0	0
Celtis occidentalis	3	0.10	1.4
Celtis tenuifolia	0	0	0
Cercis canadensis	2	0.07	0.9
Cornus florida	3	0.33	1.6
Crataegus sp.	1	0.03	0.5
Crataegus viridis	0	0	0
Diospyros virginiana	5	0.40	2.6
Euonymus atropurpurea	0	0	0
Fraxinus americana	10	7.80	12.8
Gleditsia triacanthos	0	0	0
Hypericum prolificum	1	0.03	0.5
*Hypericum stragulum**	1	0.01	0.1
Juglans nigra	0	0	0
Juniperus virginiana	0	0	0
Malus ioensis	0	0	0
Morus alba	0	0	0
Ostrya virginiana	3	0.33	1.6
*Parthenocissus quinquefolia**	19	2.49	5.7
Prunus americana	0	0	0
Prunus serotina	4	0.13	1.8
Quercus alba	4	0.13	1.8
Quercus coccinea	1	0.03	0.5
Quercus imbricaria	8	0.27	3.7
Quercus marilandica	3	0.33	1.6
Quercus prinoides acuminata	0	0	0
Quercus rubra	2	0.07	0.9
Quercus stellata	11	18.37	24.7
Quercus velutina	10	1.60	5.9
Rhamnus caroliniana	0	0	0
Rhus copallina	0	0	0
*Rosa carolina**	10	0.14	1.2
*Rubus allegheniensis**	1	0.07	0.2
*Rubus flagellaris**	4	0.27	0.8
Rubus occidentalis	0	0	0
Sassafras albidum	0	0	0
Smilax bona-nox	0	0	0
Smilax glauca	0	0	0
Smilax hispida	0	0	0
Symphoricarpos orbiculatus	6	5.83	8.9
*Toxicodendron radicans**	6	2.27	4.1
Ulmus alata	15	3.63	10.3
Ulmus rubra	0	0	0
Vaccinium arboreum	6	0.90	3.5
Vaccinium pallidum	0	0	0

*Vitis aestivalis**	1	0.07	0.2
*Vitis vulpina**	3	0.20	0.6

Herbaceous taxa	No. of plots of occurrence	Dominance	Relative Importance
Acalypha gracilens	2	0.02	0.2
Agrimonia rostellata	0	0	0
Agrostis alba	0	0	0
Ambrosia artemisiifolia	2	0.01	0.2
Amphicarpa bracteata	21	2.09	5.3
Anemone virginiana	0	0	0
Antennaria plantaginifolia	3	0.14	0.5
Apocynum cannabinum	0	0	0
Arabis canadensis	1	0.01	0.1
Arisaema dracontium	1	0.01	0.1
Aristida dichotoma	0	0	0
Aristolochia serpentaria	1	0.01	0.1
Asarum canadense	0	0	0
Asclepias tuberosa	0	0	0
Asclepias variegata	0	0	0
Asclepias verticillata	5	0.04	0.5
Asplenium platyneuron	23	0.19	2.5
Aster anomalus	0	0	0
Aster patens	1	0.01	0.1
Aster pilosus	0	0	0
Aster sp.	7	0.05	0.7
Aster turbinellus	0	0	0
Aster undulatus	0	0	0
Botrychium virginianum	1	0.01	0.1
Brachyelytrum erectum	0	0	0
Brickellia eupatorioides	0	0	0
Bromus pubescens	6	0.11	0.7
Cardamine sp.	0	0	0
Carex artitecta	0	0	0
Carex blanda	0	0	0
Carex bushii	0	0	0
Carex cephalophora	1	0.01	0.1
Carex hirsutella	6	0.11	0.7
Carex muhlenbergii	5	0.04	0.5
Carex retroflexa	2	0.02	0.2
Carex sp.	13	0.28	1.7
Carex sp. (Montanae)	14	0.18	1.6
Carex umbellata	0	0	0
Cassia fasciculata	2	0.01	0.2
Cassia marilandica	0	0	0
Cassia nictitans	0	0	0
Cheilanthes lanosa	4	0.09	0.5
Cirsium altissimum	0	0	0

Cirsium carolinianum (IL-T)	0	0	0
Clitoria mariana	1	0.07	0.2
Conyza canadensis	0	0	0
Corydalis flavula	0	0	0
Crotonopsis elliptica	0	0	0
Cunila origanoides	1	0.01	0.1
Cynanchum laeve	0	0	0
Cynoglossum virginianum	0	0	0
Cyperus ovularis	0	0	0
Danthonia spicata	26	2.18	5.9
Dentaria laciniata	0	0	0
Desmodium canescens	1	0.07	0.2
Desmodium nudiflorum	0	0	0
Desmodium paniculatum	0	0	0
Desmodium rotundifolium	5	0.10	0.6
Desmodium sp.	1	0.07	0.2
Dichanthelium acuminatum	38	5.83	12.7
Dichanthelium boscii	6	0.28	1.0
Dichanthelium depauperatum	0	0	0
Dichanthelium dichotomum	12	1.70	3.9
Dichanthelium laxiflorum	0	0	0
Dichanthelium linearifolium	5	0.36	1.0
Dichanthelium malacophyllum	0	0	0
Dichanthelium oligosanthes	11	0.15	1.3
Dichanthelium sp.	9	0.19	1.2
Dichanthelium sphaerocarpon	0	0	0
Dichanthelium villosissimum	0	0	0
Dioscorea quaternata	2	0.33	0.7
Dioscorea villosa	1	0.01	0.1
Dodecatheon meadia	0	0	0
Elymus hystrix	0	0	0
Elymus virginicus	0	0	0
Erechtites hieracifolium	0	0	0
Erigeron annuus	0	0	0
Erigeron strigosus	0	0	0
Eupatorium rugosum	0	0	0
Euphorbia corollata	9	0.07	0.9
Festuca obtusa	0	0	0
Fragaria virginiana	1	0.01	0.1
Frasera caroliniensis	0	0	0
Galactia regularis	3	0.14	0.5
Galium aparine	2	0.01	0.2
Galium circaezans	13	0.09	0.6
Galium concinnum	2	0.02	0.2
Galium pilosum	0	0	0
Galium triflorum	0	0	0
Geranium carolinianum	2	***	0.2
Geranium maculatum	0	0	0
Geum canadense	1	0.01	0.1

Gnaphalium purpureum	1	0.01	0.1
Hedeoma pulegioides	0	0	0
Hedyotis longifolia	0	0	0
Helianthus divaricatus	39	7.61	15.6
Heuchera americana	0	0	0
Hieracium gronovii	0	0	0
Hypericum gentianoides	1	0.01	0.1
Hypericum punctatum	3	0.02	0.3
Ipomoea pandurata	0	0	0
Koeleria macrantha	3	0.14	0.5
Krigia dandelion	5	0.04	0.5
Kummerowia striata	0	0	0
Lactuca canadensis	0	0	0
Lactuca floridana	0	0	0
Lactuca hirsuta (IL-E)	0	0	0
Lactuca serriola	0	0	0
Lechea tenuifolia	0	0	0
Lespedeza hirta	0	0	0
Lespedeza procumbens	4	0.15	0.6
Lespedeza repens	0	0	0
Lespedeza violacea	0	0	0
Lespedeza virginica	0	0	0
Liatris squarrosa	0	0	0
Liparis lilifolia	1	0.01	0.1
Lobelia inflata	0	0	0
Lobelia spicata	0	0	0
Manfreda virginica	0	0	0
Monarda bradburiana	9	0.36	1.4
Monarda fistulosa	2	0.02	0.2
Muhlenbergia sobolifera	2	0.02	0.2
Myosotis macrosperma	0	0	0
Nothoscordum bivalve	0	0	0
Oxalis dillenii	0	0	0
Oxalis stricta	1	0.01	0.1
Oxalis violacea	3	***	0.3
Panicum anceps	0	0	0
Panicum capillare	0	0	0
Paronychia fastigiata	0	0	0
Parthenium integrifolium	0	0	0
Passiflora lutea	1	***	0.1
Penstemon hirsutus	0	0	0
Phlox pilosa	11	0.09	1.2
Phryma leptostachya	0	0	0
Physalis virginiana	2	0.02	0.2
Podophyllum peltatum	0	0	0
Polygonatum biflorum	0	0	0
Polygonum cristatum	0	0	0
Polytaenia nuttallii	0	0	0
Porteranthus stipulatus	9	0.45	1.6

Potentilla simplex	5	0.04	0.5
Prenanthes altissima	4	0.21	0.7
Pycnanthemum tenuifolium	1	0.01	0.1
Ranunculus micranthus	5	0.04	0.5
Rudbeckia hirta	0	0	0
Ruellia humilis	0	0	0
Sanicula canadensis	4	0.09	0.5
Schizachyrium scoparium	24	1.50	9.0
Scleria pauciflora	0	0	0
Setaria glauca	0	0	0
Silene stellata	0	0	0
Sisyrinchium albidum	1	0.01	*.*
Smilacina racemosa	0	0	0
Solanum ptycanthum	0	0	0
Solidago caesia	0	0	0
Solidago juncea	0	0	0
Solidago nemoralis	0	0	0
Solidago petiolaris	0	0	0
Solidago ulmifolia	3	0.08	0.4
Sorghastrum nutans	0	0	0
Sphenopholis obtusata	0	0	0
Stylosanthes biflora	4	0.03	0.4
Tephrosia virginiana	1	0.01	0.1
Thaspium trifoliatum	0	0	0
Tradescantia subaspera	0	0	0
Tradescantia virginiana	19	0.15	2.1
Trichostema dichotoma	0	0	0
Tridens flavus	0	0	0
Triodanis perfoliata	10	0.07	1.1
Triosteum sp.	0	0	0
Verbesina helianthoides	0	0	0
Verbesina virginica	0	0	0
Vernonia gigantea	0	0	0
Viola raphanesquii	0	0	0
Viola sp.	11	0.03	1.1
Viola triloba	13	0.19	1.5
Woodsia obtusa	1	0.01	0.1

GYP WILLIAMS SANDSTONE BARRENS

Number of circular 50 m^2 plots for woody taxa: 30
Number of nested 1 m^2 plots for herbaceous taxa: 120
*indicates plant was sampled with the herbaceous taxa and, although bearing a woody stem, was located within the herb layer, i.e., within approximately 1 m of ground level.
***indicates value less than one-one hundredth of a percent.

Woody taxa	No. of plots of occurrence	Dominance	Relative Importance
Acer rubrum	1	***	0.2
Acer saccharum	0	0	0
Amelanchier arborea	11	0.67	2.7
Carya cordiformis	0	0	0
Carya glabra	10	0.92	2.7
Carya ovalis	1	0.02	0.2
Carya ovata	1	0.02	0.2
Carya texana	27	11.08	15.9
Celastrus scandens	0	0	0
Celtis tenuifolia	4	0.07	0.8
Cercis canadensis	0	0	0
Cornus florida	7	0.17	1.4
Crataegus sp.	4	0.07	0.8
Crataegus mollis	0	0	0
Diospyros virginiana	13	0.22	2.6
Fagus grandifolia	1	0.02	0.2
Fraxinus americana	27	2.37	7.2
Gleditsia triacanthos	1	0.02	0.2
Hypericum stragulum	0	0	0
Juglans nigra	5	1.23	2.1
Juniperus virginiana	8	0.60	2.0
Morus rubra	1	0.02	0.2
Ostrya virginiana	2	0.15	0.5
*Parthenocissus quinquefolia**	96	4.33	11.3
Prunus americana	0	0	0
Prunus serotina	5	0.04	0.9
Quercus alba	6	0.10	1.2
Quercus Xbushii	0	0	0
Quercus imbricaria	17	0.27	3.3
Quercus marilandica	21	4.30	8.1
Quercus prinoides acuminata	2	0.03	0.4
Quercus rubra	11	0.18	2.2
Quercus stellata	26	15.30	19.9
Quercus velutina	11	0.18	2.2
Rhamnus caroliniana	3	0.05	0.6
Rhus copallina	1	0.02	0.2
*Rosa carolina**	32	0.71	2.6
Rubus allegheniensis	0	0	0
*Rubus flagellaris**	10	0.48	1.2
*Rubus occidentalis**	2	0.17	0.4
Sassafras albidum	0	0	0
Smilax bona-nox	0	0	0
*Smilax glauca**	1	0.03	0.1
Symphoricarpos orbiculatus	14	0.22	2.7
*Toxicodendron radicans**	18	2.69	5.1
Ulmus alata	30	11.65	17.0
Ulmus rubra	1	0.02	0.2

Vaccinium arboreum	0	0	0
Viburnum rufidulum	6	0.03	1.1
*Vitis aestivalis**	5	0.42	0.4

Herbaceous taxa	No. of plots of occurrence	Dominance	Relative Importance
Acalypha gracilens	43	0.18	2.2
Achillea millefolium	0	0	0
Agrimonia rostellata	0	0	0
Agrostis perennans	0	0	0
Ambrosia artemisiifolia	5	0.08	0.4
Amphicarpa bracteata	4	0.08	0.3
Antennaria plantaginifolia	64	4.38	9.9
Arabis canadensis	2	0.01	0.1
Aristolochia serpentaria	4	0.10	0.3
Asclepias verticillata	1	0.03	0.1
Asplenium platyneuron	58	1.46	4.9
Aster patens	3	0.01	0.2
Aster sp.	46	1.42	4.4
Aster turbinellus	0	0	0
Aureolaria flava	0	0	0
Botrychium virginianum	0	0	0
Bromus pubescens	26	0.46	1.9
Campanula americana	0	0	0
Cardamine sp.	0	0	0
Carex artitecta	0	0	0
Carex cephalophora	0	0	0
Carex glaucodea	1	0.03	0.1
Carex hirsutella	0	0	0
Carex muhlenbergii	1	***	0.1
Carex sp.	42	0.41	2.6
Carex umbellata	0	0	0
Cassia fasciculata	9	0.22	0.8
Cassia nictitans	3	0.01	0.2
Cheilanthes lanosa	0	0	0
Cirsium altissimum	0	0	0
Cirsium discolor	0	0	0
Cunila origanoides	10	0.29	0.9
Cynoglossum virginianum	0	0	0
Danthonia spicata	48	1.13	3.9
Dentaria laciniata	0	0	0
Desmodium canescens	0	0	0
Desmodium glutinosum	1	***	0.1
Desmodium nudiflorum	0	0	0
Desmodium paniculatum	0	0	0
Desmodium rotundifolium	0	0	0
Diarrhena americana	0	0	0
Dichanthelium acuminatum	18	0.22	1.2

Dichanthelium boscii	13	0.72	1.7
Dichanthelium dichotomum	1	***	0.5
Dichanthelium laxiflorum	28	0.67	2.3
Dichanthelium linearifolium	0	0	0
Dichanthelium malacophyllum	24	0.48	1.9
Dichanthelium polyanthes	1	***	0.5
Dioscorea quaternata	0	0	0
Dodecatheon meadia	0	0	0
Elymus hystrix	2	0.04	0.2
Elymus villosus	1	***	0.1
Elymus virginicus	1	***	0.1
Erechtites hieracifolia	10	0.16	0.7
Erigeron annuus	0	0	0
Erigeron strigosus	6	0.08	0.4
Eupatorium rugosum	0	0	0
Euphorbia corollata	26	0.58	2.1
Festuca obtusa	0	0	0
Galactia regularis	20	0.44	1.6
Galium circaezans	18	0.47	1.6
Galium pilosum	44	0.46	2.8
Geum canadense	3	0.17	0.4
Geum virginianum	0	0	0
Hedeoma pulegioides	0	0	0
Hedyotis longifolia	0	0	0
Helianthus divaricatus	93	2.28	7.9
Helianthus sp.	3	0.48	0.9
Heuchera americana	4	0.08	0.3
Hieracium sp.	0	0	0
Hypericum punctatum	4	0.07	0.3
Juncus secundus	1	***	0.1
Juncus tenuis	1	***	0.1
Koeleria macrantha	2	0.07	0.2
Lactuca canadensis	0	0	0
Lactuca hirsuta (IL-E)	0	0	0
Lespedeza cuneata	0	0	0
Lespedeza procumbens	0	0	0
Lespedeza repens	3	0.01	0.2
Lespedeza violacea	0	0	0
Lespedeza virginica	3	0.07	0.3
Liatris squarrosa	0	0	0
Liparis lilifolia	0	0	0
Lithospermum canescens	0	0	0
Lobelia spicata	0	0	0
Manfreda virginica	1	0.03	0.1
Monarda bradburiana	0	0	0
Monarda fistulosa	0	0	0
Muhlenbergia sobolifera	18	0.41	1.5
Oxalis dillenii	0	0	0
Parietaria pensylvanica	6	0.03	0.3

Parthenium integrifolium	0	0	0
Passiflora lutea	0	0	0
Penstemon sp.	3	0.10	0.3
Phlox pilosa	3	0.10	0.3
Phryma leptostachya	0	0	0
Physalis virginiana	3	0.07	0.3
Polygonatum biflorum	0	0	0
Polygonum cristatum	2	0.01	0.1
Polygonum virginianum	0	0	0
Polytaenia nuttallii	0	0	0
Porteranthus stipulatus	7	0.09	0.5
Potentilla simplex	0	0	0
Prenanthes altissima	0	0	0
Psoralea psoralioides	0	0	0
Pycnanthemum tenuifolium	0	0	0
Rudbeckia hirta	14	0.17	0.9
Ruellia humilis	1	0.03	0.1
Sanicula canadensis	41	0.89	3.3
Schizachyrium scoparium	53	1.15	4.2
Sedum pulchellum	0	0	0
Sisyrinchium albidum	0	0	0
Soliaago caesia	0	0	0
Solidago juncea	4	0.10	0.3
Solidago nemoralis	27	0.97	2.8
Solidago petiolaris	0	0	0
Solidago ulmifolia	2	0.07	0.2
Sorghastrum nutans	9	0.25	0.8
Sphenopholis obtusata	3	0.04	0.2
Stylosanthes biflora	4	0.02	0.2
Tephrosia virginiana	0	0	0
Triodanis perfoliata	4	0.01	0.2
Verbesina helianthoides	0	0	0
Viola triloba	0	0	0
Woodsia obtusa	23	0.42	1.7

POUNDS HOLLOW SANDSTONE GLADE

Number of circular 50 m^2 plots for woody taxa: 30
Number of nested 1 m^2 plots for herbaceous taxa: 120
*indicates plant was sampled with the herbaceous taxa and, although bearing a woody stem, was located within the herb layer, i.e., within approximately 1 m of ground level.
***indicates value less than one-one hundredth of a percent.

Woody taxa	No. of plots of occurrence	Dominance	Relative Importance
Amelanchier arborea	12	0.94	6.6
Carya glabra	4	0.17	1.8
Carya ovalis	0	0	0

Carya ovata	2	0.03	0.8
Carya texana	0	0	0
Celtis tenuifolia	4	0.05	1.5
Cornus florida	0	0	0
Diospyros virginiana	4	0.05	1.5
Fagus grandifolia	1	***	0.3
Fraxinus americana	3	0.05	1.1
Hypericum stragulum	0	0	0
Juglans nigra	0	0	0
Juniperus virginiana	27	8.11	31.4
Liriodendron tulipifera	1	***	0.3
Lonicera japonica	0	0	0
Parthenocissus quinquefolia	0	0	0
Pinus echinata	2	0.02	0.7
Prunus serotina	0	0	0
Quercus alba	8	0.09	2.9
Quercus coccinea	0	0	0
Quercus imbricaria	2	0.03	0.8
Quercus marilandica	7	0.87	4.7
Quercus rubra	3	0.05	1.1
Quercus stellata	12	2.04	9.6
Quercus velutina	1	0.02	0.4
Rhamnus carolinianus	0	0	0
Rhus copallina	15	1.12	8.1
Rosa carolina	0	0	0
Rosa multiflora	0	0	0
Rubus allegheniensis	0	0	0
Sassafras albidum	0	0	0
*Smilax bona-nox**	9	0.82	5.7
Smilax glauca	0	0	0
*Toxicodendron radicans**	8	0.09	1.7
Ulmus alata	21	2.32	13.4
Vaccinium arboreum	21	2.15	12.9
Vitis aestivalis			

Herbaceous taxa	No. of plots of occurrence	Dominance	Relative Importance
Acalypha gracilens	2	0.04	0.5
Agalis tenuifolia	7	0.02	1.2
Agrostis elliotiana	9	0.04	1.6
Allium canadense	1	***	0.2
Allium vineale	0	0	0
Ambrosia artemisiifolia	2	0.17	1.2
Amphicarpa bracteata	0	0	0
Andropogon virginicus	10	0.25	2.8
Antennaria plantaginifolia	0	0	0
Aristida sp.	11	0.08	2.1
Asplenium pinnatifidum	2	0.04	0.5
Asplenium platyneuron	0	0	0

Aster pilosus	0	0	0
Aureolaria flava	0	0	0
Blephilia ciliata	0	0	0
Bromus pubescens	0	0	0
Bromus racemosus	1	***	0.2
Carex bushii	0	0	0
Carex glaucodea	0	0	0
Carex hirsutella	0	0	0
Carex sp.	14	0.39	4.2
Carex umbellata	0	0	0
Cassia fasciculata	0	0	0
Cerastium arvense	0	0	0
Chasmanthium latifolium	0	0	0
Cheilanthes lanosa	6	0.96	5.9
Claytonia virginica	0	0	0
Clitoria mariana	0	0	0
Croton monanthogynus	0	0	0
Crotonopsis elliptica	32	0.61	8.2
Cunila origanoides	1	0.03	0.3
Danthonia spicata	27	0.81	8.4
Dentaria laciniata	0	0	0
Dichanthelium acuminatum	19	0.73	6.8
Dichanthelium depauperatum	1	0.03	0.3
Dichanthelium dichotomum	0	0	0
Dichanthelium laxiflorum	17	0.42	4.8
Dichanthelium linearifolium	0	0	0
Dichanthelium malacophyllum	4	0.10	1.2
Dichanthelium oligosanthes	0	0	0
Dichanthelium sphaerocarpon	2	0.04	0.5
Dichanthelium villosissimum	1	0.03	0.3
Digitaria sanguinalis	0	0	0
Diodia teres	12	0.60	5.0
Dodecatheon meadia	0	0	0
Elymus virginicus	0	0	0
Erechtites hieracifolia	0	0	0
Erigeron strigosus	0	0	0
Eupatorium serotinum	0	0	0
Euphorbia corollata	3	0.01	0.5
Festuca arundinacea	0	0	0
Galactia regularis	0	0	0
Galium pilosum	1	***	0.2
Geranium maculatum	0	0	0
Hedyotis longifolia	3	0.01	0.5
Hedyotis purpurea	0	0	0
Hedyotis pusilla	0	0	0
Helianthus divaricatus	2	0.04	0.5
Heuchera americana	0	0	0
Hypericum denticulatum	2	0.07	0.7
Hypericum gentianoides	17	0.10	3.1

Juncus secundus	0	0	0
Juncus tenuis	0	0	0
Krigia biflora	0	0	0
Krigia dandelion	0	0	0
Kummerowia striata	1	0.03	0.3
Lactuca canadensis	0	0	0
Lechea tenuifolia	4	0.05	0.9
Lespedeza cuneata	1	0.03	0.3
Lespedeza repens	4	0.13	1.3
Lespedeza violacea	0	0	0
Liatris squarrosa	0	0	0
Linum virginianum	0	0	0
Luzula multiflora	0	0	0
Manfreda virginica	8	0.21	2.3
Melica mutica	0	0	0
Myosotis verna	1	***	0.2
Nothoscordum bivalve	0	0	0
Oenothera linifolia	1	***	0.2
Opuntia humifusa	1	0.13	0.9
Oxalis dillenii	1	***	0.2
Oxalis stricta	2	0.01	0.4
Oxalis violacea	0	0	0
Oxypolis rigidior	0	0	0
Parietaria pensylvanica	0	0	0
Paspalum ciliatifolium	0	0	0
Passiflora lutea	0	0	0
Penstemon hirsutus	5	0.08	1.2
Phlox pilosa	0	0	0
Plantago pusilla	0	0	0
Plantago virginica	2	0.01	0.3
Poa compressa	0	0	0
Polygonatum biflorum	0	0	0
Polygonum tenue	4	0.02	0.7
Psoralea psoralioides	0	0	0
Pycnanthemum tenuifolium	17	0.24	3.9
Ranunculus sp.	0	0	0
Ruellia humilis	6	0.62	4.2
Schizachyrium scoparium	26	1.31	10.9
Sedum pulchellum	4	0.01	0.7
Solidago juncea	0	0	0
Solidago nemoralis	0	0	0
Solidago ulmifolia	0	0	0
Sphenopholis obtusata	0	0	0
Sporobolus asper	2	0.04	0.5
Stylosanthes biflora	3	0.04	0.7
Tephrosia virginiana	0	0	0
Tridens flavus	0	0	0
Triodanis perfoliata	2	***	0.3
Viola raphanesquii	0	0	0

Vulpia octoflora	3	***	0.5
Woodsia obtusa	0	0	0

ROUND BLUFF SANDSTONE GLADE

Number of circular 50 m^2 plots for woody taxa: 30
Number of nested 1 m^2 plots for herbaceous taxa: 120
*indicates plant was sampled with the herbaceous taxa and, although bearing a woody stem, was located within the herb layer, i.e., within approximately 1 m of ground level.
***indicates value less than one-one hundredth of a percent.

Woody taxa	No. of plots of occurrence	Dominance	Relative Importance
Acer rubrum	1	0.03	1.7
Amelanchier arborea	1	0.07	1.8
Campsis radicans	0	0	0
Carya glabra	23	0.09	2.2
Carya ovalis	0	0	0
Carya ovata	4	0.13	2.7
Carya texana	0	0	0
Celtis occidentalis	2	0.02	0.5
Celtis tenuifolia	7	0.15	3.2
Cercis canadensis	0	0	0
Cornus florida	0	0	0
Corylus americana	0	0	0
Crataegus sp.	0	0	0
Diospyros virginiana	1	0.09	1.8
Fagus grandifolia	0	0	0
Fraxinus americana	6	0.35	4.3
Gleditsia triacanthos	0	0	0
*Hypericum stragulum**	3	0.02	0.3
Juglans nigra	0	0	0
Juniperus virginiana	4	20.24	43.3
Liquidambar styraciflua	0	0	0
Liriodendron tulipifera	0	0	0
*Lonicera japonica**	3	0.05	0.5
Morus rubra	0	0	0
*Parthenocissus quinquefolia**	2	0.09	0.5
Prunus serotina	5	***	0.4
Quercus alba	1	***	0.4
Quercus marilandica	2	0.02	0.5
Quercus rubra	0	0	0
Quercus stellata	5	3.59	12.2
Quercus velutina	15	0.04	0.9
Rhus aromatica	1	0.48	4.1
Rhus copallina	8	0.03	0.9
Rosa carolina	0	0	0

*Rubus allegheniensis**	2	0.22	1.1
Rubus enslenii (IL-E)	0	0	0
Rubus flagellaris	0	0	0
Sassafras albidum	0	0	0
*Smilax bona-nox**	2	0.01	0.2
Smilax glauca	0	0	0
Smilax rotundifolia	0	0	0
Symphoricarpos orbiculatus	2	0.04	0.9
*Toxicodendron radicans**	8	0.20	1.5
Ulmus alata	4	4.39	15.2
Vaccinium arboreum	9	0.26	2.5
Vaccinium pallidum	19	0.02	0.5
Vitis aestivalis			

Herbaceous taxa	No. of plots of occurrence	Dominance	Relative Importance
Acalypha gracilens	37	0.23	4.2
Agrimonia parviflora	0	0	0
Agrostis elliotiana	24	0.24	3.1
Agrostis perennans	0	0	0
Allium canadense	1	0.01	0.1
Allium vineale	0	0	0
Ambrosia artemisiifolia	6	0.11	0.9
Arabis canadensis	1	0.01	0.1
Aristida sp.	0	0	0
Asplenium platyneuron	2	0.09	0.5
Aster sp.	1	0.01	0.1
Bidens bipinnata	4	0.06	0.6
Blephilia hirsuta	0	0	0
Bromus commutatus	1	0.01	0.1
Bulbostylis capillaris	3	0.05	0.5
Cardamine sp.	0	0	0
Carex artitecta	0	0	0
Carex blanda	0	0	0
Carex cephalophora	0	0	0
Carex glaucodea	17	0.17	2.2
Carex hirsutella	0	0	0
Carex muhlenbergii	1	0.01	0.1
Carex retroflexa	0	0	0
Carex sp.	16	0.56	3.7
Carex umbellata	0	0	0
Cerastium arvense	0	0	0
Cheilanthes lanosa	6	0.52	2.7
Claytonia virginica	0	0	0
Conyza canadensis	0	0	0
Corydalis flavula	0	0	0
Crotonopsis elliptica	33	0.49	4.9
Cunila origanoides	0	0	0
Cyperus filiculmis	2	0.01	0.2

Cyperus sp.	2	0.01	0.2
Cyperus ovularis	2	0.01	0.2
Danthonia spicata	45	1.59	10.5
Daucus carota	0	0	0
Dentaria laciniata	0	0	0
Desmodium rotundifolium	2	0.01	0.2
Dichanthelium acuminatum	14	0.30	2.5
Dichanthelium boscii	21	0.61	4.3
Dichanthelium laxiflorum	2	0.09	0.5
Dichanthelium linearifolium	0	0	0
Dichanthelium polyanthes	1	0.01	0.1
Dichanthelium sphaerocarpon	0	0	0
Dichanthelium villosissimum	6	0.15	1.1
Diodia teres	35	0.85	6.5
Elymus villosus	1	0.01	0.1
Elymus virginicus	4	0.02	0.4
Erechtites hieracifolia	0	0	0
Erigeron strigosus	5	0.03	0.5
Festuca arundinacea	0	0	0
Galium circaezans	0	0	0
Galium pilosum	1	0.01	0.1
Gnaphalium purpureum	0	0	0
Gratiola neglecta	0	0	0
Hedyotis longifolia	0	0	0
Hedyotis nigricans	8	0.08	1.0
Hedyotis pusilla	0	0	0
Helianthus divaricatus	10	0.32	2.2
Hypericum drummondii	2	0.01	0.2
Hypericum gentianoides	15	0.11	1.8
Hypericum punctatum	0	0	0
Juncus interior	4	0.02	0.6
Juncus secundus	3	0.02	0.3
Krigia virginica	1	0.01	0.1
Kummerowia stipulacea	0	0	0
Kummerowia striata	2	0.01	0.2
Lactuca serriola	0	0	0
Lepidium virginicum	0	0	0
Lespedeza procumbens	0	0	0
Lespedeza repens	0	0	0
Linum sp.	1	0.01	0.1
Manfreda virginica	7	0.23	1.5
Muhlenbergia sobolifera	0	0	0
Nothoscordum bivalve	5	0.01	0.5
Oenothera linifolia	5	0.03	0.5
Opuntia humifusa	8	0.12	1.2
Oxalis stricta	5	0.03	0.5
Parietaria pensylvanica	4	0.02	0.4
Paronychia fastigiata	0	0	0
Penstemon sp.	3	0.05	0.5

Phlox pilosa	0	0	0
Physalis virginiana	0	0	0
Phytolacca americana	0	0	0
Plantago virginica	9	0.05	0.9
Poa compressa	0	0	0
Polygonum cristatum	0	0	0
Polygonum scandens	3	0.02	0.3
Polygonum tenue	6	0.03	0.7
Pycnanthemum tenuifolium	20	0.62	4.3
Pyrrhopappus carolinianus	0	0	0
Ruellia humilis	1	0.01	0.1
Sanicula canadensis	9	0.04	0.9
Schizachyrium scoparium	34	1.90	10.8
Sedum pulchellum	25	0.11	2.6
Setaria glauca	0	0	0
Smilacina racemosus	0	0	0
Solidago caesia	0	0	0
Solidago nemoralis	0	0	0
Solidago ulmifolia	13	0.38	2.7
Sphenopholis obtusata	2	0.01	0.2
Talinum parviflorum	9	0.20	1.6
Trichostema dichotoma	0	0	0
Tridens flavus	0	0	0
Triodanis perfoliata	14	0.06	1.5
Verbascum thapsus	0	0	0
Veronica arvensis	0	0	0
Viola raphanesquii	0	0	0
Vulpia octoflora	13	0.11	1.6
Woodsia obtusa	16	0.74	4.4

WILDCAT BLUFF LIMESTONE GLADE

Number of circular 50 m^2 plots for woody taxa: 18
Number of nested 1 m^2 plots for herbaceous taxa: 72
*indicates plant was sampled with the herbaceous taxa and, although bearing a woody stem, was located within the herb layer, i.e., within approximately 1 m of ground level.
**indicates plant was sampled with the woody taxa.

Woody taxa	No. of plots of occurrence	Dominance	Relative Importance
Acer negundo	0	0	0
Acer rubrum	4	0.04	1.7
Acer saccharum	3	1.14	5.8
Amelanchier arborea	0	0	0
Aralia spinosa	1	0.03	0.5
Asimina triloba	0	0	0
*Bignonia capriolata**	11	0.37	1.1
Carya cordiformis	0	0	0

Carya glabra	1	0.22	1.3
Carya ovata	0	0	0
Carya texana	4	0.31	2.7
Ceanothus americanus	2	0.06	0.9
*Celastrus scandens**	2	0.06	0.2
Celtis occidentalis	4	0.11	1.9
Celtis tenuifolia	6	0.12	2.7
Cercis canadensis	9	0.25	4.3
Cornus florida	1	0.01	0.4
Crataegus sp.	4	0.11	1.9
Diospyros virginiana	14	0.97	9.1
Elaeagnus umbellata	0	0	0
Euonymus atropurpurea	0	0	0
Fraxinus americana	7	0.17	3.3
Gleditsia triacanthos	0	0	0
Ilex decidua	1	0.03	0.5
Juglans nigra	5	0.14	2.4
Liquidambar styraciflua	1	0.22	1.3
Liriodendron tulipifera	0	0	0
Lonicera sp. (shrub)	0	0	0
Malus ioensis	0	0	0
Menispermum canadensis	0	0	0
Morus rubra	3	0.08	1.4
Ostrya virginiana	11	0.69	6.9
*Parthenocissus quinquefolia**	23	1.18	2.7
Prunus americana	0	0	0
Prunus serotina	0	0	0
Quercus alba	0	0	0
Quercus coccinea	2	1.11	5.3
Quercus macrocarpa	1	0.03	0.5
Quercus prinoides acuminata	17	2.11	14.9
Quercus rubra	3	0.06	1.4
Quercus shumardii	1	0.89	4.0
Quercus stellata	2	2.31	10.2
Quercus velutina	1	0.03	0.5
Rhus aromatica	13	0.56	7.1
Rosa carolina	0	0	0
*Rubus flagellaris**	1	0.06	0.1
Sassafras albidum	0	0	0
*Smilax bona-nox**	16	1.34	2.4
*Toxicodendron radicans**	7	0.67	1.1
Ulmus alata	6	0.17	2.9
Ulmus rubra	6	0.17	2.9
Viburnum prunifolium	1	0.03	0.5
Vitis aestivalis	0	0	0
*Vitis cinerea**	4	0.39	0.7
*Vitis vulpina**	7	0.34	0.8

Herbaceous taxa	No. of plots of occurrence	Dominance	Relative Importance
Acalypha gracilens	18	0.12	1.3
Agrimonia rostellata	0	0	0
Agrostis perennans	0	0	0
Ambrosia artemisiifolia	2	0.01	0.1
Amphicarpa bracteata	10	0.56	1.2
Andropogon gerardii	0	0	0
Anemone virginiana	2	0.11	0.2
Antennaria plantaginifolia	1	0.06	0.1
Apocynum cannabinum	5	0.44	0.8
Arabis laevigata	0	0	0
Arisaema dracontium	0	0	0
Arisaema triphyllum	0	0	0
Aristolochia serpentaria	1	0.01	0.1
Arundinaria gigantea	0	0	0
Asarum canadense	0	0	0
Asclepias tuberosa	2	0.11	0.2
Asclepias verticillata	11	0.12	0.8
Asclepias viridiflora	0	0	0
Aster laevis	3	0.02	0.2
Aster patens	17	0.36	1.5
Aster turbinellus	1	0.06	0.1
Aureolaria flava	0	0	0
Boehmeria cylindrica	0	0	0
Botrychium virginianum	0	0	0
Bouteloua curtipendula	3	0.12	0.3
Brickellia eupatorioides	0	0	0
Bromus commutatus	13	0.33	1.2
Bromus pubescens	0	0	0
Cacalia atriplicifolia	1	0.22	0.3
Campanula americana	0	0	0
Carex artitecta	0	0	0
Carex cephalophora	0	0	0
Carex digitalis	0	0	0
Carex grisea	0	0	0
Carex muhlenbergii	0	0	0
Carex sp.	12	0.13	0.9
Carex umbellata	0	0	0
Cassia fasciculata	11	0.35	1.1
*Cassia marilandica***	2	0.06	0.9
Chamaesyce maculata	1	0.01	0.1
Cirsium altissimum	0	0	0
Cirsium discolor	0	0	0
Clitoria mariana	1	0.01	0.1
Cunila origanoides	2	0.06	0.2
Cynanchum laeve	0	0	0
Danthonia spicata	1	0.06	0.1
Desmodium canescens	0	0	0

Desmodium rotundifolium	0	0	0
Dichanthelium boscii	13	0.33	1.2
Dichanthelium dichotomum	1	0.01	0.1
Dichanthelium laxiflorum	0	0	0
Dichanthelium polyanthes	0	0	0
Dichanthelium villosissimum	2	0.11	0.2
Dioscorea quaternata	0	0	0
Dioscorea villosa	2	0.11	0.2
Dodecatheon meadia	0	0	0
Echinacea pallida	0	0	0
Elymus hystrix	0	0	0
Elymus virginicus	4	0.08	0.3
Erechtites hieracifolia	0	0	0
Eupatorium altissimum	15	0.59	1.6
Eupatorium purpureum	0	0	0
Eupatorium rugosum	0	0	0
Euphorbia corollata	47	1.15	4.2
Galactia regularis	52	1.77	5.2
Galium circaezans	15	0.39	1.4
Galium pilosum	0	0	0
Geranium maculatum	0	0	0
Geum canadense	0	0	0
Helianthus divaricatus	63	4.45	8.7
Heliopsis helianthoides	15	0.54	1.4
Heuchera americana	0	0	0
Hybanthus concolor	1	0.06	0.1
Hydrastis canadensis	0	0	0
Hypericum denticulatum	9	0.30	0.9
Ipomoea pandurata	0	0	0
Kummerowia striata	2	0.06	0.2
Lactuca canadensis	0	0	0
Lespedeza procumbens	0	0	0
Lespedeza repens	0	0	0
Lespedeza violacea	2	0.11	0.2
Lespedeza virginica	16	0.96	2.0
Liatris scabra	0	0	0
Lithospermum canescens	6	0.25	0.6
Lysimachia lanceolata	0	0	0
Manfreda virginica	2	0.11	0.2
Monarda bradburiana	13	0.63	1.5
Monarda fistulosa	17	0.79	1.9
Muhlenbergia sobolifera	1	0.01	0.1
Muhlenbergia sp.	11	0.08	0.8
Nothoscordum bivalve	0	0	0
Onosmodium hispidissimum	3	0.17	0.4
Oxalis stricta	2	0.01	0.1
Oxalis violacea	0	0	0
Passiflora lutea	0	0	0
Pellaea atropurpurea	0	0	0

Phryma leptostachya	2	0.06	0.2
Physalis virginiana	35	1.36	3.6
Physostegia virginiana	10	0.46	1.1
Podophyllum peltatum	0	0	0
Polygonum cristatum	1	0.01	0.1
Pycnanthemum tenuifolium	3	0.01	0.2
Ratibida pinnata	17	1.35	2.5
Ruellia caroliniensis	1	0.01	0.1
Ruellia humilis	20	0.62	1.9
Sanicula canadensis	0	0	0
Schizachyrium scoparium	24	1.90	3.5
Silphium terebinthinaceum	50	16.34	20.1
Sisyrinchium albidum	0	0	0
Smilacina racemosa	0	0	0
Smilax herbacea	0	0	0
Smilax pulverulenta	0	0	0
Solidago caesia	0	0	0
Solidago petiolaris	0	0	0
Solidago sp.	55	3.17	6.8
Solidago ulmifolia	0	0	0
Sorghastrum nutans	24	1.26	2.8
Spigelia marilandica	0	0	0
Taenidia integerrima	1	0.06	0.1
Tephrosia virginiana	0	0	0
Thaspium trifoliatum	8	0.10	0.6
Tradescantia subaspera	0	0	0
Uvularia grandiflora	0	0	0
Verbesina helianthoides	11	0.79	1.5
Verbesina virginica	0	0	0
Vernonia gigantea	0	0	0
Viola sororia	6	0.13	0.5
Viola triloba	9	0.11	0.7

APPENDIX B

Maps for each of the studied forest-openings.

Figure 8a. Map of Berryville Shale Glade (unmanaged).

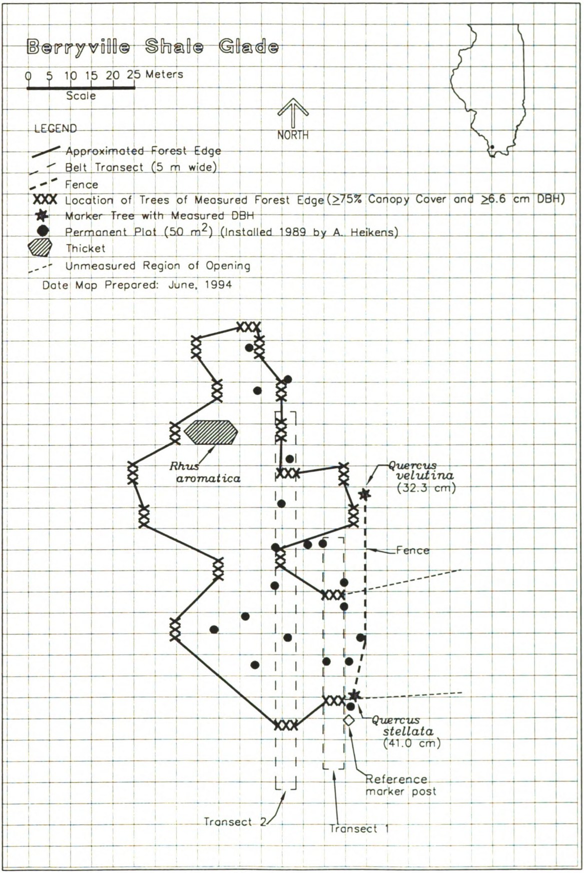

Berryville Shale Glade
0 5 10 15 20 25 Meters
Scale
NORTH
LEGEND
Approximated Forest Edge
Belt Transect (5 m wide)
Fence
XXX Location of Trees of Measured Forest Edge (≥75% Canopy Cover and ≥6.6 cm DBH)
Marker Tree with Measured DBH
Permanent Plot (50 m2) (Installed 1989 by A. Heikens)
Thicket
Unmeasured Region of Opening
Date Map Prepared: June, 1994
Rhus aromatica
Quercus velutina (32.3 cm)
Fence
Quercus stellata (41.0 cm)
Reference marker post
Transect 2
Transect 1

Figure 8b. Map of Brown Shale Barrens (managed).

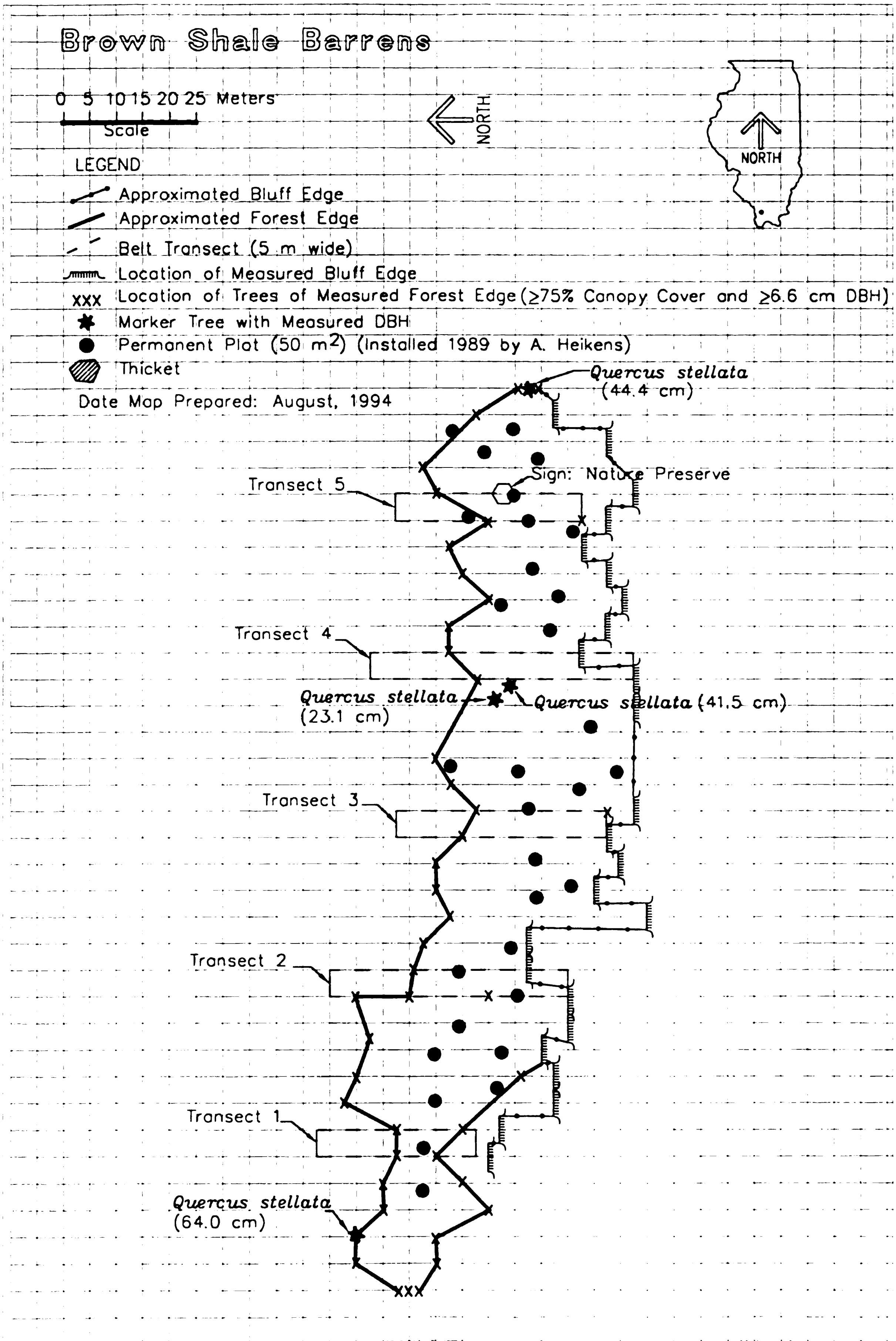

Brown Shale Barrens
0 5 10 15 20 25 Meters
Scale
NORTH
NORTH
LEGEND
Approximated Bluff Edge
Approximated Forest Edge
Belt Transect (5 m wide)
Location of Measured Bluff Edge
xxx Location of Trees of Measured Forest Edge (≥75% Canopy Cover and ≥6.6 cm DBH)
Marker Tree with Measured DBH
Permanent Plot (50 m2) (Installed 1989 by A. Heikens)
Thicket
Date Map Prepared: August, 1994
Quercus stellata (44.4 cm)
Sign: Nature Preserve
Transect 5
Transect 4
Quercus stellata (23.1 cm)
Quercus stellata (41.5 cm)
Transect 3
Transect 2
Transect 1
Quercus stellata (64.0 cm)

Figure 8c. Map of Cave Creek Limestone Glade (managed).

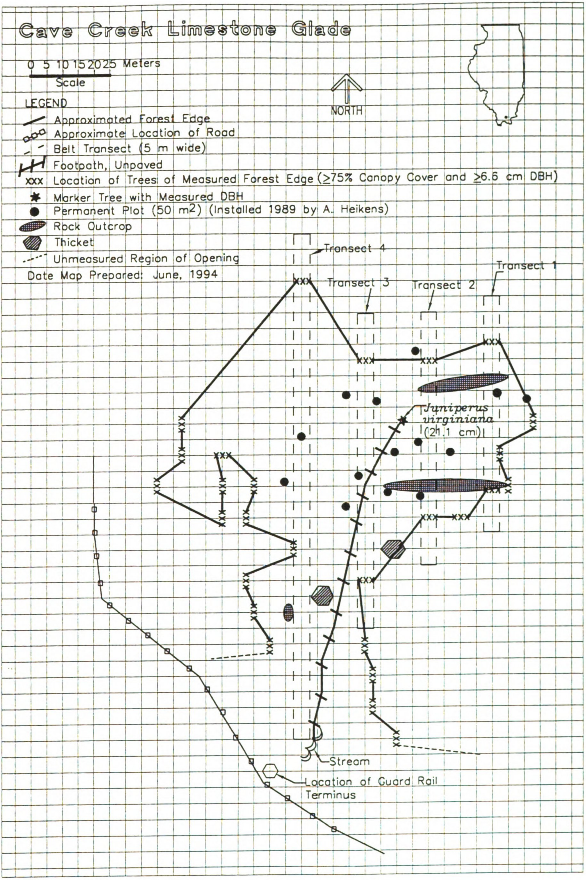

Cave Creek Limestone Glade
0 5 10 15 20 25 Meters
Scale
NORTH
LEGEND
Approximated Forest Edge
Approximate Location of Road
Belt Transect (5 m wide)
Footpath, Unpaved
xxx Location of Trees of Measured Forest Edge (≥75% Canopy Cover and ≥6.6 cm DBH)
Marker Tree with Measured DBH
Permanent Plot (50 m2) (Installed 1989 by A. Heikens)
Rock Outcrop
Thicket
Unmeasured Region of Opening
Date Map Prepared: June, 1994
Transect 4
Transect 3
Transect 2
Transect 1
Juniperus virginiana (21.1 cm)
Stream
Location of Guard Rail Terminus

Figure 8d. Map of Cedar Bluff Sandstone Glade (unmanaged).

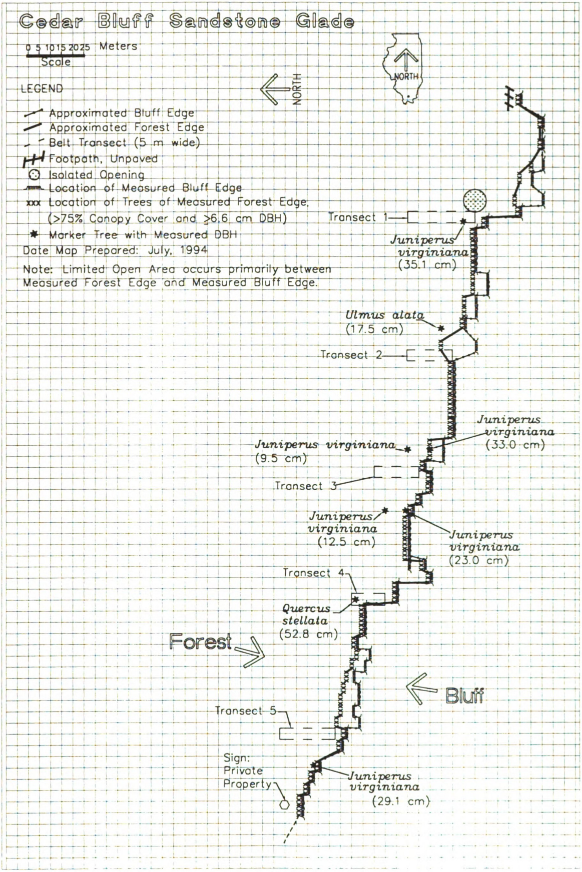

Cedar Bluff Sandstone Glade
0 5 10 15 20 25 Meters
Scale
NORTH
NORTH
LEGEND
Approximated Bluff Edge
Approximated Forest Edge
Belt Transect (5 m wide)
Footpath, Unpaved
Isolated Opening
Location of Measured Bluff Edge
xxx Location of Trees of Measured Forest Edge,
(>75% Canopy Cover and ≥6.6 cm DBH)
Marker Tree with Measured DBH
Date Map Prepared: July, 1994
Note: Limited Open Area occurs primarily between Measured Forest Edge and Measured Bluff Edge.
Transect 1
Juniperus virginiana (35.1 cm)
Ulmus alata (17.5 cm)
Transect 2
Juniperus virginiana (33.0 cm)
Juniperus virginiana (9.5 cm)
Transect 3
Juniperus virginiana (12.5 cm)
Juniperus virginiana (23.0 cm)
Transect 4
Quercus stellata (52.8 cm)
Forest
Bluff
Transect 5
Sign: Private Property
Juniperus virginiana (29.1 cm)

Figure 8e. Map of Gibbons Creek Sandstone Barrens (managed).

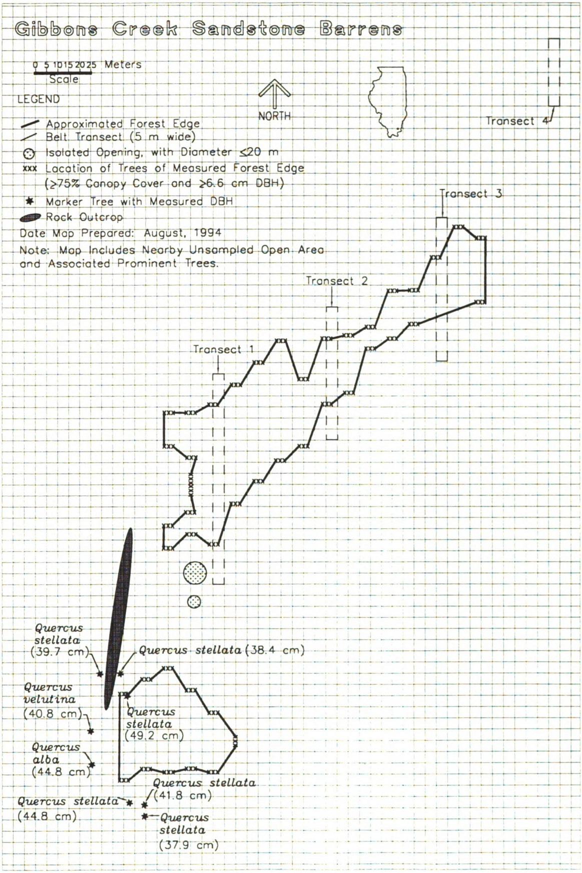

Gibbons Creek Sandstone Barrens
0 5 10 15 20 25 Meters
Scale
LEGEND
Approximated Forest Edge
Belt Transect (5 m wide)
Isolated Opening, with Diameter ≤20 m
xxx Location of Trees of Measured Forest Edge
(≥75% Canopy Cover and ≥6.6 cm DBH)
Marker Tree with Measured DBH
Rock Outcrop
Date Map Prepared: August, 1994
Note: Map Includes Nearby Unsampled Open Area
and Associated Prominent Trees.
NORTH
Transect 4
Transect 3
Transect 2
Transect 1
Quercus stellata (39.7 cm)
Quercus stellata (38.4 cm)
Quercus velutina (40.8 cm)
Quercus stellata (49.2 cm)
Quercus alba (44.8 cm)
Quercus stellata (41.8 cm)
Quercus stellata (44.8 cm)
Quercus stellata (37.9 cm)

Figure 8f. Map of Gyp Williams Sandstone Barrens (unmanaged).

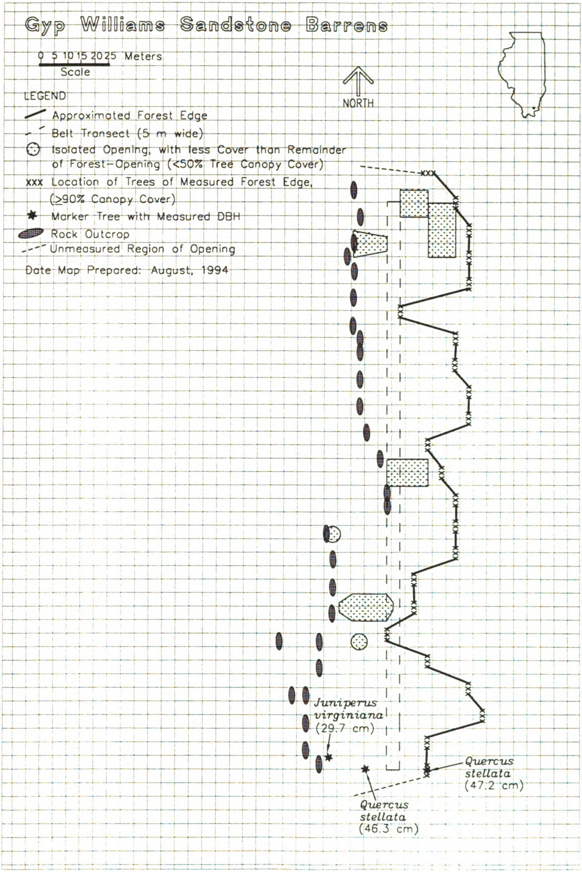

Gyp Williams Sandstone Barrens
0 5 10 15 20 25 Meters
Scale
NORTH
LEGEND
Approximated Forest Edge
Belt Transect (5 m wide)
Isolated Opening, with less Cover than Remainder of Forest-Opening (<50% Tree Canopy Cover)
xxx Location of Trees of Measured Forest Edge, (≥90% Canopy Cover)
Marker Tree with Measured DBH
Rock Outcrop
Unmeasured Region of Opening
Date Map Prepared: August, 1994
Juniperus virginiana (29.7 cm)
Quercus stellata (47.2 cm)
Quercus stellata (46.3 cm)

Figure 8g. Map of Pounds Hollow Sandstone Glade (unmanaged).

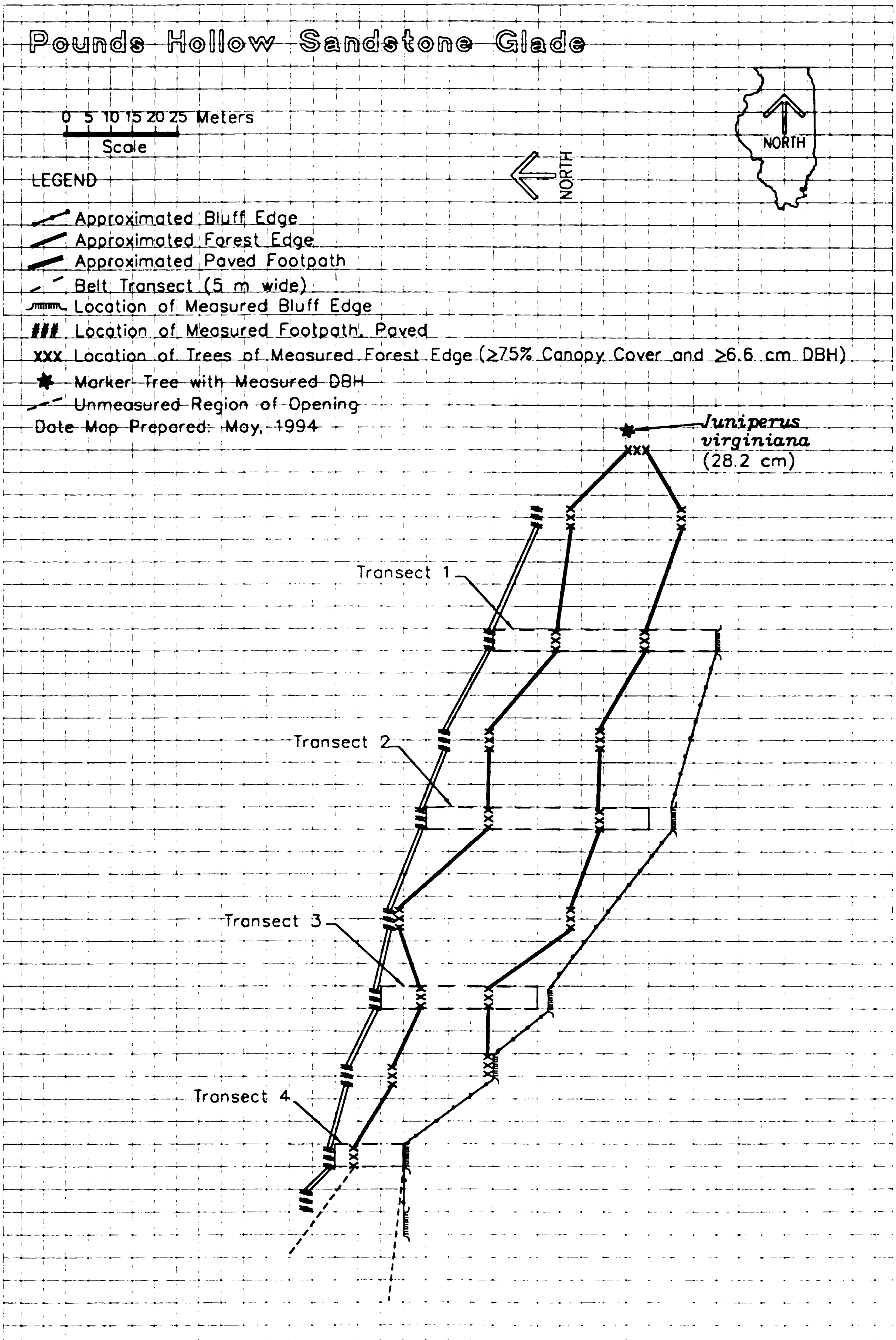

Pounds Hollow Sandstone Glade
0 5 10 15 20 25 Meters
Scale
NORTH
NORTH
LEGEND
Approximated Bluff Edge
Approximated Forest Edge
Approximated Paved Footpath
Belt Transect (5 m wide)
Location of Measured Bluff Edge
Location of Measured Footpath, Paved
XXX Location of Trees of Measured Forest Edge (≥75% Canopy Cover and ≥6.6 cm DBH)
Marker Tree with Measured DBH
Unmeasured Region of Opening
Date Map Prepared: May, 1994
Juniperus virginiana (28.2 cm)
Transect 1
Transect 2
Transect 3
Transect 4

Figure 8h. Map of Round Bluff Sandstone Glade (unmanaged).

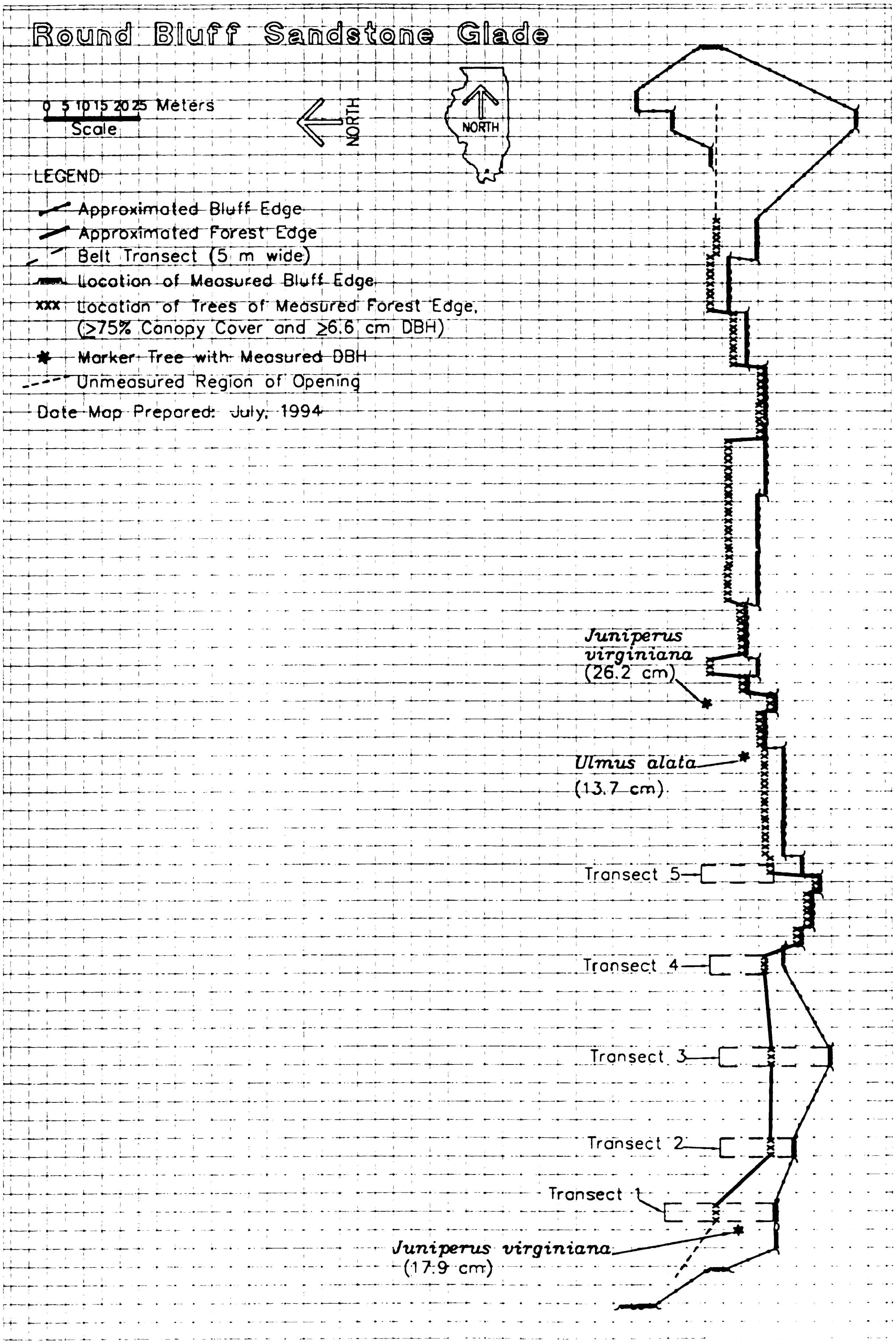
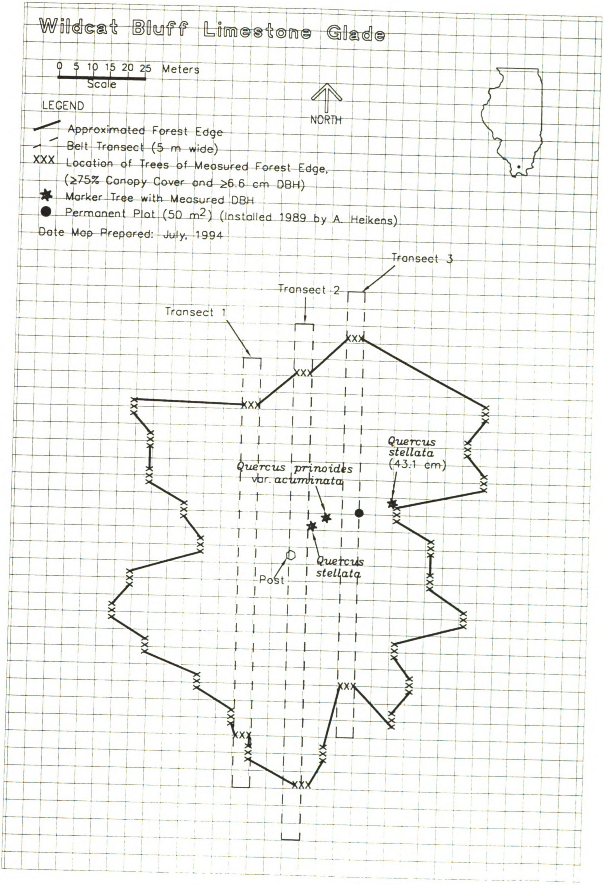

Round Bluff Sandstone Glade
0 5 10 15 20 25 Meters
Scale
NORTH
NORTH
LEGEND
Approximated Bluff Edge
Approximated Forest Edge
Belt Transect (5 m wide)
Location of Measured Bluff Edge
xxx Location of Trees of Measured Forest Edge, (≥75% Canopy Cover and ≥6.6 cm DBH)
Marker Tree with Measured DBH
Unmeasured Region of Opening
Date Map Prepared: July, 1994
Juniperus virginiana (26.2 cm)
Ulmus alata (13.7 cm)
Transect 5
Transect 4
Transect 3
Transect 2
Transect 1
Juniperus virginiana (17.9 cm)

Figure 8i. Map of Wildcat Bluff Limestone Glade (managed).



Wildcat Bluff Limestone Glade
0 5 10 15 20 25 Meters
Scale
LEGEND
Approximated Forest Edge
Belt Transect (5 m wide)
XXX Location of Trees of Measured Forest Edge,
(≥75% Canopy Cover and ≥6.6 cm DBH)
Marker Tree with Measured DBH
Permanent Plot (50 m2) (Installed 1989 by A. Heikens)
Date Map Prepared: July, 1994
NORTH
Transect 1
Transect 2
Transect 3
Quercus stellata (43.1 cm)
Quercus prinoides var. acuminata
Quercus stellata
Post

APPENDIX C

Species lists for woody and herbaceous taxa in five subhabitats of the study sites and summary of relative importance information relating to species for the sampling in 1994. Relative importance is the sum of relative dominance and relative frequency divided by two and multiplied by 100 (yielding a percentage between one and 100). Seedlings were defined as stems <2.54-cm diameter at breast height, shrubs and saplings as stems ≥2.54 to <6.6 cm dbh and trees ≥6.6 cm dbh. FI-N=Forest Interior-North, TS-N=Transition Zone-North, OP=Opening, TS-S=Transition Zone-South, FI-S=Forest Interior-South.

BERRYVILLE SHALE GLADE

Woody Seedlings:	FI-N	TS-N	OP	TS-S	FI-S
Acer saccharum	0	0	0	0	2.7
Acer rubrum	0	0	0.7	0	0
Amelanchier arborea	24.5	10.7	9.9	0	5.1
Carya glabra	1.7	0	0	0	3.1
Carya texana	1.8	2.7	5.1	10.5	12.6
Celtis tenuifolia	0	0	1.2	0	0
Cercis canadensis	0	0	0	4.1	0
Cornus florida	1.7	0	0	1.9	2.7
Diospyros virginiana	5.2	5.8	3.9	1.9	1.7
Fagus grandifolia caroliniana	1.7	0	1.2	0	1.4
Fraxinus americana	1.7	0	0.7	0	2.7
Juniperus virginiana	0	2.7	0	3.8	0
Ostrya virginiana	0	0	0	0	5.7
Prunus serotina	0	0	2.5	1.9	0
Quercus alba	3.5	7.8	2.6	4.1	7.1
Quercus imbricaria	1.7	3.6	3.1	9.8	1.4
Quercus marilandica	5.7	18.8	14.1	0	4.7
Quercus rubra	3.3	2.7	3.1	0	4.4
Quercus stellata	6.7	21.9	17.9	26.0	6.4
Quercus velutina	8.3	7.8	6.6	12.3	13.8
Rhus aromatica	0	0	4.3	11.4	9.3
Rhus copallina	0	0	12.6	3.1	0
Sassafras albidum	0	0	1.2	2.5	12.2
Ulmus alata	6.9	4.6	1.3	6.6	3.1
Vaccinium arboreum	3.7	10.9	7.6	0	0
Vaccinium pallidum	22.1	0	0	0	0

Shrub/Saplings:	FI-N	TS-N	OP	TS-S	FI-S
Carya texana	0	0	0	0	50.0
Fraxinus americana	0	0	0	25.0	0
Quercus marilandica	20.5	47.2	59.0	0	0
Quercus stellata	10.3	18.1	11.8	25.0	0
Sassafras albidum	0	0	0	25.0	0
Ulmus alata	0	0	0	25.0	50.0
Vaccinium arboreum	45.5	34.7	29.2	0	0
Vaccinium pallidum	23.7	0	0	0	0

Trees:	FI-N	TS-N	OP	TS-S	FI-S
Carya glabra	0	0	0	0	14.3
Carya texana	0	0	0	50.0	14.3
Quercus marilandica	62.5	50.0	66.8	0	14.3
Quercus stellata	37.5	50.0	33.2	50.0	14.3
Quercus velutina	0	0	0	0	42.9

Herbs:	FI-N	TS-N	OP	TS-S	FI-S
Acalypha gracilens	0	0	0	0	1.3
Amphicarpa bracteata	0	0	0	0	5.4
Antennaria plantaginifolia	10.7	0	0	0	3.8
Asclepias tuberosa	0	0	0	5.3	3.8
Aster patens	0	5.3	0	0	0
Aster sp.	0	0	0	5.3	9.2
Carex hirsutella	0	0	0	0	1.6
Carex sp. (Montanae)	0	0	6.7	2.3	4.7
Cunila origanoides	21.4	15.9	22.5	12.8	15.3
Danthonia spicata	37.2	38.4	39.9	4.2	4.7
Dichanthelium linearifolium	0	0	6.7	6.8	1.6
Euphorbia corollata	0	0	2.1	2.3	2.9
Galium circaezans	0	5.3	0	0	0
Hedyotis longifolia	0	0	0	2.3	1.6
Helianthus divaricatus	0	6.4	4.6	12.8	15.3
Lespedeza repens	0	6.4	2.1	7.5	10.5
Lespedeza sp.	4.9	0	0	0	3.8
Paronychia fastigiata	0	0	0	0	4.5
Penstemon sp.	0	0	0	2.3	1.6
Psoralea psoralioides	0	6.4	0	0	0
Rosa carolina	0	0	0	10.5	0
Sanicula canadensis	0	0	0	0	1.6
Schizachyrium scoparium	10.7	0	0	0	0
Solidago nemoralis	0	0	4.6	12.8	5.4
Solidago sp.	9.9	0	0	0	0
Tephrosia virginiana	0	15.9	9.2	5.3	1.6
Toxicodendron radicans	4.9	0	0	5.3	0
Vitis aestivalis	0	0	0	2.3	0

Vulpia octoflora	0	0	1.8	0	0

BROWN SHALE BARRENS

Woody Seedlings:	FI-N	TS-N	OP	TS-S	FI-S
Acer rubrum	1.2	0	0	0	0
Acer saccharum	3.4	7.1	1.1	2.1	0
Amelanchier arborea	1.9	1.3	0	0	2.2
Carya cordiformis	0.4	0	0	0	0
Carya glabra	6.9	8.3	6.5	4.6	2.2
Carya ovata	4.5	5.5	10.9	4.2	6.9
Carya texana	5.4	3.9	6.7	4.3	0
Cercis canadensis	0.4	0.9	0	0	2.2
Cornus florida	1.6	1.4	0	0	0
Crataegus engelmannii	0	0	1.1	0	0
Crataegus sp.	2.3	0.7	1.9	0	0
Diospyros virginiana	4.1	6.1	3.2	0	0
Euonymus atropurpurea	0	0.7	0	0	0
Fagus grandifolia caroliniana	3.0	2.5	0	0	0
Fraxinus americana	4.3	6.6	5.3	6.0	6.6
Gleditsia triacanthos	0.4	0	0	0	0
Juglans nigra	0	0.7	0	0	2.2
Ligustrum vulgare	0	0.7	2.3	3.3	0
Morus rubra	0.8	0.7	0	0	0
Ostrya virginiana	17.5	13.7	2.3	4.2	7.4
Prunus americana	0.6	0	0	0	0
Prunus serotina	3.2	2.3	0	1.7	0
Quercus alba	2.4	1.4	0	0	2.2
Quercus imbricaria	3.2	1.7	4.9	3.4	2.2
Quercus marilandica	1.3	0	0	0	0
Quercus prinoides acuminata	1.6	2.4	0	1.7	0
Quercus rubra	1.4	2.7	0	0	2.6
Quercus stellata	15.2	14.9	22.2	15.8	10.3
Quercus velutina	7.8	8.1	6.4	5.9	8.9
Sassafras albidum	0.4	0	0	0	0
Ulmus alata	3.7	5.2	12.0	16.6	23.7
Ulmus rubra	0.8	0	0	0	0
Vaccinium arboreum	0	0.8	13.2	26.0	20.4

Shrub/Saplings:	FI-N	TS-N	OP	TS-S	FI-S
Quercus stellata	0	0	50.0	0	0
Ulmus alata	0	0	0	41.7	23.8
Vaccinium arboreum	0	0	50.0	58.3	76.2

Trees:	FI-N	TS-N	OP	TS-S	FI-S
Carya glabra	25.0	15.6	0	0	0
Carya ovalis	0	10.6	0	0	0
Quercus stellata	50.0	63.3	100.0	100.0	
Ulmus alata	25.0	10.6	0	0	100.0

Herbs:	FI-N	TS-N	OP	TS-S	FI-S
Acalypha gracilens	2.3	2.1	1.5	0	2.6
Agrostis perennans	0	0.7	0	0	0
Ambrosia artemisifolia	0	0	0	0	2.6
Amphicarpa bracteata	4.7	0	0	0	0
Antennaria plantaginifolia	1.2	2.1	0	0	0
Arabis laevigata	0	0	0.5	0	0
Asclepias variegata	1.2	0	0	0	0
Asplenium platyneuron	1.2	3.5	2.4	6.9	8.7
Asplenium sp.	0	0	0	0	1.3
Aster patens	0.6	0	1.4	10.6	4.9
Aster sp.	2.5	2.1	3.3	15.7	1.3
Bromus pubescens	2.3	0	0	0	0
Carex glaucodea	1.2	0	0	0	0
Carex hirsutella	0.6	1.4	0	0	0
Carex muhlenbergii	1.2	0.7	0.5	1.8	0
Carex retroflexa	3.7	2.9	0	0	0
Carex umbellata	4.9	4.7	5.1	11.3	4.9
Chasmanthium latifolium	1.2	0	0	0	0
Croton monanthogynus	0	0	1.4	0	0
Cunila origanoides	0.6	0	0	8.8	0
Danthonia spicata	6.7	5.5	5.2	4.2	7.3
Desmodium nudiflorum	0.6	0	0	0	0
Dichanthelium acuminatum	0.6	4.2	6.0	5.6	5.3
Dichanthelium boscii	6.6	4.3	0	0	0
Dichanthelium dichotomum	1.8	0	0	0	0
Dichanthelium laxiflorum	2.9	6.9	11.9	4.2	9.8
Dichanthelium linearifolium	0	2.1	0	0	0
Dichanthelium sphaerocarpon	0	0	1.5	1.4	0
Elymus villosus	0	0.7	0	0	2.4
Galactia regularis	0	2.8	0.8	0	1.3
Galium circaezans	1.8	4.1	0	0	0
Galium pilosum	2.9	0.7	0	0	0
Geranium carolinianum	0	1.4	0	0	0
Hedyotis purpurea	0.6	0	0	0	0
Helianthus divaricatus	10.8	17.9	17.4	5.6	15.1
Lechea tenuifolia	0	0	1.1	1.4	1.3
Lespedeza procumbens	1.2	0	2.2	1.4	0
Lespedeza repens	1.7	0.7	1.5	0	1.3
Lonicera japonica	0.6	0	8.4	1.4	0
Luzula multiflora	0.6	0	0	0	0
Manfreda virginica	0	1.4	0	1.4	2.4

Muhlenbergia sobolifera	0.6	0	3.8	0	0
Oxalis sp.	0	0.7	1.6	0	0
Parthenocissus quinquefolia	8.7	4.1	0	0	0
Passiflora lutea	1.2	0	0	0	0
Penstemon sp.	0.6	0	0.5	0	0
Plantago virginica	0	0	0	1.4	0
Poinsettia dentata	0	0	0.5	0	0
Pycnanthemum tenuifolium	0	11.0	0	1.4	0
Rosa carolina	3.7	0	0	0	0
Rudbeckia hirta	1.2	0	0	0	0
Ruellia caroliniensis	0.6	2.1	0	0	0
Ruellia humilis	0.6	0	0.8	1.4	1.3
Sanicula canadensis	1.8	2.1	0	0	0
Schizachyrium scoparium	0.6	1.4	9.8	5.6	16.9
Solidago caesia	0	0.7	0	0	0
Solidago nemoralis	1.2	3.4	6.1	4.2	6.2
Solidago ulmifolia	9.7	0.7	0.8	0	0
Stylosanthes biflora	0	0	3.3	4.2	1.3
Toxicodendron radicans	0.6	0.7	0.5	0	0
Trichostema dichotomum	0	0	0	0	1.3
Woodsia obtusa	0	0.7	0	0	0

CAVE CREEK LIMESTONE GLADE

Woody Seedlings:	FI-N	TS-N	OP	TS-S	FI-S
Aesculus glabra	0	0	0.2	0	0
Acer negundo	0.7	1.4	2.8	4.5	3.4
Acer rubrum	0	0	0.3	0	0
Acer saccharum	0	0.7	1.5	2.5	9.0
Amelanchier arborea	1.7	0	0.4	0	0
Aralia spinosa	2.7	0	0	1.8	0
Betula nigra	0	0	0	1.2	0
Carya cordiformis	1.5	1.4	0.3	1.2	0.9
Carya glabra	0	0	0.4	0	0
Carya ovalis	0	0	0.9	0	0
Carya ovata	0.7	0	0	0	0
Carya texana	3.9	2.2	0.4	0	0.9
Cassia marilandica	0.7	0	0	0	0
Ceanothus americanus	0	1.1	2.4	0	0
Celtis tenuifolia	9.4	6.9	8.4	11.4	15.1
Cercis canadensis	7.7	6.9	8.5	10.8	5.3
Cornus drummondii	0	3.1	0.9	0	0
Cornus florida	1.5	0.9	3.4	5.3	8.2
Cornus sp.	0	0	0	1.8	0
Corylus americana	0.9	0	0	0	0
Crataegus engelmannii	0.7	0	0.6	0	0.9

Crataegus sp.	1.7	0.8	0.6	0	2.1
Crataegus viridis	0	0.2	0.4	0	0
Diospyros virginiana	5.1	2.7	5.0	2.8	1.1
Euonymus atropurpurea	2.9	4.1	1.7	0	1.1
Fraxinus americana	4.8	4.4	6.3	5.8	8.5
Gleditsia triacanthos	0	0	0.2	0	0
Ilex decidua	0	0	1.7	1.2	0.9
Ilex verticillata	0	0.7	0.3	0	0
Juglans nigra	0	1.6	2.2	3.6	3.9
Juniperus virginiana	0	4.5	2.6	5.0	0
Lindera benzoin	0	0	0	0	0.9
Malus ioensis	0	0	0.6	0	0
Morus rubra	0	0.7	0	1.6	0
Ostrya virginiana	3.8	3.5	1.3	0	0
Prunus americana	1.6	0	0.2	1.4	4.3
Prunus serotina	2.5	2.6	1.2	1.2	0.9
Quercus marilandica	0.7	0	0	0	0
Quercus prinoides acuminata	5.6	4.0	12.7	10.4	3.5
Quercus rubra	1.9	0.9	0	0	0
Quercus shumardii	3.0	2.8	6.5	1.6	0
Quercus stellata	0.9	0	0	0	0
Quercus velutina	3.3	0	0	0	0
Rhus aromatica	9.2	19.9	12.3	10.9	4.1
Rhus glabra	0.7	0	0.3	0	0
Sassafras albidum	0	0.7	0.6	0	0
Ulmus alata	5.6	4.7	1.7	0	1.5
Ulmus rubra	14.5	11.2	9.9	14.1	21.7
Viburnum prunifolium	0	3.2	0.2	0	1.4

Shrub/Saplings:	FI-N	TS-N	OP	TS-S	FI-S
Acer saccharum	0	21.9	0	0	0
Carya texana	16.3	0	0	0	0
Celtis tenuifolia	0	0	2.2	0	0
Cercis canadensis	0	0	19.9	70.8	0
Cornus drummondii	0	39.4	0	0	0
Cornus florida	0	0	7.4	0	0
Diospyros virginiana	0	0	13.1	0	0
Fraxinus americana	22.5	12.9	23.9	0	0
Juniperus virginiana	0	0	4.4	29.2	0
Ostrya virginiana	28.8	0	5.2	0	0
Quercus prinoides acuminata	0	0	15.7	0	0
Quercus shumardii	0	12.9	8.3	0	0
Quercus stellata	16.3	0	0	0	0
Ulmus rubra	16.3	12.9	0	0	0

Trees:	FI-N	TS-N	OP	TS-S	FI-S
Acer saccharum	0	7.1	0	0	20.8

Carya texana	0	7.1	0	0	0
Cercis canadensis	0	0	8.3	0	0
Cornus drummondii	0	0	8.3	0	0
Cornus florida	0	0	0	26.7	0
Diospyros virginiana	0	10.0	0	0	0
Fraxinus americana	35.4	17.2	16.7	18.3	14.6
Juglans nigra	0	0	0	0	14.6
Ostrya virginiana	0	10.0	8.3	0	0
Quercus prinoides acuminata	35.4	7.1	33.3	36.7	20.8
Quercus shumardii	11.8	14.2	25.0	18.3	14.6
Quercus stellata	17.4	27.2	0	0	0
Ulmus rubra	0	0	0	0	14.6

Herbs:	FI-N	TS-N	OP	TS-S	FI-S
Acalypha gracilens	0.8	0.6	0.1	0	0
Agrimonia rostellata	2.6	0	0	0	1.2
Ambrosia artemisifolia	0	0.6	0.3	0	0
Amphicarpa bracteata	0	0.6	0.2	0	0
Apocynum cannabinum	0	0	0.5	1.5	0
Aristolochia serpentaria	0	0	0.2	1.6	0
Asclepias sp.	0	0	0.1	0	0
Asclepias verticillata	0	0.6	0	0	0
Asclepias viridis	0	0	0.3	0	0
Aster oblongifolius	2.5	7.2	4.2	1.5	0
Aster patens	1.7	0	1.4	2.3	0
Aster pilosus	0	0	0.2	0	0
Aster sp.	1.8	3.7	1.3	0	3.5
Bignonia capriolata	0.8	0	1.3	0	3.1
Boehmeria cylindrica	0	0	0.1	0	0
Botrychium virginianum	0.8	0	0	0	0
Bouteloua curtipendula	0	0	0.6	0	0
Brickellia eupatorioides	0	0	33.1	0	0
Bromus commutatus	0	0	0.1	0	0
Bromus pubescens	0.8	1.8	0.5	0.8	1.5
Bromus racemosus	0	0	0.1	0	0
Campanula americana	0	0	0.1	0	0
Campsis radicans	0	0	0.6	3.9	5.2
Carex artitecta	0.8	0	0.1	0	0
Carex blanda	0	0	0.1	0	0
Carex cephalophora	0.1	1.2	0	0	0
Carex meadii	0	0	0.1	0	0
Carex muhlenbergii	0	0	0.3	0	0
Carex retroflexa	0	0	0.1	0	0
Carex sp.	0	0	0.1	0	0
Carex umbellata	0	0	0.3	0.8	0
Cassia fasciculata	0	0	0.2	0	0
Cassia marilandica	0	0	0.1	0	0
Celastrus scandens	0	0	0	0	2.3

Chamaesyce maculata	0	0	0.4	0	0
Croton monanthogynus	0	0	0.8	0	0
Crotonopsis elliptica	0	0	0.1	0	0
Cunila origanoides	0.8	0.6	0.1	0	0
Cynanchum laeve	0	0	0.1	0	0
Danthonia spicata	0	0.5	0.1	0	0
Desmodium canescens	0	0	0	0	1.2
Desmodium paniculatum	0	0	0.1	0	0
Desmodium sessilifolium	0	0	0.1	0.8	0
Dichanthelium boscii	2.6	2.5	0.6	3.1	3.5
Dichanthelium laxiflorum	0	0	0.1	0	0
Dioscorea quaternata	1.8	0	0.4	0	0
Echinacea pallida	0	0	1.7	2.3	0
Elymus virginicus	0	0	0.4	0.8	0
Erigeron annuus	0	0	0.1	0	0
Eupatorium altissimum	1.8	4.3	2.8	2.3	0.7
Euphorbia corollata	0	1.2	2.9	6.9	0.7
Festuca arundinacea	0	0	1.4	0	0
Galactia regularis	3.4	1.2	3.2	0.8	0.7
Galium circaezans	5.9	5.5	1.4	3.8	4.5
Geranium maculatum	0	0	0.1	0	1.2
Helianthus divaricatus	11.3	8.4	6.2	3.1	1.9
Helianthus microcephalus	0	0	0.1	0	1.2
Hybanthus concolor	0	0	0	0	0.7
Hypericum denticulatum	0	0	0.4	0	0
Ipomaea pandurata	0	0	0.6	0	1.2
Lactuca serriola	0	0	0.3	0	0
Lespedeza cuneata	0	0	0.4	0	0
Lespedeza procumbens	0	1.8	0.2	0.8	0
Lespedeza repens	2.6	0.6	0.4	0.7	0
Lespedeza sp.	0	0.6	0.6	0	0
Liatris scabra	0	1.2	0.3	0	0
Lithospermum canescens	0	0	0.4	0.8	0
Lonicera japonica	0	0	0	0	0.7
Lysimachia lanceolata	0	0	0.2	1.5	0
Manfreda virginica	0	0	1.6	0.8	0
Medicago lupulina	0	0	0.4	0	0
Monarda bradburiana	2.6	3.7	1.7	1.5	1.5
Muhlenbergia sobolifera	0.8	0.6	0	0	0
Onosmodium hispidissimum	0	0	0.5	0	0
Oxalis stricta	0	0	0.1	0	0
Parthenocissus quinquefolia	10.2	2.4	0.7	6.9	6.8
Passiflora lutea	0.8	0	0.3	0	0
Phlox pilosa	0.8	1.2	1.6	4.7	0
Physalis virginiana	0	0.6	1.2	0.8	0
Physostegia virginiana	0	0.6	3.4	3.8	1.9
Polygonum cristatum	0	0.6	0.3	0	0
Ratibida pinnata	6.7	0	1.6	5.4	0.7
Rosa carolina	0	2.5	0.9	0.8	1.2

Rosa multiflora	0	0	0.4	0	0
Rubus allegheniensis	0	0	0.3	0	0
Rubus enslenii	0	0	0.1	0	0
Rubus flagellaris	0	1.2	0	0.8	2.6
Rudbeckia hirta	0	0	0.1	0	0
Ruellia caroliniensis	1.8	0	0.5	3.0	1.9
Ruellia humilis	0	0.6	3.5	1.5	0.7
Salvia azurea grandiflora	0	0.6	1.0	0	0
Sanicula canadensis	2.5	1.2	0.8	2.3	3.1
Schizachyrium scoparium	1.8	0	7.9	1.5	0
Scutellaria leonardii	0	1.8	0.1	0	0
Setaria glauca	0	0	0.1	0	0
Silphium integrifolium	0	0	0.7	0	0
Silphium terebinthinaceum	0	0	7.5	1.5	5.2
Sisyrinchium albidum	0	0	0.4	0	0
Smilax bona-nox	5.3	11.9	6.3	3.0	7.2
Solidago sp.	0	0	0.3	0	0
Solidago ulmifolia	10.6	9.3	2.3	3.9	3.1
Sorghastrum nutans	0	0	2.5	4.7	0
Taenidia integerrima	1.7	5.6	0.8	0	0.7
Toxicodendron radicans	1.8	1.2	1.1	3.0	7.5
Tradescantia subaspera	0	0	0.1	0	0
Trifolium campestre	0	0	0.3	0	0
Triosteum angustifolium	0	0.6	0	0	0
Verbesina helianthoides	1.8	0	0.1	0	0
Verbesina virginica	5.3	5.5	4.3	3.9	10.4
Viola sororia	0	0	0	0.8	2.3
Viola sp.	0	0	0.4	0	0
Viola triloba	1.8	0.6	0	0	0
Vitis aestivalis	0	1.2	0.1	0.8	5.2
Vitis vulpina	0	1.2	0	0	3.1
Zizia aurea	0	0	1.2	3.9	0

CEDAR BLUFF SANDSTONE GLADE

Woody seedlings:	FI-N	TS-N
Acer saccharum	1.4	1.3
Amelanchier arborea	2.9	4.2
Carya glabra	9.4	5.7
Carya ovalis	0.9	1.3
Carya ovata	11.3	6.5
Celtis tenuifolia	4.8	3.8
Cercis canadensis	0.7	0
Diospyros virginiana	1.7	0
Fagus grandifolia caroliniana	0	1.3
Fraxinus americana	6.6	4.4

Juglans nigra	0.4	0
Juniperus virginiana	6.6	9.8
Ligustrum vulgare	0.7	0
Malus ioensis	0.4	0
Ostrya virginiana	3.3	0
Prunus serotina	0.4	0
Quercus alba	2.1	0
Quercus marilandica	1.1	6.0
Quercus rubra	2.4	0
Quercus stellata	11.8	25.1
Quercus velutina	4.7	4.8
Rhus aromatica	9.9	4.1
Rhus copallina	2.3	0
Symphoricarpos orbiculatus	2.4	0
Ulmus alata	9.4	18.6
Ulmus rubra	0.5	0
Vaccinium arboreum	1.7	3.3

Shrub/Saplings:	FI-N	TS-N
Amelanchier arborea	3.4	0
Carya ovata	3.4	0
Celtis tenuifolia	3.4	0
Diospyros virginiana	4.9	0
Fraxinus americana	9.7	0
Juniperus virginiana	33.5	100.0
Ostrya virginiana	6.8	0
Quercus rubra	3.4	0
Ulmus alata	31.6	0

Trees:	FI-N	TS-N
Carya glabra	2.4	0
Carya ovata	2.4	0
Diospyros virginiana	2.4	0
Fraxinus americana	10.6	0
Juniperus virginiana	40.2	45.3
Quercus stellata	9.8	21.9
Ulmus alata	32.1	32.8

Herbs:	FI-N	TS-N
Acalypha gracilens	2.0	4.1
Arabis laevigata	0.5	0
Aster sp.	0.5	0
Bromus pubescens	3.6	0
Carex blanda	0.5	0
Carex cephalophora	1.0	0
Carex glaucodea	0.9	0

Carex hirsutella	0.9	0
Carex muhlenbergii	0.5	0
Carex retroflexa	0.5	0
Carex umbellata	1.8	5.2
Celastrus scandens	1.4	0
Chasmanthium latifolium	8.5	2.5
Cheilanthes lanosa	0.5	2.5
Cunila origanoides	0.9	2.5
Danthonia spicata	11.9	36.5
Dichanthelium dichotomum	0	1.4
Dichanthelium laxiflorum	2.3	3.8
Dichanthelium linearifolium	0.9	5.2
Dichanthelium villosissimum	6.9	4.9
Elymus virginicus	2.9	5.4
Euphorbia corollata	0.9	1.4
Helianthus divaricatus	0.9	0
Juncus tenuis	0.5	0
Lactuca serriola	0.9	0
Lepidium virginicum	0	2.6
Manfreda virginica	0	6.4
Muhlenbergia sobolifera	1.0	0
Myosotis verna	0	1.2
Oxalis sp.	1.9	1.4
Parthenocissus quinquefolia	10.4	0
Penstemon sp.	0.5	1.4
Phlox pilosa	3.2	2.6
Polygonum cristatum	1.5	0
Polygonum tenue	0	1.4
Rubus enslenii	0	2.5
Sanicula canadensis	5.1	0
Schizachyrium scoparium	0.5	0
Smilax bona-nox	2.8	0
Solidago caesia	1.5	0
Solidago nemoralis	0	1.4
Toxicodendron radicans	18.9	0
Vulpia octoflora	0	1.2
Woodsia obtusa	0	2.7

GIBBONS CREEK SANDSTONE BARRENS

Woody Seedlings:	FI-N	TS-N	OP	TS-S	FI-S
Amelanchier arborea	4.4	1.7	6.1	3.8	9.2
Carya cordiformis	1.7	0	1.8	2.1	
Carya glabra	2.9	1.2	0.8	1.3	2.6
Carya ovalis	0	1.3	0	0	0
Carya ovata	3.9	0	0.4	1.3	4.6

Carya texana	12.3	12.9	14.1	8.1	10.6
Celtis tenuifolia	0.9	0	0.8	0	0
Cercis canadensis	0	1.1	0.4	0	0
Cornus florida	1.1	1.1	0	1.9	3.2
Crataegus sp.	3.8	3.7	1.1	0	1.1
Diospyros virginiana	0	1.1	2.4	3.5	3.5
Fraxinus americana	3.9	1.7	1.5	2.5	4.2
Juglans nigra	0.9	0	0	0	0
Malus ioensis	0	1.5	0	0	1.3
Morus rubra	0	0	0.5	1.2	0
Ostrya virginiana	2.6	0	0	0	0
Prunus americana	0	0	0.4	2.0	0
Prunus serotina	1.8	1.4	1.7	1.5	2.4
Quercus alba	0	0	0.5	0	3.8
Quercus coccinea	0.9	0	0.4	0	0
Quercus imbricaria	4.7	4.9	7.5	8.0	2.4
Quercus marilandica	2.0	1.1	7.9	10.8	8.5
Quercus prinoides acuminata	0	0	0	0	1.8
Quercus rubra	3.2	1.1	1.5	2.6	2.6
Quercus stellata	8.6	7.6	16.3	16.3	16.1
Quercus velutina	5.5	8.1	7.1	7.0	9.9
Rhus copallina	0	0	7.4	2.6	1.6
Symphoricarpos orbiculatus	23.1	21.2	0	1.9	0
Ulmus alata	10.3	25.6	9.2	9.1	9.1
Ulmus rubra	0	0	0.4	0	0
Vaccinium arboreum	1.2	1.5	0.5	9.5	1.5
Vaccinium pallidum	0	0	9.5	2.9	0

Shrub/Saplings:	FI-N	TS-N	OP	TS-S	FI-S
Amelanchier arborea	0	0	14.8	0	0
Carya ovata	0	0	0	0	50.0
Carya texana	25.0	15.5	14.8	0	0
Diospyros virginiana	0	0	7.4	0	0
Fraxinus americana	25.0	0	0	0	0
Juniperus virginiana	0	15.5	0	0	0
Quercus marilandica	0	0	7.4	0	0
Quercus stellata	0	0	7.4	0	0
Ulmus alata	50.0	69.0	48.1	45.0	50.0
Vaccinium arboreum	0	0	0	55.0	0

Trees:	FI-N	TS-N	OP	TS-S	FI-S
Carya glabra	0	0	0	0	8.9
Carya ovalis	9.5	0	0	0	0
Carya ovata	9.5	0	0	12.7	0
Carya texana	19.1	19.1	17.8	18.3	17.8
Fraxinus americana	14.1	9.5	5.9	0	0
Juniperus virginiana	9.5	0	4.2	0	0

Quercus marilandica	0	9.5	16.9	0	0
Quercus stellata	28.6	33.2	44.9	43.7	73.3
Ulmus alata	9.5	28.6	10.2	25.4	0

Herbs:	FI-N	TS-N	OP	TS-S	FI-S
Acalypha gracilens	7.0	5.6	7.9	5.8	6.3
Ambrosia artemisifolia	1.8	1.8	6.1	4.9	2.4
Antennaria plantaginifolia	3.4	1.8	0.9	2.5	0
Aristida sp.	0	0	0.9	0	0
Asclepias verticillata	0.8	0	0	0	0
Asplenium platyneuron	6.2	4.5	1.9	0	0
Aster patens	0.8	1.8	0	0	0
Aster pilosus	0	0	0.6	0	0
Bromus pubescens	1.6	0	0	2.5	0
Carex artitecta	0	0	1.7	0	0
Carex cephalophora	0	0	0	1.2	0
Carex hirsutella	0.8	0	0.3	7.4	4.9
Carex muhlenbergii	0	0.9	2.9	4.9	2.4
Carex retroflexa	4.4	2.8	1.2	2.5	3.7
Carex sp.	0	0	1.2	0	0
Carex umbellata	1.8	3.6	6.9	4.8	4.8
Cassia nictitans	0	0	0.3	0	0
Clitoria mariana	0	1.8	1.2	0	0
Crotonopsis elliptica	0	0	0.3	0	0
Cunila origanoides	0	0	0	0	3.6
Danthonia spicata	1.5	9.2	5.0	5.9	2.6
Desmodium rotundifolium	0.8	0	0	0	0
Dichanthelium acuminatum	0	0	1.3	1.2	0
Dichanthelium boscii	0.8	1.8	0	1.2	2.4
Dichanthelium laxiflorum	9.5	14.9	9.6	5.9	2.4
Dichanthelium linearifolium	0.8	0	1.3	1.2	1.3
Dichanthelium sphaerocarpon	0	0	1.6	0	1.3
Dichanthelium villosissimum	0	0	2.8	0	0
Elymus virginicus	1.8	0	0	1.2	0
Euphorbia corollata	0.8	3.7	4.1	1.2	1.3
Galium circaezans	0	0.9	0	2.5	0
Galium pilosum	5.2	5.5	2.2	4.8	7.4
Helianthus divaricatus	9.0	11.2	8.6	12.8	16.4
Hypericum gentianoides	0	0	0.3	0	0
Ipomaea pandurata	0	1.8	0	0	0
Koeleria macrantha	1.8	6.6	3.3	0	0
Kummerowia striata	0	0	0.3	0	0
Lactuca hirsuta	1.6	0	0	0	0
Lechea tenuifolia	0	0	0.6	0	0
Lespedeza procumbens	1.8	0	0.6	2.5	0
Lespedeza repens	0	0	1.9	0	0
Manfreda virginica	0	0	0.9	0	0
Monarda bradburiana	0	0.9	0	0	0

Monarda fistulosa	2.6	1.8	0	0	0
Oxalis stricta	0	0	0.3	0	0
Paronychia fastigiata	0	0	1.3	9.3	0
Parthenocissus quinquefolia	7.2	3.7	0.3	8.4	10.9
Passiflora lutea	1.8	0	0	0	0
Phlox pilosa	2.4	1.9	0.3	0	0
Physalis virginiana	0.8	0	0.3	1.0	0
Polygonatum biflorum	0	1.8	0.3	0	0
Porteranthus stipulatus	2.6	0	0.9	0	0
Potentilla simplex	0	0	0	1.2	1.3
Rosa carolina	3.6	0	1.2	0	6.1
Rubus flagellaris	0	0	0	0	4.9
Rudbeckia hirta	2.4	0.9	0	0	0
Ruellia humilis	0	0	0	0	2.4
Sanicula canadensis	0.8	0.9	0	0	0
Schizachyrium scoparium	3.4	2.8	8.9	3.6	2.4
Scleria pauciflora	0	0	0.3	0	0
Smilax glauca	0.8	0	0	0	2.4
Solidago nemoralis	1.8	0	0.6	0	0
Solidago petiolaris	0	0	0	0	6.4
Sorghastrum nutans	0	2.7	4.6	0	0
Stylosanthes biflora	1.8	0.9	1.6	0	0
Verbesina helianthoides	1.8	0	0	0	0
Viola triloba	0.8	0.9	0	0	0
Woodsia obtusa	0.8	0	0	0	0

POUNDS HOLLOW SANDSTONE GLADE

Woody Seedlings:	FI-N	TS-N	OP	TS-S	FI-S
Amelanchier arborea	4.2	13.9	19.2	13.8	13.0
Carya glabra	6.9	3.3	3.0	4.9	2.6
Carya ovalis	1.0	0	0	0	0
Carya ovata	1.0	1.1	0	2.9	1.3
Carya texana	0	0	0	1.1	0
Celtis tenuifolia	1.6	3.7	0	0	0
Cornus florida	1.0	0	0	0.9	1.3
Diospyros virginiana	0	1.1	1.0	4.7	4.9
Fagus grandifolia caroliniana	3.6	2.2	6.0	3.0	5.3
Fraxinus americana	1.2	0	3.0	0	0
Juglans nigra	1.0	1.1	1.0	0	0
Juniperus virginiana	6.4	6.6	6.7	2.8	1.3
Liriodendron tulipifera	0	0	0	0	1.8
Pinus echinata	2.1	2.2	0	3.3	1.5
Prunus serotina	0	1.1	2.0	0.9	
Quercus alba	3.3	3.3	9.8	21.5	23.4
Quercus coccinea	2.2	2.2	0	4.4	6.4

Quercus imbricaria	0	1.1	1.0	0	0
Quercus marilandica	8.4	5.9	2.2	2.7	2.8
Quercus rubra	2.9	1.1	1.0	4.5	9.9
Quercus stellata	21.6	19.9	16.2	7.7	5.5
Quercus velutina	4.7	5.4	3.2	5.8	5.7
Rhamnus caroliniana	1.0	0	0	0	1.3
Rhus copallina	5.3	5.8	2.5	5.4	1.3
Sassafras albidum	0	0	0	0	1.3
Ulmus alata	6.4	6.3	6.5	2.9	1.3
Vaccinium arboreum	14.0	12.6	15.7	6.9	8.0

Shrub/Saplings:	FI-N	TS-N	OP	TS-S	FI-S
Amelanchier arborea	0	26.3	11.7	0	16.7
Diospyros virginiana	0	0	0	0	33.3
Juniperus virginiana	9.4	41.7	31.7	32.5	0
Pinus echinata	0	0	0	7.5	0
Quercus alba	0	0	0	15.0	16.7
Quercus coccinea	0	0	0	10.0	0
Quercus marilandica	22.6	0	11.7	10.0	0
Quercus stellata	9.4	0	0	0	0
Quercus velutina	0	0	0	7.5	16.7
Ulmus alata	18.8	9.6	23.3	0	0
Vaccinium arboreum	39.7	22.5	21.7	17.5	16.7

Trees:	FI-N	TS-N	OP	TS-S	FI-S
Carya glabra	7.9	0	0	12.7	0
Diospyros virginiana	0	0	0	0	12.5
Juglans nigra	15.9	0	0	0	0
Juniperus virginiana	21.8	66.7	68.3	56.4	37.5
Quercus alba	0	0	0	0	12.5
Quercus coccinea	0	0	0	0	12.5
Quercus marilandica	21.8	8.3	18.3	9.1	
Quercus stellata	32.6	16.7	0	21.8	12.5
Ulmus alata	0	8.3	13.3	0	12.5

Herbs:	FI-N	TS-N	OP	TS-S	FI-S
Antennaria plantaginifolia	6.9	1.7	0	0	0
Aristida sp.	0	0	2.5	0	0
Asplenium platyneuron	0	1.7	0	0	0
Aureolaria flava	0	0	0	0	4.1
Carex bushii	0	1.7	0	0	0
Carex sp. (Montanae)	7.2	3.5	22.9	30.0	19.9
Cheilanthes lanosa	0	5.1	2.5	0	0
Crotonopsis elliptica	0	1.7	2.5	10.0	0
Cunila origanoides	1.8	1.7	0	0	4.1
Danthonia spicata	10.5	1.7	5.0	10.0	0

Dichanthelium depauperatum	1.8	0	2.5	0	0
Dichanthelium dichotomum	0	1.7	0	0	4.1
Dichanthelium laxiflorum	5.4	0	8.6	10.0	15.9
Dichanthelium linearifolium	5.1	0	2.5	0	0
Dichanthelium villosissimum	0	1.7	6.1	0	4.1
Diodia teres	0	0	2.5	0	0
Dodecatheon meadia	5.1	12.3	0	0	0
Elymus virginicus	1.8	0	0	0	0
Hedyotis purpurea	0	1.7	0	0	0
Helianthus divaricatus	4.1	17.8	0	0	0
Hypericum gentianoides	0	0	2.5	0	0
Krigia biflora	1.8	0	0	0	0
Krigia dandelion	7.2	5.2	5.0	0	12.2
Krigia sp.	0	1.7	0	0	0
Lespedeza repens	8.9	1.7	0	0	0
Luzula multiflora	0	0	0	30.0	8.1
Manfreda virginica	0	3.4	2.5	0	0
Opuntia humifusa	0	0	0	0	11.8
Oxypolis rigidior ambigua	0	1.7	0	0	0
Parthenocissus quinquefolia	5.1	8.9	0	0	0
Phlox pilosa	0	1.7	0	0	0
Polygonatum biflorum	0	0	0	0	11.8
Ruellia humilis	1.8	1.7	6.1	0	0
Schizachyrium scoparium	5.4	3.4	5.0	0	0
Smilax bona-nox	0	0	18.5	10.0	0
Smilax glauca	0	0	2.5	0	0
Solidago sp.	1.8	0	0	0	0
Stylosanthes biflora	1.8	0	0	0	0
Toxicodendron radicans	16.6	10.7	0	0	0
Triodanis perfoliata	0	1.7	0	0	4.1
Vulpia octoflora	0	1.7	0	0	0
Woodsia obtusa	0	1.7	0	0	0

ROUND BLUFF SANDSTONE GLADE

Woody Seedlings:	FI-N	TS-N	OP
Acer rubrum	2.0	5.2	0
Amelanchier arborea	4.7	4.6	4.9
Carya glabra	4.1	4.9	0
Carya ovata	9.3	10.7	0
Carya texana	0.5	0	0
Celtis tenuifolia	8.7	7.5	0
Cercis canadensis	0.4	0	0
Cornus florida	0.9	0	0
Crataegus sp.	0.4	0	0
Diospyros virginiana	5.5	1.5	0

Fagus grandifolia caroliniana	0.5	0	0
Fraxinus americana	7.2	5.1	0
Juniperus virginiana	11.0	8.6	9.8
Liquidambar styraciflua	0.4	0	0
Liriodendron tulipifera	1.8	0.9	0
Morus rubra	0.6	0	0
Ostrya virginiana	0.4	0	0
Prunus serotina	1.8	1.7	0
Quercus alba	1.5	1.8	0
Quercus marilandica	0.4	0.9	0
Quercus rubra	0.5	0	0
Quercus stellata	8.0	8.0	11.3
Quercus velutina	3.1	1.1	0
Rhus aromatica	8.8	16.1	0
Sassafras albidum	0.9	0	10.9
Symphoricarpos orbiculatus	0.5	3.7	0
Ulmus alata	13.9	16.6	12.8
Vaccinium arboreum	1.8	1.0	50.2

Shrub/Saplings:	FI-N	TS-N	OP
Carya glabra	50.0	0	0
Carya ovata	11.3	0	0
Juniperus virginiana	16.3	73.3	70.8
Ulmus alata	22.5	26.7	26.7

Trees:	FI-N	TS-N	OP
Carya glabra	9.1	19.8	0
Fraxinus americana	15.5	0	0
Juniperus virginiana	47.2	31.3	100.0
Ulmus alata	28.2	48.9	0

Herbs:	FI-N	TS-N	OP
Acalypha gracilens	5.9	6.2	0
Agrostis sp.	0	4.9	0
Aristida sp.	0	2.9	0
Bidens bipinnata	1.3	0	0
Blephilia sp.	1.4	0	0
Bromus pubescens	0.7	0	0
Carex blanda	0.7	0	0
Carex cephalophora	1.4	0	0
Carex hirsutella	2.7	1.0	0
Carex muhlenbergii	0	0	4.7
Carex retroflexa	0.7	0	0
Carex sp.	0	0	13.9
Carex umbellata	7.9	3.8	0
Cheilanthes lanosa	0	1.0	0

Crotonopsis elliptica	0	8.7	12.1
Danthonia spicata	12.0	8.8	4.7
Dichanthelium acuminatum	0	1.0	9.3
Dichanthelium linearifolium	0.7	2.9	0
Dichanthelium polyanthes	0.7	0	0
Dichanthelium villosissimum	7.5	3.8	0
Diodia teres	0	5.7	16.7
Echinacea pallida	0.7	0	0
Elymus virginicus	3.3	0	0
Erigeron strigosus	0	1.0	0
Galium circaezans	1.3	0	0
Galium pilosum	0.7	1.0	0
Helianthus divaricatus	2.0	3.9	0
Hypericum gentianoides	0	2.9	12.4
Lespedeza procumbens	1.4	0	0
Lespedeza repens	0.7	0	0
Lonicera japonica	4.1	0	0
Manfreda virginica	0	1.9	0
Muhlenbergia sobolifera	0.7	0	0
Opuntia humifusa	0	2.9	2.8
Parietaria pensylvanica	0.7	0	0
Paronychia fastigiata	0	1.0	0
Parthenocissus quinquefolia	9.9	2.1	0
Polygonum cristatum	3.4	0	0
Rosa carolina	1.4	0	0
Rubus enslenii	2.7	0	0
Sanicula canadensis	8.9	2.9	0
Schizachyrium scoparium	0.7	17.9	23.3
Sedum pulchellum	0	1.0	0
Smilax bona-nox	1.4	0	0
Smilax glauca	0	1.0	0
Solidago caesia	1.4	1.9	0
Solidago nemoralis	0	1.9	0
Solidago ulmifolia	1.4	0	0
Toxicodendron radicans	4.1	3.8	0
Vitis aestivalis	2.0	0	0
Woodsia obtusa	3.8	1.9	0

WILDCAT BLUFF LIMESTONE GLADE

Woody Seedlings:	FI-N	TS-N	OP	TS-S	FI-S
Acer negundo	1.9	0.8	0.1	3.5	2.7
Acer rubrum	0	0.8	0.1	0.9	0
Acer saccharum	8.9	7.2	2.2	0.9	0.8
Amelanchier arborea	2.1	0	0.4	0	0
Aralia spinosa	2.4	3.4	1.6	0	0

Asimina triloba	0	0	0.1	0	0
Carya cordiformis	0.9	0.8	0.2	0.9	0
Carya glabra	2.6	3.6	0.2	1.8	1.7
Carya ovalis	0	0	0.1	0	0
Carya ovata	1.1	1.7	0.6	0	1.3
Carya texana	0.9	0.8	1.4	0	0
Cassia marilandica	0	0	0.2	2.6	0
Ceanothus americanus	0	0	1.3	0	0
Celtis tenuifolia	1.9	4.1	5.7	4.9	5.4
Cercis canadensis	4.4	5.2	7.4	8.3	9.3
Cornus florida	3.7	5.3	1.2	1.4	0
Crataegus sp.	0	0.9	1.5	3.1	4.3
Diospyros virginiana	7.0	5.5	5.3	0.9	0.8
Elaeagnus umbellata	0	0	0	0.9	0.8
Euonymus atropurpurea	0	0	1.1	0	0.8
Fraxinus americana	6.0	5.3	4.3	6.8	7.4
Gleditsia triacanthos	0	0	0.1	0.9	0.8
Ilex decidua	0	0.8	0.1	0	0
Juglans nigra	0	1.7	1.3	0	0.8
Juniperus virginiana	0	0	0.1	0	0
Liquidambar styraciflua	0	0	0.2	0	0.8
Lonicera sp. (shrub)	0	0	0	0	0.8
Malus ioensis	0	0	0.8	0	0.8
Morus rubra	2.3	0.9	2.2	1.8	4.1
Ostrya virginiana	19.3	19.9	11.6	5.6	11.2
Prunus americana	0	0	0.8	2.2	0
Prunus serotina	0.9	0	0.9	1.8	1.7
Quercus alba	2.4	0.8	0.5	0	0
Quercus prinoides acuminata	1.9	3.9	4.4	0.9	4.3
Quercus rubra	0.9	2.2	0.1	0	0
Quercus shumardii	0.9	2.0	2.9	5.9	3.7
Quercus stellata	0	0	0.9	0	0
Quercus velutina	2.3	3.1	1.8	0	1.1
Rhus aromatica	2.8	2.4	17.0	8.8	8.3
Rhus glabra	0	0	0.1	0	0
Sassafras albidum	1.9	5.6	1.4	0.9	0.8
Ulmus alata	2.4	0	4.9	8.6	7.5
Ulmus rubra	17.6	11.1	12.9	24.9	16.8
Viburnum prunifolium	0	0	0	0.9	0.8

Shrub/Saplings:	FI-N	TS-N	OP	TS-S	FI-S
Acer saccharum	21.6	25.0	6.3	0	5.1
Amelanchier arborea	10.8	0	0	0	0
Carya ovata	10.8	0	0	0	0
Celtis tenuifolia	0	0	6.3	25.0	0
Crataegus sp.	0	0	0	0	29.4
Ostrya virginiana	46.0	75.0	55.6	50.0	25.3
Quercus prinoides acuminata	0	0	6.3	0	0

Quercus stellata	0	0	6.3	0	0
Ulmus rubra	10.8	0	19.0	25.0	40.2

Trees:	FI-N	TS-N	OP	TS-S	FI-S
Acer saccharum	0	26.8	10.4	0	0
Carya glabra	0	13.4	0	0	0
Carya ovata	16.3	13.4	0	18.3	24.7
Carya texana	0	0	11.7	0	0
Cornus florida	0	0	5.2	0	0
Crataegus sp.	0	0	0	0	24.7
Fraxinus americana	11.3	0	3.8	0	10.1
Ostrya virginiana	27.5	13.4	5.2	18.3	10.1
Quercus alba	11.3	19.6	0	18.3	0
Quercus prinoides acuminata	11.3	13.4	20.9	18.3	0
Quercus rubra	0	0	2.6	0	0
Quercus shumardii	0	0	16.9	0	10.1
Quercus stellata	11.3	0	15.5	0	10.1
Quercus velutina	11.3	0	2.6	0	0
Sassafras albidum	0	0	2.6	0	0
Ulmus rubra	0	0	2.6	26.7	10.1

Herbs:	FI-N	TS-N	OP	TS-S	FI-S
Acalypha gracilens	2.6	0	1.0	0.8	0.9
Agrostis perennans	0	0	0.1	0	0
Ambrosia artemisifolia	0	0	0.1	0	0
Amphicarpa bracteata	2.6	0	0.2	0	1.8
Andropogon gerardii	0	0	0.7	0	0
Anemone virginiana	0	0	0.1	0	0
Apocynum cannabinum	0	0	3.6	0	0
Aristolochia serpentaria	0	1.2	0.3	3.1	1.9
Arundinaria gigantea	2.6	2.5	0.4	0	0
Asclepias tuberosa	0	0	0.7	0	0
Asclepias verticillata	0	0	0.3	0	0
Asclepias viridis	0	0	0.1	0	0
Aster laevis	0	0	0.1	0	0
Aster patens	0	0	0.5	0	0
Bignonia capriolata	1.4	0	1.8	6.1	8.9
Botrychium virginianum	17.5	2.5	0.1	0	0.9
Bouteloua curtipendula	0	0	0.1	0	0
Brickellia eupatorioides	0	0	2.1	0	0
Bromus pubescens	2.6	2.3	0.9	1.5	0.9
Cacalia atriplicifolia	2.6	2.5	0	0	0
Campanula americana	0	0	0.2	0	1.8
Carex digitalis	0	2.5	0	0	0.9
Carex grisea	0	0	0	1.5	1.8
Carex umbellata	2.6	3.7	0.7	0	1.8
Cassia fasciculata	0	0	0.9	1.5	0

Chamaesyce maculata	0	0	0.1	0	0
Clitoria mariana	0	0	0.2	0	0
Cunila origanoides	0	0	0.3	0	0
Danthonia spicata	13.5	0	0.3	2.3	0
Desmodium canescens	0	0	0.3	0	0
Desmodium paniculatum	0	0	0.1	0	0
Desmodium sp.	0	0	0.1	0	0
Dichanthelium boscii	1.4	5.0	1.9	3.8	3.6
Dichanthelium linearifolium	0	0	0.3	0	0
Dioscorea quaternata	3.9	0	0.7	1.5	1.8
Echinacea pallida	0	0	0.1	0	0
Elymus hystrix	0	1.2	0.1	0	0
Elymus virginicus	0	0	0.3	0	0
Erechtites hieracifolia	1.4	0	0	0	0
Eupatorium altissimum	0	3.7	2.4	0	0
Eupatorium rugosum	5.2	0	0.4	4.6	5.3
Euphorbia corollata	0	0	2.6	1.5	0
Galactia regularis	0	0	2.9	0	1.8
Galium circaezans	2.6	4.9	1.9	2.3	1.8
Galium pilosum	0	0	0.3	0	0
Helianthus divaricatus	2.6	2.5	7.3	7.2	0
Helianthus helianthoides	1.4	4.9	3.1	3.8	0
Helianthus microcephalus	0	0	1.0	0	0
Hybanthus concolor	3.9	1.2	0.9	3.1	0
Hypericum denticulatum	0	0	0.1	0	0
Ipomaea pandurata	0	0	0.3	0	3.6
Lespedeza procumbens	0	0	0.1	0	0
Lespedeza repens	0	0	0.7	0.8	0
Lespedeza sp.	0	0	1.1	0	0
Lespedeza violacea	0	0	0.6	1.5	0
Lespedeza virginica	0	0	0.3	0	0
Liatris scabra	0	1.2	1.6	0	0
Lysimachia lanceolata	0	1.2	0.2	0	0
Manfreda virginica	0	2.5	0.2	0	0
Monarda bradburiana	1.4	5.0	0.9	0	1.8
Monarda fistulosa	0	0	1.3	0	0
Muhlenbergia sobolifera	2.6	3.5	0.8	2.5	0.9
Onosmodium hispidissimum	0	0	0.4	0	0
Oxalis stricta	0	2.5	0.2	2.3	2.8
Parthenocissus quinquefolia	6.6	12.6	4.7	7.6	9.9
Passiflora lutea	6.6	0	0.3	0	0
Pellaea atropurpurea	0	0	0.1	0	0
Phryma leptostachya	1.4	0	0.4	4.6	2.8
Physalis virginiana	0	0	1.2	0	0
Physostegia virginiana	0	0	0.7	0	0
Polygonum cristatum	0	0	0.4	0	0
Ranunculus sp.	0	0	0	0	1.8
Ratibida pinnata	0	0	1.4	1.5	0
Rubus flagellaris	0	0	0.1	0	0

Ruellia caroliniensis	0	0	0.3	3.8	7.1
Ruellia humilis	0	0	1.2	0	0
Sanicula canadensis	3.9	3.7	0.5	3.8	3.6
Schizachyrium scoparium	0	0	1.1	0	0
Silphium terebinthinaceum	0	0	11.4	1.5	0
Smilacina racemosa	0	0	0	1.5	0
Smilax bona-nox	0	0	1.2	0	1.8
Smilax herbacea	0	0	0	0	1.8
Solidago caesia	0	1.2	0	0	0
Solidago petiolaris	0	5.0	0.9	0	0
Solidago sp.	0	0	0	0	1.8
Solidago ulmifolia	0	7.5	4.9	5.4	3.6
Sorghastrum nutans	0	0	0.8	0	0
Spigelia marilandica	0	0	0.2	2.3	1.9
Taenidia integerrima	0	0	0.6	0.8	0
Thaspium trifoliatum	1.4	3.7	0.5	0	0
Toxicodendron radicans	0	3.7	5.7	1.5	0.9
Verbesina virginica	0	2.5	6.1	2.3	11.3
Vernonia gigantea	0	0	0.3	1.5	0
Viola sororia	2.8	0	0.3	1.5	1.8
Viola sp.	0	0	0.2	2.3	1.9
Viola triloba	2.6	1.2	1.6	3.1	2.8
Vitis aestivalis	2.5	1.6	3.1	0	0

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